An Economic Assessment of the Potential Benefits of Breeding for Drought Tolerance in Crops:

A Case of Groundnut in India

Research Bulletin no. 25

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Abstract

This report provides estimates of the potential benefits from the adoption of an improved drought-tolerant groundnut variety ICGV 91114 in Anantapur district of Andhra Pradesh (India), one of the most chronically drought-prone districts known for its groundnut production. Groundnut area in the district ranges between 0.8 and 1.0 milllion ha and variety TMV 2 , which was released 70 years ago, continues to dominate. A new drought-tolerant groundnut variety ICGV 91114, developed by ICRISAT, was found a suitable alternative to TMV 2 through farmer-participatory varietal selection trials. At the farm level, adoption of ICGV 91114 has a pod yield advantage of 23%, reduces yield variability by 30% and generates 36% higher net income compared to TMV 2. Its adoption in 35% of the 0.8 million ha under groundnut in Anantapur by 2020-21 is likely to generate a surplus of Rs 694 million a year; of which 65% would accrue due to higher yield and 35% due to reduction in yield variability. Despite a reduction in yield advantage (30%) and variance, the benefits remain huge. Small farmers being more risk averse than other farmers, they can benefit more from the adoption of improved drought-tolerant varieties. These benefits are illustrative and a widespread adoption of drought-tolerant varieties in the dryland tropics is likely to reduce farmers' vulnerability to climatic shocks. The need is to reorient the research and extension agenda with adequate focus on generation and dissemination of climate-resilient crop varieties.

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Executive Summary

Extreme climatic events such as drought and flood always pose a significant threat to agricultural production and consequently to the livelihood of people directly or indirectly dependent on agriculture. The threat is more pronounced in developing countries dominated by smallholders who cultivate small pieces of land and maintain a few animals to eke out their subsistence. If farmers were to successfully adapt to such climatic changes, they would need to have access to and grow crops and crop varieties that can withstand the pressures of changing rainfall patterns and rising temperature, besides improving the resilience of agro-ecosystems by applying appropriate agronomic and management practices.

Over the past several years, there has been an increasing recognition in both international and national agricultural research of the potential adverse effects of climate change on agricultural production, and the need to develop and disseminate climate resilient crop varieties. Notable progress has been made in crop breeding research for drought tolerance in crops like maize, rice and grain legumes (chickpea, groundnut and beans). A few cultivars of these crops are already being grown in farmers' fields.

This paper provides estimates of the potential economic benefits of the adoption of an improved drought-tolerant groundnut variety ICGV 91114 in Anantapur district of Andhra Pradesh (India), one of the most drought-prone districts in peninsular India, and which is also renowned for its groundnut production. Annual precipitation in the district is about 500 mm, and every third year is a drought year. Depending on the sowing period rainfall, groundnut is grown on 0.8 million–1.0 million ha, which is more than three-fourths of the district's total cropped area, and 12–15% of India's total groundnut area. Groundnut yield in the district is, however, low and has rarely exceeded 1.0 t ha^{-1}. Yield variability, as measured by the coefficient of variation, is high and has increased considerably, from 27% during 1965–66 to 1985–86 to 43% during 1986–87 to 2007–08. Likewise, the probability of yield falling short by 20% or more below the trend increased from 23% during 1965–66 to 1985–86 to 32% during 1986–87 to 2007–08.

Groundnut variety ICGV 91114 was developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and was introduced in Anantapur in 2002 through farmer-participatory varietal selection (FPVS) along with 10 other varieties to find a suitable substitute for the traditionally ruling variety TMV 2, which occupies 75–80% of the total groundnut area in the district. Farmers preferred ICGV 91114 over other varieties because of its higher pod and haulm yields, medium-to-large kernels, uniform maturity and its ability to tolerate mid-season and terminal drought. Findings of this study confirm many of these observations from FPVS trials. On farmers' fields, the mean yield (2004–05 to 2008–09) of ICGV 91114 is 23% more than that of TMV 2. Its cost of production per hectare is 17% higher, yet it provides 36% larger net returns per hectare. Switching over to ICGV 91114 can generate additional net returns of ` 3325 ha^{-1}. Moreover, yield variability of ICGV 91114 is also lower by 30% compared to that of TMV 2. These findings clearly bring out ICGV 91114's comparative advantage over TMV 2 in terms of both higher yield and lower risk.

Farm-level economic benefits of adopting ICGV 91114 were scaled-up to its target domain, i.e., Anantapur district. Assuming that the variety would spread over to 35% of the total groundnut area by 2020–21, the annual value of total benefits is estimated at ` 694 million and ` 508 million at a discount rate (r) of 5% and 8%, respectively (Fig. 1). Risk benefits comprise 35% of the total benefits. These results are quite optimistic; hence we simulated these by discounting yield advantage and variance reduction by 30%, i.e. yield advantage of 17% and variance reduction to 21%. Even with these conservative levels of yield advantage and variance reduction, the annual value of total

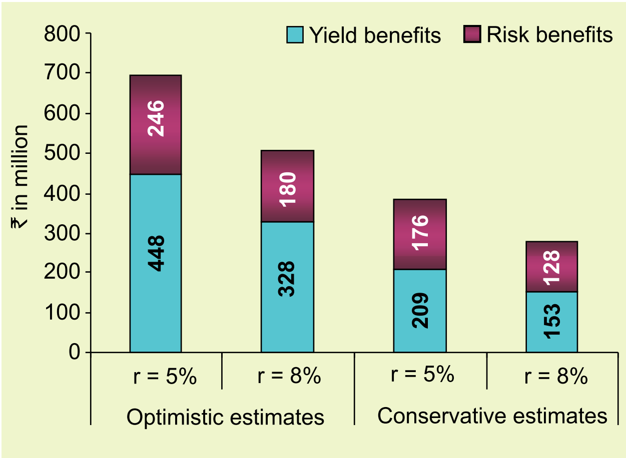

Figure 1. Annual value of yield and risk benefits from the adoption of groundnut variety ICGV 91114 in Anantapur district, Andhra Pradesh, India.

benefits of the adoption of ICGV 91114 remains huge – ` 385 million at a discount rate of 5% and ` 281 million at a discount rate of 8%.

Farmers vary in their risk aversion behavior. Often, small farmers are more risk-averse; hence they benefit more from the adoption of improved drought-tolerant varieties than do the less risk-averse large farmers. At conservative yield advantage (17%) and variance reduction (21%) risk benefits marginally outweigh yield benefits on small farms. ICGV 91114 has been taken as a case to demonstrate benefits of the groundnut breeding for drought tolerance, and these observations hold good for any drought-tolerant groundnut variety having similar yield advantage and variance reduction traits.

Yield and risk benefits of improved drought tolerance in groundnut are clear and compelling, and these reiterate the need for: (i) wider dissemination of available drought-tolerant varieties by strengthening research-extension-policy linkages; (ii) targeting public sector efforts and investment towards multiplication and distribution of seeds of such varieties, especially of crops like groundnut where incentives for private sector participation in the seed business are limited by high seed transportation, storage and distribution costs, low seed multiplication ratio and a low seed to kernel price ratio; (iii) developing informal village-level seed systems to enhance local seed availability; and (iv) prioritization of the agricultural research agenda considering impending changes in climate and their potential impacts on agricultural production and productivity.

1. Introduction

Despite significant technological progress in the last four decades, Indian agriculture remains enslaved to monsoon rains that are often erratic and sub-optimal leading to drought[1] or a drought-like situation in one or another region of the country. Over two-thirds of the country's agricultural land is vulnerable to droughts of various intensities, with the probability of its occurrence being as high as 35% (Bhandari et al. 2007). Such frequent droughts lead to unsustainable livelihoods, especially for the poor landless and small farm households for whom agriculture is an important source of livelihood. Drought affects livelihoods directly by reducing agricultural production and wage opportunities in agriculture, and indirectly through rise in food prices. Bhandari et al. (2007) reported that in the event of a drought in eastern India, rural households experience a 24–58% decline in their income and a 12–33% rise in head-count poverty ratio over a normal agricultural year.

A significant fall in food production triggers food inflation. Since a majority of the landless and small farm households are net buyers of food, rise in food prices may result in a loss in their purchasing power and access to food and other necessities. A severe drought reduces seed availability for the next cropping season, diminishes production potential of livestock and causes a loss of biodiversity due to overexploitation of forests, pastures, grazing lands and water resources. All these have a long-term adverse effect on the productive capacity of agriculture and natural resources.

When drought is severe, occurring over a large area, its effects are unlikely to remain localized. They may spill over to other segments of the economy through inter-sectoral linkages. A widespread, high-intensity drought may threaten a nation's food security, lead to depletion of food stocks and rise in food prices, and an increase in food imports and consequently, the import bill straining the national exchequer. Reduction in farm incomes may aggravate rural poverty, force rural populations to migrate to towns and cities, and reduce demand for industrial products including agricultural inputs and equipment. Furthermore, mitigating the effects of drought requires financial resources for drought relief, safety nets and other development programs.

Farmers adopt a number of ex-ante and ex-post strategies to cope with drought. Some common ex-post strategies are: borrowing, changing the production portfolio in favor of short-duration and water-efficient crops, diversification into non-farm activities and mortgage or sale of productive assets (Walker and Jodha 1986). While a few of these help farmers regain their previous level of livelihood, others like the loss of productive assets may not be replenished in the years following drought. Often, the level of production and livelihoods do not recover fully. Bhandari et al. (2007) observed that such strategies rarely compensate the income loss, and adversely affect agricultural productivity in subsequent years.

While ex-post adaptation strategies are unaffordable by farmers as well as governments, ex-ante institutional mechanisms such as crop insurance are not fully developed, and are inaccessible to a majority of farm households (GoI 2005)[2]. Farmers also adopt ex-ante agronomic and management measures, such as crop diversification, mixed cropping, cultivation of short-duration crops and conservation and judicious use of limited irrigation water, to contain anticipated adverse effects of drought. Most of these, however, provide only short-term solutions.

Agricultural research that reduces production risk without sacrificing crop yields can make significant contributions towards mitigating adverse effects of drought; and unlike other mitigation strategies, it can provide a long-term solution too. Crop breeding for drought-

1. Based on rainfall deficiency, the Meteorological Department of the Government of India defines drought as a condition when the seasonal rainfall deficiency during the south-west monsoon season is 10% or more. If the seasonal rainfall deficiency is 26–50%, it is a moderate drought; and if it exceeds 50%, it is a severe drought (http://www.imdpune.gov.in/research/reinfo_index.html).

2. At any point of time, the proportion of farm households in India availing crop insurance has hardly ever exceeded 5%.

tolerance or escape is claimed to be one of the most plausible, effective and long-term risk management options (Gollin 2006; Kostandini et al. 2009). The research product, i.e., seed, has embedded in it traits that shorten crop duration to escape terminal drought or enhance crop vigor (efficient utilization of limited water) to withstand moisture stress at critical growth stages. Besides, seeds/varieties are easy to adopt, require less operational expenses and can be multiplied by farmers and/or seed companies in a short period without much capital investment.

Evidence of returns on investment in drought-tolerance or drought-escape crop breeding research is scarce and anecdotal, probably because in the past agricultural research was largely focused on yield improvement. However, with impending changes in climate, there is an increasing recognition of drought tolerance research in the national and international research and policy arena. In this context, Lybbert and Bell (2010) have observed that in the past decade, few agricultural research objectives have attracted as much attention and investment as drought tolerance. Investment in drought tolerance research has crossed over US$ 1.0 billion. Experimental evidence shows that under moisture stress conditions, drought-tolerant varieties of cereals (rice, wheat and maize) can yield 10–30% more than their traditional counterparts (Garg et al. 2002; Abebe et al. 2003; Quan et al. 2004). In farmers' fields in Eastern and Southern Africa, drought-tolerant varieties of maize have produced an average 20% more than the varieties they replaced (CGIAR 2009). In Latin America, average yield of drought-tolerant bean varieties has been reported to be almost double that of the traditional commercial varieties (CGIAR 2009).

Investments in drought tolerance breeding research have yielded attractive rates of return. Gollin (2006) found a reduction in yield variability of maize and wheat in developing countries, which he attributed to longstanding efforts in breeding for drought tolerance, disease and pest resistance, and improved cropping systems among others. He estimated annual economic benefits from improved yield stability in wheat and maize at US$ 149 million and US$ 143 million, respectively. In the case of millets, variety Okashana 1 which matures 4–6 weeks earlier than the traditional varieties, occupied about half of Namibia's total millet area in the mid-1990s, and continues to generate about US$ 1.5 million annually. Likewise, a sorghum variety in Chad, which has a yield advantage of 50% over traditional varieties, generates annual stream of discounted benefits of US$ 4 million (CGIAR:http://www.cgiar.org/pdf/drought-tolerant_crops_for_drylands.pdf). Kostandini et al. (2009) estimated potential yield and risk benefits from the adoption of improved drought-tolerant varieties of maize, rice and wheat in selected countries of Asia and Africa, and on average, risk benefits comprised one-third of the total benefits. In drought-prone areas, risk benefits even outweighed yield benefits. In another study focused on maize in sub-Saharan Africa (SSA), La Rovere et al. (2010) reported that even with conservative yield improvements, adoption of drought-tolerant varieties would generate substantial benefits, with risk benefits contributing more than one-third to total benefits.

Since it was set up in 1972, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has invested heavily in drought tolerance research. Considerable scientific progress has been made in breeding improved varieties of its mandate crops – pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*) – that can withstand moisture stress at various growth stages without sacrificing grain yield. Yet, relatively few ICRISAT improved varieties have been adopted for their perceived drought tolerance per se.

This report examines a concrete case of the adoption of an improved drought-tolerant groundnut variety in Anantapur district of Andhra Pradesh, regarded as one of the most drought-prone districts in peninsular India, and also one of the most important groundnut producing districts of India. Specifically, we provide estimates of the potential economic benefits from adoption of an improved groundnut variety ICGV 91114, which has a yield advantage of 15–25% over traditional varieties under water-stressed conditions (Nigam et al. 2005). This variety was recently released for cultivation in Andhra Pradesh, Orissa and Karnataka, and is also being cultivated in Gujarat, Maharashtra and Jharkhand states of India.

The report is organized into six sections. The next section presents a brief overview of the groundnut production systems in India followed by a description of the agro-climatic and socio-economic characteristics of the study region. The sampling framework used to elicit information required for impact assessment is described in section 3. Farm-level effects of improved drought-tolerant groundnut variety ICGV 91114 are discussed in section 4. Potential market-level yield and risk benefits of adopting ICGV 91114 are presented in section 5. The last section summarizes the main findings and discusses their implications for research and development.

2. An Overview of India's Groundnut Economy

Groundnut is the third most important oilseed crop in India after soybean and rapeseed-mustard. It is cultivated over 6.2 million ha, which is nearly 23% of the total area under oilseeds. India dominated the global groundnut economy until the early 1990s with a share of around one-third in the global groundnut production (Birthal et al. 2010). Though its global share fell to one-fifth in 2009–10, it continues to have the largest area under groundnut cultivation in the world. In India, groundnut is grown as a rainfed crop. The decline in its share can be ascribed to lack of adoption of improved production technologies and increased weather uncertainty among others. This section provides a brief overview of the dynamics of India's groundnut economy.

Consumption and Demand

Fuelled by sustained economic and income growth and a rising urban population, demand for edible oils in India has increased considerably in the past three decades. Between TE[3] 1975–76 and TE 2008–09, the annual per capita consumption of edible oils increased from 4.1 to 11.2 kg (Table 1). Rapid growth occurred since the mid-1990s; the per capita consumption grew at an annual rate of 4% between 1993–94 and 2008–09, almost twice the annual growth between 1972–73 and 1992–93. Total consumption of edible oils increased from 2.4 million t in TE 1975–76 to 6.2 million t in TE 1995–96 and further to 13.2 million t in TE 2008–09.

Until the mid-1990s, groundnut used to be the dominant edible oil in India. Its share in total edible oil consumption was 55% in the mid-1970s, which gradually declined to 30% in the mid-1990s

Table 1. Demand for edible oils in India by oil type ('000 t).

Type of edible oil	TE 1975–76	TE 1985–86	TE 1995–96	TE 2008–09
Groundnut	1,352	1,450	1,793	1,490
Rapeseed-mustard	592	1,045	1,765	2,065
Coconut	216	220	362	426
Cotton seed	212	296	543	1,013
Soybean	30	602	679	2,410
Palm	23	675	552	5,226
Sunflower	15	134	492	576
Total	2,441	4,422	6,186	13,207
Per capita consumption (kg year^{-1})	4.1	5.8	6.6	11.2

Source: http://www.fas.usda.gov/psdonline/psdQuery.aspx.

3. TE stands for triennium ending average.

and further to 11% in the late 2000s, although its total consumption didn't undergo any drastic change during this period. Its declining share in total consumption of edible oils can be attributed to increased availability of cheaper substitutes, mainly palm and soybean oils, whose combined share in total consumption increased to 50% in the late 2000s from a meagre 2.2% in the mid-1970s.

India has never been self-sufficient in edible oils in the past four decades, and its dependence on imports has increased, especially since the late 1990s (Fig. 2). India imported 30–40% of its edible oil demand during 1976–77 to 1987–88, which declined to as low as 2% in 1992–93. This happened because of technological, institutional and policy interventions. In order to achieve self-sufficiency in oilseeds or edible oils, the Government of India launched a 'Technology Mission on Oilseeds' (TMO) in 1986 that focused on dissemination of high-yielding seeds, pest management technologies and information. Besides, domestic markets were protected from threats of cheap imports through tariff and regulatory means.

The strategy of import substitution worked well until the mid-1990s. Production of oilseeds that had been oscillating between 9 million t and 13 million t from the mid-1970s to the mid-1980s soared to 18 million t in 1988–89 and further to 25 million t in 1998–99. Prices of oilseeds declined at an annual rate of 1.4% during the TMO period, but grew at 0.4% during 1998–99 to 2008–09. The Mission's success was largely due to the protectionist policy of containing external competition through quantitative restrictions and import tariffs. Upon becoming a signatory to the Agreement on Agriculture under the World Trade Organization in 1994, India lifted quantitative restrictions on imports and reduced import tariffs substantially. This resulted in an influx of imports of cheap edible oils, mainly palm oil[4].

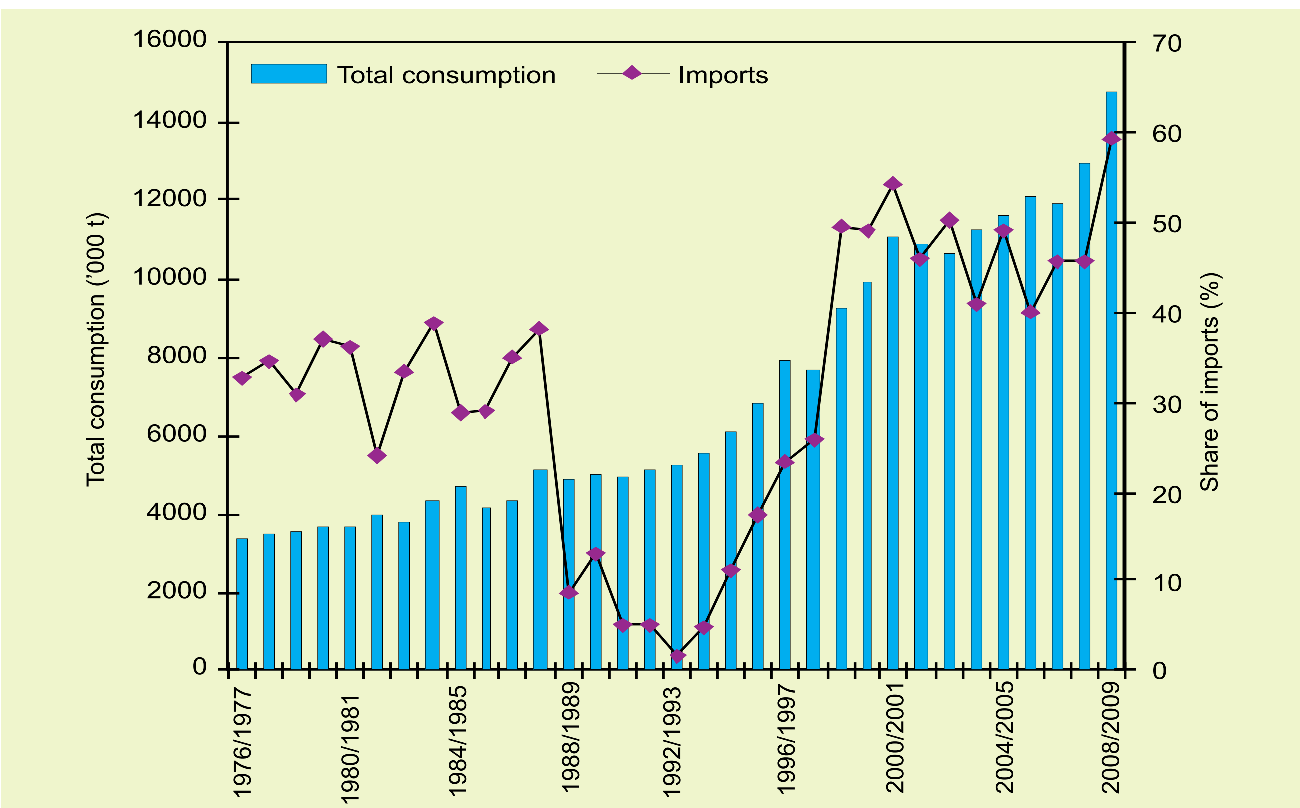

Figure 2. India's domestic demand and imports of edible oils.

Source: http://www.fas.usda.gov/psdonline/psdQuery.aspx

4. Since the mid-1990s, palm oil has comprised 50–60% of India's total imports of edible oils.

Large imports kept domestic prices of oilseeds depressed, and acted as a disincentive for domestic production. It may be noted that from 1998–99 onwards, production of oilseeds in India has not grown much.

Oilcake meal – a by-product of crushing groundnut for edible oil – is a protein-rich animal feed whose demand has been on the rise. Total consumption of all oilcake meals increased from 2.5 million t in 1976–77 to 11.0 million t in 2008–09. Groundnut oilcake meal, with a share of over 40% of total meal demand, was a dominant meal until the late 1980s; its share, however, has fallen to below 20% in recent years (Fig. 3).

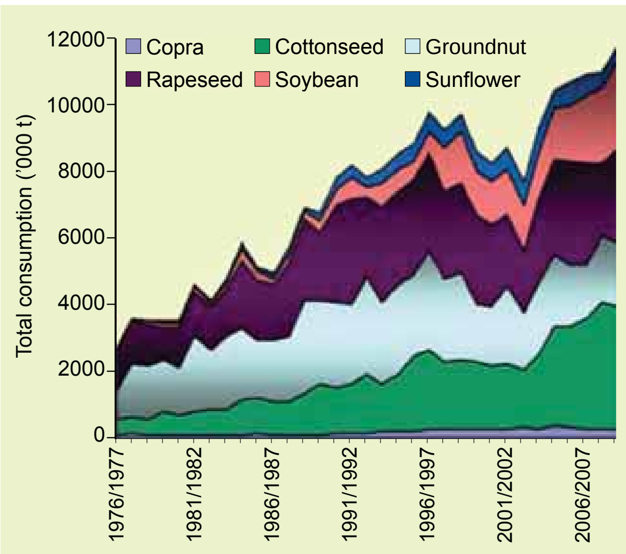

Figure 3. Trends in demand for oilcake meals in India.

Source: http://www.fas.usda.gov/psdonline/psdQuery.aspx

India exports substantial quantities of oilcake meals. Until the late 1980s, groundnut meal accounted for between 30–70% of total oilcake meal exports. This was gradually substituted by soybean and rapeseed-mustard oilcake meals because of stringent food safety restrictions on imports of groundnut and groundnut products contaminated with aflatoxin (Birthal et al. 2010).

Production and Productivity

In TE 2006–07, groundnut occupied 23% of India's total area under oilseeds and contributed 26% to total oilseeds' production, down from its share of 49% in area and 68% in production in the late 1960s. Though no significant changes have occurred in the groundnut economy in the past four decades, decline in its area and output shares has been the result of faster growth in production of other oilseeds such as soybean, rapeseed-mustard and sunflower. During 1965–66 to 2006–07, India's groundnut production increased at an annual rate of close to 1.0%, and the growth was driven by yield that increased from 639 kg ha^{-1} to 1033 kg ha^{-1} (Table 2). The growth in production was more pronounced until the mid-1980s, after which though yield improvements continued, groundnut area shrank leading to stagnation in production.

Table 2. Trends in area, production and yield of groundnut in India.

Year/period	Area (million ha)	Production (million t)	Yield (kg ha^{-1})
TE 1967–68	7.5	4.8	639
TE 1985–86	7.3	6.2	854
TE 2006–07	6.3	6.5	1033
	Annual growth (%)		
1965–66 to 1985–86	0.29	1.68	1.33
1985–86 to 2006–07	–1.12	–0.09	1.05
1965–66 to 2006–07	–0.16	0.98	1.14

Source: GoI (2010).

Groundnut in India is primarily grown under rainfed conditions during the main rainy or *kharif* season (Jun/Jul – Oct/Nov). Around 83% of India's total groundnut area is rainfed, and the remaining 17% is irrigated, mostly in the postrainy or *rabi*/summer season (Oct/Nov–Mar/Apr). Rainy-season groundnut contributes around 80% of the total groundnut production; and the rest comes from the postrainy season crop. *Rabi* groundnut production is utilized mainly for sowing in the following *kharif* season.

Though groundnut grows under varied agro-ecological conditions, it is mainly concentrated in semi-arid and arid parts of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Rajasthan states, which together account for 92% of the country's groundnut area as well as

Table 3. Trends in area, production and yield of groundnut in different agro-climatic zones of India.

Year	Humid	Semi-Arid Temperate	Semi-Arid Tropics	Arid	India
			Area ('000 ha)		
TE 1967–68	553 (7.4)[1]	643 (8.6)	5943 (79.0)	380 (5.1)	7520
TE 1985–86	905 (12.3)	225 (3.1)	5544 (75.5)	666 (9.1)	7340
TE 2004–05	567 (9.1)	173 (2.8)	4525 (72.8)	948 (15.3)	6214
			Production ('000 t)		
TE 1967–68	500 (10.1)	478 (9.7)	3702 (75.0)	257 (5.2)	4937
TE 1985–86	1123 (18.6)	157 (2.6)	4221 (70.1)	521 (8.7)	6022
TE 2004–05	900 (14.1)	167 (2.6)	4710 (73.9)	595 (9.3)	6371
			Yield (kg ha^{-1})		
TE 1967–68	903	744	623	676	656
TE 1985–86	1241	698	761	782	820
TE 2004–05	1586	962	1041	627	1025

1. Figures in parentheses are % share in country's total.

Source: ICRISAT database.

production. As such, the semi-arid tropical region[5] accounts for 70–80% of total groundnut area and 70–75% of its production (Table 3). Groundnut area in semi-arid tropical and semi-arid temperate regions has declined considerably. Between TE 1967–68 and TE 2004–05, it declined by about 25% in the semi-arid tropical region and by 75% in the semi-arid temperate region.

Despite shrinking area, groundnut production increased, except in the semi-arid temperate region. In the semi-arid tropical region, its production increased from 3.7 million t in TE 1967–68 to 4.7 million t in TE 2004–05 primarily because of yield improvements. There was also a substantial increase in production in the arid region, but mainly due to area expansion. Average yield of groundnut in India is low, and varies considerably across regions. It is about 1.6 t ha^{-1} in the humid region, higher than in any other region. Its yield in the semi-arid tropics is almost at par with the national average.

As groundnut cultivation is concentrated in high-risk semi-arid tropical and arid regions, its area, yield and production are expected to fluctuate considerably over time. Table 4 presents growth rates and coefficient of variation[6] in yield of groundnut along with the probability[7] of yield falling 10% or more below the trend. The table shows that yield growth has decelerated, except in the semi-arid temperate region; the coefficient of variation in yield, and the probability of yield falling short of the trend are higher in arid and

5. Agro-ecological regions are differentiated on the basis of average annual temperatures, annual rainfall and soil types. The humid region has a length of growing period (LGP) exceeding 270 days. In the semi-arid tropical region, LGP ranges from 70–180 days, and all months have a mean monthly temperature exceeding 18°C and a daily mean temperature higher than 20°C during the growing period. The semi-arid temperate region has LGP ranging from 70–180 days; daily mean temperature during the growing period ranges between 5°C and 20°C and one or more months with monthly mean temperature, corrected to sea level, below 5°C. In the arid region, LGP is less than 75 days.

6. The coefficient of variation was estimated from the time-series data de-trended using Hodrick-Prescott filter with an adjustment factor of 100 which is generally used for annual time series.

7. Following Hazell (1985), the probability of shortfall in area, production and yield below their trends, say a minimum of 5%, was estimated using the formula, $Pr(u_t/SD \leq -0.05\ \bar{x}/SD)$, where $\bar{x}$ is the mean and SD is the standard deviation of the series. Assuming that the deviation from trend (u_t) is approximately normally distributed, the probability of area, production or yield being a minimum of 5% below the trend can be obtained from the tabulated values of cumulative normal distribution.

Table 4. Growth and variability in groundnut yield in different agro-ecological zones of India.

Region	Annual growth in yield (%)		Coefficient of variation in yield (%)		Probability of yield falling ≥10% below the trend yield (%)	
	1965–66 to 1985–86	1986–87 to 2004–05	1965–66 to 1985–86	1986–87 to 2004–05	1965–66 to 1985–86	1986–87 to 2004–05
Humid	1.55	1.36	7.09	4.34	7.93	1.07
Semi-arid temperate	0.01	1.62	12.71	19.62	21.77	30.85
Semi-arid tropics	1.51	1.22	14.11	20.03	23.89	31.27
Arid	1.32	–0.79	18.88	26.89	29.81	35.57

Source: Estimated by authors.

semi-arid tropical regions; and that both the yield variability and probability of yield shortfall have increased, except in the humid region.

A number of studies have looked into trends in growth and variability in Indian agriculture in the past. Mehra (1981); Hazell (1982); and Rao et al. (1988) found agricultural growth accompanied by an increase in yield variability in the initial phase of the Green Revolution, and attributed it to the uneven spread of high-yielding crop varieties across different production environments and their differential responses to input use. Recently, two studies, one by Larson et al. (2004) and another by Chand and Raju (2009), based on long time-series data, observed a mixed trend in yield variability of different crops – a decline in the case of some crops and a rise in others.

As long as yield growth is stable or accelerating, an increase in yield variability is not of much concern. Our results, however, indicate a rise in variability in yield at a decelerating yield growth. In the semi-arid tropical region, growth in groundnut yield decelerated to 1.22% per year during 1986–87 to 2004–05 and to 1.51% during 1965–66 to 1985–86, and this was accompanied by a rise in the coefficient of variation, from 14.11 to 20.03%, and the probability of yield falling ≥10% below the trend from 23.9 to 31.3% during this period (Table 4). These trends in growth and variability are a cause of concern.

Reversing these trends is a major challenge confronting agricultural research and policy in order to ensure sustainable agricultural growth and better livelihoods to small farmers who dominate Indian agriculture. In 2005–06, small and marginal holdings comprised over 83% of total holdings and they controlled only 41% of the land area (Table 5). Their share in groundnut area is almost similar to their share in arable land. Since groundnut production is riskier, smallholders being more risk-averse, do not allocate much area to groundnut. Nonetheless, groundnut is an important income source for farm households

Table 5. Distribution of groundnut area across different farm categories in India, 2005–06.

Farm size	Share in total holdings (%)	Share in total area (%)	Share in groundnut area (%)	Groundnut area irrigated (%)
Marginal (<1.0 ha)	64.8	20.2	12.3	13.2
Small (1.0–2.0 ha)	18.5	20.9	24.2	10.8
Medium (2.0–4.0 ha)	10.9	23.9	30.1	11.2
Large (>4.0 ha)	5.8	35.0	33.4	12.6
All	100.0	100.0	100.0	11.8

Source: Agricultural Census. Available at: http://agcensus.nic.in/cendata/databasehome.aspx in the semi-arid tropics where it is widely grown. For instance, in the semi-arid states of Gujarat and Andhra Pradesh, which together share more than half of the country's total groundnut area, the crop contributes 18% and 7%, respectively to total value of agricultural production (GoI 2008). Therefore, technologies and policies that reduce variance in yield stand to reduce vulnerability of smallholders to economic hardships, poverty and malnutrition.

In the past two decades, ICRISAT has developed groundnut varieties such as ICR 48, ICGV 87846, ICGV 00350 and ICGV 91114 (all released for cultivation by central/state varietal release committees in India) that possess greater capacity to withstand moisture stress and also produce more per unit of land compared to ruling varieties such as TMV 2, J 11/SB XI, AK 12-24 and JL 24.ICGV 91114, which we have chosen for an economic evaluation, was derived from a cross between two advanced breeding lines (ICGV 86055 x ICGV 86533) following bulk pedigree method. The cross was made in 1987. The variety was evaluated in replicated on-station trials in the rainy season of 1991. It was released in Andhra Pradesh in 2006, in Orissa in 2008 and in Karnataka in 2009. It is also grown in the states of Gujarat, Maharashtra and Jharkhand, and is being marketed as Akshay Prabhat by Akshay Seed Tech Co in Gujarat and Maharashtra.

3. Study Region and Sampling Framework

A field survey was conducted in Anantapur district of Andhra Pradesh to obtain important parameters to assess the impact of drought-tolerant groundnut variety ICGV 91114. Anantapur is known both for its frequent droughts and groundnut production. In TE 2007–08, groundnut occupied 819,000 ha, equivalent to three fourths of total cropped area in the district, and 15% of the country's total groundnut area. Groundnut yield, however, is low and highly variable. Incidentally, Anantapur has been one of the sites where ICRISAT has implemented two projects – IFAD Grant 932 and IFAD Grant 954 in succession from 2002, focusing on dissemination of improved drought-tolerant groundnut cultivars.

Characteristics of the Study Region

Anantapur spans 19.1 thousand sq km, and is home to 3.6 million people, with a population density of 191 persons per sq km (Table 6). Three fourths of the district's population is rural, and about two-third of the total population is engaged in agriculture. Livelihood opportunities in agriculture, however, are constrained by a number of biotic and abiotic stresses. Arable land comprises 58% of the geographical area, and scope to grow a second crop in the postrainy seasons is extremely limited because of lack of rainfall and irrigation facilities. Only 11% of the net sown area in the district is irrigated. The length of growing period is 119 days, from July to October (Rukmani and Manjula 2009), and only about 6% of net cropped area is cultivated more than once.

Table 6. Selected indicators of development in Anantapur district, Andhra Pradesh, India.

Indicators	Value
Land area ('000 sq km), 2005–06	19.1
Total population ('000), 2001	3640
Rural population ('000), 2001	2720
Population density (persons sq km^{-1}), 2001	191
Literacy rate (%), 2001	56.1
Workers engaged in agriculture (%), 2001	64.6
Net sown area (%), 2005–06	57.8
Cropping intensity (%), 2005–06	106
Net sown area irrigated (%), 2005–06	11.2
Road density (1000 sq km^{-1}), 2005–06	540

Source: ICRISAT database.

Average size of land holdings in Anantapur is 1.9 ha (Table 7), slightly less than twice the national average (1.06 ha). Distribution of land holdings is unequal. About 35% of the holdings are of less than or equal to 1.0 ha with an average size of 0.56 ha. These share only 10% of total land area. Another one-third of the holdings range from 1.0 to 2.0 ha, and these account for 24% of total area. Together, these comprise two-thirds of total land holdings and share slightly more than one-

Table 7. Distribution of land holdings in Anantapur district, Andhra Pradesh, India, 2005–06.

Farm size	Number of holdings (%)	Area (%)	Average size (ha)	Share in groundnut area (%)	Groundnut area irrigated (%)
Marginal (≤1.0 ha)	34.5	10.0	0.56	9.9	5.6
Small (1.0–2.0 ha)	31.7	24.1	1.47	24.6	3.1
Medium (2.0–4.0 ha)	24.6	32.4	2.54	33.7	3.6
Large (>4.0 ha)	9.3	33.5	6.99	31.8	3.4
Total	100.0	100.0	1.93	100.0	3.6

Source: Agricultural Census. Available at: http://agcensus.nic.in/cendata/databasehome.aspx

third of total land area. At the other extreme of distribution, there are 9.3% holdings of more than 4.0 ha and share over one-third of total land area. Their average size is about 7.0 ha.

The climate of Anantapur district is of semi-arid tropical type. Temperature ranges from 16°C in winter to 40°C in summer. Precipitation is low – long-term average annual rainfall (1970–2008) in the district is slightly above 500 mm, of which 60% is received during June to September and 28% during October to December (Table 8). The probability of actual rainfall falling short of the normal level by 25% or more is 26% in the main rainy season and 28% in the immediate postrainy season.

Groundnut in India is grown during June/July to September/October under rainfed conditions. It grows well even with low rainfall if it is evenly distributed during cropping season. Table 9 shows distribution of rainy season precipitation in Anantapur district. About one-third of the rainfall is received during June–July and 40% in September. The probability of rainfall being 25% or more below normal is around 35% in June, July and August and 31% in September, indicating that farmers in the district face a moderate or severe drought every third year.

Soils in the district are predominantly light textured, gravelly, shallow Alfisols with depth varying from 30 to 60 cm. They are low in organic matter, nutrients and water-holding capacity and are prone to wind and water erosion (Rukmani and Manjula 2009). The cropping pattern is overwhelmingly dominated by groundnut, which occupies three-fourths of the total cropped area in the district (Table 10). Pulses and cereals are cultivated in about 10% and 6% of the total cropped area, respectively. Rice and sorghum are the main cereal crops; and chickpea and pigeonpea are important pulse crops. Fruits and vegetables occupy 2.4% and 0.5% of total cropped area, respectively.

Groundnut, a prominent crop in Anantapur now, was not so five decades ago. In the late 1960s, it occupied about 200,000 ha, equivalent to one

Table 8. Mean annual rainfall (mm) and its distribution in Anantapur district, Andhra Pradesh, India, 1970–2008.

Parameters	Annual rainfall	Rainy season (Jun–Sep)	Postrainy season (Oct–Dec)	Winter season (Jan–Feb)	Summer season (Mar–May)
Mean (mm)	507.3	299.9	138.7	7.0	61.7
Coefficient of variation (%)	25.1	38.7	42.9	103.4	57.9
Probability of rainfall being 10% or more below the normal (%)	34.5	40.1	40.9	46.0	43.3
Probability of rainfall being 25% or more below the normal (%)	16.1	25.8	28.1	40.5	33.6

Source: AICRP on Meteorology, CRIDA, Hyderabad.

Table 9. Mean monthly rainfall (mm) during the rainy season in Anantapur district, Andhra Pradesh, India, 1970–2008.

Parameters	June	July	August	September
Mean (mm)	50.2	55.0	71.0	123.8
Coefficient of variation (%)	68.2	91.0	70.9	51.4
Probability of rainfall being 10% or more below the normal (%)	44.0	49.6	44.4	42.1
Probability of rainfall being 25% or more below the normal (%)	35.6	38.2	35.2	31.2

Source: AICRP on Meteorology, CRIDA, Hyderabad.

fifth of total cropped area. Its area increased rapidly during the 1970s and the 1980s, reaching 733,000 ha in 1989–91 and 819,000 ha in 2006–08. In years with early onset of monsoon, groundnut area has exceeded 1 million ha. Besides groundnut, other crops that have gained in area during the last two decades are chickpea, maize, fruits and vegetables.

Groundnut attained prominence by replacing crops such as millets and sorghum. Between TE 1968 and TE 2008, groundnut area increased by 620,000 ha, while sorghum and millets lost 428,000 ha. In other words, more than two thirds of the area gained by groundnut during this period came from replacing sorghum and millets.

An important reason for the spectacular rise of groundnut in Anantapur had been its higher profitability compared to sorghum and millets. Figure 4 shows trends in gross value of output of groundnut in relation to competing crops. Higher gross value of output per unit of area has been observed for groundnut than for sorghum, pearl millet and finger millet for most part of the last four decades. Compared to other crops grown under similar agro-climatic conditions, groundnut has a better capacity to withstand long dry spells and can revive itself even with little rain after a dry spell (Nigam et al. 2005). Other factors associated with the rise of groundnut in Anantapur include the rising demand for edible oils and increasing

Table 10. Changes in cropping pattern in Anantapur district, Andhra Pradesh, India.

	TE 1968		TE 1991		TE 2008	
Crops	Area ('000 ha)	% of total cropped area	Area ('000 ha)	% of total cropped area	Area ('000 ha)	% of total cropped area
Rice	52.4	5.7	63.9	6.2	41.9	3.8
Wheat	1.2	0.1	0.7	0.1	0.3	0.0
Sorghum	158.7	17.1	38.3	3.7	25.1	2.3
Pearl millet	82.7	8.9	11.9	1.2	1.0	0.1
Maize	0.7	0.1	1.0	0.1	9.6	0.9
Finger millet	32.6	3.5	13.0	1.3	2.6	0.2
Small millets	183.6	19.8	29.7	2.9	0.5	0.0
Chickpea	2.5	0.3	9.3	0.9	69.2	6.2
Pigeonpea	24.1	2.6	29.2	2.8	32.6	2.9
Other pulses	69.3	7.5	14.1	1.4	3.4	0.3
Groundnut	199.5	21.6	732.7	70.9	819.3	73.8
Other oilseeds	23.4	2.5	14.8	1.4	53.9	4.9
Cotton	36.2	3.9	12.3	1.2	2.8	0.2
Fruits	9.4	1.0	20.8	2.0	27.2	2.4
Vegetables	2.3	0.2	3.7	0.4	5.5	0.5
Other crops	47.0	5.1	37.6	3.6	16.0	1.4
Total cropped area	925.7	100.0	1033.0	100.0	1110.8	100.0

Source: ICRISAT database.

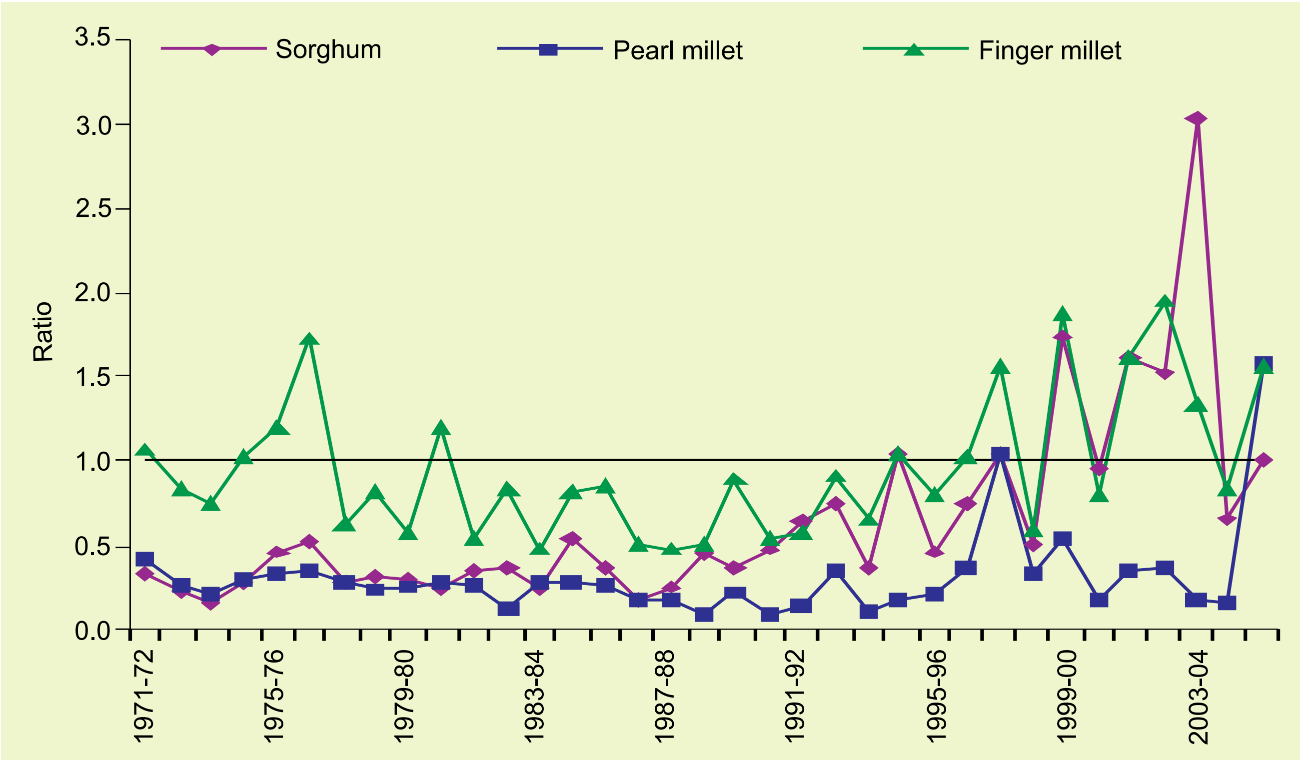

Figure 4. Trends in profitability of groundnut in relation to competing crops in Anantapur district, Andhra Pradesh, India.

Source: ICRISAT database.

substitution of sorghum and millets as food by subsidized rice and wheat provided through the public distribution system. Besides, groundnut haulm is an important fodder for livestock that can be stored and is available in drought years.

Groundnut's rise in Anantapur was accompanied by an increase in variability in its yield and production (Fig. 5). Groundnut production grew rapidly until the mid-1990s, after which both production and yield almost ceased to grow, and became more unstable (Table 11). Coefficient of variation (CV) in groundnut production increased from 35.1% during 1965–66 to 1985–86 to 49.9% during 1986–87 to 2007–08. Much of the variability in production was due to variability in yield; CV in yield increased from 26.7% during 1965–66 to 1985–86 to 42.9% during 1986–87 to 2007–08. The CV in planted area, however, declined from 11.4% during 1965–66 to 1985–86 to 8.5% during 1986–87 to 2007–08.

Table 11 also presents probability of groundnut area, production and yield falling below their trend levels. During 1965–66 to 1985–86, the probability of production and yield being 5% or more below their trend was 44.4% and 42.9%, respectively, which further increased during 1986–87 to 2007–08. Such high probabilities are expected for a small deviation from the trend. However, the probability of a larger shortfall also remains high. For example, during 1986–87 to 2007–08, the probability of production and yield falling 30% or more below the trend was 27.4% and 24.5%, respectively. The probability of a shortfall of 5% or more in the planted area below its trend was 33.4% during 1965–66 to 1985–86, which declined to 28.1% during 1986–87 to 2007–08. But the probability of a significant decline in planted area is very low, indicating that farmers rarely forego planting the intended area because of poor rains at the beginning of the cropping season.

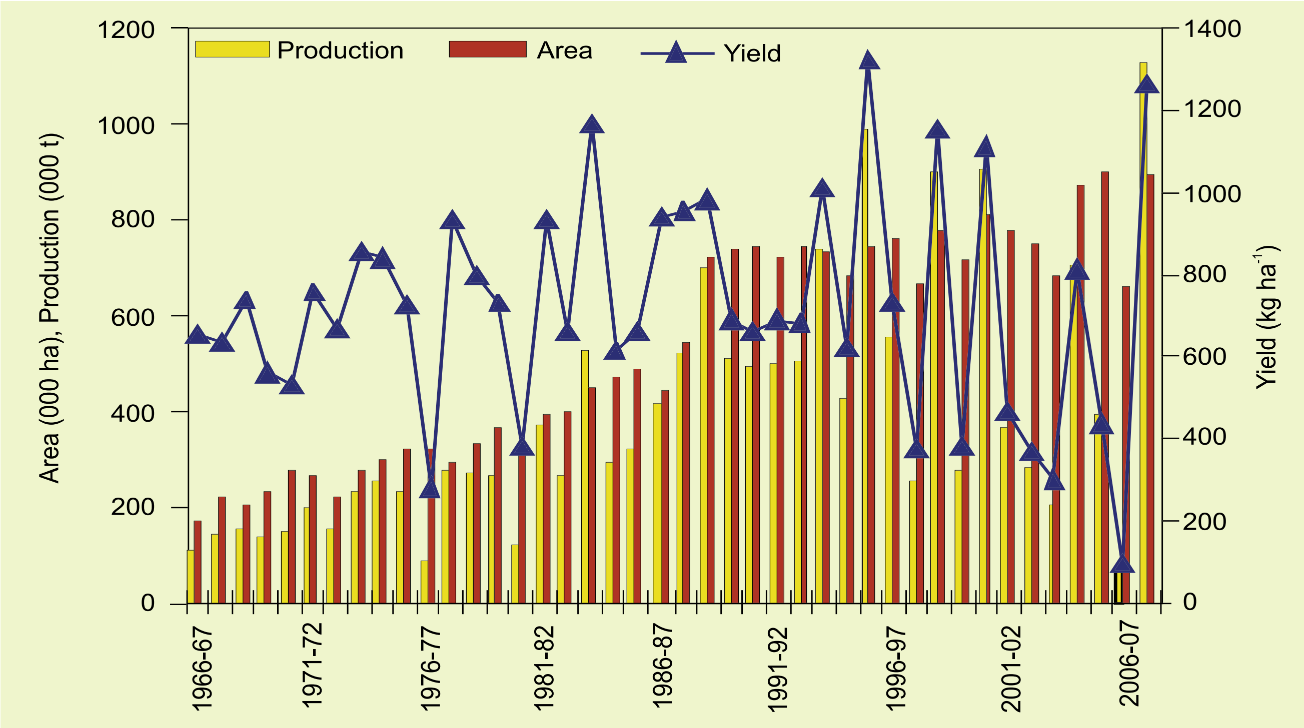

Figure 5. Trends in production, area and yield of groundnut in Anantapur district, Andhra Pradesh, India, 1966–67 to 2007–08.

Source: ICRISAT database.

Can agricultural research contribute towards reducing production risks? If yes, what are the technological options, and which among these is more plausible, efficient and sustainable? Among various technological options, breeding for drought tolerance is claimed to be one of the most promising because of its cost effectiveness and ease of adoption (Kostandini 2009).

Farmer Participatory Varietal Selection: An Effective Vehicle for Technology Transfer

TMV 2 continues to be the ruling groundnut variety in Anantapur, occupying as much as 75–80% of the total groundnut area (Nigam et al. 2005). The variety was developed by Tindivanam Oilseeds Research Station in Tamil Nadu in 1942 and was introduced in Anantapur in the early 1970s

Table 11. Coefficient of variation and probability of shortfall in production, yield and area of groundnut in Anantapur district, Andhra Pradesh, India.

	Production		Yield		Area	
Parameters	1965–66 to 1985–86	1986–87 to 2007–08	1965–66 to 1985–86	1986–87 to 2007–08	1965–66 to 1985–86	1986–87 to 2007–08
Coefficient of variation (%)	35.05	49.88	26.73	42.87	11.38	8.49
Probability of shortfall from trend (%)						
≥5%	44.43	46.02	42.86	46.00	33.36	28.10
≥10%	38.97	42.07	35.57	40.90	19.22	12.10
≥20%	28.43	34.46	22.96	32.28	4.01	0.94
≥30%	22.66	27.43	13.14	24.51	0.43	0.02

Source: ICRISAT database.

because of its drought tolerance trait. However, this trait has reduced considerably; moreover the variety has now become susceptible to a number of insect pests and diseases (Rukmani and Manjula 2009). JL 24, which was released in the late 1970s, occupies 10–15% of the area, and is suitable for cultivation under irrigated conditions. Few past attempts to replace TMV 2 with new varieties have proved unsuccessful since these varieties did not meet farmers' expectations of higher pod and haulm yields, higher shelling outturn, early maturity, drought tolerance and uniform small to medium kernel size.

To find a suitable substitute for TMV 2, ICRISAT in collaboration with Accion Fraterna (AF)[8] – a local non-governmental organization (NGO) – introduced 10 varieties including ICGV 91114 in two villages of Anantapur district, ie, Dhanduvaripalli and Rekulakunta, through farmer participatory varietal selection (FPVS) trials in the rainy season of 2002 (Nigam et al. 2005). During this season, rainfall in the district was low (146 mm), and a continuous dry spell of 45 days soon after sowing adversely affected yields of all the varieties. Yet, ICGV 91114 performed better than the other varieties. Its pod and haulm yields were 28% and 7% more than those of TMV 2. Another variety, ICGV 89104, was the next best performer. In the following rainy season, FPVS trials focused on these two varieties, and were extended to another village, West Narsapuram. In this season too, rainfall was scarce (168 mm). Nonetheless, ICGV 91114 again performed better than ICGV 89104 and TMV 2. Compared to TMV 2, its pod and haulm yields were 12% and 25% more, respectively. Impressed with ICGV 91114's higher yield during two consecutive drought years, a woman farmer of West Narsapuram village took up multiplication of its seeds on 0.63 ha in the postrainy season of 2003–04 under irrigated conditions. She produced 1200 kg of pods (1920 kg ha^{-1}) and after meeting her own seed requirement, sold the remaining seeds to other farmers in the village for cultivation in the following rainy season.

Farmers preferred ICGV 91114 because of its higher pod and haulm yields, short duration (90–95 days in the rainy season) and better capacity to withstand mid-season and terminal drought. Its ability to withstand mid-season drought implies its higher physiological vigor to utilize available water more efficiently, while its shorter duration helps escape terminal drought. Besides, it has an average shelling out-turn of 75%, oil content of 48% and protein content of 27%. Qualitatively, its haulms are an excellent fodder for livestock. They are more palatable and have better digestibility than the haulms of TMV 2 (Vellaikumar et al. 2004; Blümmel et al. 2006).

In the next rainy season (2004), 84 farmers from these three villages grew ICGV 91114 with the onset of monsoon rains. But soon after sowing, there was a dry spell of 36 days. Mean rainfall during this season was 225 mm. ICGV 91114 again performed better than TMV 2 (Table 12). During the cropping season, awareness activities were organized to popularize ICGV 91114 among the farmers.

Table 12. Pod and haulm yields (kg ha^{-1}) of ICGV 91114 and TMV 2 in FPVS trials in Anantapur district, Andhra Pradesh, India, 2002–04 rainy seasons.

	Pod yield			Haulm yield		
Year	ICGV 91114	TMV 2	Difference (%)	ICGV 91114	TMV 2	Difference (%)
2002	385	305	26.2	1460	1355	7.7
2003	507	453	11.9	1391	1111	25.2
2004	1585	1433	10.6	1971	1982	–0.6
Mean	826	730	13.1	1607	1483	8.4

Source: Nigam et al. (2005).

8. Accion Fraterna, with headquarters in Anantapur, is engaged in multifarious activities related to agriculture, health and rural development in 230 villages in the district.

Better yields were realized from both ICGV 91114 and TMV 2 in 2004 than in previous years mainly because of higher rainfall in July that facilitated sowing and better plant establishment. Of total precipitation received in the 2004 rainy season, over 45% was received in July 2004 as compared to 14% in July 2002 and 22% in July 2003.

Convinced of its consistently better performance, 111 farmers from 23 villages across 10 *mandals* or administrative sub-divisions of Anantapur district and two villages each from the adjoining Kurnool and Chittoor districts took up seed production of ICGV 91114 in the postrainy season of 2004–05 under technical guidance of ICRISAT and AF. Farmers saved their produce for sowing in the following rainy season, and surplus produce was sold as seed to other farmers. In the 2005 rainy season, ICGV 91114 spread to 41 villages in 18 *mandals*. In 2006, ICGV 91114 was officially released by the Government of Andhra Pradesh for cultivation in rainfed areas of the state. Farmers in Anantapur district have named this variety 'Anantha Jyothi'. By 2010, it had spread to most villages in the operational area of AF and beyond in the neighbouring districts of Andhra Pradesh and Karnataka.

Sampling Framework for Impact Assessment

The canvas of impact assessment has broadened beyond a simple comparison of yield, cost and returns, to encompass various social, economic and environmental outcomes of technological change. Therefore, impact assessment procedures too have become complex and data-intensive.

The impact of a project can be assessed using information generated during its lifetime. This requires setting baseline surveys and the continuous collection and monitoring of required information to compare changes in impact indicators 'before and after' the project. This approach is costly and time consuming. Besides, it is also felt that a 'before and after' comparison is inappropriate for environments characterized by a high degree of production uncertainty, as in Anantapur. For instance, if the base year of the project is a normal agricultural (rainfall) year and the final year is a drought year or vice versa, the 'before and after' comparison of impact indicators would be erroneous. Hence, we followed a 'with and without approach', where we compared various impact indicators of adopters and non-adopters of ICGV 91114. This was supplemented with qualitative information regarding changes in impact indicators before and after the adoption of ICGV 91114.

Anantapur district has 63 administrative sub-divisions called *mandals*. We conducted a survey in eight *mandals* –Atmakur, Beluguppa, Dharmavaram, Kalyandurg, Kudair, Kundurpi, Rapathadu and Settur (all in the operational area of AF) – representing the average agro-climatic condition in the district where ICGV 91114 was first introduced by ICRISAT in 2002 and 2003.

In the next stage of sampling, the sample size from each *mandal* was fixed using information on area under ICGV 91114 in each *mandal* generated and maintained by AF. We decided to collect information from 200 farm households that had grown ICGV 91114 in the 2008 rainy season, and another 200 households that hadn't. The sample of households growing ICGV 91114 from each *mandal* was drawn in proportion to their share in the total area under ICGV 91114. An equal number of non-growers of ICGV 91114 from each *mandal* were selected for comparison (Table 13).

To ensure representation of different farm categories, the sample size of adopters and non-adopters of ICGV 91114 from each *mandal* was distributed in proportion to the distribution of land holdings. Having decided the sample size from each category, a list of households growing ICGV 91114 in the *mandals* was prepared in consultation with field staff of AF. Since growers of ICGV 91114 were thinly spread out, the survey was conducted in a cluster of 4–7 villages in each *mandal*, so that the desired number of households from each farm category could be selected randomly. As TMV 2 is the ruling variety in these

Table 13. Number of farm households selected for the survey in different mandals of Anantapur district, Andhra Pradesh, India.

	ICGV 91114 growers					Non-ICGV 91114 growers				
Mandal	<1 ha	1–2 ha	2–4 ha	>4 ha	Total	<1 ha	1–2 ha	2–4 ha	>4 ha	Total
Atmakur	4	5	8	5	22	4	5	8	5	22
Beluguppa	2	4	5	2	13	2	4	5	2	13
Dharmavaram	15	19	14	5	53	15	19	14	5	53
Kalyandurg	4	9	13	4	30	4	9	13	4	30
Kudair	3	7	8	2	20	3	7	8	2	20
Kundurpi	3	6	6	1	16	3	6	6	1	16
Rapathadu	3	9	9	3	24	3	9	9	3	24
Settur	3	8	9	2	22	3	8	9	2	22
Total	37	67	72	24	200	37	67	72	24	200

mandals as elsewhere in Anantapur district, we randomly selected non-adopters of ICGV 91114 from each cluster of villages. In all, the survey was conducted in 49 villages and information pertains to the rainy season of 2008.

Questionnaire schedules were used to collect information on crop economics (yield, costs and returns), ownership of assets, income sources, seed sources, marketing, credit and other socio-economic indicators from 400 farm households. Information on village characteristics and area under different groundnut varieties was obtained through focused group discussions. Twenty-one households were dropped from the sample because of incomplete or incorrect information.

Among selected villages, 57% were connected to roads, 39% had a post office, 45% had a watershed program and every village had a primary or secondary school. The average distance between any village and the nearest urban center was 16 km and none of the villages had banking and public agricultural extension facilities. Farmers had to travel to urban centers to avail of credit, inputs and agricultural information.

In the 2008 rainy season, Anantapur received 437 mm rainfall, 1.5 times the normal amount during the season. In fact, every month in this season had above normal rainfall – 25% in June, 60% in July, 55% in August and 43% in September, raising expectations of a good groundnut crop. However, there was a continuous rainfall spell of 16 days – starting 25 August to 9 September 2008. This resulted in vigorous vegetative growth, but adversely affected pod development.

Farm and Household Characteristics

Cropping Pattern

The cropping pattern on the sample farms, as expected, was dominated by groundnut, which occupied 83% of the total cropped area (Fig. 6). Rice and pigeonpea were grown on about 9% and 5% of the total cropped area, respectively. Finger millet, sorghum and pearl millet were other crops being cultivated by some sample farm households.

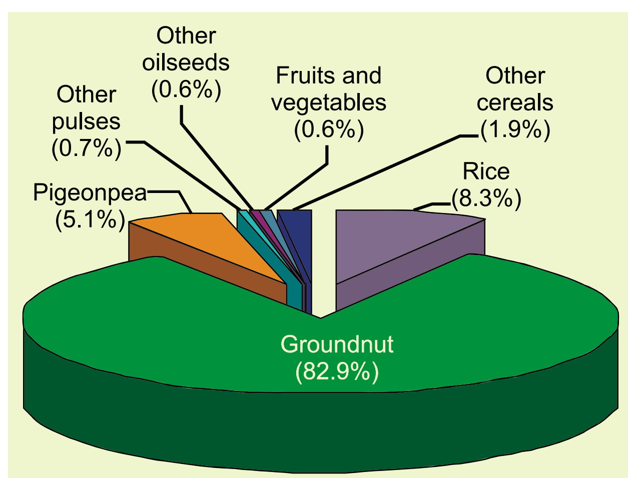

Figure 6. Share (% of the total cropped area) of different crops on sample farms in Anantapur district, Andhra Pradesh, India, 2008–09.

Source: Field survey.

The groundnut production system in Anantapur has not experienced any significant technological transformation. Over the last two decades, fertilizer consumption has remained static at around 45 kg ha^{-1}; and increase in irrigation coverage has been negligible, in absolute as well as relative terms. Irrigated area as a proportion of gross cropped area has hovered around 15%. Cropping intensity in the district has rarely exceeded 110% in the last five decades. TMV 2 continues to be the ruling variety even after four decades of its introduction. Observations from focused group discussions with farmers of surveyed villages indicated that about 88% of total groundnut area was covered by TMV 2 in 2008–09 (Fig. 7). JL 24 is another old variety, introduced about three decades ago, being grown on about 6.4% of the total groundnut area. ICGV 91114 occupied 3.2% of the total groundnut area.

It is not that new groundnut varieties befitting agro-climatic conditions of Anantapur were not available. An important reason for non-replacement of TMV 2 has been the lack of availability of seeds of new varieties to farmers, as no concerted efforts were made for their multiplication and distribution either by public sector agencies or by private seed companies. Groundnut seed business is not profitable for private seed companies because of high acquisition, storage and distribution costs, and low seed to kernel price ratio. The public sector (Andhra Pradesh State Seeds Corporation and the State Department of Agriculture), on the contrary, continues to concentrate on multiplication and distribution of seeds of TMV 2. Seeds of TMV 2 are provided at a subsidized price, though in limited quantity (not more than 90 kg pods per household), while the seed rate to sow one hectare is 150–225 kg pods. Besides, new varieties could not meet farmers' expectations of higher pod and haulm yields, uniform maturity, medium kernel size, drought tolerance, disease resistance, etc.

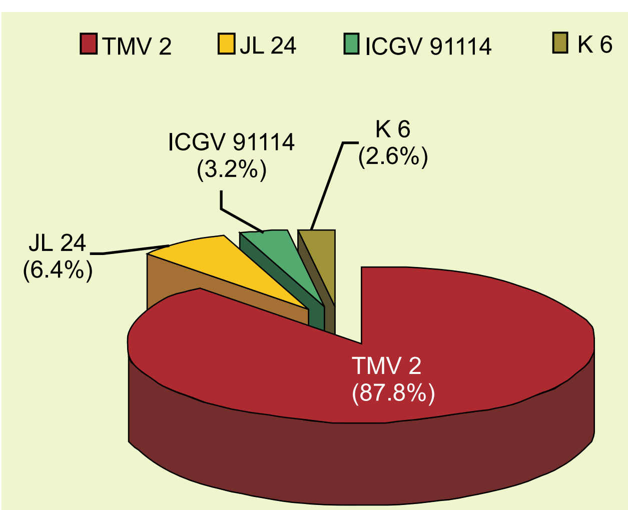

Figure 7. Share (%) of different varieties in the total groundnut area in sample villages in Anantapur district, Andhra Pradesh, 2008–09.

Source: Field survey.

Personal and Household Characteristics

Farmers' choice of technology is influenced by personal- and household-specific factors, besides the social, economic and institutional environment surrounding the groundnut production system. Selected households were post-stratified as adopters, partial adopters and non-adopters of ICGV 91114. Of the total 379 households, 166 grew only TMV 2, 129 households grew only ICGV 91114, 19 grew only JL 24 and 3 grew only K 6. The rest of the 62 households grew ICGV 91114 along with other varieties, mainly TMV 2; and these are termed as 'partial adopters'.

Table 14 presents averages of the salient characteristics of growers of ICGV 91114 vis-à-vis those who cultivated TMV 2 and JL 24. Average age of head of the household was around 43 years, and this did not differ much across growers of different varieties. They also did not differ much in their level of education, family size and gender composition. An important characteristic of the sample households was that most of them, adopters or non-adopters of ICGV 91114, were associated with one or the other village-level organization, mainly self-help groups (SHGs), which abound in the sample villages, and undertake multifarious agricultural and rural development activities.

Land Holding and Income Sources

Mean land holding size for adopters of ICGV 91114 was slightly more than 3 ha, and larger

Table 14. Means of selected characteristics of growers and non-growers of ICGV 91114 in sample villages in Anantapur district, Andhra Pradesh, India, 2008–09.

Characteristics	Only ICGV 91114	Only TMV 2	Only JL 24	ICGV 91114 and others	Total
Number of households	129	166	19	62	376
Age of the head of the household (years)	43.1	41.7	43.8	42.7	42.5
Schooling (years)	5.0	4.3	5.5	5.0	4.7
Member of village organization (%)	82.2	80.1	100.0	91.9	83.6
Family size (no.)	4.9	4.9	4.8	5.1	4.9
Male	2.6	2.5	2.6	2.7	2.6
Female	2.3	2.4	2.3	2.4	2.4
Landholding size (ha)	3.1	2.8	2.2	3.5	3.0
Gross household income (` year^{-1})	105,919	74,415	72,342	96,740	88,635
Income sources (%)					
Cereals	12.4	8.0	13.7	13.8	11.1
Pulses	2.1	2.7	4.0	1.9	2.3
Oilseeds	47.5	62.7	51.3	58.3	55.3
Fruits and vegetables	11.7	0.4	0.2	0.9	5.1
Livestock	9.3	10.3	20.5	14.3	11.0
Salaries and remittances	2.2	0.4	0.1	0.6	1.2
Wages	5.7	6.2	7.6	1.9	5.3
Crop insurance and commensuration	9.1	8.4	2.5	8.0	8.3
Others	0.1	0.7	0.0	0.1	0.4

Source: Field survey.

than those who grew TMV 2 and JL 24. Likewise, the annual household income of ICGV 91114 adopters was 25–50% more than that of TMV 2 and JL 24 growers. This difference, however, need not necessarily be attributed to the adoption of ICGV 91114 as most households obtain their income from more than one source and in varying proportions.

On average, oilseeds contributed as much as 55% to their total annual income (Table 14), and as expected, among oilseeds, groundnut was the main source of income for the sample households. The share of cereals, mainly rice, and livestock each was estimated at 11%. Fruits and vegetables accounted for 5% of the total income. The rest of their income came from wages, salaries and remittances including insurance indemnities and other non-farm sources. These findings clearly reveal that farm households rely heavily on groundnut cultivation for their livelihood, and any technological intervention that enhances yield and stabilizes income is likely to generate significant income benefits to farmers.

4. Farm-level Effects

Seed Sources of Improved Varieties

Seed rate of groundnut is very high (150–225 kg pods ha^{-1}). Farmers procure groundnut seeds from various formal and informal sources. Our survey indicated that more than half of the groundnut seed demand was met from own farm-saved seeds, followed by purchases from other farmers (Table 15). State parastatals, including the Department of Agriculture and the State Farms Corporation of India (SFCI), fulfilled 18% of their seed demand. In recent years, some NGOs (eg, Accion Fraterna and Aakruthi Agricultural Associates of India) have ventured into seed multiplication and distribution. They fulfilled 11% of total seed demand. The share of commercial private seed suppliers was negligible.

Seed sources, however, vary by variety. Approximately 59% of TMV 2 seed demand was met from own farm-saved seeds, and the state parastatals contributed 27%. For JL 24, 'the other

Table 15. Farmers' seed sources (% of total) in sample villages in Anantapur district, Andhra Pradesh, India, 2008–09.

Source	TMV 2	JL 24	ICGV 91114	K 6	All
Farm-saved own seed	58.7	34.1	43.5	41.2	51.8
Other farmers	11.5	52.7	26.6	6.1	18.8
Non-governmental organizations	2.1	1.7	26.2	0.0	11.4
State parastatals	27.2	8.3	3.6	52.7	17.5
Private seed dealers	0.6	3.2	0.0	0.0	0.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Field survey.

farmer' was the most important source (53%), followed by own farm-saved seeds. The State Department of Agriculture was the main source of K 6 seed[9]. K 6 is a new variety, and along with TMV 2 and JL 24, is being promoted by the state government through seed multiplication and distribution at subsidized prices, 25–30% less than the market prices. Further, it is interesting to note that seed subsidies are not targeted at any specific category of farmers. These are available to all irrespective of land holding size or income. On the other hand, there is hardly any seed provision of ICGV 91114 by the state government. The SFCI, however, undertakes multiplication and distribution of seeds of ICGV 91114. It may be indicated here that about one-third of the groundnut seed procured by SFCI is exported to other states. Own farm-saved seeds comprised the main source of seed of ICGV 91114 (44%), followed by 'the other farmer' and NGOs, each contributing over one-fourth to the total seed requirement. Among state parastatals, SFCI provided seeds of ICGV 91114 but could meet only about 4% of its total requirement.

Based on official statistics, Rukmani and Manjula (2009) found that the State Department of Agriculture fulfilled barely 10% of the total seed requirement in Anantapur district until 2001, but its seed supply gradually increased to about one-third of the total requirement in 2008. Further, the state government focused mainly on providing seed of TMV 2 and JL 24, which shared 64% and 24%, respectively of the total seed supply in the district.

Yield and Yield Variability

Farmers' decision to adopt a new variety depends on its cost and benefit compared to those of existing varieties. Farmers often weigh choices of different varieties based on their yields, net returns and risk, and adopt the one that generates higher and stable net returns. Table 16 compares pod and haulm yields of different varieties grown by the sample farm households. Mean pod yield of ICGV 91114 was 704 kg ha^{-1} in 2008 (rainy season), higher than the yield of any other variety. It had a yield advantage of 23.6% over TMV 2

Table 16. Means and coefficient of variation in pod and haulm yields of different groundnut varieties on sample farms in Anantapur district, Andhra Pradesh, India, 2008 rainy season.

Variety	Pod yield (kg ha^{-1})	CV in pod yield (%)	Haulm yield (kg ha^{-1})	CV in haulm yield (%)
TMV 2	567	11.57	898	12.81
JL 24	643	11.00	921	9.88
ICGV 91114	704	6.97	1150	6.54

Source: Field survey.

9. K 6 was grown by only a few farmers in our sample.

and 8.9% over JL 24. ICGV 91114 was found to possess almost a similar yield advantage over TMV 2 in FPVS trials in the neighboring districts of Karnataka state, under similar agro-climatic conditions as in Anantapur.

Table 16 also presents coefficient of variation (CV) in yields of different varieties using cross-section data from sample households. The CV in pod yield for ICGV 91114 was 6.97%, which is about 40% less than that for TMV 2 (11.57%) and JL 24 (11%). The CV in haulm yield for ICGV 91114 was also less compared to those for the other two varieties. These results provided an indication of the robustness of ICGV 91114.

Cross-section data on the CV in yield of different varieties cannot be used to infer about their relative drought tolerance capabilities. This is best done using time-series data on yield. We had generated information on area and production of different varieties from sample households for the past five years, including the survey year, and used this series to estimate average yield and CV therein for ICGV 91114, TMV 2 and JL 24. Table 17 shows pod yields of these varieties for the period 2004–05 to 2008–09, and the CV therein. Across years, yield advantage of ICGV 91114 over TMV 2 varied from 9.5 to 41.6%, and over JL 24 from 4.8 to 41.9%. ICGV 91114 showed higher yield advantage when yields were low due to low rainfall or some other factors. It may be noted that distribution of rainfall is an important determinant of groundnut yield. The crop may perform well even when rainfall is low but well distributed with sufficient sunshine days.

Based on five-year information, ICGV 91114 had an average yield advantage of 22.8% over TMV 2 and 13.6% over JL 24 (Table 17). ICGV 91114's performance was more consistent compared to other varieties. The CV in yield of ICGV 91114 was estimated to be 24.8%, which was 29.6% less than that of TMV 2 and 22.7% less than that of JL 24. This clearly showed that switching over from TMV 2 and JL 24 to ICGV 91114 would not only enhance groundnut production but would also provide a more stable stream of benefits to farmers.

We had also sought farmers' opinions on the drought-tolerance capacity of ICGV 91114 in relation to TMV 2 and JL 24 (Table 18). A majority of farmers reported TMV 2 to be moderately tolerant to moisture stress. This is perhaps one of the reasons for its dominance in Anantapur district for such a long time. Compared to it, JL 24 was assessed to have a lower drought tolerance capacity. On the other hand, a sizeable proportion of adopters of ICGV 91114 found it to possess moderate to high resistance to moisture stress. Thus, farmers' perceptions too confirm that ICGV 91114 has a greater capacity to withstand moisture stress compared to the other two varieties.

Besides being drought-tolerant, seeds of ICGV 91114 also embody other traits that partially meet farmers' expectations. It offers moderate resistance to insect pests (thrips and leaf minor)

Table 17. Mean yield and coefficient of variation in pod yield of different groundnut varieties in Anantapur district, Andhra Pradesh, India, 2004–05 to 2008/09.

	Yield (kg ha^{-1})			Difference (%)			
Year	TMV 2	JL 24	ICGV 91114	ICGV 91114 over TMV 2	ICGV 91114 over JL 24	JL 24 over TMV 2	Rainy season rainfall (mm)
2004–05	757	775	886	17.0	14.4	2.3	224
2005–06	614	607	861	40.2	41.9	–1.2	404
2006–07	544	654	770	41.6	17.8	20.2	194
2007–08	1163	1216	1273	9.5	4.8	4.5	508
2008–09	567	643	704	23.9	9.5	13.2	437
Mean	727	786	893	22.8	13.6	8.1	353
CV (%)	35.2	32.1	24.8	–29.6	–22.7	–8.9	38.9

Source: Field survey.

Table 18. Distribution of farmers' response (%) to drought tolerance and other traits of different groundnut varieties in Anantapur district, Andhra Pradesh, India, 2008–09.

Trait	ICGV 91114	TMV 2	JL 24
Drought tolerance capacity			
Low	0.8	41.5	52.6
Moderate	53.5	77.7	31.6
High	45.7	7.8	15.8
Resistance to insect pests			
Low	3.1	13.9	78.9
Moderate	57.4	78.9	21.1
High	39.5	7.2	0.0
Resistance to diseases			
Low	3.1	14.5	68.4
Moderate	48.1	77.7	26.3
High	48.8	7.8	5.3
Uniform maturity			
Yes	91.5	22.9	26.3
No	8.5	77.1	73.7
Kernel size			
Small	7.8	34.9	84.2
Medium	45.7	61.4	10.5
Large	46.5	3.6	5.3
Haulm yield			
Low	3.9	7.2	0.0
Moderate	50.4	80.1	57.9
High	45.7	12.7	42.1
Acceptability of haulms by animals			
Good	38.8	68.1	94.7
Very good	38.0	31.3	5.3
Excellent	23.3	0.6	0.0

Source: Field survey.

and diseases (foliar diseases), while TMV 2 and JL 24 are susceptible. A majority of farmers indicated uniform pod setting and early and uniform pod maturity as important traits in ICGV 91114, whereas these traits are relatively less prominent in TMV 2 and JL 24. They also reported that kernels of ICGV 91114 were medium to large in size, while that of TMV 2 were small to medium sized.

Groundnut haulms are an important feed for livestock. Average haulm yield of ICGV 91114 was 1150 kg ha^{-1}, which was 28% and 25% more than those of TMV 2 and JL 24, respectively (Table 16). Haulms of ICGV 91114 are also qualitatively better feed than haulms of TMV 2 and JL 24 (Vellaikumar et al. 2004; Blümmel et al. 2006). Feeding haulms of ICGV 91114 resulted in more body weight gain in sheep (Vellaikumar et al. 2004) and more milk yield in cows (Blümmel et al. 2006). Farmers vetted this observation.

Costs and Returns

Partial budgets were developed to assess the relative economic performance of ICGV 91114, TMV 2 and JL 24 (Table 19). As seed rate of groundnut is high, seed cost alone accounted for around 30% of the total variable cost. Human labor also had a similar share in the total cost. Fertilizers, including manure, accounted for 20–25% of the total variable cost. Together, seed, fertilizers and human labor accounted for over 80% of the total variable cost of groundnut cultivation. Further, these shares did not differ much across different varieties.

For ICGV 91114, total cost of cultivation was ` 9235 ha^{-1} –17% more than that for TMV 2, and 6% less than that for JL 24. Gross revenue from

Table 19. Costs and returns from different groundnut varieties (` ha^{-1}) on sample farms in Anantapur district, Andhra Pradesh, India, 2008–09.

Cost item	TMV 2	JL 24	ICGV 91114
Seed	2,694	2,852	2,727
Fertilizers and manure	1,488	2,276	2,044
Pesticides	67	264	170
Machine operations	922	1,082	917
Animal labor	490	494	615
Human labor	2,237	2,806	2,763
Total cost	7,898	9,774	9,235
Pod yield (kg ha^{-1})	567	643	704
Price of pod (` 100 kg^{-1})	2,873	2,956	2,945
Value of pods	16,286	19,007	20,624
Value of haulms	1,112	1,141	1,436
Gross revenue	17,398	20,148	22,060
Net revenue	9,500	10,374	12,825
Unit cost of production (` 100 kg^{-1} pod)	1,393	1,520	1,319

Source: Field survey.

pods and haulms of ICGV 91114 was estimated at ` 22,060 ha^{-1}, which was 27% and 9% more than that for TMV 2 and JL 24, respectively. The difference in net revenue was even greater. ICGV 91114 yielded 36% more net revenue over TMV 2 and 24% over JL 24. The marginal rate of return on investment in ICGV 91114 was close to 239% compared to 220% for TMV 2 and 206% for JL 24. These figures clearly underscore the comparative profitability of ICGV 91114 over TMV 2 and JL 24. Hence, switching over to ICGV 91114 from TMV 2 and JL 24 would generate an additional net revenue of ` 3325 ha$^{-1}$ and ` 2451 ha^{-1}, respectively.

Unit cost of production of ICGV 91114 was also less; 13% compared to JL 24 and 5% compared to TMV 2. Output price of ICGV 91114 was almost similar to that of JL 24, but marginally (2.5%) higher than for TMV 2. This is expected as ICGV 91114 has large and uniform kernels, while the kernels of TMV 2 are not uniform.

A simple comparison of average of costs and returns of different varieties may not reflect their true costs and benefits because of bias in sample selection, which cannot be ruled out in initial adoption stage of a new variety. The bias in estimates may also arise due to differences in unobservable characteristics, such as management skills of adopters and non-adopters of a new variety. To test for this bias, we employed a standard treatment effects model (Greene 2003), where we first estimated an adoption equation with binary dependent variable taking a value of 1 for adopters of ICGV 91114, and a value of 0 for TMV 2 growers on a set of explanatory variables that are thought to influence adoption of ICGV 91114. In the second stage, we regressed gross revenue on a set of explanatory variables including a dummy for adopters of ICGV 91114 and the Inverse Mills Ratio obtained from the adoption equation[10]. These equations are specified as:

(1) $$R_i = a + bC_i + cX_i + \varepsilon_i$$

(2) $$C_i = \gamma_1 + \gamma_2 Z_i + u_i$$

In equation 1, R_i is gross revenue of the i^{th} farmer, C_i is a dummy variable taking a value 1 for adopter of ICGV 91114, or 0 otherwise, X_i is a vector of variables thought to affect gross revenue and ε_i is a zero mean random variable. b_1 is the regression coefficient in equation 1 and measures impact of adoption of ICGV 91114 on gross revenue.

An ordinary least squares (OLS) estimate of equation 1 could be biased because of sampling bias. To correct for sampling/selectivity bias, equation 2 (probit) is estimated with C_i as dependent variable and a set of explanatory variables Z_i. Variables in Z_i will overlap with variables in X_i. Identification requires that there be at least one variable in Z_i that is not in X_i. If this condition is met, predicted values (Inverse Mills Ratio) from the probit model can be used as an instrument in equation 1.

Results of the standard treatment effects model are presented in Table 20. Estimates of the adoption equation suggested that probability of adoption of ICGV 91114 was significantly higher for households that had higher income from sources other than groundnut, and were headed by males. Adoption of ICGV 91114 was also positively influenced by schooling of the head of the household but was significant at 15% level. These results are expected. Greater income alleviates liquidity constraint in the adoption of a new technology, and male heads seem to be better decision makers than females. Likewise, education helps farmers have greater and easy access to technology and related information. Family size – a proxy for labor endowment – had a significantly negative impact on adoption, which is counterintuitive. This could be because in drought-prone areas households with a larger labor endowment in relation to land may be more engaged in non-farm activities. An interesting observation is that land holding size did not have any significant impact on adoption of ICGV 91114.

In income equation the coefficient on the dummy for adopters of ICGV 91114 is positive and significant at 1% level, confirming that returns

10. Partial adopters of ICGV 91114 were not included in this analysis.

Table 20. Results of the treatment effects model.

Explanatory variable	Adoption equation: Dependent variable: adopters of ICGV 91114=1, otherwise =0		Income equation: Dependent variable: Gross revenue (` ha-1)	
	Regression coefficient	t-value	Regression coefficient	t-value
Age of the household (yrs)	0.01332	1.437		
Sex of the head of the household : Male =1, female=0	–0.54313	1.659*[1]		
Years of schooling of the head of the household	0.02823	1.525	42.38	1.494
No. of family members	–0.09434	1.718*	1,171.50	2.349**
Land holding size (ha)	–0.01873	0.6744		
Non-groundnut income (` household-1)	0.00001	4.010***		
Dummy for adopters of ICGV 91114			4,653.44	5.340***
Seed cost (` ha-1)			–0.0661	0.519
Fertilizer and manure cost (` ha-1)			–0.0765	0.775
Human labor cost (` ha-1)			0.1583	1.040
Draft power cost (` ha-1)			–0.1315	0.674
Inverse Mills Ratio			–399.83	0.723
Constant	–0.66530	1.412	18,515.79	29.587***
Log-likelihood function	–186.45			
Restricted log-likelihood	–201.32			
Chi-squared	29.74***			
R-squared			0.4902	
Adjusted R-squared			0.4759	
F-test			34.25***	

[1] ***, ** and * significant at 1, 5 and 10% level, respectively.

from ICGV 91114 are significantly higher than those from TMV 2. Moreover, the Inverse Mills Ratio is not significant, indicating that there was no sample selection bias. Among other explanatory variables, sex of the head of the household had a significantly positive impact on gross revenue, again implying that male-headed households through their better decision making and improved access to technology, inputs and information, are able to reap a better harvest than are female-headed households.

Table 21. Utilization of main products by farmers (% of total output) on sample farms in Anantapur district, Andhra Pradesh, India, 2008–09.

Use	TMV 2	JL 24	ICGV 91114	Total
Retained for own use	25.0	25.7	22.9	24.1
Food	7.9	5.4	5.6	6.8
Seed	17.2	20.3	17.3	17.3
Marketed surplus	75.0	74.3	77.1	75.9

Source: Field survey.

Utilization and Marketing

Table 21 shows the utilization pattern of groundnut pods/kernels. Farmers retained about one-fourth of their total produce for household consumption –as food and seed. Bulk of the retained produce, however, was meant for seed in the next cropping season. The remaining 75% of the total produce was sold, which could have been utilized for food, seed and crushing to produce edible oil. This utilization pattern was similar for all varieties.

Farmers sold their produce to different market functionaries – commission agents, local traders, regulated markets, farmers and NGOs (Table 22). There is a difference between a commission agent and a local trader. A commission agent procures produce on behalf of a large trader on

Table 22. Distribution of marketed surplus to various market functionaries (%) on sample farms in Anantapur district, Andhra Pradesh, India, 2008–09.

Functionary	TMV 2	JL 24	ICGV 91114
Regulated market	3.4	5.1	2.0
Commission agents	32.5	10.6	6.9
Local traders	48.3	84.3	33.6
NGOs	1.2	0.0	5.3
Farmers	14.6	0.0	51.4
Oil processors	0.0	0.0	0.3
Moneylenders	0.0	0.0	0.5
Total	100.0	100.0	100.0

Source: Field survey.

commission basis, while a local trader procures produce from farmers, assembles it and sells it at a profit to large traders or back to farmers as seed at the time of sowing. Local traders were dominant buyers of TMV 2 and JL 24; approximately 48% of TMV 2 and 84% of JL 24 output was sold to local traders. Commission agents shared about one-third of the marketed surplus of TMV 2 and 11% of JL 24.

One of the reasons for the dominance of commission agents and local traders in groundnut marketing is that they pick up produce from the farm gate, thus saving transportation and other market costs including market fee, labor costs of loading and unloading, commission charges, etc.

More than half of the marketed surplus of ICGV 91114 was sold to other farmers, mainly for seed. Local traders shared about one-third of their marketed surplus. AF, which has been promoting ICGV 91114 in Anantapur, also procured a small quantity of its output for further multiplication as seed.

Beyond Economic Efficiency

Incremental income from the adoption of a new technology may be utilized by farmers to create new assets or improve existing ones, like land, residential buildings, livestock, irrigation infrastructure, machinery and equipment; to finance their children's education; to improve and balance their household food consumption; to improve their savings; to repay debt and to buy quality inputs. Such quantitative and qualitative improvements in their physical, financial and human capital further enhance technology uptake, increase agricultural production and improve food and nutrition security. We compared some of these indicators before and after the adoption of ICGV 91114. ICGV 91114 appeared as the most preferred variety in FVPS trials between 2002–03 and 2004–05. In 2004–05 and 2005–06, only 11 of the total 191 sampled ICGV 91114 growers (2008–09) had grown this variety. Their number increased to 42 in 2006–07 and further to 134 in 2007–08. To ascertain whether these farmers have benefited from the adoption of ICGV 91114, we examined changes in their asset profile between 2004–05 and 2008–09, and contrasted these with the changes of those growing TMV 2.

Table 23 presents changes in the asset profile of full adopters of ICGV 91114 and those growing TMV 2. The land holding size of ICGV 91114 adopters remained pretty much the same as in 2004–05. The change in mean land holding size of TMV 2 growers was no different than that of ICGV 91114 growers. Nonetheless, irrigation coverage appears to have improved for ICGV 91114 growers. Their irrigated area increased by 16.3% during this period. The number of wells/ tube-wells and electric pumps also registered an impressive increase (53%); so did the number of sprayers. Ownership of tractors and other farm equipment, like threshers and rice transplanters also improved on adoption of ICGV 91114. TMV 2 growers also realized an increase in irrigation coverage, equipment and machinery, but not differently than for ICGV 91114 growers.

Livestock are an integral component of agriculture. They are an important source of food (milk and meat), draft power, manure and domestic fuel and of wealth and income. They are reproducible. They can easily be liquidated in times of crisis, and their products can be sold for cash, which can be utilized to meet household expenses. The importance of livestock is more pronounced in arid and semi-arid tropical regions where probability of crop failure is high. In such environments, livestock act as an insurance providing a cushion against shocks of crop failure. In our sample, most households maintained one or another species of livestock, and when their income increased, they utilized some of it to buy milch and draft animals. For adopters of ICGV 91114, the number of milch buffaloes increased by 32%, milch cows by 11% and draft animals by 15%. The number of small ruminants, however, declined considerably. Growers of TMV 2 could also improve their herd but with a difference. There was a substantial increase in the number of milch cows and small ruminants rather than buffaloes and draft animals as for ICGV 91114 growers. This indicates that when income increases, farm households tend to replace small ruminants with large ruminants, especially buffalo.

Besides investing in productivity-enhancing assets, infrastructure and equipment, farm households also utilized incremental income to buy household gadgets and articles. Figures in Table 23 indicate a significant rise in the number of televisions and two-wheelers after the adoption of ICGV 91114. A few farm households also reported buying refrigerators, washing machines, etc. For TMV 2 growers, these changes were in the form of two-wheelers and televisions.

These changes in the asset position need not necessarily be ascribed to the adoption of improved varieties alone. Farmers might have sought supplementary investment from other sources, including increased non-farm incomes. Besides, state and central governments also provide subsidized long-term credit to farmers to buy farm machinery, equipment and livestock, to create/improve on-farm irrigation facilities and other infrastructure, and for land improvement. Nonetheless, these findings indicate that adoption

Table 23. Changes in assets of adopters and non-adopters of ICGV 91114 in Anantapur district, Andhra Pradesh, India, 2008–09.

	ICGV 91114			TMV 2		
Assets household^{-1}	2004–05	2008–09	Change (%)	2004–05	2008–09	Change (%)
Land and farm infrastructure						
Land holding size (ha)	2.244	2.256	0.54	2.179	2.221	1.89
Irrigated land (ha)	0.356	0.414	16.32	0.091	0.101	9.60
No. of wells/tubewells	0.241	0.366	52.17	0.108	0.151	38.89
No. of electric and diesel pumps	0.298	0.450	50.88	0.120	0.175	45.00
No. of tractors	0.021	0.031	50.00	0.006	0.120	50.00
No. of harvesters/threshers/shellers	0.005	0.010	100.00	0.000	0.0120	na
No. of sprayers	0.246	0.309	25.53	0.145	0.187	29.17
No. of bullock carts	0.440	0.387	–11.90	0.277	0.295	6.52
Livestock						
No. of milch cows	0.696	0.770	10.53	0.452	0.620	37.33
No. of milch buffaloes	0.461	0.607	31.82	0.235	0.265	12.82
No. of draft animals	0.361	0.414	14.49	0.259	0.259	0.00
No. of small ruminants	1.010	0.330	–67.36	1.777	1.120	36.95
Other assets						
No. of four-wheelers	0.026	0.026	0.00	0.000	0.000	0.00
No. of auto-rickshaws	0.000	0.021	na	0.000	0.012	na
No. of two-wheelers	0.084	0.178	112.50	0.006	0.042	600.00
No. of televisions	0.194	0.508	162.16	0.108	0.359	231.78
No. of refrigerators	0.005	0.031	500.00	0.000	0.012	na
No. of air coolers	0.005	0.010	100.00	0.006	0.006	0.00
No. of washing machines	0.000	0.016	na	0.000	0.000	na

Source: Field survey.

of ICGV 91114 has made a contribution towards asset deepening and improving livelihood of farmers.

To further substantiate that adoption of ICGV 91114 had positively impacted farmers' livelihoods, we examined its impact on household income and its utilization pattern. Of the total 191 growers of ICGV 91114, nearly 70% reported an increase in their income. Of these, 26% experienced an increase of more than 10% in their income and the rest less than or equal to 10%.

Table 24 presents the utilization pattern of incremental income of the sample farm households. Income was utilized for more than one purpose. Improving human capital was the main priority for farm households, as about half of them reported utilizing a portion of the incremental income to finance their children's education. Investment in productivity-enhancing farm infrastructure (irrigation) ranked next; 44% farmers reported investing incremental income in on-farm irrigation facilities (wells or tube-wells). Forty percent households utilized it to repay debt, and 30% invested in farm machinery and equipment.

Table 24. Frequency distribution of response of ICGV 91114 growers' regarding utilization of incremental income in Anantapur district, Andhra Pradesh, India, 2008–09.

Investment window	Households (no.)	Total households (%)
Childrens' education	65	48.9
Irrigation facilities	58	43.6
Repayment of debt	53	39.8
Purchase of farm machinery and equipment	40	30.1
Expansion of existing house	30	22.6
Purchase of cows and buffaloes	27	20.3
Bank deposit	19	14.3
Purchase of draft animals	11	8.3
Construction of pucca house	2	1.5
Purchase of land	1	0.8
Total number of households	133	

Source: Field survey.

Other important avenues for investment of incremental income reported by adopters of ICGV 91114 included purchase of milch animals (23%) and draft animals (8%) and expansion of existing residential buildings (23%). About 14% households reported depositing the surplus income in banks.

Haulm yield of ICGV 91114 is higher and its haulms are more palatable to animals. Their better palatability/digestibility had a positive impact on animal productivity and body weight. Among adopters of ICGV 91114, 51% had maintained in-milk animals, cows or buffaloes, and 43% of these reported a moderate increase (<10%) in milk yield upon feeding animals haulms of ICGV 91114. This is consistent with the experimental results reported by Blümmel et al. (2006), where cows fed with haulms of ICGV 91114 yielded 11% more milk than those fed with haulms of TMV 2. Vellaikumar et al. (2004) also found sheep fed with haulms of ICGV 91114 gaining more weight than those fed with haulms of other varieties.

5. Market-level Effects

The comparison of yield and yield variability of different varieties has shown that switching over to ICGV 91114 can yield significant yield and risk benefits. Applying appropriate aggregation methodologies, these farm-level effects were scaled up to the next successive level, that is, Anantapur district. We used the economic surplus method to scale-up the yield-increasing benefits in a partial equilibrium framework. To quantify benefits of improved yield stability, we followed the method developed by Newbery and Stiglitz (1981) to capture welfare benefits of price stabilization programs. Walker et al. (1986) and Walker (1989) used the Newbery-Stiglitz framework to assess likely benefits from crop insurance in semi-arid tropical region of India. Kostandini et al. (2009) and La Rovere et al. (2010) used economic surplus in combination with the stabilization method to assess potential economic benefits of drought-tolerant crop varieties for selected Asian and African countries.

Estimation Procedure

Yield-increasing Benefits

The economic surplus method is widely used to evaluate impacts of technological change on social welfare because of its less restrictive assumptions and minimum data requirement. Alston et al. (1998) formulated a number of variants of the economic surplus approach befitting different economic structures (depending on the country's openness, trade flows, incentives, taxes, etc). This study used the economic surplus method for an open economy to estimate aggregate benefits from yield improvement. There are two reasons for using an open economy framework. One, India imports nearly half of its edible oil demand and any efforts to enhance domestic production of groundnut or any other oil-bearing crop would substitute imports benefiting domestic producers. Two, Anantapur produces close to 10% of the country's total groundnut, and a significant proportion of it is exported to other regions within the country. Hence, we assume Anantapur to behave like a small exporting economy where entire benefits of yield improvements would accrue to the producers in the district.

Figure 8 illustrates changes in economic surplus due to yield improvement. Adoption of a yield-increasing technology shifts the supply curve downward from S_0 to S_1; and the demand curve for groundnut and its products is assumed to remain unchanged. Price of groundnut is determined by world market at P_0 and will not change because of increase in domestic production. Consumer surplus thus remains constant, and entire benefits of the adoption of improved varieties accrue to producers. In this case, the producer surplus increases equal to the area *abcd*.

Mathematically, the change in producer surplus in case of a small open economy can be represented as:

$$\Delta PS_t = \Delta TS_t = P_0 Q_0 (K_t - Z_t)(1 + 0.5 Z_t \eta) \quad \text{..... (1)}$$

where ΔPS_t is the change in producer surplus in year t, ΔTS_t is the change in total surplus in year t, P_0 is the initial price, Q_0 is the initial level of production, Z_t is the reduction in price in year t as a result of an increase in supply due to adoption of improved variety, η is the absolute value of demand elasticity and K_t is the proportionate supply shift in year t due to adoption of an improved variety. The value of K_t can be obtained thus:

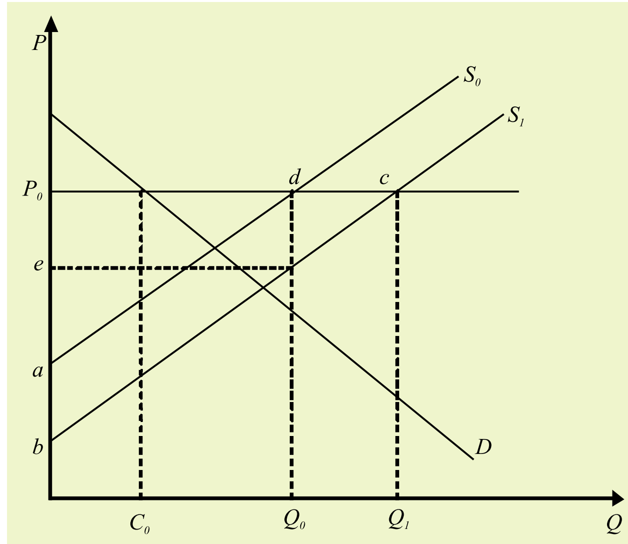

Figure 8. Changes in economic surplus due to yield improvement in an open economy framework.

$$K_t = \{[E(Y)]/\varepsilon - [E(C)]/[1 + E(Y)]\}\rho A_t (1 - \delta_t) \quad \text{.....(2)}$$

where, $E(Y)$ is the change in yield per hectare, $E(C)$ is the change in variable cost per hectare to achieve the yield change, ε is the supply elasticity, ρ is success rate of probability, A_t is the adoption rate in year t and δ_t is the depreciation on improved variety, that is reduction in expected yield in year t.

Risk Benefits

An important objective of agricultural research is to develop varieties and technologies that can withstand or escape moisture stress without any significant tradeoffs between stabilization and yield augmenting traits. Benefits to producers from drought tolerance research are estimated using the Newbery-Stiglitz framework. This method assumes that risk-averse producers benefit more from reduction in yield variance as it influences income distribution. The method is outlined:

Let $\overline{Y}_0$ be the mean yield and σ_{y0} be its coefficient of variation with existing technology. Adoption of an improved drought-tolerant variety changes mean yield to $\overline{Y}_1$and its coefficient of variation to σ_{y1}. Then, producers' benefits due to change in the yield variance can be estimated as:

$$B/\overline{Y_0} = 0.5R(\sigma_{y1}{}^2 - \sigma_{y0}{}^2) \qquad (3)$$

Where, B is monetary benefits associated with the change in reduction in yield variance, and R is the risk aversion coefficient.

Assumptions and Parameters

Changes in yield, cost of production and yield variance, and risk aversion are most important components of this analysis. A few of these parameters were estimated from the data generated through field surveys, while others were obtained from published sources. The CV in groundnut yield was estimated from the time-series data for the period 1986–87 to 2007–08. Data on groundnut production was taken from the ICRISAT database, and price of groundnut was estimated as the average of the world export price of groundnut-in-shell for the years 2003 to 2005 (FAOSTAT). The average price of groundnut was US$ 705.4 t^{-1}, which is equivalent to ` 31,974 $t^{-1}$ at a mean exchange rate of ` 45.3 per US$ (Table 25).

Table 25. Values of the parameters used in estimating benefits of improved groundnut varieties.

Parameter	Anantapur
Production quantity ('000 tons); TE 2004–05	540
Price (` t^{-1}); TE 2004–05	31,974
Yield change ha^{-1} (%)	22.8
Variable cost change ha^{-1} (%)	16.9
Maximum adoption rate (%)	35
Time period to achieve maximum adoption	2005–20
Supply elasticity	0.644
Demand elasticity	–1.02
Coefficient of variation in yield (%), 1986–2007	42.87
Reduction in coefficient of variation in yield (%)	–29.6
Relative risk aversion coefficient	
Small farmers	3.10
Medium farmers	2.45
Large farmers	1.77

Proportionate difference in yield and CV in yield of TMV 2 and ICGV 91114 was estimated for the period 2004–05 to 2008–09 using household level information from the field survey. Compared to TMV 2, the mean yield of ICGV 91114 was 22.8% more, which we have used to estimate yield-increasing benefits of ICGV 91114. Changes in cost are derived from the survey data pertaining to the 2008 rainy season.

Information on area under cultivation of improved varieties is not available in published sources. ICRISAT in collaboration with AF introduced groundnut variety ICGV 91114 in a few villages of Anantapur district in 2002. By 2008–09, this variety had been disseminated to 230 villages under the operational areas of AF. Not only that, its adoption also spilled over to other *mandals* of Anantapur district and its neighboring districts in Andhra Pradesh as well as Karnataka. According to our field survey, ICGV 91114 had occupied 3.2% of the total groundnut area in the selected villages in 2008–09. Besides, a few other improved varieties were also found to be cultivated in these villages. Together, improved varieties occupied close to 6% of total groundnut area in 2008–09. According to expert opinion, ICGV 91114 or other drought-tolerant varieties may occupy 35% of the total groundnut area by 2020–21. Further, we have assumed that adoption of drought-tolerant varieties will follow a sigmoid curve to reach the ceiling level. No depreciation on yield of the improved varieties is anticipated.

Other important parameters used in the economic surplus approach are the elasticities of demand and supply. Though groundnut is consumed in various forms, about 70% of the total groundnut produced in India is crushed to produce edible oil (Birthal et al. 2010). Hence, in this study we have used price elasticity of demand for groundnut oil as proxy for groundnut-in-shell. Estimates of demand elasticity, however, vary widely in different studies. Beghin and Matthey (2003) estimated demand elasticity at –0.38; Srinivasan (2005) at –1.02 and Pan et al. (2008) at –1.27. We have taken demand elasticity of –1.02 in this analysis.

Estimates of supply elasticity also vary considerably. Beghin and Matthey (2003) in their study reported a supply elasticity of 0.35 for the country as whole. Srinivasan (2005) and Pandey et al. (2005) estimated supply elasticity for the two major groundnut growing states of Andhra Pradesh and Gujarat. Srinivasan arrived at an estimate of 0.404 for Andhra Pradesh and 0.681 for Gujarat, while Pandey et al. estimated 0.644 for Andhra Pradesh and 0.870 for Gujarat. For Andhra Pradesh, we used supply elasticity coefficients as reported in Pandey et al.

Quantification of risk benefits of drought-tolerant varieties requires estimates of CV in yield of different varieties and the risk aversion coefficient. The CV in yield of ICGV 91114 between 2004–05 and 2008–09 was 29.6% lower than for TMV 2. Information on risk aversion is limited. Binswanger (1980) estimated relative risk aversion coefficient from a sample of farmers in India's semi-arid tropical region ranging from 0 to 7 with a median of 1. Morduch (1990) and Rosenzweig and Wolpin (1993) using household panel data for India's semi-arid tropical region for the period 1975–1984, estimated a relative risk aversion coefficient of 1.39 and 0.93, respectively. Using the same panel data with additional information for 1991, Fafchamps and Pender (1997) estimated relative risk aversion coefficients ranging from 1.77 to 3.10 under different assumptions. Kurosaki and Fafchamps (2002) estimated a relative risk aversion coefficient for farm households in Pakistan in the range of 1.34 to 4.12 with an average of 1.83.

Risk aversion behavior in farmers is influenced by a number of factors including their age, education, family size, access to non-farm income and ownership of livestock and land. Binswanger (1980) found small farmers in India's semi-arid tropical region more risk averse than large farmers. A similar relationship between risk aversion and land holding size was reported by Yesuf and Bluffstone (2007) for Ethiopian farmers. Likewise in Tanzania, farmers with a few assets were found to specialize in crops with less variability and yield (Dercon 1998). To estimate risk benefits from the adoption of drought-tolerant groundnut varieties, we assumed risk aversion coefficients as reported in Fafchamps and Pender (1997), ie, 3.10 for small farmers who are more risk averse and 1.77 for large farmers who are less risk averse. For medium farmers, risk aversion coefficient was assumed to be average of the risk aversion coefficients for small and large farmers.

Future stream of benefits need to be discounted using an appropriate discount rate to find out their net present value (NPV). There is, however, little agreement among economists regarding 'what ought to be an appropriate discount rate'. Alston et al. (1998) have argued that when analysis is conducted using constant prices, the discount rate (r) should be a real rate of interest, and suggested that in most situations the real discount factor will fall in the range of 3–5%. For agricultural projects in India, Kula (2004) estimated a discount rate of 5.2%. In this study, we applied a discount rate of 5% and also 8%.

Estimated Benefits

Table 26 shows stream of potential benefits from yield improvement and variance reduction due to adoption of ICGV 91114 for different categories of farm households in Anantapur district, based on the assumption that yield advantage, variance reduction and prices are similar across farm categories. In 2008–09, aggregate gains from adoption of ICGV 91114 on about 2.1% of the total groundnut area in Anantapur district[11] were estimated at ` 125 million at 2003–05 prices. These are likely to increase to ` 2047 million by 2015–16 (at an adoption rate of 31.8%), and further to ` 2332 million in 2020–21 when its adoption rate reaches a ceiling of 35%. The net present value of the stream of benefits for 17 years (from 2004–05 to 2020–21) is estimated to be ` 11,805 million at a discount rate of 5% and ` 8646 million at a discount rate of 8%. These translate into an annual value of ` 694 million at 5% discount rate and ` 508 million at 8% discount

11. The adoption rate of 2.1% is obtained using a sigmoid curve and is different from our estimate of 3.2%. While our estimate is for selected *mandals* in Anantapur district where more efforts were made to promote this variety, the figure of 2.1% appears to be reasonable for the district as a whole.

Table 26. Value of benefits (million `) from the adoption of groundnut variety ICGV 91114 in Anantapur district, Andhra Pradesh, India.

	Small farms (≤2.0 ha)			Medium farms (2.0–4.0 ha)			Large farms (>4.0 ha)			Total		
	Yield benefits	Risk benefits	Total benefits	Yield benefits	Risk benefits	Total benefits	Yield benefits	Risk benefits	Total benefits	Yield benefits	Risk benefits	Total benefits
2004–05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005–06	0.2	0.1	0.3	0.2	0.1	0.3	0.2	0.1	0.3	0.6	0.3	0.9
2006–07	2.3	1.5	3.8	2.2	1.2	3.4	2.1	0.8	2.9	6.6	3.5	10.1
2007–08	13.0	8.6	21.6	12.7	6.7	19.4	12.0	4.6	16.6	37.6	19.9	57.5
2008–09	28.1	18.7	46.8	27.5	14.4	41.9	25.9	10.0	35.9	81.5	43.1	124.6
2009–10	72.9	48.7	121.6	71.2	37.6	108.8	67.2	26.1	93.3	211.2	112.3	323.5
2010–11	146.4	98.6	245.0	143.0	76.1	219.1	135.0	52.8	187.8	424.4	227.5	651.9
2011–12	235.6	160.1	395.7	230.1	123.6	353.7	217.1	85.7	302.8	682.8	369.4	1,052.2
2012–13	318.2	218.1	536.3	310.8	168.4	479.2	293.3	116.7	410.0	922.4	503.2	1,425.6
2013–14	381.6	263.2	644.8	372.8	203.2	576.0	351.8	140.9	492.7	1,106.2	607.2	1,713.4
2014–15	425.5	294.6	720.1	415.6	227.5	643.1	392.2	157.7	549.9	1,233.3	679.8	1,913.1
2015–16	454.8	315.8	770.6	444.3	243.8	688.1	419.2	169.0	588.2	1,318.4	728.5	2,046.9
2016–17	483.7	336.6	820.3	472.5	259.9	732.4	445.8	180.2	626.0	1,401.9	776.6	2,178.5
2017–18	494.5	344.4	838.9	483.0	265.9	748.9	455.8	184.3	640.1	1,433.3	794.6	2,227.9
2018–19	502.9	350.4	853.3	491.2	270.5	761.7	463.5	187.5	651.0	1,457.6	808.4	2,266.0
2019–20	510.4	355.7	866.1	498.6	274.6	773.2	470.5	190.4	660.9	1,479.4	820.8	2,300.2
2020–21	517.5	360.8	878.3	505.5	278.5	784.0	477.0	193.1	670.1	1,499.9	832.4	2,332.3
NPV												
r = 5%	2,627.0	1,816.1	4,443.1	2,566.1	1,402.0	3,968.1	2,421.4	972.0	3,393.4	7,614.6	4,190.0	11,804.6
r = 8%	1,924.5	1,329.1	3,253.6	1,879.8	1,026.1	2,905.9	1,773.9	711.4	2,485.3	5,579.2	3,066.6	8,645.8

Source: Estimated by authors.

rate. These benefits include contributions of yield improvement and variance reduction. The benefits due to variance reduction comprise about 35% of the total benefits, and the rest are due to yield improvements. Kostandini et al. (2009) for drought-tolerant rice and maize in selected Asian and African countries, and La Rovere et al. (2010) for drought-tolerant maize in sub-Saharan Africa arrived at a similar share of risk benefits in the total benefits.

Table 26 presents estimates of yield and risk benefits for different categories of farm households on the assumption that farm households vary in their risk preferences, but face similar changes in yield and its variance and production cost due to the adoption of improved drought-tolerant varieties. Production estimates of groundnut are not available for different categories of households. Therefore, share of different categories of farms in total groundnut production was assumed in proportion of their share in the total groundnut area, assuming identical productivity across farms. The share of small (≤2.0 ha), medium (2.0–4.0 ha) and large farms (>4.0 ha) in total groundnut production in Anantapur district in 2001 was 34.5%, 33.7% and 31.8%, respectively.

Small farmers are more risk averse; hence they benefit most from switching over from TMV 2 to ICGV 91114. Risk benefits are estimated to comprise 42% of their total benefits. For medium farmers, share of risk benefits is 36% and for large farmers 29%. Further, small farmers share 37.5% of the total benefits – 43% of the risk benefits and 35% of the yield benefits. Their share in both yield and risk benefits is larger than their share in land area. Rosenzweig and Binswanger (1992) using ICRISAT panel data, reported that the costs of risk reduction of uncertain rainfall are not small, and are borne heavily by the poor, as much as 35% of their average profits. Our results suggest that with a share of 35% in total benefits, drought-tolerant varieties can contribute significantly towards stabilization of farm income.

These results are sensitive to changes in assumptions and parameters. The yield advantage of 22.8% and reduction in yield variance by 29.6% due to adoption of ICGV 91114 can be considered quite optimistic. Hence, we simulated yield and risk benefits of ICGV 91114 discounting yield advantage and variance reduction by 30%, lowering yield advantage to 15.98% and variance reduction to 20.72%. Under this scenario, total benefits from the adoption of ICGV 91114 decline to ` 6542 million at a discount rate of 5% and to ` 4792 million at a discount rate of 8% (Table 27). The risk benefits now increase to 45.7% of the total benefits, on average. For small farmers, risk benefits outweigh yield benefits but at the margin. The share of risk benefits in total benefits also increases for large farmers.

Table 27. The net present value (NPV) of benefits (million `) from the adoption of groundnut variety ICGV 91114 with conservative yield advantage and variance reduction in Anantapur district, Andhra Pradesh, India.

Farm category	Yield benefits	Risk benefits	Total benefits
		Discount rate 5%	
Small	1226	1295	2521
Medium	1198	1000	2197
Large	1130	694	1824
Total	3554	2988	6542
		Discount rate 8%	
Small	899	948	1847
Medium	878	732	1610
Large	828	508	1336
Total	2604	2188	4792

Source: Estimated by authors.

Variety ICGV 91114 has been used as a case for illustrating benefits of drought- tolerant groundnut breeding research, and the results would hold true for any other variety having similar yield advantage and yield variance reduction in similar agro-climatic conditions as in Anantapur. The results of this study clearly reveal that adoption of improved drought-tolerant varieties would make significant contributions to reducing farmers' vulnerability to income shocks from frequent crop failure. The need is to (i) demonstrate benefits of drought-tolerant varieties to farmers, and disseminate existing drought-tolerant varieties to farmers by strengthening the research-extension-policy interface and seed production program, and (ii) reorient the agricultural research agenda with a greater focus on breeding for drought tolerance without sacrificing yield.

6. Conclusions and Implications

Groundnut production in India is concentrated in the semi-arid tropical region characterized by low and erratic rainfall, poor irrigation, frequent droughts and poor soils. This study has assessed potential impacts of an improved drought-tolerant groundnut variety in Anantapur district of Andhra Pradesh, which is known for its frequent droughts and groundnut production. Groundnut yield in the district is low and has become more unstable in recent decades. The coefficient of variation in groundnut yield in Anantapur increased from 26.7% during 1965–66 to 1985–86 to 42.9% during 1986–87 to 2007–08, and the probability of yield falling a minimum of 20% below the trend has increased from 23.0 to 32.3%.

A field survey was conducted in 2008–09 to elicit various indicators of impact of the adoption of an improved drought-tolerant groundnut variety ICGV 91114. At farm-level, yield of ICGV 91114 was 22.8% more than the traditionally grown variety TMV 2. Though its cost of production per hectare was 17% higher, it provided 36% more net income per hectare. Besides, its yield variability was also lower compared to TMV 2 to the extent of 29.6%, which indicates its better ability to withstand moisture stress. In other words, ICGV 91114 does not only give higher yield but also contributes to farm income stabilization.

Farm-level economic benefits were aggregated to the next successive level, ie, Anantapur district, to estimate the potential benefits from adopting ICGV 91114 or any other improved drought-tolerant variety. The adoption ceiling of ICGV 91114 was assumed to reach 35% by 2020–21. In the sample villages in the selected *mandals* of Anantapur district, the adoption rate of ICGV 91114 was estimated to be 3.2% in 2008–09. Based on the sigmoid curve the adoption rate for the entire district is 2.1%. At this rate, ICGV 91114 generated cumulative benefits worth ` 192 million from 2004–05 to 2008–09. The cumulative net present value of the flow of benefits for the period 2004–05 to 2020–21 was estimated at ` 11,805 million at a discount rate of 5% and ` 8646 million at a discount rate of 8%. Of the total benefits, risk benefits comprised 35% and the rest were due to improved yield. At a conservative yield advantage of about 17% and variance reduction to about 21%, these benefits remain huge – ` 6542 million at a discount rate of 5% and ` 4792 million at a discount rate of 8%, and the share of risk benefits increased to 46% of the total benefits. Further, small farmers are more risk-averse than others and they are expected to benefit more from adoption of improved drought-tolerant varieties.

The potential benefits from the adoption of improved drought-tolerant groundnut varieties are clear and compelling. Farmers in arid and semi-arid tropical regions are risk-averse and prefer crops/varieties that offer stability even at lower yield levels. The study offers some important implications for agricultural research and public policy.

First, drought-tolerant varieties have insurance embedded in them, and can provide cost-effective long-term solutions against adverse effects of drought. Returns to investment in breeding for drought tolerance are likely to be higher compared to those in other drought management strategies. A wider dissemination of drought-tolerant material would provide a cushion to the livelihood of farmers, especially small farmers who are more vulnerable to income shocks of crop failure. This warrants revisiting the agricultural research agenda for rainfed agriculture, and an enhanced allocation of resources for drought tolerance breeding research among others.

Second, even though the potential economic benefits of drought tolerance breeding research are attractive, farmers may not benefit from it if appropriate institutional arrangements are not in place for multiplication and distribution of seeds. This is more so in the case of groundnut whose seed requirement is very high; costs of seed multiplication, acquisition, processing, storage and distribution are exorbitant; and seed to kernel price ratio is very low. These factors restrict private sector participation in the groundnut seed business. At present, a considerable proportion of farmers' seed demand is met from their own farm-saved seeds. However, when drought is severe, seed availability with farmers for the next season gets reduced drastically. Thus, the public sector should undertake multiplication and distribution of seeds of improved drought-tolerant varieties until their seeds are available in sufficient quantity at village level, and informal village seed systems are in place. Simultaneously, the public sector should phase out distribution of seeds of old varieties whose genetic potential has deteriorated.

Third, governments implement a number of programs to mitigate adverse effects of drought on the livelihood of farmers, and to avoid asset depletion. These measures are ad hoc, generally implemented when drought has occurred, and require huge financial resources. Drought-tolerant seeds, on the other hand, provide long-term solutions ex-ante, with small investment in research and development. Besides, increased and stable domestic production of groundnut or any other oilseed will reduce the import bill, which often gets inflated during drought years.

Fourth, groundnut haulms and oilcakes are protein-rich fodder/feed for livestock. Benefits of the reduced yield variance could spill over to the livestock sector, an important source of income for farmers. Reduced variability in fodder/feed supplies could contribute towards enhancing animal productivity and health, and prevent depletion of livestock assets during drought years.

Finally, benefits of adopting improved drought-tolerant varieties would go beyond the farm gate, encompassing the whole groundnut supply/value chain. Oil manufacturers would experience stability in supplies of raw material, and can optimally utilize their processing capacity and financial and human resources.

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About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger, malnutrition and a degraded environment through better and more resilient agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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