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Impact Assessment of Crop and Resource Management Technology

A CASE OF GROUNDNUT PRODUCTION TECHNOLOGY

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

Quantification of adoption and impact of crop and resource management technologies is complex, although this area of research shares a significant proportion of research resources. This publication discusses some methodological complexities in assessing the impact of crop and resource management technologies, and estimates the impact and spread of various components of a technology, popularly known as the 'Groundnut Production Technology[5]. Collaborative research by ICRISAT and the Indian NARS resulted in the development of this technology; some of its components are now used in Indonesia and Vietnam. The technology was developed in 1986, and widely tested on farmers' fields during 1987-91. The technology integrates various crop and resource management options, which includes land management, nutrient management, insect pest and disease management, seed management, and water management. Based on a survey conducted in Maharashtra, India, the study observed partial and step-wise adoption of different components of the technology that range between 31% for raised-bed and furrow method of land management to 84% for improved varieties. In comparison to the prevailing technology, the groundnut production technology gives 38% higher yields, generates 71% more income, and reduces unit cost by 16%. The technology also contributes in improving the natural resource base, and eases certain women specific agricultural operations. The total net present value of benefits from collaborative research and technology transfer is more than US$ 3 million, representing an internal rate of return of 25%. The study suggests important lessons for research and technology transfer policies, and for development of future research priorities.

Résumé

L'évaluation de l'impact de la technologie de gestion de cultures et de ressources: le cas de la technologie de la production de l'arachide. La quantification de l'adoption et de l'impact des technologies de gestion de cultures et de ressources est un processus complexe. Cet ouvrage examine des complexités méthodologiques de l'évaluation de l'impact des technologies de gestion de cultures et de ressources. Plus précisément, il détermine l'impact et la diffusion des composantes de la technologie dénommée la "technologie de la production de l'arachide" (GPT, Groundnut Production Technology) mise au point dans le cadre de la recherche collaborative réalisée par l'ICRISAT et les systèmes nationaux de recherche agricole (SNRA) de l'Inde. Quelques composantes de cette technologie sont actuellement utilisées en Indonésie et au Viétnam. Mise au point en 1986 et largement testée en milieu réel pendant les années 1987–91, cette technologie intègre diverses options de gestion de cultures et de ressources, y compris l'exploitation de terres, d'éléments nutritifs, la lutte contre les insectes nuisibles et les maladies, la gestion de semences et l'exploitation des eaux. Une étude effectuée dans l'état indien de Maharashtra a permis de constater une adoption partielle et étagée des composantes différentes de la technologie, allant de 31% pour la méthode d'exploitation de terres dite "de planches élevées et sillons", jusqu'à 84% pour les variétés améliorées. Par rapport à la technologie disponible précédemment aux paysans, la nouvelle technologie GPT donne des rendements 38% plus élevés, engendre 71% de revenue en plus, et réduit le coût unitaire de 16%. En outre, elle contribue à l'enrichissement de la base de ressources naturelles, et rend plus faciles certaines opérations agricoles effectuées particulièrement par les femmes. La valeur actuelle nette totale des bénéfices découlant de la recherche collaborative et du transfert de technologie est de l'ordre de US$ 3 millions, ce qui se traduit par un taux interne de rendement de 25%. Enfin, l'étude propose des leçons importantes pour les politiques de recherche et de transfert de technologie, ainsi que pour l'élaboration des priorités de la recherche future.

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Contents

Introduction

Studies measuring returns to investment on agricultural research and technology transfer for a wide range of commodities and countries have shown high social payoffs, suggesting that increasing investment on agricultural research and technology transfer would be worthwhile (Akino and Hayami 1975, Arndt et al. 1977, Evenson and Jha 1973, Lindner and Jarrett 1978, Ruttan 1982). The topic has been well reviewed by Arndt et al. (1977) and Ruttan (1982). Most of the earlier studies were confined to the quantification of research benefits at the aggregate level with a focus on improved varieties. Adoption assessment and evaluation of returns on research investment related to crop and resource management including research on crop husbandry, soil-water-nutrient management, and plant protection measures received little attention, although this area of research shares a significant proportion of the research resources. For example, at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), about 30% of the research expenditure was associated with the resource management program in 1991 and 1992 (ICRISAT 1993). Traxler and Byerlee (1992) reported that crop management research accounted for about one-half of all investment in crop research. Earlier studies in this area of agricultural research were concerned mainly with assessing the diffusion of different components of technology, and determining the constraints to their adoption. Traxler and Byerlee (1992) attempted to evaluate the returns to investment in crop and resource management research and reported a positive rate of returns.

The objective of crop and resource management research is to raise production potential by generating research information on various crop production components and integrating them into a package of technology options. Figure 1 depicts a model research process adopted to develop crop and resource management technology. The figure is organized in three parts: (1) the left-hand portion shows independent research and development processes of different crop and resource management practices over time and space, (2) the middle component depicts the process of integrating and packaging all the important technology components derived from the first stage, and (3) the right-hand side shows the technology dissemination process and adoption of various technology components. Alternative technology options are reviewed and evaluated at all three stages, and refined for their adaptability to different regions or ecological conditions.

Adoption and impact assessment studies related to technologies derived from crop and resource management research often become complicated when the technology options are modified and/or partially adopted at farm level. The technology packages are divisible and can easily be disaggregated into subsets of one or two or a mixture of components,

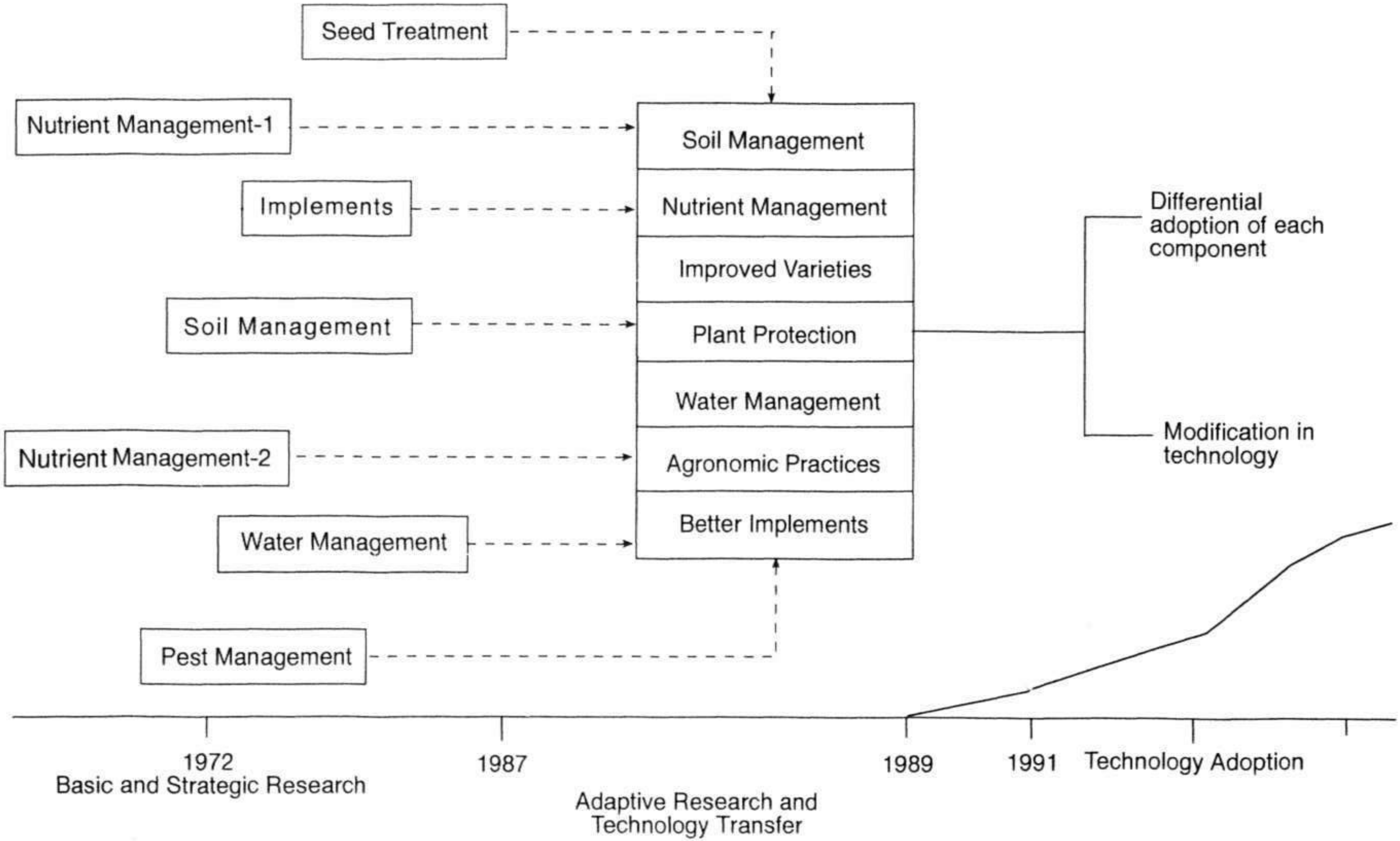


Figure 1. Process and adoption of crop and resource management research.

providing flexibility to farmers who tend to opt for only those components which meet their objectives, e.g., provide a higher rate of return on capital expenditure or alleviate major production constraints. A high degree of spatial and temporal variability is observed in the adoption of different technology options related to crop and resource management research. Evidently, these constrain the assessment of the adoption process and impact evaluation of various technology components. A systematic appraisal is, therefore, needed to quantify the returns to research investment in crop and resource management research. This study is an attempt in this direction.

The study has three objectives:

- First, to develop a framework to understand the adoption pattern of a package related to crop and resource management research.
- Second, to estimate the adoption rate of different crop and resource management components.
- Third, to estimate research and technology transfer costs, and quantify benefits from crop and resource management research and technology transfer related investment.

The study evaluates a specific technology - the Groundnut Production Technology (GPT) - a joint research product of ICRISAT and the Indian National Agricultural Research System (NARS) program on genetic enhancement, crop and resource management research, and technology transfer. The technology aimed at enhancing the production of groundnut, an important oilseed crop which contributes more than 55% to oilseed production in India.

The paper is divided into six parts. The introductory section describes the background and objectives while the second section presents the history of the GPT and its dissemination in farmers' fields. This is followed by a description of the research evaluation framework to assess adoption and evaluate the impact of GPT. This section also presents the sampling design used to conduct the study. The fourth section presents the results of the study, and the paper concludes with implications for farther research, policy recommendations, and outlines priorities for research.

History of the technology

The development of GPT in India evolved with the need to enhance groundnut production and yield to meet the rising demand in the country and to reduce the import of edible oils. In 1986, the Government of India introduced a massive program known as the 'Oilseed Technology Mission', allocating more resources to research and technology transfer activities, and offering remunerative prices to oilseed producers, among other measures. ICRISAT, through its Legume On-Farm Nursery Network (LEGOFTEN) was an active partner with the Ministry of Agriculture and the NARS in identifying appropriate technology options for increased groundnut production and transferring these during the period 1987-91. LEGOFTEN yielded desirable results. The area under groundnut expanded from 6.84 million ha in 1987/88 to 8.67 million ha in 1991/92, and production increased from 5.88 million tons in 1987/88 to 7.07 million tons in 1991/92 (Government of India 1993). Production of other oilseeds also substantially increased during the late 1980s.

After reviewing all available and relevant research information and carefully identifying production constraints in the major oilseed-producing regions in India a technology package was integrated at ICRISAT. This package was thoroughly discussed with the NARS and State Departments of Agriculture. Since a particular technological package performed well in one type of environment and poorly in another, a unique technology package was suggested for each location after characterizing soil, climate, nutrients, water, pests, and diseases. Several on-farm trials and demonstrations were conducted in eight Indian states, covering Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, and Uttar Pradesh. These on-farm trials were launched under LEGOFTEN. During the on-farm trials, the suggested technology options for different locations were regularly monitored, adjusted, and refined to meet local requirements. For example, when the crop showed symptoms of iron deficiency, the application of ferrous sulphate was specifically recommended, and added to the technology package. The following steps were adopted to develop GPT options for on-farm trials:

(a) Identify major constraints:

- identification of farm-level constraints related to soil, water, nutrients, insects, and diseases;

(b) Test available technology options:

- review of relevant ICRISAT/NARS research results that could alleviate production constraints;
- collation of published and unpublished literature for relevant research activities;
- determination of research components and integration of these into a package for on-station and on-farm trials;

- discussion of various technology options with the NARS, Departments of Agriculture, and such important agencies as the National Dairy Development Board (NDDB);

(c) Disseminate new technology components:

- conduct 141 on-farm trials jointly with NARS and State Departments of Agriculture to demonstrate the potential of GPT in comparison to existing practices,
- conduct 1338 on-farm demonstrations by the State Oilseeds Growers' Cooperative Federation through NDDB during 1987-91, and 447 on-farm demonstrations by different State Departments of Agriculture during 1987-91,
- conduct training programs for extension staff, and organize farmers' days to disseminate the technology;

(d) Complementarity between varieties and resource management:

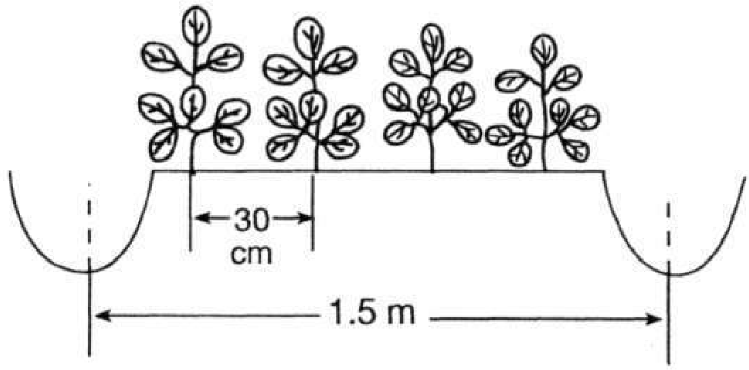
- modification and adaptation of technology options to suit local requirements.
- Important GPT options are listed in Table 1. The components of the GPT can broadly be divided into:
  - land management: preparation of raised-bed and furrows (RBF) for groundnut production;
  - nutrient management: efficient application of macro- and micro-nutrients;
  - improved varieties: high-yielding variety seeds, seed rate and seed dressing/ treatment;
  - insect and pest management: effective control of insects, diseases, and weeds; and
  - water management: improve efficiency of irrigation use.

Four components of the GPT package were in use by the farmers before the package was introduced: These included: (i) improved varieties, (ii) single super phosphate, (iii) seed dressing, and (iv) seed drying. Other components have been developed through NARS R&D, and ICRISAT's Groundnut Improvement Program. ICRISAT's Resource Management and Farming Systems Programs had research data on the land management and configuration system. This area had been extensively researched by ICRISAT scientists since the mid-1970s, so understandably, ICRISAT was interested in the performance of these components. This collaboration with Indian NARS and Ministry of Agriculture in the technology transfer program provided an opportunity to confirm the suitability and viability of the concept in farmers' fields.

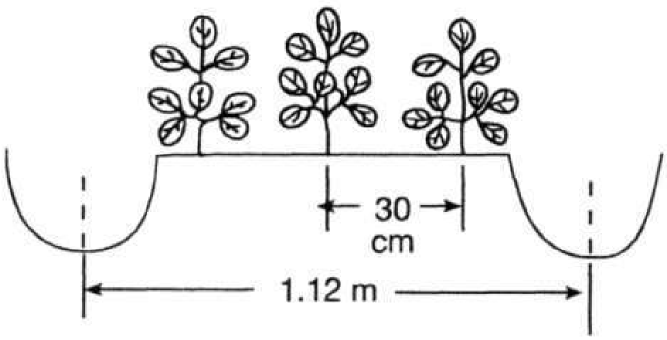
Table 1. Important components of the groundnut production technology (GPT) package and local practices.

Component	Improved package (GPT)	Local practice
Land management	Raised-bed and furrow	
Seedbed	(RBF)	Flat
Nutrient management (ha^{1})		
Farmyard manure	5-12 t	10 t
Ammonium sulphate	100 kg	Diammonium phosphate: 100 kg
Single super phosphate	300-400 kg	Murate of potash: 100 kg
Zinc sulphate	10-20 kg every 3 years	20 kg
Ferrous sulphate	2-3 g kg^{-1}	-
Gypsum	400 kg	200 kg
Seed		
Improved variety	ICRISAT varieties	Local varieties
Seed rate	125-150 kg ha^{-1}	120-125 kg ha^{-1}
Seed treatment	Thiram, Bavistin® or Dithane M 45®	Thiram
Disease and pest management	Bavistin®, dimethoate, monocrotophos	Need-based
Water management	Furrow or sprinkler	Flood

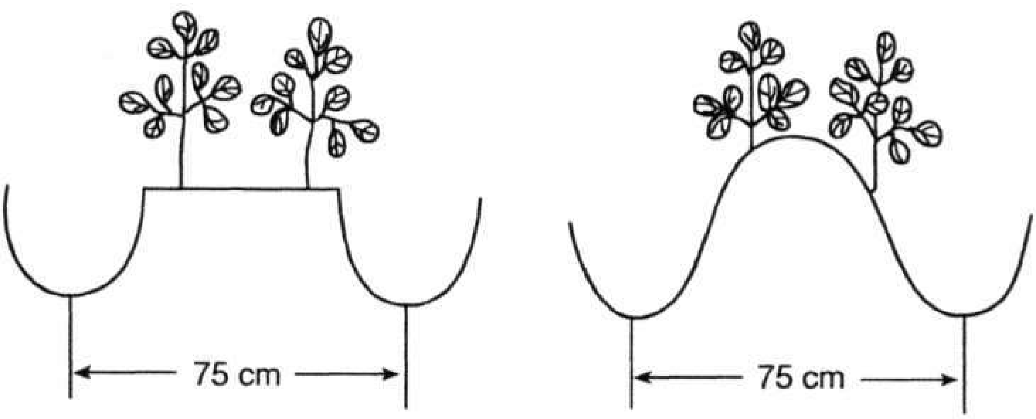
The RBF was viewed as an important component of the GPT. It is prepared by opening a furrow 30 cm wide and 22.5 cm deep at 1.5-m intervals to sow four rows of groundnut with a distance of 30 cm between rows. This specific land preparation system is known as broad-bed and furrow (BBF). Over a period of time, the concept of BBF was modified to suit the requirements of the farmers into narrow-bed and furrow, a bed of 75 cm, and ridge and furrow systems (Figure 2). Traditionally, farmers use 1-2 harrowings to sow groundnut on flat land. The advantages of raising the bed and forming furrows were to: (i) reduce soil erosion, (ii) provide surface drainage, (iii) concentrate organic matter and fertilizer application, and (iv) reduce soil compaction around plants. It was initially designed for the micro-watershed of the Vertisol technology to achieve optimal use of land and water resources in rainfed agriculture.



1. Broadbed-and-furrow: ideal for rainy and postrainy seasons, under sprinkler in all soils



2. Bed and furrow: ideal for rainy and postrainy seasons under furrow irrigation in sandy loam soils



3. Narrow bed or ridge and furrow: ideal for postrainy seasons under furrow irrigation in black and lateritic red soils

Figure 2. The raised-bed and furrow (RBW) method of groundnut cultivation.

On nutrient management, GPT suggested a balanced and efficient use of macro- and micro-nutrients to control nutrient mining from the soil. These included use of ammonium sulphate, single super sulphate, gypsum, zinc sulphate, and ferrous sulphate. These were recommended after nutrient deficiencies were detected in groundnut-growing regions. The application of macro-nutrients - ammonium sulphate and single super phosphate - had been previously recommended, and was adopted by farmers even before the GPT was packaged this recommendation was essential because these fertilizers supply nitrogen, phosphorous, sulphur, and calcium, that are essential for the groundnut crop. Gypsum was recommended as a source of calcium to improve pod development. Zinc sulphate and ferrous sulphate were recommended to overcome zinc and iron deficiencies. Potdar and Anders (1995) reported that iron chlorosis led to groundnut yield reductions of 32% for pod, 18% for fodder, and 25% for total dry matter production. Therefore, the use of ferrous sulphate was considered important to increase groundnut yields.

Leaf spot, rust, collar rot, and bud necrosis are common diseases of groundnut. The yield losses due to these diseases were estimated to be 20-25%. Similarly, 15-20% yield losses were caused by insects (Pawar et al. 1993). Collar rot and other seedling diseases are also common in groundnut crops. Very few farmers treat their seed with fungicides. Fungicidal seed treatment was incorporated into GPT package. Similarly, herbicides and pesticides recommended by ICRISAT and NARS, to control weeds and pests before the GPT was developed were also included in the package.

Water management is another important component of the GPT as irrigation water is scarce in the semi-arid tropics. Irrigation-use efficiency increases with the use of furrows compared to irrigation on flat land. Sprinkler irrigation was included in the GPT to enhance irrigation water-use efficiency.

Varieties developed at ICRISAT were recommended as part of the GPT. Generally, farmers were adopting either local or improved varieties released in the mid-1970s. ICRISAT varieties were high-yielding and less susceptible to pests and diseases.

Most of the above components of the GPT package were not new; they were known and independently recommended earlier by various research institutions, including ICRISAT. Ironically, their adoption at farm level was limited, and the most often cited constraints were inadequate information and insufficient resources. The aim of this publication is to confirm the effectiveness of the technology transfer program jointly undertaken by ICRISAT and the Indian NARS; and to evaluate the benefits gained by farmers when the technology options recommended for groundnut production were adopted. The critical role of ICRISAT as a catalyst in partnership with the NARS in this program will be examined. The authors also describe how the essential components were taken up and how popularization of the GPT amongst policy makers, extension personnel, and farmers has influenced the adoption process.

Research evaluation framework

Sampling

A key issue in the assessment of adoption of crop and resource management technology packages is the definition of adopters. This is because several components of the technology package are already known and adopted even before the introduction of the package. Another issue is that farmers are free to choose and adopt any subset of the technology package. To systematically evaluate the adoption process, components of the package were categorized and key components were selected to distinguish farmers who adopted the full package, those who only adopted some components, and those who continued to use components that were recommended before the introduction of the GPT. The analysis also considered evaluation of adoption where one key component was selected to distinguish the adopters of the technology package. A high correlation of adoption of this component with other technology options is an important consideration in selecting this key component. The selected component should also be distinguished from technologies practiced before the package was introduced.

In the case of GPT, the raised-bed and furrow (RBF) method of land configuration was selected as the key component to distinguish the adopters of the technology. It was noted that this component distinguished the GPT from any technologies recommended earlier. Other components also differ from those recommended earlier but largely in terms of their recommended quantity.

As stated earlier, the technology was targeted at eight states of the Indian semi-arid tropics: Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, and Uttar Pradesh. Upon reviewing the recommendations for groundnut production in different states, it was noted that the RBF component of the GPT was deleted from the recommendations by almost all the state Departments of Agriculture. Maharashtra was the sole exception, because the method is most suited to the agroclimatic conditions of this state. Therefore, it was only in Maharashtra that government and non-government agencies followed up the dissemination of the technology even after ICRISAT withdrew its on-farm activities. Since the objective was to assess the adoption and evaluate the impact of the package, and the RBF method was the deciding component, Maharashtra state was selected to confirm the adoption of the technology.

Maharashtra state spans the western and central part of India. Vertisols are the major type of soil in this state where about 800 000 ha are allocated to the groundnut crop; this accounts for about 10% of the total groundnut area in India.

Multi-stage stratified random sampling was used to select a representative group of farmers to track the adoption of different components of the GPT.

As a first step, all districts growing summer groundnut were stratified into high- and low-intensity categories according to area grown. The top 50% groundnut-growing districts were all categorized as high intensity, while the lower 50% groundnut-growing districts were classified as low-intensity. Two districts, Parbhani and Nanded, from the high-intensity stratum, and two districts, Yavatmal and Amravati, from the low-intensity stratum, were randomly selected. The important features of groundnut production in these four selected districts are given in Table 2.

Each selected district in the second stage of sampling was further stratified into three groups of *talukas* depending upon whether the intensity of groundnut cultivation was

Table 2. Area, production, and yield of groundnut in selected districts of Maharashtra, India, 1994.

District	Area (ha)	Production (t)	Yield (kg ha^{-1})
Amravati	1133 (4.00)[1]	1333 (5.23)	1224
Nanded	23433 (82.32)	28767 (92.30)	1234
Parbhani	47167 (84.03)	73567 (94.03)	1558
Yavatmal	9267 (50.82)	11900 (70.97)	1282
Maharashtra State	233900 (26.95)	384850 (39.06)	1640

1. Numbers in parentheses represent the percentage share of summer groundnut in total groundnut.

high, medium or low. All *talukas* in a district were listed in descending order of the area under groundnut. The top 33% groundnut-producing *talukas* were classified as high intensity, the next 33% as medium, and rest as low-intensity groundnut-producing areas. Three *talukas,* one from each stratum, in every district were selected to cover representative groundnut-producing areas. The low-intensity *talukas* in Amravati district were left out of the sampling because the area under groundnut during the summer season was very small.

The villages in each *taluka* were then divided into three strata according to whether the area under groundnut was high, medium, or low, in consultation with the Sub-Divisional Officer of the Training and Visit (T&V) Program of the Department of Agriculture. One village from each stratum was randomly selected to make a total of three villages from each *taluka.* This approach was followed uniformly except in two cases - Pathari in district Parbhani, and Yavatmal in district Yavatmal - where the area under groundnut was almost nil. To select the final sampling unit, the farm household, a random selection of farmers was made from each village with the sample size depending upon total number of groundnut producers in that village. In all, the study sample was 355 farm households (Table 3).

Table 3. Number of *talukas,* villages, and sample farmers in selected districts, Maharashtra.

District	*Talukas*	Villages	Sample farmers
Amravati	2	6	60
Nanded	3	9	100
Parbhani	3	8	100
Yavatmal	3	10	95
All districts	11	33	355

Data

Information was collected from selected farmers using a specially structured questionnaire. Farmers were personally interviewed from late-1994 to mid-1995. Data on the following aspects were collected from the farmers for the 1994/95 crop season:

- Size of holding, operational area, irrigated and nonirrigated area,
- Land use and cropping pattern,
- Technology adoption
  - total groundnut area,
  - first year of adoption of different components of GPT,
  - extent of adoption of different components of GPT in the first year,
  - extent of adoption during the last 3 years ending 1994, and
  - modification in technology components, if any.
- Cost of groundnut production according to item and operation,
- Yield and price of groundnut and its by-product,
- Farmers' perception on sustainability issues, and
- Constraints to adoption of GPT.

Information was also compiled from the T&V Program of the Department of Agriculture, the Office of the Agricultural Development Officer, and several traders dealing with components of the GPT.

Analytical framework

This section describes the analytical framework used to estimate the adoption of various technology options and quantify their impact. This is divided into three parts. The first part deals with the framework for adoption assessment, the second with the attributes governing adoption, and the third gives the method for impact assessment.

Adoption assessment framework

Adoption at the farmer's level is commonly defined as the degree of persistent use of a new technology when the farmer has complete information about the new technology and its potential benefits. At the aggregate level, it is defined as the process by which new technology spreads within a region. In their pioneering review, Feder et al (1985) commented that most adoption research viewed the adoption decision in dichotomous terms (i.e., adoption or non-adoption). But for many types of innovations, the interesting question is the intensity of use (e.g. how much macro- or micro-nutrients are used per hectare or how much land is sown to improved varieties). Recently, Feather and Amacher (1994) and Saha et al. (1994) incorporated intensity decision, a factor that allows for a more realistic and informative assessment of the adoption process. Feder et al. (1985) pointed out that such a two-stage approach is essential when dealing with problems such as fertilizer applications where intensity may vary widely among individuals who adopt.

Most agricultural technologies are recommended as a package that include several components, for example, management of soil, nutrients and water, improved agronomic practices, and use of high-yielding varieties. In most cases, the components of a package complement each other to enhance crop production. Most of the components of the package can usually be disaggregated into subsets and can be adopted independently. Under such circumstances, several distinct technological options are available to the farmers. They are free to adopt either the complete package or a subset of components of the package introduced in the region. Farmers may partially adopt subsets of packages or adopt a modified form of the recommendations. Farmers' adoption of improved technological components is also observed to occur in a stepwise manner (Byerlee and Polanco 1986, Ryan and Subrahmanyam 1975). Adoption of partial or modified subsets of a package is influenced by a wide range of economic and social factors, the physical and technical aspects of farming, and farmers' attitudes to risk. In stepwise adoption, elements initially adopted were those that provided the highest rate of return on capital expenditure (Ryan and Subrahmanyam 1975).

Adoption tracking of agricultural technologies becomes complex when several components are involved. While assessing the adoption of an array of technological options, two major problems are encountered:

- identification of the specific research recommendation adopted by the farmers, and
- quantitative evaluation of the adoption of different components.

To overcome such problems, a few studies in the past (Ryan and Subrahmanyam 1975, Byerlee and Polanco 1986, Traxler and Byerlee 1992) suggested the following steps:

- identify each component of the technology relevant to the recommended package adopted by the farmer,
- assess the proportion of each technology adopted by the farmer, and
- ascertain the area covered under particular components of the technology.

The GPT encompasses several components related to soil, nutrient, crop, water, and pest management. The adoption pattern of all these components was assessed. Each participating farmer was asked whether he/she practiced different components of the

GPT. If the answer was yes, the farmer was asked to recall the year of first adoption for the different components which were further complemented by inquiry on:

- the area allocated to each component of the GPT and
- the intensity of application of each component of the GPT.

The same questions were repeated for 1992, 1993, and 1994. Using the information on first year of adoption and the 3 years ending 1994, the adoption path for each component of the GPT was developed, and logistic curves were estimated to describe the rate of adoption of each component. The logistic curve is defined as:

$$A_{it} = K_i / (1 + e^{-(a + bt)}) \qquad (1)$$

where, A_{it} is the percentage adoption of the ith component of the GPT in tth year; K_i is the adoption ceiling of the ith component; t is the time; b is the rate of adoption; and a is a constant. The ceiling level for each technology component was determined by estimating the function under several assumed ceiling levels and choosing the one that yielded the best coefficient of determination (R^2).

Since most of the components of the technology other than the RBF method were also recommended either independently or as a package of practices for groundnut production, the influence of GPT adoption, particularly RBF, in changing the rate or extent of adoption of different technology components was examined by using intercept and slope dummy in the logistic functions after the introduction of the GPT.

Factors influencing adoption

An analysis to determine the factors influencing adoption of the RBF method was undertaken by estimating probit functions. The probability of adoption was specified as a function of information about technology, soil type, resource availability/constraints, and the technology traits:

$$PA (RBF) = f(INFO, SOIL, RESORC, RETRNS, TECHTR)$$

where PA is the probability of adoption of the RBF method for groundnut cultivation. INFO is defined as information about the RBF method. Information was defined in two ways: (i) farmer's knowledge about the RBF method, and (ii) the farmer's contacts with research and extension agencies, and frequency of using mass media. SOIL is the type of soil where the groundnut crop was grown. It was defined as 0 for light to medium black soil, and 1 for deep black soils. RESORC is the availability of capital, labor, appropriate implements, and irrigation water. RETRNS is the returns from groundnut crop.

TECHTR relates to technology-specific traits. It explores whether technology traits, e.g., making and/or managing RBFs, are appropriate in terms of the resource availability of the farmers.

Impact assessment framework

The main objective of investment in research and technology transfer is to generate economic surplus for the society and increase the total well-being of producers and consumers. Information on the following aspects is required to quantify the economic surplus:

- research and technology transfer cost,
- adoption rate and spread of the technology, and
- benefits accrued from research and technology transfer programs.

This section describes the procedure adopted to estimate research costs and benefits to measure economic surplus and distribution of welfare gains.

Estimation of research cost. Information on actual cost of research and development (R&D) and technology transfer is required to evaluate the returns to investment in agricultural research and technology transfer. Approximations can also be made to estimate the annual cost of developing and packaging the technology, and its transfer. These can be based upon discussions with the scientists and extension staff who were directly involved in conducting research, on-farm trials, and technology transfer activities.

The annual cost of developing and packaging the GPT, and the cost of its diffusion and transfer was systematically estimated by adopting the following procedure:

$$GPTRC = C_{ic} + C_{nars} + C_{ext} \qquad (2)$$

where GPTRC is the annual research and technology transfer cost of all components; C. is the annual research and overhead costs incurred at ICRISAT; C_{nars} is the annual research and other costs at the NARS; and C_{ext} is the annual cost of extension incurred by the technology transfer department of the NARS.

To estimate the research and technology transfer cost at ICRISAT, four components were included: (i) salary of the research team, (ii) operational cost of research; (iii) overhead cost at the Institute, and (iv) on-farm demonstration and technology transfer cost. This was derived as follows:

$$C_{ic} = SAL_{ic} + OPR_{ic} + OVR_{ic} + OFD_{ic} \qquad (3)$$

where, C_{ic} is defined above; SAL. is the annual salary of the research team; OPR_{ic} is the annual operational expenses required to undertake GPT development, packaging, and diffusion; OVR_{ic} is the annual overhead cost at the Institute; and OFD_{ic} is the annual cost incurred to conduct on-farm trials and demonstrations in farmers' fields.

The salary (SAL_{ic}) of the research team at ICRISAT was estimated by adding the salaries of all those associated with the research project, each weighted by the proportion of their time devoted to the project:

$$(4) \quad SAL_{ic} = \sum_{i=1}^{n} w_i * SAL_i$$

where, SAL_{ic} is as expressed above; SAL_i is the annual salary of the ith research team member; and w_i is the proportion of time allocated by the research team member to developing and packaging the GPT.

The operational cost (OPR_{ic}) of developing and packaging the GPT was assumed at 35% of the salary. This assumption is based upon the past experience and existing norms at ICRISAT. The overhead costs (OVR_{ic}) are usually considered to take half of the research expenses (Byerlee 1996); this figure was also based on the recent research resource allocation to different research projects at ICRISAT. Since the technology components were packaged and recommended for groundnut, pigeonpea, and chickpea, the research and packaging cost for GPT was proportionately distributed. The share of groundnut in the total area of the three crops was used as a basis for allocating research cost to GPT. Similarly, the cost of on-farm research and technology transfer activities (OFD_{ic}) undertaken through LEGOFTEN, which started in 1987, was proportionately allocated.

The NARS was also involved in packaging the technology and conducting on-farm trials. To assess this cost, several researchers were consulted and it was fixed at 10% of the total cost incurred by ICRISAT, essentially on the basis of NARS participation in the development and packaging of the technology.

The expenses incurred in technology transfer (C_{ext}) through the state department during the post-LEGOFTEN period were calculated using the share of groundnut in total area in the state as no separate document exists on resource allocation for each commodity or technology.

Estimation of research benefits. The conventional, comparative-static, partial equilibrium model of supply and demand in the commodity market was used to estimate the economic surplus generated as a result of GPT. It was assumed that adoption of the GPT would shift the supply function and benefit both producers and consumers.

The following set of linear demand and supply equations ware assumed to compute the economic surplus and distribution of welfare gains from investment in the research and technology transfer program:

$$DD_t = a_t - bP_t \qquad (5)$$

$$SS_t = a'_t + b'P_t \qquad (6)$$

where P is price of groundnut, DD is total quantity demanded, SS is total quantity supplied in the region, t is the time, b in each equation represents either the demand or supply slope, and a in each equation is the intercept term, which may vary over time. These equations can determine the equilibrium price and quantity.

A supply shift is expected to occur as a result of the research and technology transfer program. The shift is represented by reduction in unit cost of production due to adoption of GPT. The cost reduction is denoted as k_t. The new supply equation is then:

$$SS_t' = a'_t + b'k_t + b'P_t \qquad (7)$$

where, all terms are as defined earlier except SS' which is the quantity supplied with the research and technology transfer efforts.

In the case of crop and resource management technologies, when several technology components are involved and adoption patterns are differential and step-wise, the computation of shift in 'k' becomes very complex and difficult. This is mainly due to the effect of different components of the technology, and interaction effects among the components adopted.

To estimate 'k', i.e., shift in supply function, information available from on-farm trials was used. In this particular case, results obtained during on-farm surveys were used to compute the shift in 'k'. There were different sets of treatments under on-farm trials (Pawar et al. 1993):

- With and without improved package: This allowed comparison of the improved package of the GPT, including improved varieties, RBF method, and other management practices, with the local package.
- With and without raised-bed and furrow: This set compared only the RBF with the flat method of groundnut production keeping the remaining components of the improved technology at their recommended level.

- With and without improved management practices: This option compared the improved management practices, including RBF and other management practices, with flat method of groundnut production and other local management practices.

Using the above equations, the economic surplus from research and technology transfer can be derived as follows:

(a) Consumer's gain:

$$CG_t = 1/2\ (P - PP`)\ (DD_t + DD_t`)$$
$$= (Q/g)\ DD_t + (b\ Q_t^2)/\ (2\ g^2) \quad \text{--- (8)}$$

(b) Producer's gain:

$$PG_t = 1/2\ (P - P')\ (SS_t + SS_t`)$$
$$= (k - (Q/g))\ SS_t + (b72)(k_t - \quad (Q_t/g))^2 \quad \text{--- (9)}$$

(c) Aggregate welfare gain:

$$WG_t = CG_t + PG_t$$
$$= k_t\ SS_t - (Q/g)(SS_t - DD_t + (b\ Q_t^2)/(2\ g^2) + (b'/2)(k_t - (Q/g))^2 \quad \text{--- (10)}$$

where, $Q = b'k_t$ and $g = b + b'$

The streams of benefits from research and technology transfer were derived using the aggregate benefit (derived from equation 10), adoption rate, and adoption ceiling level. Net present value, internal rate of return, and benefit-cost ratio were computed to justify the research and technology transfer investment on GPT.

On-farm benefits of GPT relevant to the farmers were also assessed. These were measured in terms of increase in groundnut yield and income, changes in labor productivity and employment potential, and gender-related aspects. Farmers' perceptions on sustainability were also assessed to understand the importance attached by farmers to these issues.

Results and discussion

Adoption of GPT

The survey data were analyzed to estimate the adoption patterns of different GPT components (Tables 4 through 9). The adoption behavior for different components of GPT is discussed below:

Land management. Land management, considered to be a distinguishing feature of the GPT package, was an important component. It was observed that farmers adopted the concept of RBF method, but in the absence of appropriate implements they did not

Table 4. Percentage of sample farmers who adopted different technology components of the groundnut production technology (GPT) in selected districts of Maharashtra, India, 1989–94.

Component	Ist year of adoption	1989	1990	1991	1992	1993	1994
Raised-bed and furrow (RBF)	1989	3.4	11.8	17.2	28.2	33.8	34.9
Improved varieties	1976	47.6	69.3	73.2	75.5	80.6	83.1
Single super phosphate	1981	23.7	43.7	55.5	59.4	63.9	64.5
Zinc sulphate	1988	4.2	5.9	6.5	7.3	14.1	15.5
Ferrous sulphate	1989	2.0	3.1	3.1	3.1	7.3	7.3
Gypsum	1988	4.8	12.4	20.3	35.5	46.2	47.3
Seed dressing	1981	5.3	15.2	20.8	26.5	33.8	34.4
Drying	1982	0.9	1.4	2.0	3.1	9.9	9.9
Sprinkler	1990	-[1]	0.3	0.3	2.5	3.7	3.7

1. Not adopted.

strictly follow the recommended practice of making the 1.5-m bed. A modified form of RBF was developed by narrowing the width of the bed. About 35% of the farmers had adopted the concept of RBF in 1994. Their number increased from less than 4% in 1989 to 35% in 1994 (Table 4). The highest adoption of the raised-bed and furrow system occurred among farmers who cultivated between 5-10 ha of land. About 43% of the farmers in this category adopted the RBF concept. No farmer owning less than 1 ha of land adopted the RBF system in any form.

The area under this important component increased from 3.8% of the total groundnut area in 1989 to 25.5% in 1992, and reached about 31% in 1994 (Table 5). The adoption

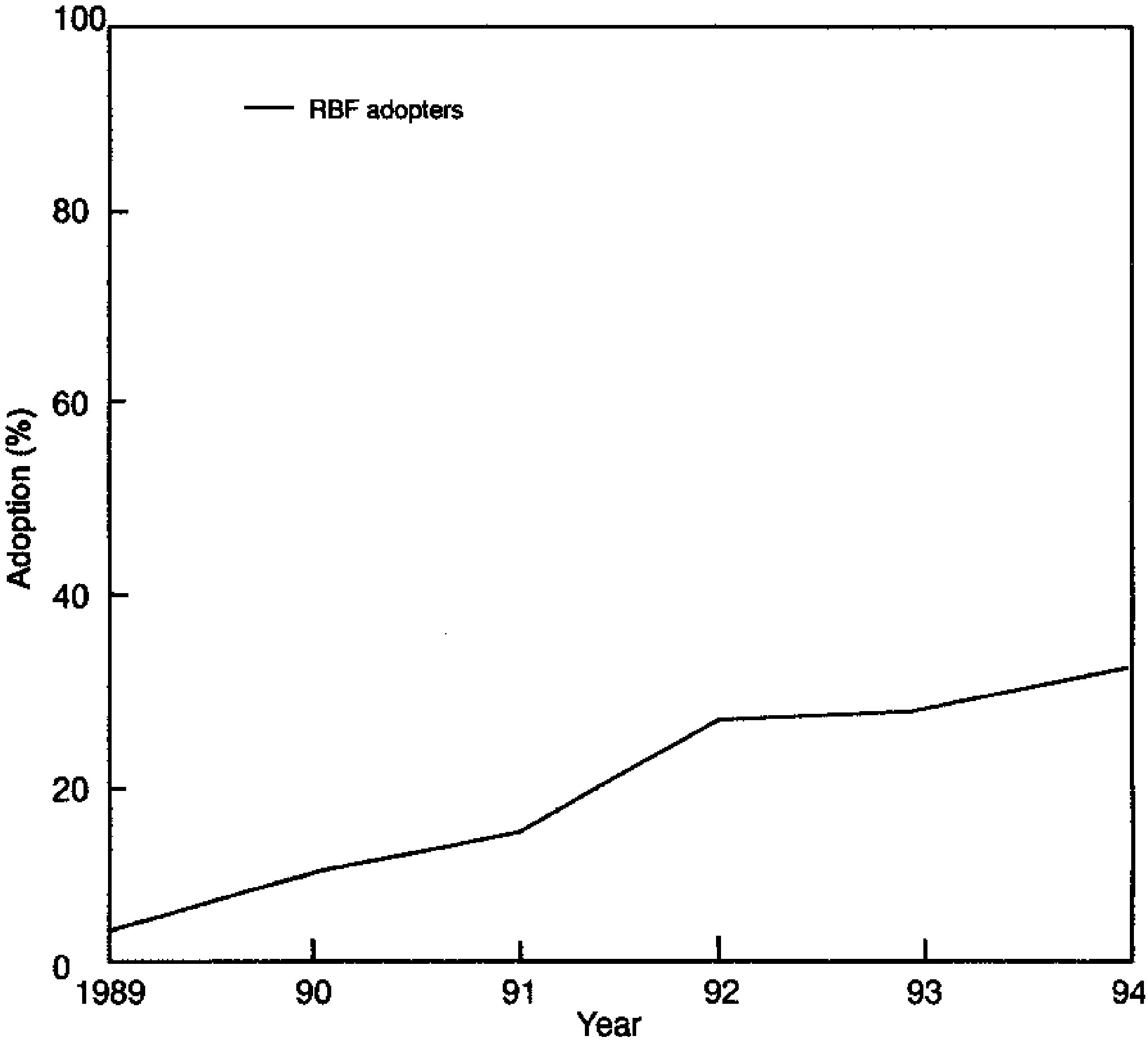


Figure 3. Adoption of the raised-bed and furrow (RBF) method for groundnut cultivation.

Table 5. Estimates of the adoption (percentage of total groundnut area) of different technology components of the groundnut production technology (GPT) in selected districts of Maharashtra[1], India.

Technology component	1989	1990	1991	1992	1993	1994	Ceiling (%)
Raised-bed and furrow (RBF)	3.8	10.2	14.4	25.5	27.2	31.1	40.0
Improved varieties	6.2	23.8	22.7	80.3	82.0	83.7	90.0
Single super phosphate	9.6	22.1	34.4	61.6	64.6	68.9	75.0
Zinc sulphate	3.6	5.2	6.1	7.8	11.6	14.0	20.0
Ferrous sulphate	1.5	2.4	3.2	2.8	5.4	6.0	10.0
Gypsum	3.8	10.2	17.2	35.3	41.6	41.8	45.0
Seed dressing	5.9	14.6	19.2	36.5	40.9	46.4	60.0
Drying	1.5	1.7	1.9	4.1	8.1	9.2	10.0
Sprinkler	0.0	0.2	0.2	2.5	3.4	3.6	15.0

1. Selected districts listed in Table 2.

Table 6. Estimates of logistic function parameters on adoption of the raised-bed and furrow (RBF) method.

Parameter	Coefficient	Standard error	t value
K	40.00		
a	-2.6363	0.3124	8.4388***[1]
b	0.6898	0.0747	9.2342***
b'	0.2759		
r^2	0.9552		

1. *** = significant at 1% probability level.

path, estimated using the logistic function, showed a consistent increase in adoption of the raised-bed and furrow method for groundnut cultivation (Table 6 and Figure 3). This indicates that farmers now realize the importance of the concept for the cultivation of summer groundnut.

Nutrient management. Balanced and efficient nutrient management was one of the objectives of the GPT. It may be noted that prior to the introduction of GPT, farmers were already applying macro-nutrients to groundnut and other crops. Application of single super phosphate was actually started in 1982. It took 7 years for single super phosphate application to be adopted in about 10% of the area since 1982, but only 1 year to cover an additional 10% of the area after the GPT was introduced. Such a trend was further confirmed by estimating the logistic functions which revealed that the adoption rate of single super phosphate was higher among those who adopted the raised-bed and furrow method than among those who did not (Table 7 and Figure 4). Such a change in adoption pattern can be attributed to the GPT.

Those farmers adopting the raised-bed and furrow method were applying about 318 kg ha^{-1} of single super phosphate, about 103% more than non-adopters were using (Table 8). The highest quantity of single super phosphate (340 kg ha^{-1}) was applied by farmers holding 5-10 ha of land who adopted the concept of raised-bed and furrow, followed by the 1-5 ha farm size group (329 kg ha^{1}). Among the non-adopters of the raised-bed and furrow, the highest quantity of single super phosphate was applied by farmers with land holdings greater than 10 ha.

Table 7. Estimates of logistic function parameters on adoption of different groundnut production technology (GPT) components.

Parameter[1]	Improved varieties		Single super phosphate[1]		Gypsum	
	ADOP-RBF[2]	NADOP-RBF[3]	ADOP-RBF	NADOP-RBF	ADOP-RBF	NADOP-RBF
k	98.00	77.00	99.00	60.00	80.00	30.00
a	–3.2147**[4]	–4.1721**	–5.3026***	–7.1015***	–3.8720***	–0.5092
	(0.6590)	(0.5553)	(0.1991)	(0.5290)	(0.3597)	(0.9448)
b	0.3377*	0.4754**	0.7093***	0.4340*	0.9646	0.7477
	(0.1017)	(0.0857)	(0.0457)	(0.1266)	(0.6798)	(0.2259)
aD	–6.4776*	–6.9819**	0.8442@	–0.0166	–[5]	–[5]
	(1.5998)	(1.3481)	(0.4092)	(1.1341)		
bD	0.6454*	0.6417**	–0.1633@	0.3349@	–[5]	–[5]
	(0.1608)	(0.1355)	(0.0583)	(0.1615)		
b'	0.3309	0.3660	0.7022	0.2604	0.7717	0.2243
bD'	0.9634	0.8602	0.5405	0.4613	–[5]	–[5]
R^2	94.72	97.08	99.49	98.25	97.57	73.26

1. aD is the intercept dummy and bD is the slope dummy. b' is the adjusted rate of adoption before and bD' is the adjusted rate of adoption after introduction of the GPT.
2. ADOP-RBF = adopters of RBF.
3. NADOP-RBF= non-adopters of RBF.
4. ***= coefficient significant at 1% probability level; ** = significant at 5% probability level, * = significant at 10% probability level; and @ = significant at 20% probability level.
5. Dummy variable was not included in this probit function.

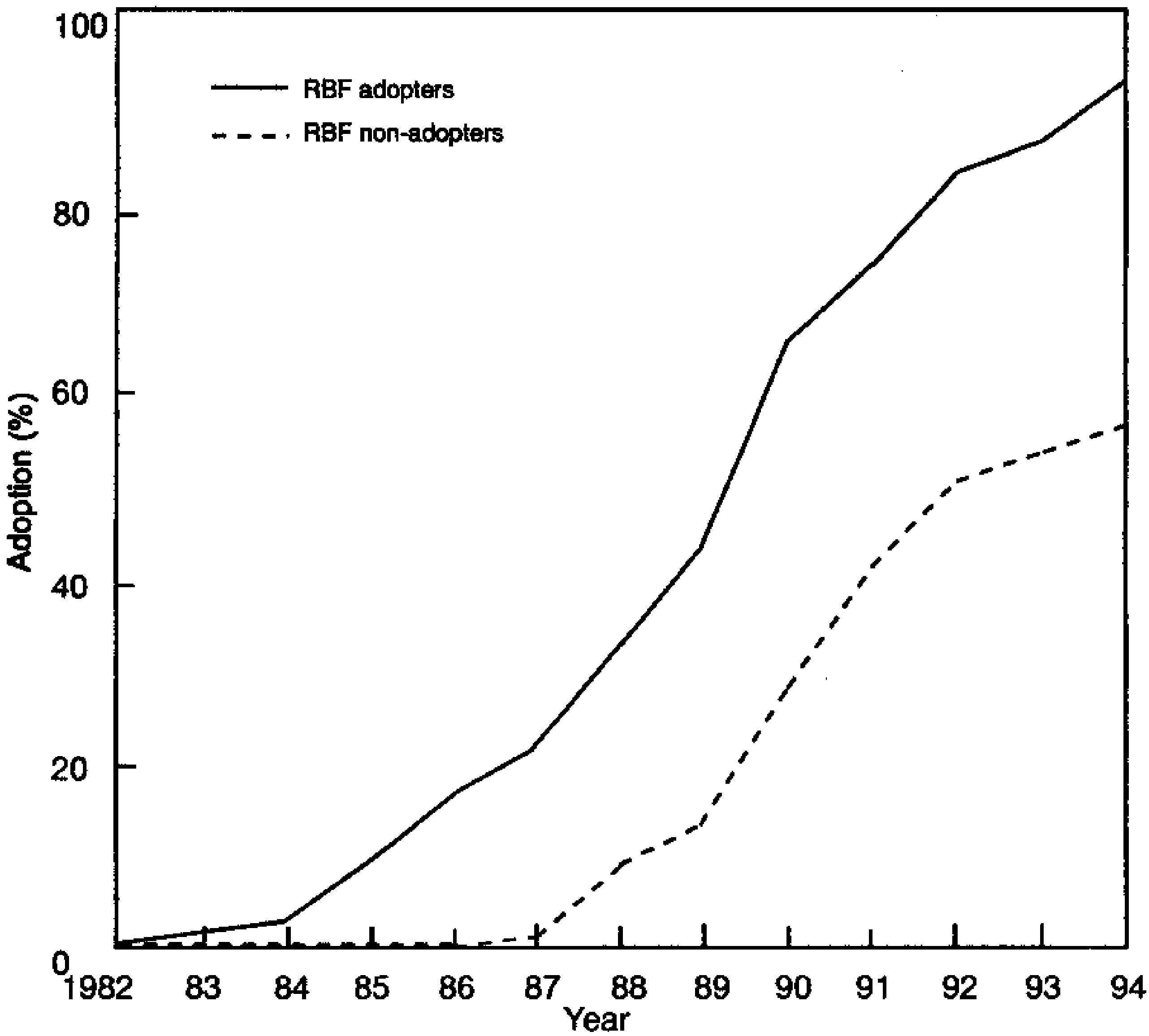


Figure 4. Adoption of single super phosphate use by adopters and non-adopters of the raised-bed and furrow (RBF) method.

Gypsum is the most important and popular micro-nutrient recommended with the GPT. It improves the physical and chemical properties of soil, and contributes to the increase in crop yields. Gypsum application by the sample farmers started in 1988. Less than 5% of the farmers adopted gypsum application that year. By 1994, about 48% farmers applied gypsum to their groundnut crops. The area under gypsum application increased from 3.8% in 1988 to more than 40% in the 1994 season. The adoption rate and area receiving gypsum application was again much higher among those who adopted the raised-bed and furrow method (Table 7 and Figure 5).

About 48% farmers apply gypsum during groundnut production. About 262 kg gypsum ha"[1] was applied by those who had adopted the raised-bed and furrow method,

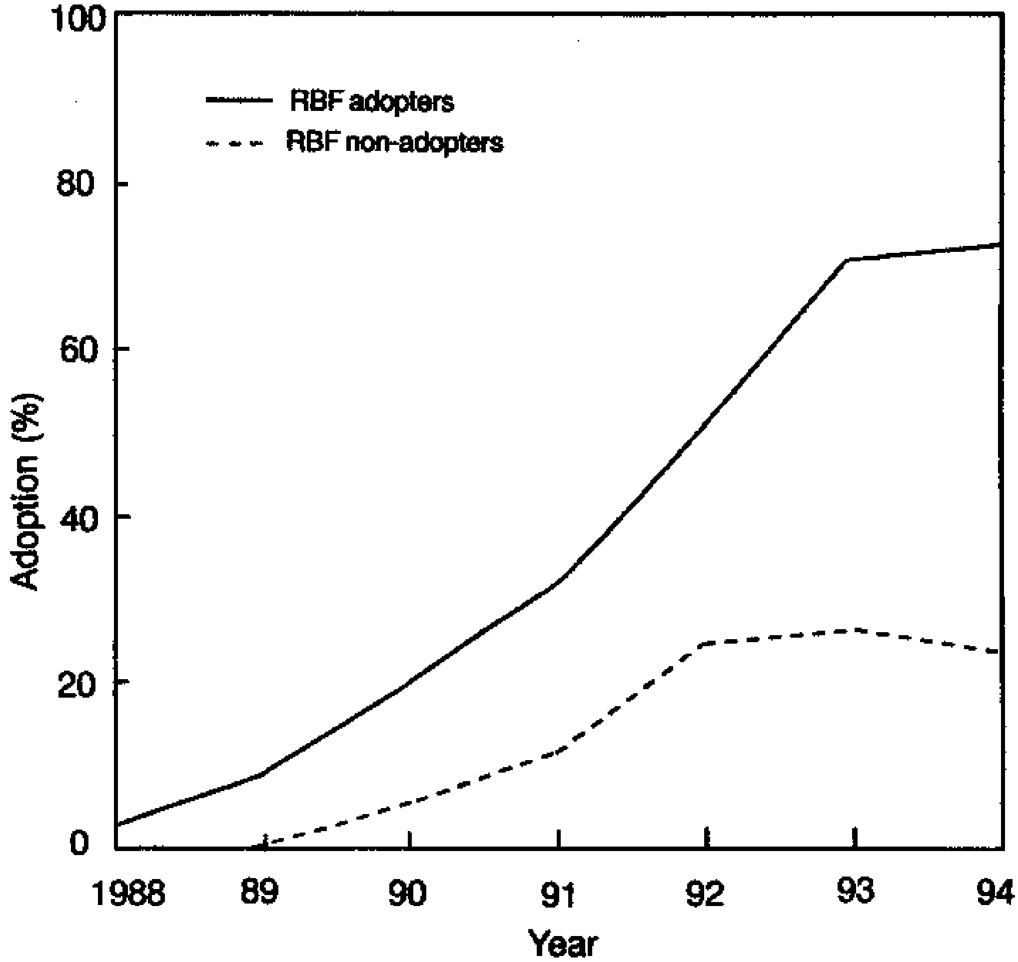


Figure 5. Adoption of gypsum use by adopters and non-adopters of the raised-bed and furrow (RBF) method.

Table 8. Intensity of use of important inputs to groundnut crop among adopters and non-adopters of the raised-bed and furrow (RBF) method.

Input	Unit	Adopter	Non-adopter	Change in use (%)	t values[1]
Single super phosphate	kg ha^{-1}	317.82	215.3	102.52	5.50***
Zinc sulphate	kg ha^{-1}	3.22	0.06	3.16	5.22***
Ferrous sulphate	kg ha^{-1}	1.07	0.00	1.07	4.26***
Gypsum	kg ha^{-1}	261.84	69.65	191.86	8.54***
Seed treatment	Rs ha^{-1}	35.95	16.95	19.00	3.33***
Pesticide	Rs ha^{-1}	166.47	58.82	107.65	4.67***
Seed rate	kg ha^{-1}	102.35	97.29	5.06	2.00**

1. *** = significant at 1% probability level, and ** = significant at 5 % probability level.

compared to only 70 kg ha^{-1} by those grew groundnut using the traditional method (Table 8). Farmers adopting raised-bed and furrow and owning more than 10 ha land were using the highest quantity of gypsum (363 kg ha^{1}). The corresponding quantity of gypsum application by the non-adopters was 236 kg ha^{1}. In both cases, farmers were yet to apply gypsum at the recommended level of 400 kg ha^{-1}.

Zinc sulphate and ferrous sulphate were important micro-nutrients recommended as part of the GPT. About 16% of the sample farmers applied zinc sulphate to groundnut crops in 1994. The area treated with zinc sulphate increased from 3.6% in 1989 to 14%

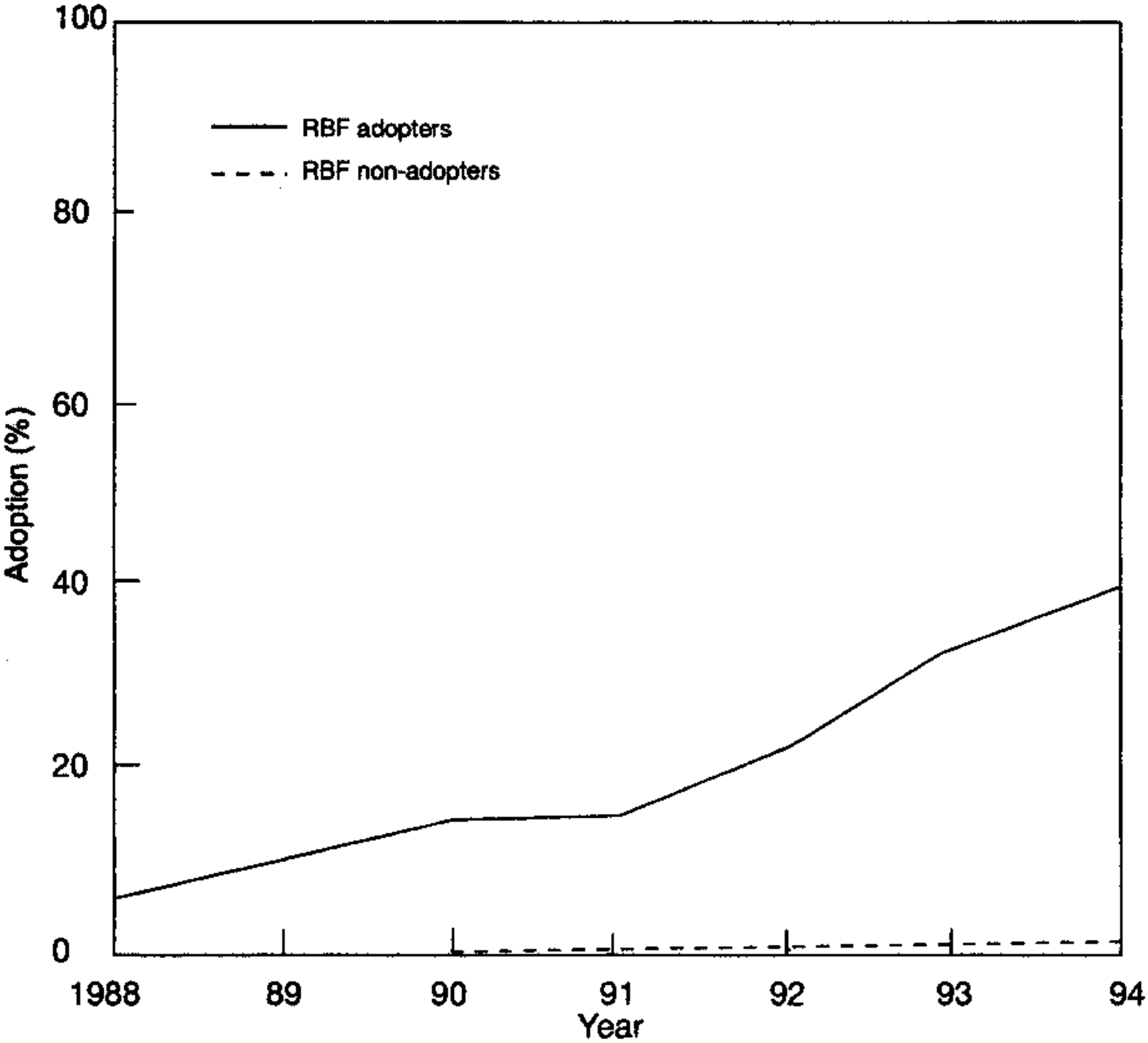


Figure 6. Adoption of zinc sulphate use by adopters and non-adopters of the raised-bed and furrow (RBF) method.

in the 1994 season. The adoption level of zinc sulphate was about 4 kg ha^{-1} by those practicing the RBF method compared to only 70 gm ha^{-1} by other farmers (Table 8).

Few farmers adopted the use of ferrous sulphate. About 7% of the sample farmers in 1994 applied ferrous sulphate in 6% of the groundnut area. Though farmers have been aware of the use and importance of this micro-nutrient, its adoption has been constrained by unavailability.

The rate of adoption of zinc sulphate was much higher than that of ferrous sulphate (Table 9 and Figures 6 and 7). These micro-nutrients were applied mainly by those who

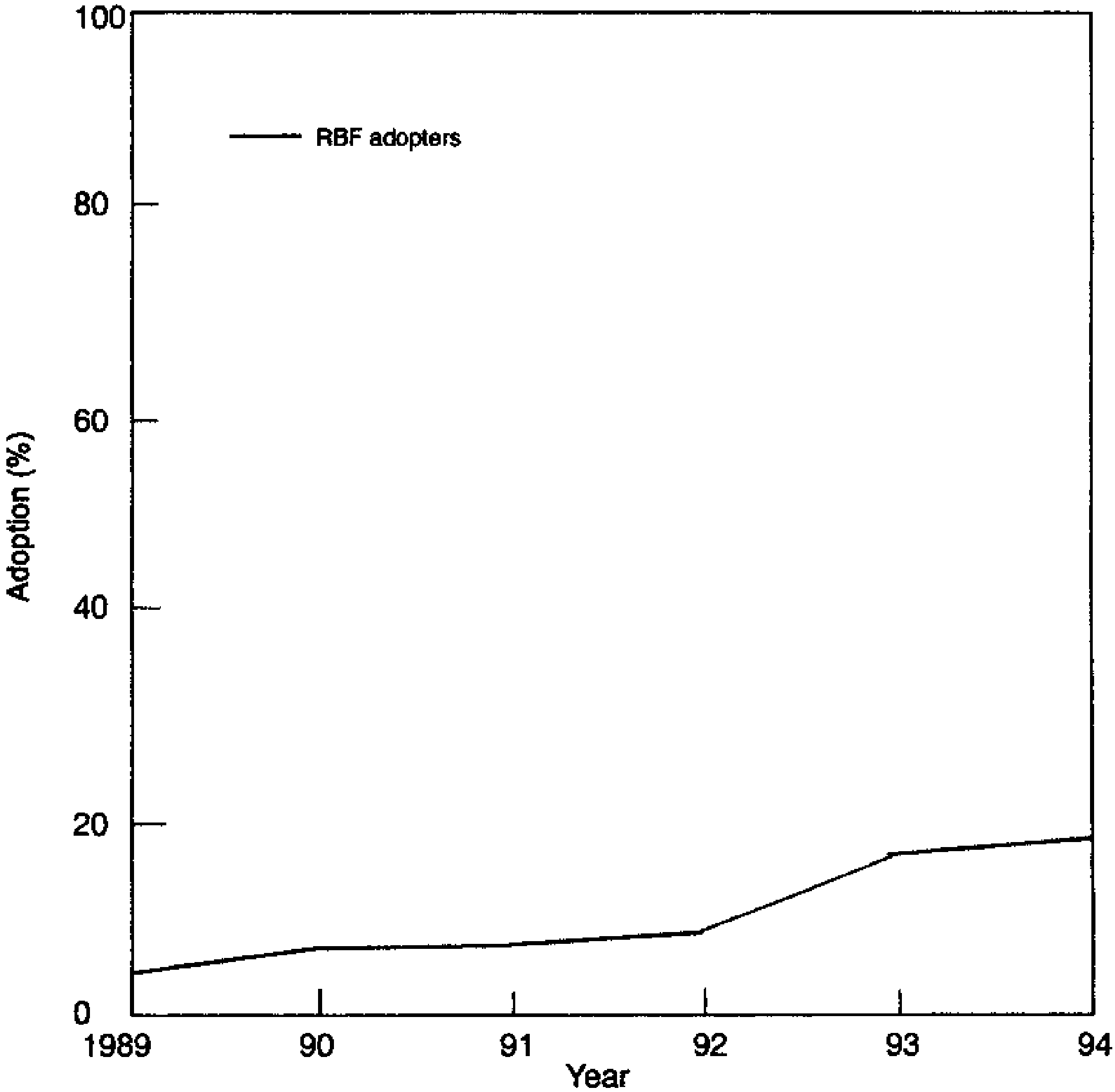


Figure 7. Adoption of ferrous sulphate use by adopters of the raised-bed and furrow (RBF) method.

Table 9; Estimates of the logistic function parameters on adoption of technology components adopted after introducing groundnut production technology (GPT).

Parameter	Zinc sulphate	Ferrous sulphate
K	40.00	18.00
a	-2.7847**[1]	-2.3841*
	(0.5891)[2]	(0.7057)
b	0.7217**	0.8007**
	(0.1113)	(0.1687)
b^1	0.2887	0.1441
r^2	0.8937	0.8492

1. ** = significant at 5% probability level, * = significant at 10% probability level.
2. Figures in parentheses are standard errors of the coefficients.

Table 10. Adoption of improved groundnut varieties (as a percentage of total groundnut area) by sample formers in Maharashtra, India.

Variety	Adopters of RBF	Non-adopters of RBF	All farmers
ICGS 11	12.71	6.34	8.35
ICGS 21	38.76	2.56	14.93
ICGS 44	8.57	0	2.93
ICGS 76	5.14	0	1.76
TAG 24	8.78	0	3.00
JL 24	3.43	10.34	7.98
SB 11	22.27	66.07	51.10
Other local varieties	0.84	14.69	9.95

practiced the raised-bed and furrow. It may be noted that zinc sulphate and ferrous sulphate were also applied to other crops, most importantly, rice.

Ammonium sulphate was not applied by any of the sample farmers because of its high prices, and its relative non-availability in the market.

Improved varieties. Among all the technology options, prior to 1989, improved varieties were adopted the earliest (1976) even before the introduction of the GPT. Adoption of improved varieties was about 48% in 1989, reaching a level of 83% in 1994. The adoption rate of improved varieties was highest among all the components of GPT. The adjusted rate of adoption of improved varieties was higher for those practicing the RBF method (Table 7 and Figure 8). There was a significant difference in the adoption of

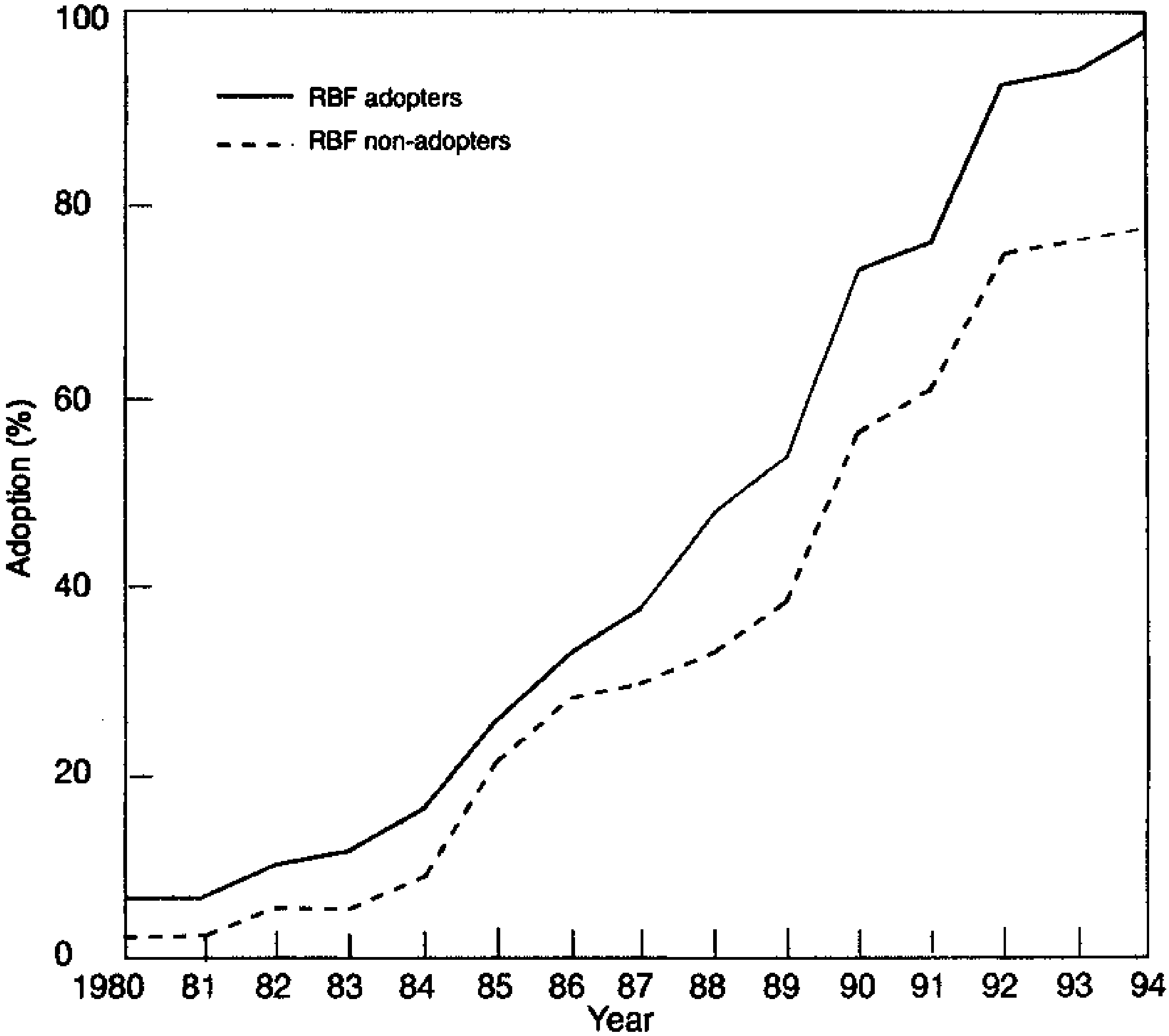


Figure 8. Adoption of improved groundnut varieties by adopters and non-adopters of the raised-bed and furrow (RBF) method.

improved varieties between adopters and non-adopters of the RBF method. A higher rate of adoption of improved varieties was observed after GPT introduction among adopters of the RBF method; the accelerated adoption of improved varieties may be attributed to the dissemination of information on GPT.

SB 11, a variety released in the mid-1970s, still dominates the groundnut area in Maharashtra. ICGS 21 and ICGS 11 have also gained prominence among varieties released during the 1980s and early 1990s. There was a distinct difference in the adoption of improved varieties by adopters and non-adopters of the RBF method. As many as 68% of the farmers who adopted the RBF method have sown new varieties (e.g., ICGS 11, ICGS 21, ICGS 44, ICGS 76, and TAG 24) in about 73% of the area (Table 10). TAG 24 is at an early stage of adoption and is expected to cover a large area because of its high yield potential and other physiological benefits. Among farmers who did not adopt the RBF method, only 8% had sown improved varieties on 9% of the total groundnut area. In the same group, SB 11 is grown by about 62% farmers on 66% of the area. Non-availability of seed of new varieties was reported to be one of the important constraints to their adoption. There is also a general belief among farmers that only new varieties yield better under RBF method of cultivation. Adoption behavior for improved varieties appears to be linked to farmers' perceptions of constraints to adoption of the RBF method.

Seed treatment and pest/disease management. Seed treatment has been practiced since 1981. Its adoption picked up after 1990 when it was applied in about 6% of the groundnut-growing area. It may be noted that it took 8 years for the seed treatment to be adopted in about 6% of the groundnut area before it was a part of the GPT package, but only 4 years to extend to another 30% of the area after it became a part of the GPT package. Its use was higher (Rs 36 ha^{-1}) in the RBF adopter category than among non-adopters (Rs 17 ha^{-1}).

Among RBF adopters, farmers owning more than 10 ha of land incurred the highest expenses (Rs 238 ha^{-1}) for pesticides and disease management. The corresponding expenses by the non-adopters of the RBF concept amounted to only Rs 86 ha^{-1}. The average pesticide use among RBF adopters was significantly higher (Rs 166 ha^{-1}) than among non-adopters (Rs 59 ha^{-1}). With the increasing incidence of pests and diseases, this area receives more attention from both farmers and Government. Potentially, 60% of the area can be covered by pest management, as the T&V Program has given it high priority under their Integrated Pest Management Program.

Other components. Harvesting at 65-70% pod maturity, and using the sprinkler method of irrigation are components yet to be adopted by the majority of groundnut cultivators. The former component was adopted by 10% of the farmers, while the latter by only 4%. Since the Government of India now offers a subsidy (ranging from 25-50%) on sprinkler sets, their wide-scale adoption is imminent.

Present and potential adoption of GPT

The results obtained from the sample survey were used to extrapolate the present and potential adoption of different components of the GPT (Table 11). Conservative estimates indicate that about 47 048 ha of the groundnut area in the country could be cultivated using the RBF method of land configuration during the summer season. The adoption ceiling of this component is assessed at 40% of the groundnut area during the summer season. At this ceiling level, the potential adoption of the raised-bed and furrow method may reach about 60 512 ha.

Table 11. Estimates of extent of adoption (ha) of different groundnut production technology (GPT) components.

Technology component	Present status	Potential
Raised-bed and furrow (RBF)	47 048	60 512
Improved varieties	126 872	136 152
Single super phosphate	104 232	113 460
Zinc sulphate	21 179	30 256
Ferrous sulphate	9 077	15 128
Gypsum	63 235	68 076

Extrapolating the adoption indicators for macro- and micro-nutrients, it was estimated that an area of about 104 232 ha might be receiving single super phosphate for groundnut during the summer season. This may extend to a little over 113 460 ha by the year 2000. For gypsum application, it was estimated at 63 235 ha, zinc sulphate at 21 179 ha, and ferrous sulphate at 9 077 ha. Their potential adoption for summer groundnut is expected to be about 68 076 ha for gypsum, 30 256 ha for zinc sulphate, and 15 128 ha for ferrous sulphate. Similarly, improved varieties could cover an area of about 126 872 ha during the summer season. These might ultimately cover about 90% of the summer groundnut area to occupy about 136 152 ha.

Factors influencing adoption of GPT

The findings described in the earlier section indicate that different technology components of GPT are adopted in a phased manner. Farmers follow a rational, step-wise process of adopting improved varieties, nutrient management, soil management, and other components of the package depending upon: (i) information about the technology, (ii) niches for the technology, (iii) availability of necessary resources or inputs, (iv) marginal returns on the technology, (v) risks, and (vi) suitability of technology traits. It is important to understand the role of these factors in the decision to adopt a specific technology. The analysis helps to assess the need to design appropriate strategies for technology development, technology transfer, and facilitating required resources or inputs.

Probit functions were estimated to determine factors influencing the adoption of RBF. The results are presented in Table 12. A coefficient of determination (R^2) of 71% is noted. Table 12 clearly shows that availability of capital, implements, irrigation facilities, technology traits, information about technology, and soil type are important factors influencing adoption of the RBF method for groundnut cultivation.

Table 12. Estimated probit functions to determine factors influencing adoption of groundnut production technology (GPT), 1994.

Variable	Function 1[1]	Function 2[1]
Soil type	-1.8465**	
	(0.8456)	—
Operated area (ha)	0.0550	0.0282
	(0.0570)	(0.0599)
Irrigated area (%)	0.0276**	0.0237**
	(0.0114)	(0.0106)
Information	1.9581*	2.0235*
	(1.2043)	(1.1155)
Capital	0.0095***	0.0091***
	(0.0029)	(0.0026)
Labor	-0.5424	-0.6280
	(0.5494)	(0.5078)
Implement	2.5325***	1.6943**
	(0.8998)	(0.7005)
Technology trait	-1.4526***	-1.2271***
	(0.4550)	(0.3786)
Constant	-10.503***	-10.723***
	(3.1875)	(2.9358)
R^2	0.7106	0.6690

1.*** = significant at 1 %, ** = significant at 5 %, and * = significant at 10 % probability levels.

In terms of resource availability, capital, implements, and irrigation have the expected positive effect on the probability of adoption of the RBF method. An implement, known as the wheeled tool carrier, was designed to make broadbed and furrows for groundnut cultivation. It was observed that the draft power of the implement could not be successfully used. It was possible to reduce the width of the bed by using a 'marker' or 'bed-former' developed by a local manufacturer. However, this new implement was also not easily available to the farmers. Those who had access to this implement adopted the RBF method of cultivation.

The results show that the availability of more resources to spend on inputs increases the probability of adoption of RBF. Availability of irrigation is also an important factor determining RBF adoption. The RBF improves irrigation-use efficiency, and helps conserve soil moisture for longer periods.

Technology is a highly significant (1%) factor. Difficulty in making the RBFs was the most important critical determinant of adoption. In the absence of appropriate implements the beds are neither formed nor managed properly. There is a need to design cost-effective implements to make beds that meet the farmers' requirements.

Adequate information about the technology is also an important factor in the adoption process. As anticipated, information about the technology has a positive effect on adoption of the RBF. It was found that farmers who adopted the technology had better contacts with research and extension organizations, and mass media (Table 13). This is an

Table 13. Farmers' sources of information about groundnut production technology (GPT) (percentage of sample farmers).

Sources of information	Adopters	Non-adopters
Contacts with extension agencies	52	18
Contacts with research organizations	80	63
Farmers' days	92	94
Agricultural programs on TV	76	55
Agricultural programs on radio	56	28
Agricultural columns in daily paper	24	14
Agricultural magazine	44	32
Visits to agricultural agencies	64	23
T&V Program membership	96	45

indication that exposure to outside information through different sources greatly increases the probability of adoption of the RBF.

Soil type was also found to be significant, indicating that the RBF method was largely adopted by farmers growing groundnut on light to medium black soil Adoption of the technology may be difficult in black and deep black soils in the absence of appropriate implements to work the soil.

These results have clear implications for technology design, technology transfer, and institutional arrangements.

For extension agencies, the message is to create a better information network and develop mass media programs about the technology. While the RBF is already included in the extension agenda of the T&V Program, there is a need to convince more farmers about the positive gains from the technology and its various components. To meet this, large-scale demonstrations and wide mass media coverage are essential.

Research organizations must design a cost-effective technology that suits the requirements of the farmers. Research efforts should be directed more aggressively to design suitable implements that require minimal efforts to maintain the RBFs.

For banks and input delivery systems, the recommendation is to develop a system of delivering required inputs to those willing to adopt the improved technology. It is expected that there might be credit requirements for the purchase of sprinkler systems for irrigation, and implements for making RBFs.

Farm-level benefits of the GPT

Substantial on-farm benefits were realized by those farmers who adopted the GPT. These benefits include yield gains, higher income, better output prices, cost saving, and conservation of soil and water resources. These are discussed below:

Yield gains. The contribution of the improved technology to enhanced crop yields is an important impact indicator that attracts farm producers. A technology is often preferred if the potential yields using the improved technology are higher than that of the existing technology with the same level of resources. GPT leads to higher yield potential than the traditional practices. This was confirmed by on-station and on-farm trials conducted in different agroclimatic regions of India. Pawar et al. (1993) reported a 60.3% yield gain during 1987-90 summer seasons in 58 on-farm trials conducted in different regions in India. Yield gain was most impressive in Maharashtra where it rose from 1.74 t ha^{-1} with local practices to 3.49 t ha^{-1} with GPT, an increase of about 100%.

Table 14. Yield (t ha^{-1}) of different groundnut varieties obtained by adopters and non-adopters of the groundnut production technology (GPT).

Variety	Adopters	Non-adopters	Change (%)	t values[1]
ICGS 11	2.13	1.27	67.96	2.98***
ICGS 21	2.26	1.21	85.85	6.00***
SB 11	2.07	1.62	56.70	6.08***
JL 24	2.03	1.69	20.12	10.21***
All varieties	2.20	1.60	37.73	10.28**

1 *** = significant at 1 % probability level, ** = significant at 5 % probability level.

In the present study, it was the adopters who obtained higher yields of groundnut than non-adopters. The average groundnut yield of the adopter category was more than 2 t ha^{-1}, an increase of about 38%, in contrast to 1.60 t ha^{-1} of the non-adopter category (Table 14 and Figure 9 and 10). More than 70% of the farmers who adopted the technology obtained groundnut yields of more than 2.5 t ha^{-1}, while only 13% non-adopter farmers achieved this level (Table 15). As many as 97% of the farmers who adopted various components of the technology obtained groundnut yields greater than 1.5 t ha^{-1}, while about 64% non-adopter farmers reached this level. Bhoyar (1992) reported that the yield levels with the GPT ranged from 2.08 t ha^{-1} on light soil to 2.9 t ha^{-1} on medium soil. The corresponding values for the local practices ranged between 1.6 and 2.0 t ha^{-1}.

The performance of recently released groundnut varieties was better when they were cultivated in RBFs. ICGS 44 performed best (2.96 t ha^{-1}) followed by ICGS 76 (2.9 t ha^{-1}),

Table 15. Frequency distribution of farmers' (percentage of sample) yield levels for groundnut production technology (GPT) adopters and non-adopters.

Yield (kg ha^{-1})	Adopters	Non-adopters
< 1500	2.7	29.4
1501-2000	25.3	51.4
2001 - 2500	52.0	12.9
>2500	20.0	0

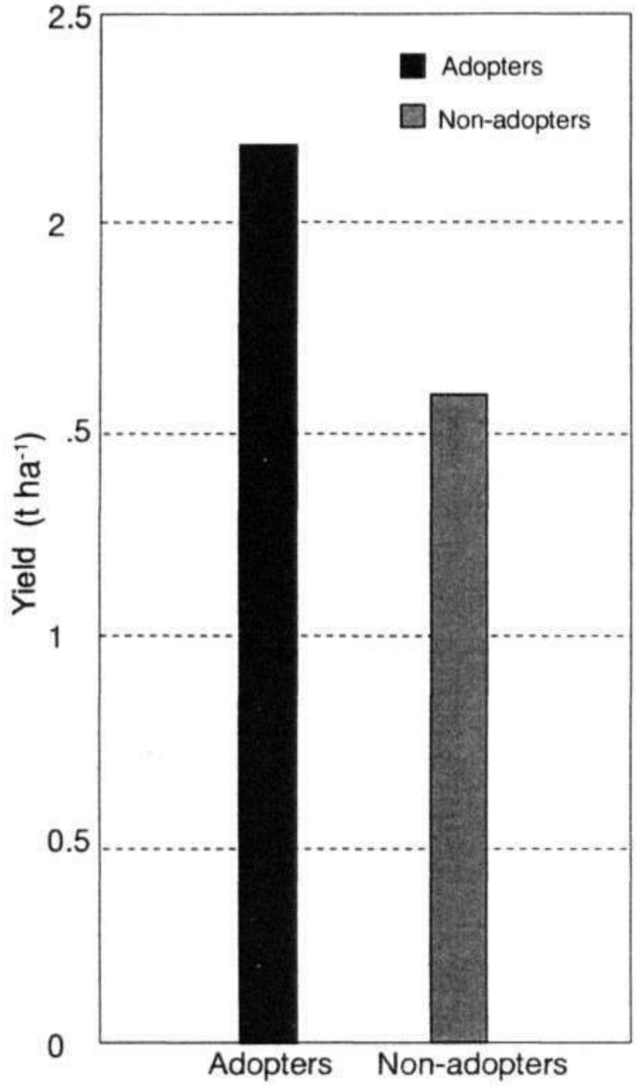


Figure 9. Groundnut yield of adopters and non-adopters of the raised-bed and furrow (RBF) method.

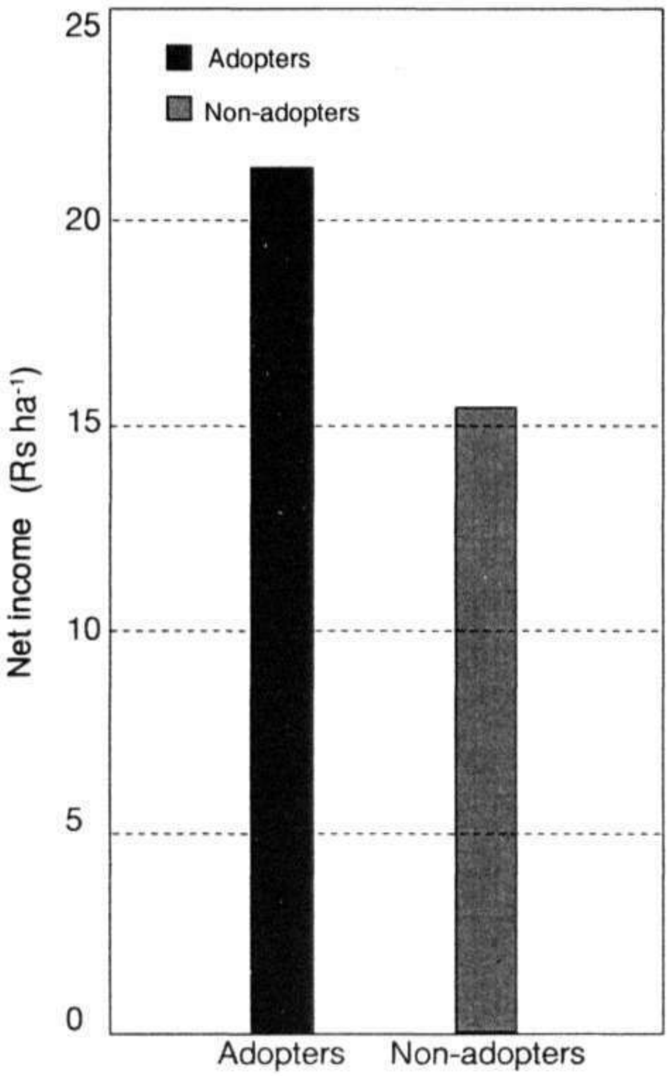


Figure 10. Net income derived from groundnut by adopters and non-adopters of groundnut production technology (GPT).

TAG 24 (2.3 t ha^{-1}), ICGS 21 (2.26 t ha^{-1}), and ICGS 11 (2.13 t ha^{-1}). Among existing popular varieties, JL 24 and SB 11 performed better with the non-adopters of the RBF method. Table 14 shows that yield gain due to the GPT was highest with ICGS 21 (85.8%) followed by ICGS 11 (68%). SB 11 also showed a yield gain of about 57% with the adopters of the RBF method over non-adopters.

According to the sample farmers, improved GPT provided better plant growth, and yielded more fodder. The average fodder yield of the GPT adopter farmers was 1.91 t ha^{-1} while that of non-adopter farmers was 1.78 t ha^{-1}, an increase of about 7.13%.

Income. Groundnut is a cash crop and is produced commercially by farmers. As expected, incomes in the adopter category of farmers were higher than among non-adopters: average income was Rs. 21 470 ha^{-1} for those who adopted the GPT in contrast to Rs. 15 580 ha^{-1} for non-adopters, an additional net gain of about 70% for the adopters. This higher income was generated because of higher groundnut yield and better output prices. It was observed that improved practices helped achieve better pod development and therefore the adopter farmers received a price premium (of about 10%) for the bold grain. More than 50% of the adopter farmers reported that the improved management practices facilitate better pod development.

Increase in yield is the combined result of use of improved varieties and better soil, water, and nutrient management practices, and increased use of certain inputs. The income, according to variety, of adopter and non-adopter farmers was assessed (Table 16). Among adopters of the GPT, ICGS 21 yielded the highest net returns, followed by TAG 24, ICGS 11, SB 11, and JL 24. It was the opposite with non-adopters; JL 24 yielded the highest net income followed by SB 11, ICGS 21, and ICGS 11. This confirms the farmers' belief that new varieties (especially from ICRISAT) perform better with the components of GPT. While the high net income gained from ICGS 21 clearly indicates why farmers in the study area preferred to adopt it rather than other new varieties, SB 11 remains the most popular variety covering 51% of the total groundnut area.

Cost saving. Another important impact of the technical change is saving in cost per unit of production. Pooled results of all varieties indicated that the (variable) cost of production under improved management was Rs. 3.86 kg^{-1} in comparison to Rs. 4.58 kg^{-1} under local practices, a saving of about 15.7% (Table 17 and Figure 11). Analyzing the results

Table 16. Net income (Rs ha^{-1}) of adopters and non-adopters of the groundnut production technology (GPT).

Variety	Adopter	Non-adopter	Change (%)	t values[1]
ICGS 11	16928.47	6243.53	171.17	3.43***
ICGS 21	25389.23	7115.39	256.82	7.88***
SB 11	18107.12	12765.93	41.83	6.19***
JL 24	18066.51	14337.12	26.01	8.23***
All varieties	21465.88	15581.41	70.62	9.46***

1. *** = significant at 1% probability level.

Table 17. Unit cost (Rs kg^{-1}) of groundnut production for different varieties for adopters and non-adopters of the groundnut production technology (GPT).

Variety	Adopters	Non-adopters	Change (%)	t values[1]
ICGS 11	4.33	6.94	37.61	2.82**
ICGS 21	3.87	6.35	39.07	3.38**
SB 11	3.82	4.54	15.84	4.17***
JL 24	3.54	4.04	12.25	2.99***
All varieties	3.86	4.58	15.72	5.42***

1. *** = significant at 1% probability level, ** = significant at 5% probability level.

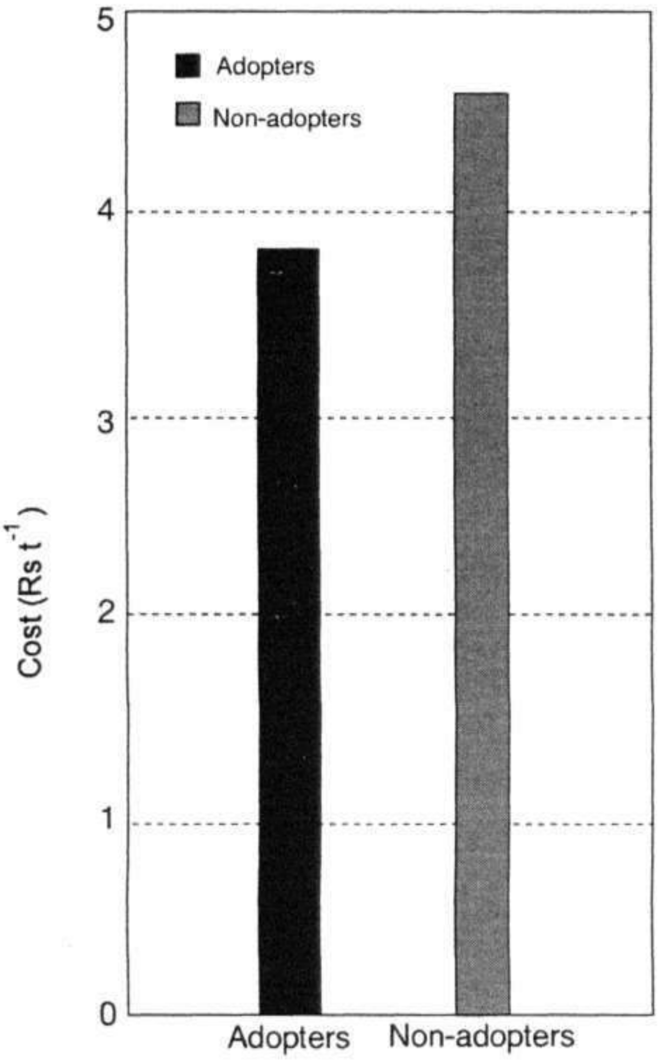


Figure 11. Unit cost (Rs t^{-1}) of groundnut production to adopters and non-adopters of groundnut production technology (GPT).

obtained for each variety, it was observed that saving was highest for ICGS 21 (about 40%). It was about 38% for ICGS 11. The improved package was not so attractive with the existing varieties, namely SB 11 (16%) and JL 24 (12%). The results indicate high complementarity between improved varieties and better land management practices.

Adoption of the GPT also brings about savings on some critical inputs, and increases efficiency in input use. For example, furrow cultivation or the sprinkler method of irrigation save irrigation water and at the same time improve irrigation water-use efficiency. The results also showed that adopter farmers spent about 9 days of labor to produce 1 t of groundnut compared to about 12 days spent by the non-adopter, a saving of about 25%. Water is a critical input in the semi-arid tropics. Saving water and its efficient utilization may facilitate extensive irrigation cover in the semi-arid tropics and contribute to increasing production.

Implications for labor and gender. Labor productivity and gender implications are important impact indicators especially in regions where unemployment and underemployment persist. The overall labor requirement favored GPT adoption. It was about 12% higher with the improved technology option than with the existing local practices (Figure 12). Both male and female labor use was higher in the adopter category of sample farmers. Average productivity of labor (calculated as the total groundnut production divided by the total labor used) was also computed for adopters and non-adopters of GPT (Figure 12). It was observed that labor productivity was 22% higher in the adopter category. In terms of labor used for groundnut production, those who adopted different GPT components used about 12% more labor than the non-adopters. These observations clearly reveal that GPT options: (i) increase labor use, and (ii) generate on-farm employment opportunities in the groundnut-producing regions.

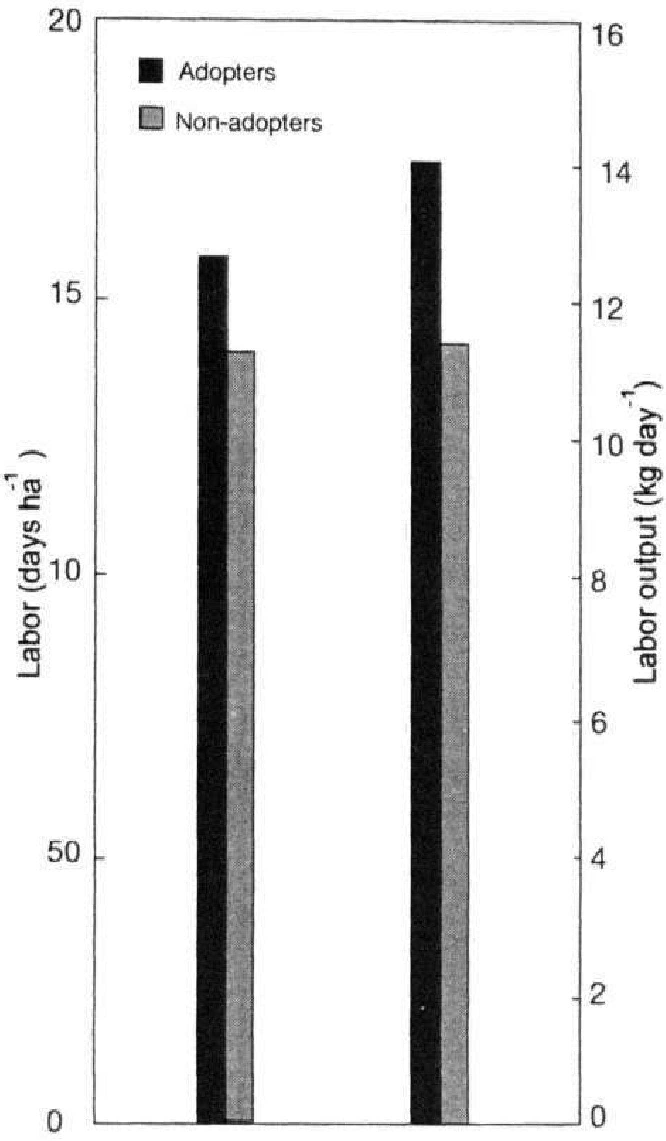


Figure 12. Labor productivity (days ha"[1] and kg day[1]) of adopters and non-adopters of groundnut production technology (GPT).

The RBF component of the GPT was designed and advocated to ease certain agricultural operations. It was observed that labor-use efficiency improved for such operations as interculture, weeding, irrigation, and harvesting for those who adopted the improved package (Table 18). Labor use per unit of output was lower for those who adopted the GPT. This ranged from 19% for harvesting to 23% for weeding, and 25% for irrigation. Most weeding and harvesting operations are traditionally performed by the female labor force. Almost all weeding and about 90-93% of harvesting were done by women in both adopter and non-adopter categories. Less exertion and lower labor re-

Table 18. Labor use (days t^{-1} of groundnut) for weeding, irrigation and harvesting by adopters and non-adopters of the groundnut production technology (GPT).

Operation	Adopters	Non-adopters	Change (%)
Weeding	16.35	21.28	-23.16
Irrigation	8.90	11.83	-24.77
Harvesting	23.08	28.68	-19.52

quirement, especially by female family members, will have implications for gender-related issues. These may include issues of health, child development, and engagement in more productive activities. These gender implications require further attention. Though gender analysis of groundnut technology innovation (Ramadevi Kolli and Bantilan 1997) was not included in this study, it has helped focus attention on the gender research at ICRISAT.

Spillover effects. The assessment of spillover effects is considered important in the research evaluation literature (Bantilan and Davis 1991). Most resource and input-based technologies are relevant to several commodities. Evenson (1989) reported that pre-technology science findings may spillover across commodities because they enhance invention potential in several commodity technology programs. The GPT options were observed to be applicable beyond the commodity for which the technology was developed. In the present analysis, questions were posed to the sample farmers if they were adopting the RBF method for crops other than groundnut. It was found that the RBF method was not confined to groundnut (Table 19). It also found applicability in the cultivation of such other crops as chickpea, chilies, soybean, pigeonpea, sunflower, mustard, and some vegetables. In our sample, 23% farmers applied the RBF method to different crops — chickpea (13%), chilies (6%), pigeonpea (2%), and such other crops as sunflower, soybean, and vegetables (2%). An increasing trend in adoption of the RBF method was reported in chickpea and soybean. Farmers reported 15-45% yield gain in chickpea, and 15% in sunflower. Similarly, application of micro-nutrients in some important crops was also becoming popular in regions where farmers had learnt about the GPT package.

Table 19. Percentage of groundnut farmers adopting the raised-bed and furrow (RBF) method in other crops.

Crop	Adopters (%)
Chickpea	13
Chilies	6
Pigeonpea	2
Other crops	2
Total	23

Sustainability issues. The study investigated the impact of the RBF method of land management on the sustainability of soil and water resources. Farmers were questioned about how they perceived the benefits of the RBF on soil and moisture conservation. 75% of the farmers reported that the RBF method of land configuration improved the moisture conservation of the soil (Table 20). An equal number perceived the benefit of RBF in improving the drainage of excess water. Input saving is another benefit seen, that is reflected in unit cost reduction of the GPT.

Table 20. Farmers' perceptions of sustainability indicators for the raised-bed and furrow (RBF) method of land configuration for crop production.

Sustainability indicator	Farmers (%)
Improves moisture conservation	75
Improves drainage of excess water	75
Saves nutrients and water	28

Economic surplus and distribution of welfare gains

Research and technology transfer cost

As stated earlier, the research leading to the design of the RBF system began in 1974 at ICRISAT and was assumed to continue until 1986. NARS were also involved in technology packaging and conducting on-station and on-farm trials. Since the exact cost of research and technology transfer was not available, it was estimated at three levels: (i) ICRISAT, (ii) NARS, and (iii) technology transfer system of the state Department of Agriculture/None of these institutions maintained cost data on research and technology transfer. However, since 1994, ICRISAT has been maintaining records of the research budget of each project.

The research and technology transfer activities related to GPT at ICRISAT were implemented *in* four erstwhile programs: (i) Groundnut Improvement Program, (ii) Farming Systems Program, (iii) Resource Management Program, and (iv) LEGOFTEN. While the first three programs were largely involved in developing the technology, the fourth program dealt with the packaging of various crop and resource management practices, their on-farm testing, and large-scale demonstrations on farmers' fields.

The estimated cost of research and technology transfer for each component is given in Table 21. The salary of the research team, operational expenses, and overhead costs were estimated in consultation with scientists and by using historical evidence. Using the annual salary of each member of the research team, weighted by proportionate time in the particular research activity, the annual cost of the salary component was estimated at US$ 34 900. The operational expenses to conduct research were assumed to be 35% of the salary component based upon past experience and estimated at US$ 12 215. As

Table 21. Annual research and technology transfer cost (US $) of groundnut production technology (GPT).

Component	Year	Cost (US 8)
Research		
Salary	1974-86	34 900
Operations	1974-86	12 215
Overheads	1974-86	47 115
NARS	1974-91	9 500
Technology transfer		
Packaging/on-farm trials	1987	24 000
On-farm trials	1988-90	20 000
On-farm trials	1991	10 000
State expenses	1992-2000	7 500

stated earlier, the overhead cost was considered to be half of the total cost. Accordingly, it was calculated to be US$ 47 115. Aggregating these three cost components, the total annual research cost of developing the technology at ICRISAT was US$ 94 230. This cost was apportioned into three crops, as the technology components were similar for groundnut, pigeonpea, and chickpea. Research costs were allocated to each crop based on the proportionate area grown. Adopting this criterion, the annual research cost for GPT was calculated at US$ 45 600. Annual cost of NARS for their participation in packaging the technology was considered to be 10%, i.e., US$ 4 560.

The technology packaging and its transfer started from 1987 through a program known as LEGOFTEN. The initial budget for this program (1987 and 1988) was met through ICRISAT's core funds, and later (1989 to 1991) through financial assistance from the International Fund for Agricultural Development (IFAD) under a special project entitled 'On-Farm Research on Groundnut, Pigeonpea, and Chickpea, and Transfer of Technology to the Semi-Arid Tropics in India*. The program was responsible for three crops, groundnut, pigeonpea, and chickpea. In the first year when different components of technology were integrated, the cost of GPT (US$ 24 000) was computed on the basis of the proportionate area under groundnut. In subsequent years, the total budget allocated to LEGOFTEN was distributed (US$ 20 000) to represent the GPT package which was apportioned according to the number of on-farm trials conducted on groundnut. The budget of the State Department of Agriculture for GPT extension activities during the 1987-91 period was also met through the LEGOFTEN program.

The expenses incurred in technology transfer through the State Department of Agriculture during the post-LEGOFTEN period were calculated using the share of groundnut in the total cropped area in the state, as no separate information on resource allocation to each commodity/technology is documented. On the basis of the salary, operations, and overheads, the annual technology transfer cost during the post-LEGOFTEN period was calculated to be US$ 7 500. This cost was considered from 1992 until 2000.

Research and technology transfer benefits

The shift in supply function under different technology options was assumed to be the saving in unit cost of groundnut production by adopting the GPT package instead of the existing practice. The cost reduction was about 37% if the full package was adopted, and 22% if only management practices were followed (Table 22). There was about 100% yield enhancement if the total GPT package was adopted, and about 36% if only the management practices were adopted.

Table 22. Cost of production and yield of groundnut under on-farm trials with different technology options.

Technology components		Yield	Cost	Cost
Management	Variety	(t ha^{-1})	(Rs ha^{-1})	(Rs t^{-1})
Improved	Improved	3.49	6 990	2002.86
Improved	Local	1.97	5 990	3040.61
Local	Improved	2.56	6 570	2566.40
Local	Local	1.74	5 570	3201.15

Source: Adapted from Pawar et al. (1993)

Returns to research on GPT and its transfer are determined by comparing estimates of welfare gains with the investment in research and technology transfer. The economic surplus approach was used to quantify the gains due to the technology. The approach assumed a perfect market economy and a parallel shift in supply function. The estimated adoption rates, ceiling levels, and reduction in unit cost of production were used to derive the stream of benefits from research and technology transfer investment in GPT. The net present value, the internal rate of return, and the benefit-cost ratio were estimated with the following assumptions:

- the ceiling level of technology adoption at 40%, and
- the demand elasticity was considered at 0.5%, while that of the supply at 0.1% (Radhakrishna and Ravi 1990).

Economic surplus was computed under three options:

- full adoption of the GPT,
- adoption of only management practices, and
- adoption of only RBF, with other practices unchanged.

Sensitivity analysis was also performed by increasing the cost of research and technology transfer by 10 and 20%.

Table 23 presents the stream of research and technology transfer costs and the research benefits and estimated net present value, internal rate of return, and benefit-cost ratio under different technology options. The analysis revealed that the internal rate of return of GPT was 25.26% if total package of the GPT is adopted. The net present value of

Table 23. Cost and benefit of research and technology transfer of the full groundnut production technology (GPT) package.

Year	ICRISAT Cost (US$ '000)	NARS Cost (US$ '000)	Benefits: Full package (US$ '000)	Benefits: Mng[1] (US$ '000)	Benefits: RBF[2] (US$ '000)
1974	45.6	4.56	0	0	0
1975	45.6	4.56	0	0	0
1976	45.6	4.56	0	0	0
1977	45.6	4.56	0	0	0
1978	45.6	4.56	0	0	0
1979	45.6	4.56	0	0	0
1980	45.6	4.56	0	0	0
1981	45.6	4.56	0	0	0
1982	45.6	4.56	0	0	0
1983	45.6	4.56	0	0	0
1984	45.6	4.56	0	0	0
1985	45.6	4.56	0	0	0
1986	24.0	4.56	0	0	0
1987	20.0	4.56	0	0	0
1988	20.0	4.56	0	0	0
1989	20.0	4.56	162.57	76.15	36.42
1990	10.0	4.56	460.62	215.75	103.19
1991	0.0	7.50	650.29	304.59	145.68
1992	0.0	7.50	1151.56	539.39	257.97
1993	0.0	7.50	1228.33	575.34	275.17
1994	0.0	7.50	1404.45	657.84	314.63
1995	0.0	7.50	1580.57	740.33	354.08
1996	0.0	7.50	1670.89	782.64	374.31
1997	0.0	7.50	1761.21	824.94	394.54
1998	0.0	7.50	1806.37	846.09	404.66
1999	0.0	7.50	1806.37	846.09	404.66
2000	0.0	7.50	1806.37	846.09	404.66
2001	0.0	0.00	1806.37	846.09	404.66
2002	0.0	0.00	1806.37	846.09	404.66
2003	0.0	0.00	1806.37	846.09	404.66
2004	0.0	0.00	1806.37	846.09	404.66
2005	0.0	0.00	1806.37	846.09	404.66
Internal rate of return, IRR (%)			25.26	19.15	13.50
Net present value (US$ '000)			3452.94	1389.06	453.45
Benefit-cost ratio			9.37	4.39	2.10

1. Mng = management practices only. 2. RBF = raised-bed and furrow only.

information from the research and technology transfer program on GPT was estimated to be US$ 3.45 million. The benefit-cost ratio was 9.37, which means that every US$ 1 invested in developing and disseminating GPT produced an average benefit of US$ 9.37 throughout the period.

When only management practices (including RBF, nutrient management, plant protection measures, etc.) were adopted, the internal rate of return (IRR) was 19.15%. The net present value was about US$ 1.4 million with a benefit-cost ratio of 4.39. The rate of return was low (13.5%) when RBF alone was compared with the flat method of cultivation. This shows high complementarity between different management practices, especially with RBF. These results confirm farmers' perceptions that RBF yields higher returns if adopted along with other technology components, including improved varieties. The IRR under farmers' partial adoption level was 21.1%. These results clearly reveal that the research and technology transfer investments on GPT package yielded positive returns. It was noted that even when the components of GPT were partially adopted, the research and technology transfer investments were justified.

Since the research and technology transfer costs incurred by ICRISAT, NARS, and the State Departments of Agriculture were not actual figures, sensitivity analysis was carried out by enhancing these cost estimates by 10 and 20%. The results revealed that the IRR is rather insensitive to changes in costs of research and technology transfer (Figure 13). Assuming that the cost of research and technology transfer increases by 20%, the rate of return is lowered by about 6% (from 25.26 to 23.76%) if the full GPT package was adopted. In another case, when only management practices were adopted, an increase of 20% in research and technology transfer cost lowered the IRR by about 7% (from 19.15 to 18.40%). This shows that even under the severe assumption of raising the cost of research and technology transfer by 20%, the IRR did not significantly change. Sensitivity analysis was also done by increasing the NARS research cost by 10 and 20% as correct information was not available. It was observed that there was no significant decline in the internal rate of return as the research cost increased by 20%. The rate of return declined from 25.26% to 25.11% in the case of the full package; from 19.15 to 19.00% for management practices; and 13.5 to 13.34% for RBF.

It was stated earlier that a number of farmers were unaware of the different components of the technology. Extension efforts may play an important role in popularizing the technology. It was therefore assumed that if the investment in technology transfer of GPT increased by 25%, shifting the ceiling level to 50%, the additional

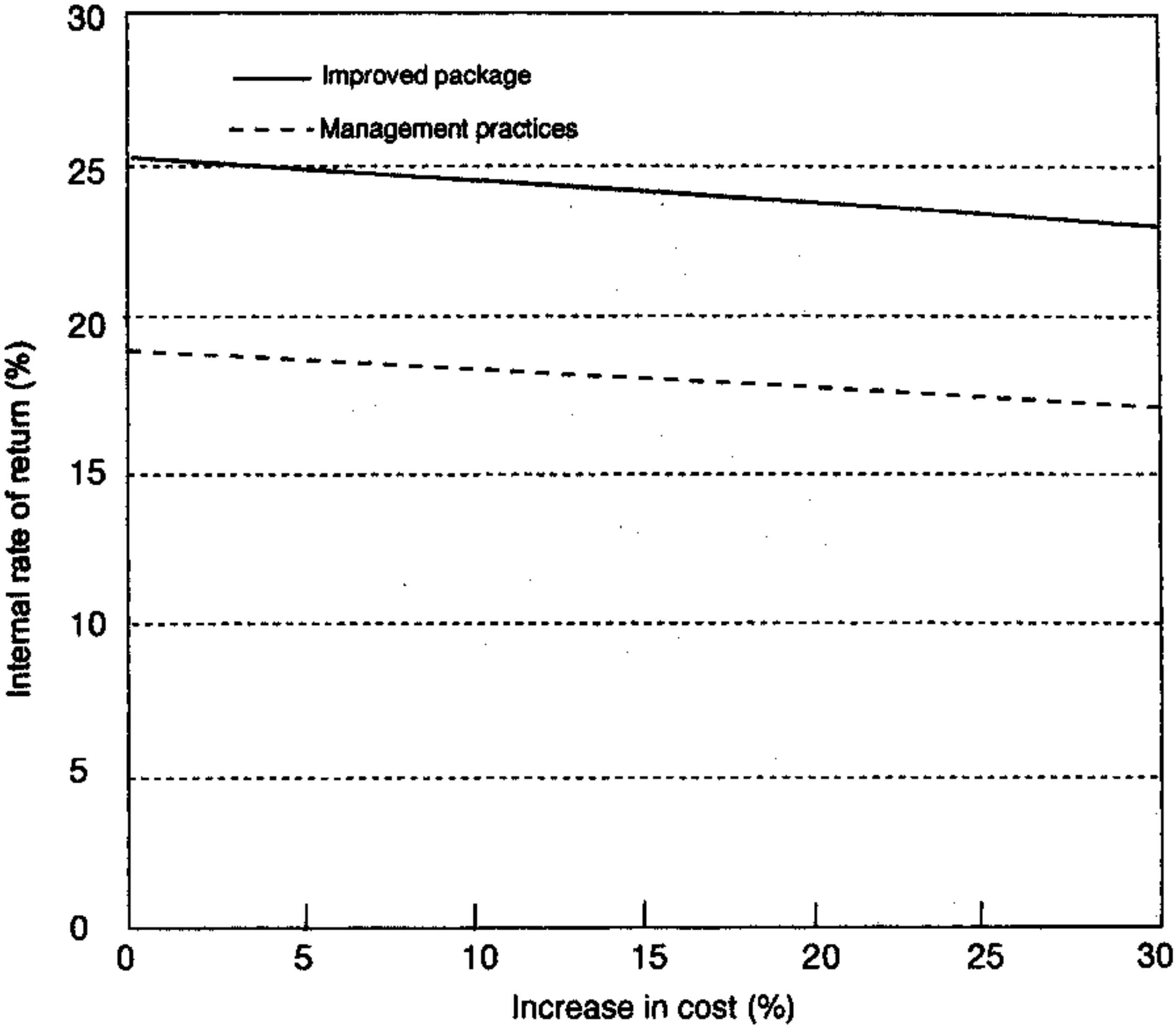


Figure 13. Internal rate of return (IRR) with change in groundnut production technology (GPT) research and technology transfer cost.

gains were estimated to be about US$ 270 260. If the ceiling level further increases to 60%, the additional gains were estimated to be US$ 440 180. This would support the investment on technology transfer of GPT, which in turn increases its popularity among farmers.

The distribution of welfare gains between farmers and consumers is shown in Figure 14. The distribution of economic surplus to producers and consumers clearly showed that producers were the primary beneficiaries of the GPT. Their share in the total gain was about 84%. This calls for increased adoption of the improved technology by a wide range of farmers.

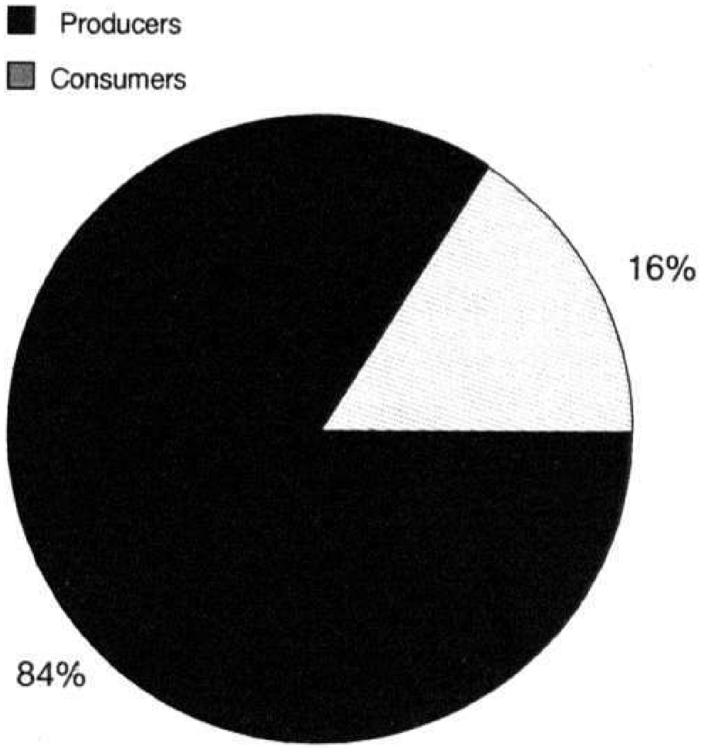


Figure 14. Groundnut production technology (GPT) and distribution of welfare gains.

Summary and conclusions

Earlier studies measuring returns to investment in agricultural research and technology transfer were mostly restricted to genetic enhancement of various commodities. Adoption assessment and evaluation of returns to investment on crop and resource management research were practically ignored., although this area of research shares a significant proportion of total research investments. To justify future financial support on a sustainable basis, it is important to continuously monitor and evaluate the impact of research investment in this area.

This study is concerned with (a) adoption tracking of different crop and resource management options; and (b) estimation of research cost and evaluation of research benefits. A specific case, the groundnut production technology (GPT), was taken for the study. GPT is an integrated technology package put together at ICRISAT based on a review of all the available information, and after carefully identifying the constraints in major groundnut-producing regions. Important components of the GPT are grouped as: (i) land management: making RBF for groundnut cultivation, (ii) macro- and micro-nutrient management, (iii) improved varieties, (iv) insect, disease, and weed management;

and (v) water management. The technology was initially tested in eight states of India, but it was found mainly suited to Maharashtra state. 355 farmers in Maharashtra were randomly selected for the study following a multi-stage stratified random sampling technique. Relevant information was collected from the selected farmers using a structured questionnaire; interviews were conducted between late 1994 and mid-1995 to track the adoption of different GPT components.

To quantify the returns to investment on research and technology transfer, three aspects were examined: (i) adoption rates and the spread of different components of GPT, (ii) research and technology transfer cost, and (iii) benefits from the research and technology transfer program. Logistic growth functions were estimated to describe the rate of adoption of each component of the GPT. Economic surplus and distribution of welfare gains due to investment in the research and technology transfer program were estimated by assuming a parallel shift in supply function. Internal rates of return, net present values and benefit-cost ratios were computed under three options: (i) full adoption of the GPT package, (ii) adoption of only management practices, and (iii) adoption of only RBF with other practices remaining the same. Sensitivity analysis was also carried out under various assumptions related to changes in research and technology transfer investment.

The study found that farmers partially adopted the concept of crop and resource management research products, and modified the technology options according to their needs, convenience, and resource endowments. Differential adoption of various components of the technology was observed. About 31% of the summer season groundnut in the study area was assessed under RBF. The adoption rates for improved varieties was about 84% and for single super phosphate was about 70%. Farmers who cultivated groundnut on RBFs also adopted ICRISAT groundnut varieties in about 65% of the groundnut area. In contrast, those who did not adopt the RBF method, had sown ICRISAT varieties on less than 10% of the groundnut area. Gypsum and seed dressing are becoming popular and their adoption reached slightly above 40%. The use of ferrous sulphate and sprinkler irrigation were in the early stages of adoption. It was noted that the adoption of different components was associated largely with the RBF method, with adoption of all components being significantly higher among those who had adopted this method. The probability of adopting the RBF was high when farmers had access to technology-generating and technology-transfer systems. Availability of appropriate implements, capital, and irrigation also determined the adoption of the RBF technology option.

At farm level, benefits were realized in terms of yield gains (38%), higher income (71%), and efficient utilization of inputs. Benefits related to gender and sustainability issues were also realized by farmers who adopted components of the GPT. The technology helped generate employment and improve labor productivity. There were also some positive implications for gender and sustainability issues.

At an aggregate level, the benefits from the GPT were higher than the costs in terms of investment on research, packaging, and technology transfer. The IRR on GPT was 25.26% if the total package was adopted. It was 19.15% when only management practices, including RBF, nutrients, etc., were adopted. The IRR was only 13.5% if only RBF was practiced. The distribution of economic surplus to producers and consumers showed that producers were the primary beneficiaries of the GPT, sharing about 84% of the total benefits.

The following conclusions may be made on the basis of the above discussion:

Partial and modified adoption. Different components of the GPT were partially adopted and modified by farmers. A key component, i.e., the RBF method of cultivation, was becoming popular amongst farmers. The level of adoption of improved varieties and use of macro- and micro-nutrients was impressive. Other components, especially the sprinkler method of irrigation and use of ferrous sulphate, need better market access for their adoption. The Government of India is already extending a subsidy (ranging between 25-50%) on purchase of sprinkler sets. It is expected that in years to come the sprinkler method of irrigation will be more popular and widely adopted.

Positive on-farm benefits. Adoption of the technology had a positive impact in terms of higher grain yield and income, better grain prices, saving of important inputs, including irrigation and labor (particularly for the female labor force) for some tedious operations. The technology generates employment and also improves labor productivity. The GPT has significant implications for issues related to gender and sustainability.

Modest economic surplus. Investment on research and extension on GPT, studied under different options, revealed that it was paying modest dividends. It generated a surplus for consumers and producers, with the latter being the primary beneficiaries.

Research on developing appropriate implements. In view of the high cost of the implements available to make RBFs, it is important to allocate resources for the design of cost-effective technology which suits the farmers' requirements. There is a need for a well-designed suitable implements that will facilitate easy maintenance of the RBFs.

Need for technology dissemination. Additional investment in technology transfer activities of GPT will be rewarding, particularly in the Vertisol region. It is necessary to conduct large-scale demonstrations and give wide mass media coverage. This should be done after the technology transfer target areas have been carefully identified.

Follow-up action. It was observed that there was no follow-up activity on the GPT after the LEGOFTEN program concluded in all regions except Maharashtra state. There is a need to follow up GPT dissemination in areas where the technology yields better results.

Identify constraints. It would be worth assessing constraints to adoption of different components of the GPT, particularly of RBF, to propose an appropriate strategy for the wide-scale adoption of the technology. Such a study could reveal whether adoption was limited by lack of necessary inputs and implements or by the wrong choice of target regions.

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The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

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