Agricultural Economics Research Review
Vol. 25(No.1) January-June 2012 pp 1-14

Potential Economic Benefits from Adoption of Improved Drought-tolerant Groundnut in India

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Abstract

The paper has examined the potential economic benefits from adoption of an improved drought-tolerant variety, viz. ICGV 91114 of groundnut in one of the most drought-prone districts in the semi-arid tropics of India. At farm-level, the variety had 23 per cent yield advantage, required 17 per cent less of variable cost and had 30 per cent less variability in its yield as compared to the ruling variety in the district. At the aggregate level, potential benefits from the adoption of this high-yielding, drought-tolerant variety are substantial. The benefits from the reduced yield variance comprise one-third of the total benefits. At a lower yield advantage and yield variance reduction, the share of risk benefits in the total benefits increase was estimated 46 per cent. Small farmers are more risk-averse; hence they would benefit more from the adoption of improved drought-tolerant varieties. These results are compelling and speak of the need for reorientation of the agricultural research agenda taking into consideration the existing and emerging abiotic stresses, and the development and dissemination of improved drought-tolerant technologies, crops and their varieties so as to enhance resilience of agriculture and adaptive capacity of farmers to cope with the risks of extreme climatic events *ex-ante*.

Key words: Drought tolerance, improved varieties, groundnut, yield benefits, risk benefits

JEL Classification: Q16, Q18

Introduction

Extreme climatic events, of which drought is one of the most important, pose a major threat to the agricultural production, and consequently to the livelihood of the people dependent directly or indirectly on agriculture. The threat is more pronounced in countries like India that have a sizeable proportion of their area falling in the semi-arid tropics. Over two-thirds of India's agricultural land is vulnerable to droughts of various intensities, and the probability of occurrence of a drought is over 35 per cent (Bhandari *et al*., 2007). Small landholders, who comprise 83 per cent of the total farm households in India, are more vulnerable to such extreme climatic events. The drought affects household economy directly by reducing crop and livestock production, and wage opportunities; and indirectly through a rise in food prices. According to Bhandari *et al*. (2007), a drought could reduce household income by 24-58 per cent, and lead to a rise in head-count poverty by 12-33 per cent in the eastern India. Besides, a severe drought reduces production potential of livestock, causes a loss to biodiversity, increases rural-urban migration and reduces demand for industrial products and agricultural inputs.

Farmers follow many *ex-ante* and *ex-post* strategies to cope with droughts. Some commonly used

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ex-post strategies are: borrowing, change in production portfolio in favour of short-duration and water-efficient crops, diversification towards non-farm activities, and mortgaging or selling of productive assets (Walker and Jodha, 1986). Farmers also follow *ex-ante* agronomic and management practices, such as crop diversification, mixed cropping, cultivation of short-duration crops, conservation and judicious use of irrigation water and adoption of crop insurance. Most of these measures provide only short-term solutions, and may not help the farmers regain their previous level of livelihood and replenish the loss of productive assets in the years following a drought (Bhandari *et al*., 2007). Mitigating post-drought effects requires financial resources for drought relief, safety nets and other development programmes. *Ex-ante* institutional mechanisms, such as crop insurance, are not fully developed, and accessible to the majority of farm households.

Technologies that reduce yield variance without sacrificing yield can significantly contribute towards mitigation of drought effects; and unlike other strategies, these can provide a long-term solution too. In the past, agricultural research has largely focused on yield improvement, and the research on drought-tolerance has not received adequate attention may be due to its complex nature. However, with increased frequency of droughts and impending changes in climate, there is increasing recognition of the importance of drought-tolerance research. Through *ex-ante* evaluation of yield-increasing and risk-reducing benefits of an improved drought-tolerant groundnut variety in a highly drought-prone region of India, this paper contributes to the understanding of how breeding research on drought-tolerance can contribute towards stabilizing farm incomes and smoothening livelihood of the poor small landholders.

Materials and Methods

The Study Region

Groundnut is among the most important oilseed crops of India, after soybean and rapeseed-mustard. It is cultivated in about 6.0 million hectares , which is about one-fifth of the total area under oilseeds in the country. However, three-fourths of the total groundnut area falls in the high-risk semi-arid tropics characterized by low and erratic rainfall and poor soils. In this paper, we have provided estimates of risk benefits from adoption of an improved groundnut variety, viz. ICGV 91114 in the Anantapur district of Andhra Pradesh — one of the most drought-prone districts in the semi-arid tropics of India, and also an important groundnut producing districts in the country. Groundnut is the main crop in the Anantapur district. In 2006-08, it was cultivated on 819 thousand hectares, which is equivalent to 75 per cent of the gross cropped area in the district, and 15 per cent of the country's total groundnut area.

Over two-thirds of Anantapur's population is engaged in agriculture. Livelihood opportunities in agriculture, however, are constrained by limited land and water resources. The average size of landholding in the district is 1.9 ha. More than two-thirds of the holdings are of less than or equal to 2.0 ha. Rainfall is scarce. Normal rainfall is 507mm (average for the period 1970-2008) and 60 per cent of it is received during June to September (rainy season) and 28 per cent during October to December (Table 1). Groundnut is grown mainly during the main rainy season (July-September), and can perform well even under low rainfall if it is evenly distributed. Of the total rainy season precipitation, more than one-third is received during June-July, one-fourth during August and 40 per cent in September. The probability[1] of rainfall falling 25 per cent or more below the normal is around 35 per cent in June, July and August and 31 per cent in September; indicating that farmers in the district face a moderate or severe drought[2] every third year. Soils are predominantly light textured, gravelly, shallow Alfisols with depths varying from 30 cm to 60 cm. They are low in organic matter, nutrients and water-

[1] The probability of actual rainfall falling short of the normal by some level, say 5 per cent was estimated as: Pr (u_t / SD ≤ – 0.05 $\overline{X}$ / SD);
where, $\overline{X}$ is the mean rainfall, SD is the standard deviation in the rainfall. Assuming that the deviation from normal rainfall (u_t) is approximately normally distributed, the probability of rainfall falling 10 per cent or more below the normal can be obtained from the tabulated values of cumulative normal distribution. For details, *see* Hazell (1985).

[2] The Meteorological Department of Government of India defines drought as a condition when the rainfall deficiency during the south-west monsoon season is 10 per cent or more, and more than 20 per cent area is affected by drought conditions. For small areas, if the seasonal rainfall deficiency is 26-50 per cent, it is a moderate drought; and if it exceeds 50 per cent, it is a severe drought.

Table 1. Rainy season precipitation in Anantapur district, Andhra Pradesh: 1970-2008

Parameters	Jun-Sep	Jun	Jul	Aug	Sep
Mean normal rainfall (mm)	300.0	50.2	55.0	71.0	123.8
Coefficient of variation (%)	38.7	68.2	91.0	70.9	51.4
Probability of rainfall being 10% or more below the normal (%)	40.1	44.0	49.6	44.4	42.1
Probability of rainfall being 25% or more below the normal (%)	26.1	35.6	38.2	35.2	31.2

Source: Estimated by authors.

holding capacity and are prone to wind and water erosions (Rukmani and Manjula, 2009). The scope of growing crops in the post-rainy season is extremely limited due to lack of rains and irrigation water. Irrigation is limited to only 11 per cent of the net sown area. Length of growing period is 119 days, from July to October (Rukmani and Manjula, 2009), and the cropping intensity hardly ever exceeds 110 per cent.

Introduction of Improved Groundnut Varieties

Groundnut has emerged as a dominant crop in the Anantapur district replacing millets and other coarse cereals because of its resilience, higher profitability and increasing demand. Between 1966-68 and 2006-08, groundnut area in the district increased by 620 thousand ha, while sorghum and millets lost 428 thousand ha. The groundnut production system, however, did not experience any significant technological transformation. Varieties such as TMV 2 and JL 24, which were introduced during the 1970s in this district, continue to be cultivated in a large area. According to an estimate, TMV 2 alone occupies 75-80 per cent of the total groundnut area in the district (Nigam *et al.,* 2005). This variety was introduced because of its drought-tolerance characteristic, but now this trait has degenerated considerably and the variety has also become susceptible to many insect pests and diseases (Rukmani and Manjula, 2009). JL 24 is suitable for cultivation under the irrigated conditions and occupies 10-15 per cent of the groundnut area.

A few attempts made in the past to replace TMV 2 did not succeed, as the substitute varieties did not meet farmers' expectations of higher pod and haulm yields, higher shelling out-turn, early maturity, drought-tolerance and uniform kernel size. To find a suitable substitute for TMV 2, ICRISAT in collaboration with Accion Fraterna (AF)[3] — a local non-governmental organization (NGO) — conducted farmers participatory varietal selection (FPVS) trials with 10 varieties (ICGV # 92020, 91114, 89104, 94080, 92093, 92267 and 86590, ICGS 76, K 134 and the ruling TMV 2) in the rainy season of 2002 in two villages of the Anantapur district (Nigam *et al*., 2005). Despite rainfall being less than half of the normal (146 mm) during this season, ICGV 91114[4] performed better than other varieties. Its pod and haulm yields respectively were 28 per cent and 7 per cent higher than those of TMV 2. Another variety, ICGV 89104, was the next best performer. In the following rainy season, these two varieties with TMV 2 as the check were retained in FPVS trials, and the trials were extended to one more village. In this season too, rainfall was scarce (168 mm). ICGV 91114 again performed better than TMV 2 and ICGV 89104. Its average pod yield was 13 per cent and haulm yield 25 per cent more as compared to that from TMV 2.

Farmers preferred ICGV 91114 because of its shorter duration (90-95 days), better capacity to withstand mid-season and terminal drought, higher pod and haulm yields, and higher shelling out-turn (75%), oil content (48%) and protein content (27%). Its haulms constitute an excellent fodder for livestock. They are more palatable and digestible compared to the haulms of TMV 2 (Vellaikumar *et al.,* 2004; Blummel *et al.,* 2006). In the next rainy season (viz., 2004), 84 farmers from these three FPVS villages sowed ICGV 91114.

[3] Accion Fraterna, with headquarters in Anantapur city, is engaged in multifarious activities related to agriculture, health care and rural development in 230 villages in the district.

[4] ICGV 91114, which we have chosen for the economic evaluation, was derived from a cross between two advanced breeding lines (ICGV 86055 × 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.

But soon after sowing, there was a dry spell of about 5 weeks. The mean rainfall during this season was 225 mm. The performance of ICGV 91114 was, however, better than that of TMV 2. Its average pod yield was 11 per cent more than that of TMV 2.

Convinced of its consistent better performance under drought conditions, many farmers from 23 villages in 10 *mandals* (administrative sub-divisions) of the Anantapur district and two villages each from the adjoining Kurnool and Chittoor districts took up seed production of ICGV 91114 in the post-rainy season of 2004-05 under irrigated conditions. Farmers saved their produce for sowing in the following rainy season, and the surplus produce was sold as seed to other farmers. In 2005 rainy season, this variety spread to 41 villages in 18 *mandals*. ICGV 91114 was officially released by the Government of Andhra Pradesh in 2006 as a special case, bypassing the formal protocol of variety release. By 2010, it had spread in many villages in the operational area of AF and beyond in the neighbouring districts in Andhra Pradesh and in Karnataka. It was officially released in Orissa in 2008 and in Karnataka in 2009. It is also grown in Gujarat, Maharashtra and Jharkhand.

Data

The information used in this paper was obtained through field surveys, published sources and literature reviewing. Information on cost of production, crop yield, output prices and other relevant variables pertaining to the rainy season of 2008 was collected through a field survey involving about 400 farmers from 49 villages in 8 *mandals* (out of 63) in the Anantapur district where ICGV 91114 was first introduced in 2002 and 2003. These *mandals* were: Atmakur, Beluguppa, Dharmavaram, Kalyandurg, Kudair, Kundurpi, Rapathadu and Settur (all in the operational area of AF) and they represented the average agro-climatic conditions of the district. Since adoption of ICGV 91114 was thin, the survey was conducted in a cluster of 4-7 villages in each *mandal* covering a total of 200 households who grew ICGV 91114 and an equal number of those who had not grown this variety. The AF is actively engaged in the promotion of ICGV 91114, and maintains records of its adopters. The sample of households growing ICGV 91114 from each *mandal* was drawn in proportion to their share in the total area under ICGV 91114. Non-adopters of ICGV 91114 were randomly selected from each cluster. Twenty-one households were dropped from the analysis due to incomplete or incorrect information.

Of the total sample households, 166 households grew only TMV 2, 129 grew only ICGV 91114, 19 grew only JL 24 and 3 grew only K 6. Sixty-two households grew ICGV 91114 in combination with other varieties, mainly TMV 2. We also collected information from the sample households on area and production of different varieties grown during the past 5 years. In each village, focussed group discussions were conducted to elicit adoption pattern of ICGV 91114. Observations from these discussions indicated that TMV 2 had occupied 87.8 per cent of the total groundnut area in the selected villages, followed by JL 24 (6.4%), ICGV 91114 (3.2%) and K 6 (2.6%).

Methods of Analysis

There have been significant advances in quantification methodologies of the economic benefits due to technological change. Economic surplus is a widely used approach to evaluate impact of technological change because of its less restrictive assumptions and minimum data requirement (Alston *et al*., 1998). Newbery and Stiglitz (1981) had developed a method to capture benefits of the price stabilization programmes, which can be applied for quantifying risk benefits of new technologies. Walker *et al*. (1986) had used this approach to assess the likely benefits from crop insurance in India. Kostandini *et al*. (2009) and La Rovere *et al*. (2010) have followed these approaches, in combination, to estimate the economic benefits of drought-tolerant crop varieties. We have followed Kostandini *et al*. (2009) and La Rovere *et al*. (2010) to demonstrate the potential economic benefits from adoption of groundnut variety ICGV 91114.

Yield-increasing Benefits — Alston *et al*. (1998) have suggested a number of variants of the economic surplus approach depending on the economic structure of region/country. In this study, we have estimated economic surplus in an open economy framework because of two reasons. One, India imports nearly half of its edible oils demand, and any effort to enhance domestic production of groundnut or any other oil-bearing crop would substitute imports, benefiting local producers. Two, Anantapur district produces about 10 per cent of the country's total groundnut, and a significant proportion of it is transported to other regions of the country. Hence, we assumed Anantapur to behave like a small exporting economy wherein the entire benefits of technological change would accrue to the producers in the district itself.

The changes in economic surplus due to yield improvement have been illustrated in Figure 1. Adoption of a yield-increasing variety shifts groundnut supply curve downwards, from S_0 to S_1; and the demand curve for groundnut and its products is assumed to remain unchanged at C_0. The price of groundnut is determined by the world market at P_0 and will not change due to increase in domestic production. Consumer surplus, thus, remains constant, and the entire benefits from adoption of the improved variety accrue to the producers. In this figure, the producer surplus increases equal to the area *abcd*.

Mathematically, the change in producer surplus in a small open economy can be represented by Equation 1:

$$\Delta PS_t = \Delta TS_t = P_0Q_0\,(K_t - Z_t)\,(1+0.5\,Z_t\eta) \qquad \ldots(1)$$

where, ΔPS_t is the change in producer surplus in the year t; “TS_t is the change in total surplus in the year t; P_0 is the initial price; Q_0 is the initial level of production;

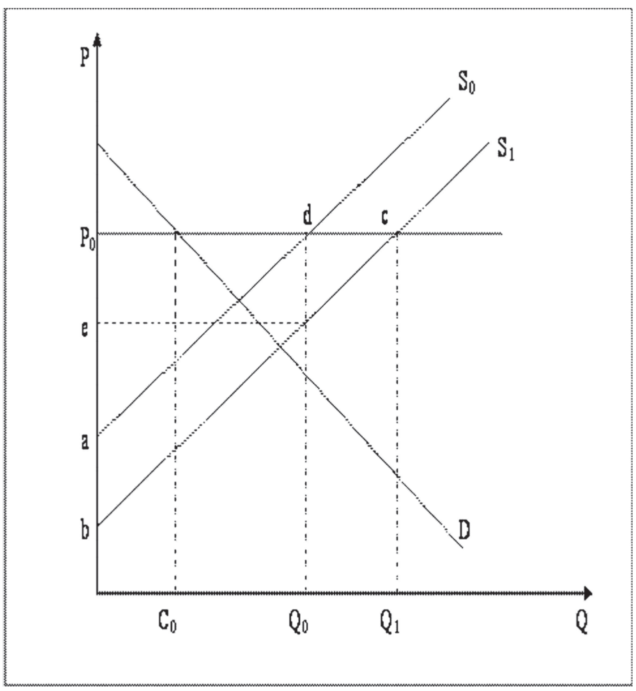

Figure 1. Economic surplus due to yield improvement in an open economy framework

Z_t is the reduction in price in the 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 the year t due to adoption of improved variety. The value of K_t can be obtained as:

$$K_t = \{[E(Y)] / \varepsilon - [E(C)] / [1 + E(Y)]\}\ \rho A_t\,(1 - \delta_t) \qquad \ldots(2)$$

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

Risk Benefits — Benefits from reduction in yield variance due to adoption of drought-tolerant variety have been estimated using the Newbery-Stiglitz approach. It assumes that risk-averse producers benefit more from reduction in yield variance as it influences income distribution (Kostandini *et al.*, 2009). The Newbery-Stiglitz method is outlined below:

Let, $\overline{Y}_0$ be the mean yield and σ_{y0} be its coefficient of variation for the old variety. Adoption of a drought-tolerant variety changes mean yield to $\overline{Y}_1$ and the coefficient of variation to $\sigma_{y1.}$ The benefits due to change in variance in yield then can be estimated using Equation 3:

$$B / \overline{Y}_0 = 0.5\,R\,(\sigma_{y1}^2 - \sigma_{y0}^2) \qquad \ldots(3)$$

where, B represents the monetary benefits associated with the change in reduction in yield variance, and R is the risk aversion coefficient. Note that in an open economy framework, the benefits from reduction in yield variance will accrue to the producers only.

Results

Growth and Variability in Groundnut Production

Groundnut production in the Anantapur district increased at an annual rate of 6.5 per cent during 1965-66 to 1985-86, which decelerated to less than 1 per cent during 1987-88 to 2007-08 (Table 2). During both the periods, the growth occurred mainly due to area expansion. The yield growth rather turned out to be negative in the latter period. The deceleration in growth was accompanied by increased variability. The

Table 2. Growth and variability in groundnut production in Anantapur district, Andhra Pradesh: 1965-66 to 2007-08

Parameters	Production		Yield		Area	
	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
Annual compound growth rate (%)	6.46	0.96	1.37	-0.88	5.01	1.85
Coefficient of variation (%)	35.05	49.88	26.73	42.87	11.38	8.49
Probability of shortfall from the 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: Estimated by authors.

coefficient of variation (CV) in production increased from 35.1 per cent during 1965-66 to 1985-86 to 49.9 per cent during 1986-87 to 2007-08, and much of the variability could be explained by the variability in yield — the CV in yield increased from 26.7 per cent during 1965-66 to 1985-86 to 42.9 per cent during 1986-87 to 2007-08. The CV in planted area, on the other hand, declined from 11.4 per cent to 8.5 per cent during 1986-87 to 2007-08.

Table 2 also presents the probability of shortfall in area, production and yield below their trend levels. During 1965-66 to 1985-86, the probability of production and yield being 5 per cent or more below their trend levels was 44.4 per cent and 42.9 per cent, respectively, which further increased during 1986-87 to 2007-08. Such high probabilities are expected for a small deviation from the trend. However, the probabilities of a larger shortfall also remain very high. During 1986-87 to 2007-08, the probability of production and yield falling 30 per cent or more below the trend levels was 27.4 per cent and 24.5 per cent, respectively. For planted area, the probability of a shortfall of 5 per cent or more below the trend was 33.4 per cent during 1965-66 to 1985-86, which declined to 28.1 per cent during 1986-87 to 2007-08. However, the probability of a significant decline in the planted area was found extremely low, implying that farmers rarely forego planting their intended area because of poor rains at the beginning of the cropping season.

These findings have clearly brought out that risk in groundnut production has increased over time. The question is: Can technology reduce production risks? If yes, what are the technological options? Amongst various technological options, drought-tolerant varieties are considered to be more plausible, effective and sustainable (Gollin, 2006; Kostandini *et al*., 2009). The seed has embedded in it the traits that shorten crop duration to escape terminal drought or enhance crop vigour (efficient utilization of limited water) to withstand moisture stress at critical growth stages. Besides, these varieties are easy to adopt, require less operational expenses, and can be multiplied in a short period by farmers and/or seed companies.

Farm-level Effects of Improved Drought-tolerant Variety

A comparison of yield of different groundnut varieties grown on sample farms in the rainy season of 2008 is presented in Table 3. The variety ICGV 91114 had a yield advantage of 23.6 per cent over TMV 2 and 8.9 per cent over JL 24. Its cost of cultivation, however, was 17 per cent more than that for TMV 2, but 6 per cent less compared to that for JL 24. Seed cost alone accounted for around 30 per cent of the total variable cost. Human labour also had a similar share in the total cost. Fertilizers, including manure, accounted for 20-25 per cent of the total variable cost. Together, seed, fertilizers and human labour accounted for over 80 per cent of the total variable cost of groundnut cultivation. These shares did not vary much across different varieties.

Nonetheless, the gross and net revenues (pods and haulms) were higher from ICGV 91114 than those from

Table 3. Economics of cultivation of different groundnut varieties on sample farms in 2008-09 in Ananatapur district, Andhra Pradesh

(₹/ha)

Cost item	TMV 2	JL 24	ICGV 91114
Seed	2694	2852	2727
Fertilizers and manures	1488	2276	2044
Pesticides	67	264	170
Machine operations	922	1082	917
Animal labour	490	494	615
Human labour	2237	2806	2763
Total cost	7898	9774	9235
Pod yield (100 kg/ha)	5.67	6.43	7.04
Price of pod (₹/100 kg)	2873	2956	2945
Value of pods	16,286	19,007	20,624
Value of haulms	1112	1141	1436
Gross revenue	17398	20148	22060
Net revenue	9500	10374	12825
Unit cost of production (₹/100 kg- of pod)	1393	1520	1319

Source: Field survey

other varieties. The net revenue was higher by 36 per cent over TMV 2 and 24 per cent over JL 24. The marginal rate of return on investment in ICGV 91114 was close to 239 per cent compared to 220 per cent for TMV 2 and 206 per cent 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 additional net revenue of ₹ 3325/ha and ₹ 2451/ ha, respectively.

A simple comparison of the means of yield and net revenue from different groundnut varieties may not reflect their true values because of sampling bias, which cannot be ruled out in the initial stages of adoption of new varieties. The bias in estimates may also arise due to differences in unobservable characteristics, such as management skills of adopters and non-adopters of new varieties. To test for this bias, we employed the 'standard treatment effects' model (Greene, 2003) as specified below:

$$R_i = a + b_1C_i + cX_i + \varepsilon_i \qquad \ldots(4)$$

$$C_i = \gamma_1 + \gamma_2 Z_i + u_i \qquad \ldots(5)$$

where, R_i is the gross revenue of the i^{th} farmer; C_i is a dummy variable taking the value 1 for adopters of ICGV 91114, or zero 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 (4) and measures the impact of adoption of ICGV 91114 on gross revenue. An ordinary least squares (OLS) estimate of Equation (4) could be biased because of sampling bias. To correct for sampling/selectivity bias, Equation (5) was estimated with as the dependent variable and a set of explanatory variables Z_i (probit). The variables in Z_i will overlap with variables in X_i. Identification requires that there should be at least one variable in Z_i that is not present in X_i. If this condition is met, the predicted values (Inverse Mills Ratio) from the probit model can be used as an instrument in Equation (4).

The results of the 'standard treatment effects' model are presented in Table 4. The 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 the education of household-head, but the coefficient was significant at 15 per cent level. These results were as expected. Higher income alleviates liquidity constraint in adoption of a new technology, and the male household-heads seem to be better decision-makers than female-heads. Likewise, education helps the farmers to have greater and easy access to technology

Table 4. Results of the treatment effects model

Explanatory variable	Adoption equation: Dependent variable: ICGV 91114=1, otherwise =0		Revenue equation: Dependent variable: Gross revenue (₹/ha)	
	Coefficient	t-value	Coefficient	t-value
Age of household-head (years)	0.01332	1.437		
Sex of household-head : Male =1, female=0	-0.54313	1.659*		
Schooling of household-head (years)	0.02823	1.525	42.38	1.494
Family members (No.)	-0.09434	1.718*	1171.50	2.349**
Landholding size (ha)	-0.01873	0.6744		
Non-groundnut income (₹/household)	0.00001	4.010***		
Dummy for adoption of ICGV 91114			4653.44	5.340***
Seed cost (₹/ha)			-0.0661	0.519
Fertilizer and manure cost (₹/ha)			-0.0765	0.775
Human labour cost (₹/ha)			0.1583	1.040
Draft power cost (₹/ha)			-0.1315	0.674
Inverse Mills Ratio			-399.83	0.723
Constant	-0.66530	1.412	18515.79	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***	

Note: ***, ** and * denote significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.

and related information. Family size — a proxy for labour endowment — had a significantly negative impact on adoption of ICGV 91114, which is counterintuitive. This could be because in a drought-prone area a household with a larger labour endowment in relation to land may be more engaged in non-farm activities. An interesting observation was that landholding size did not have any significant impact on adoption of ICGV 91114.

In the revenue equation, the coefficient of dummy for adoption of ICGV 91114 is positive and significant at 1 per cent level, confirming its better performance over TMV 2. Inverse Mills Ratio is not significant, suggesting that there was no sample selection bias. Among other explanatory variables, sex of the household-head had a significantly positive impact on revenue, implying that male-headed households through their better decision-making capacity and improved access to technology, inputs and information, are able to have a better harvest than female-headed households do.

Another variable of interest is the variance in yield of different varieties, which we have estimated using the yield data on sample farms for five-year period from 2004-05 to 2008-09. The CV in yield of ICGV 91114 was 24.8 per cent, which is 29.6 per cent and 22.7 per cent less compared to the CV in yield of TMV 2 and JL 24, respectively (Table 5). The mean yield of ICGV 91114 was 22.8 per cent more over TMV 2 and 13.6 per cent more over JL 24. These findings clearly establish the comparative advantage of ICGV 91114 over other varieties in terms of both yield improvement and risk reduction.

Aggregate Benefits from the Adoption of Improved Drought-tolerant Groundnut Varieties

Combining the economic surplus and stabilization approaches, the farm-level benefits of the ICGV 91114 were scaled up to the level of Anantapur district under certain assumptions (Table 6). Changes in yield, cost of production and yield variance, and the risk aversion coefficient are the main components of this analysis.

Table 5. Yield and yield variability of different groundnut varieties on sample farms in Anantapur district, Andhra Pradesh: 2004-05 to 2008-09

Year	Groundnut variety		
	TMV 2	JL 24	ICGV 91114
2004-05	757	775	886
2005-06	614	607	861
2006-07	544	654	770
2007-08	1163	1216	1273
2008-09	567	643	704
Mean	727	786	893
CV	35.2	32.1	24.8

Source: Field survey

Price of groundnut was taken 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, which was equivalent to ₹ 31,974/ t at a mean exchange rate of ₹ 45.30 per one US $. The CV in groundnut yield for the period 1986-87 to 2007-08 was taken from Table 2. Proportionate difference in yield and CV in yield of TMV 2 and ICGV 91114 was taken from Table 5. The changes in production were taken from Table 3. Information on area under improved varieties was not available in the published sources. Our estimates from the focussed group discussions suggested that ICGV 91114 had occupied 3.2 per cent of the total groundnut area in the selected villages in 2008-09, and according to experts this or other drought-tolerant varieties may occupy 35 per cent of the total groundnut area by 2020-21. Further, we have assumed that their adoption rate will follow a sigmoid curve to reach the ceiling. No depreciation on yield of improved varieties is anticipated.

Other parameters required for estimation of economic surplus are the elasticities of demand and supply. In India, about 70 per cent of the total groundnut produced is crushed to produce edible oil (Birthal *et al*., 2010). Hence, we took the price elasticity of demand for groundnut oil as proxy for groundnut-in-shell. Estimates of demand elasticity, however, vary widely. Beghin and Matthey (2003) have estimated the demand elasticity at -0.38; Srinivasan (2005) at -1.02 and Pan *et al*. (2008) at -1.27. In this paper, we have taken demand elasticity estimate of -1.02. Estimates of supply elasticity also vary considerably. Beghin and Matthey (2003) have reported a supply elasticity of 0.35 for the country as whole. Srinivasan (2005) and Pandey *et al*. (2005) have 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*. have estimated 0.644 for Andhra Pradesh and 0.870 for Gujarat. We have used supply elasticity coefficient of 0.644.

The estimation of risk benefits requires information on risk behaviour of farm households.

Table 6. Values of the parameters used in estimation of aggregate benefits from the adoption of drought-tolerant groundnut variety ICGV 91114 in Anantapur district, Andhra Pradesh

Parameter	Value	Source
Production quantity ('000 tonnes): TE 2004-05	540	ICRISAT database
Price (₹ /t): TE 2004-05	31974	FAOSTAT
Yield change (%)	22.8	Field survey
Per ha variable cost change (%)	16.9	Field survey
Maximum adoption rate (%)	35	Expert opinion
Time period to achieve maximum adoption	2005-20	Expert opinion
Supply elasticity	0.644	Pandey *et al.* (2005)
Demand elasticity	-1.02	Srinivasan (2005)
Coefficient of variation in yield (%): 1986-2007	42.87	Estimated by authors
Reduction in coefficient of variation in yield (%)	-29.6	Field survey
Relative risk aversion coefficient		Fafchamps and Pender (1997) (1997)
Small farmers	3.10	
Medium farmers	2.45	
Large farmers	1.77	

Table 7. Net present value of the benefits from adoption of improved drought-tolerant groundnut variety ICGV 91114 for the period 2004-05 to 2020-21

Farm size	Optimistic scenario: Yield advantage: +22.8% Variance reduction: -29.6%			Conservative scenario: Yield advantage: +16.0% Variance reduction: -20.7%		
	Yield benefits	Risk benefits	Total benefits	Yield benefits	Risk benefits	Total benefits
			Discount rate 5 per cent			
Small	2627	1816	4443	1226	1295	2521
Medium	2566	1402	3968	1198	1000	2197
Large	2421	972	3393	1130	694	1824
Total	7614	4190	11804	3554	2988	6542
			Discount rate 8 per cent			
Small	1925	1329	3254	899	948	1847
Medium	1880	1026	2906	878	732	1610
Large	1774	711	2485	828	508	1336
Total	5579	3066	8645	2604	2188	4792

Source: Estimated by authors

Information on risk aversion, however, is limited. Binswanger (1980) reported relative risk aversion coefficients for India's semi-arid tropical region ranging from 0 to 7 with a median value of 1. Morduch (1990) and Rosenzweig and Wolpin (1993) using the 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) have estimated relative risk aversion coefficients ranging from 1.77 to 3.10. Kurosaki and Fafchamps (2002) estimated relative risk aversion coefficients for farm households in Pakistan in the range of 1.34 to 4.12 with an average of 1.83.

Risk aversion behaviour of farm households is influenced by a number of factors, such as age, education, family size, access to non-farm income and ownership of assets. Binswanger (1980) found the small farmers more risk-averse than the large farmers. A similar relationship between risk aversion and landholding size was reported by Yesuf and Bluffstone (2007) from Ethiopia. Likewise in Tanzania, farmers with a few assets were found to specialize in crops with less variability at low yield (Dercon, 1998). With this kind of relationship in view, we assumed the risk aversion coefficients as reported by Fafchamps and Pender (1997) - 3.10 for small farmers (≤ 2.0 ha), 1.77 for large farmers (>4.0ha) and the average of these two for medium farmers (2.0-4.0 ha).

The future stream of benefits needs to be discounted using an appropriate discount rate to obtain 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 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 per cent. For agricultural projects in India, Kula (2004) has estimated a discount rate of 5.2 per cent. Alpuerto *et al*. (2009) have applied a discount rate of 5 per cent in their study on *ex-ante* assessment of the benefits of marker-assisted breeding in rice in India, Bangladesh, Indonesia and Philippines. We have applied a discount rate, r, of 5 per cent and also 8 per cent in the present study.

Table 7 presents the estimates of NPV of yield-increasing and risk-reducing benefits of ICGV 91114 on different categories of farms[5] assuming that farmers

[5] Estimates of groundnut production by farm size were not available, hence the share of different categories of farms in total groundnut production was considered in proportion of their share in the total groundnut area, assuming identical productivity across farms. In 2005-06, the share of small (≤ 2.0 ha), medium (2.0-4.0 ha) and large farms (>4.0 ha) in total groundnut area was 34.5 per cent, 33.7 per cent and 31.8 per cent, respectively.

differ in their risk preferences, but face similar changes in crop yield, its variance and cost of production. As small farmers are more risk-averse, they benefit more from the adoption of ICGV 91114. We have estimated risk benefits comprising 42 per cent of the total benefits for small farmers, 36 per cent for medium farmers and 29 per cent for large farmers. The total benefits from the adoption of ICGV 91114 for the period 2004-05 to 2020-21 have been estimated as ₹ 11,804 million at a discount rate of 5 per cent and ₹ 8645 million at a discount rate of 8 per cent. These translate into ₹ 694 million and ₹ 508 million per annum at the respective discount rates of 5 per cent and 8 per cent. On average, the reduction in yield variance contributed 35 per cent of the total benefits, and the rest were due to yield improvement. This implies that a widespread adoption of drought-tolerant varieties can make significant contributions towards stabilization of farm income.

These results are sensitive to changes in the assumptions and parameters, particularly those related to yield advantage and variance reduction. The yield advantage of 22.8 per cent and variance reduction by 29.6 per cent on adoption of ICGV 91114 may be considered quite optimistic. Hence, we simulated yield and risk benefits of ICGV 91114 by scaling down the observed yield advantage and variance reduction by 30 per cent, that is yield advantage to 16.0 per cent and variance reduction to 20.7 per cent. With this scenario, the total benefits from adoption of ICGV 91114 declined to ₹ 6542 million at a discount rate of 5 per cent and to ₹ 4792 million at a discount rate of 8 per cent (Table 7). The share of risk benefits in the total benefits, however, increased to 46 per cent. On small farms, the risk benefits even outweighed the yield benefits though at the margin. The share of risk benefits in the total benefits also increased on medium and large farms.

Discussions

Over the past several years, there has been an increasing recognition in both international and national agricultural research systems of the potential adverse effects of extreme climatic events, such as droughts on agricultural production and livelihood of the farmers, and the need to enhance resilience of agriculture through technological and other interventions. Lybbert and Bell (2010) have observed that in the past one decade, few agricultural research objectives have attracted as much attention and investment as drought-tolerance.

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 drought-tolerant strains of these crops are already in farmers' fields. In this paper, we illustrated risk benefits of a drought-tolerant groundnut variety ICGV 91114 in the Anantapur district of Andhra Pradesh. The potential risk benefits from its adoption are huge — 35 to 46 per cent of the total benefits, depending on the extent of its comparative advantage in yield and yield stability over other varieties. These results would hold true for any other variety having similar yield advantage and drought-tolerance. Rosenzweig and Binswanger (1992) have reported that costs of risk reduction of uncertain rainfall in semi-arid tropical region of India are not small, and are borne heavily by the poor, as much as 35 per cent of their average profits in agriculture.

The experimental evidence has shown that under moisture-stressed conditions the drought-tolerant varieties of rice, wheat and maize yield 10-30 per cent more output 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 on an average 20 per cent more than of the varieties they had replaced (CGIAR, 2009). In Latin America, the average yield of drought-tolerant varieties of bean was reported to be almost double of the traditional commercial varieties (CGIAR, 2009).

Evidence of returns on investment in drought-tolerance crop breeding research is scarce, probably because agricultural research in the past was largely focused on yield improvement. However, with the impending changes in climate, there is an increasing recognition of the drought-tolerance research. According to Lybbert and Bell (2010), investment in drought tolerance research has crossed US$ 1.0 billion. Investments in drought-tolerance breeding research have yielded attractive rates of return also. Gollin (2006) has reported a reduction in yield variability of maize and wheat in the developing countries, and has attributed it to the longstanding efforts in breeding for drought-tolerance, disease- and pest-resistance, as well as improved cropping systems among others. He has estimated the annual economic benefits from improved yield stability in wheat and maize at US$ 149 million and US$ 143 million, respectively. A pearl millet 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 per cent over the traditional varieties, generates annual stream of discounted benefits of US$ 4 million (CGIAR, undated).

Kostandini *et al*. (2009) have estimated *ex-ante* 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 have found that on average, risk benefits comprised one-third of the total benefits. For India, they have estimated producer benefits from variance reduction as much as two-thirds of the total benefits in the case of rice, 44 per cent in maize and 18 per cent in wheat. They have also reported significant benefits to consumers from the reduction in yield variance. On the whole, they have concluded that (i) the sum of benefits from yield variance reduction, for maize and rice, are greater than the sum of benefits from their yield increases; and (ii) the producers and consumers of maize and rice in high-drought risk zones benefit more from the adoption of drought-tolerant varieties.

In an *ex-ante* assessment of impact of drought-tolerant varieties of maize in 13 countries of Africa, La Rovere *et al*. (2010) have reported that with conservative yield gains of 3-20 per cent and variance reduction of 10 per cent, the potential benefits from the adoption of drought-tolerant maize during 2007-2016 will be US $0.53 billion, of which over 36 per cent will be due to reduction in yield variance. Risk benefits will be more for the regions/countries with high probability of crop failure.

The benefits of drought-tolerance crop breeding research are clear and compelling. Climate is changing, and the frequency of extreme climatic events, of which drought is one, is predicted to increase over the next century. This will adversely affect agricultural production, food security and livelihood of the farmers in the absence of appropriate mitigation and adaptation measures. Given this scenario, our results speak the need for (i) prioritization of the agricultural research agenda with more emphasis on the development of water-efficient high-yielding crop varieties, and (ii) multiplication and distribution of the seeds of such varieties by both public and private sectors.

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Received: February 2012; Accepted: March 2012