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RISK AND THE CHOICE OF CROPPING SYSTEMS : HYBRID SORGHUM AND COTTON IN THE AKOLA REGION OF CENTRAL PENINSULAR INDIA

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Risk and the Choice of Cropping Systems: Hybrid Sorghum and Cotton in the Akola Region of Central Peninsular India

T.S. Walker and K.V. Subba Rao*

Experimental evidence convincingly indicates that high yielding sorghum hybrids have greater yield stability than unimproved local varieties (Barah et al. 1980). Whether this conclusion applies to less protected and less fertile environments typical of many farmers' fields in the Semi Arid Tropics of India is an open and probably site specific question.

A more fundamental issue relates to the basis for comparisons on yield stability. Clearly, for rabi sorghum that is largely sole cropped on residual soil moisture in the postrainy season stability comparisons between improved and traditional cultivars are valid and thoroughly informative. But for sorghum hybrids planted in the rainy season stability evaluations that use local varieties as a yardstick do not tell the whole story. In the rainy season, local varieties are commonly planted in intercropping systems. They often are relatively minor components in those systems particularly in the black soil cotton growing regions of Maharashtra where sorghum hybrids are more widely diffused than in most other states in India. Although sorghum hybrids are eminently suitable for intercropping (Willey et al. 1981), farmers have steadfastly refused to plant them in their traditional and semi-improved intercropping systems. Most hybrid sorghum is sole cropped and managed more intensively than in competing intercropping systems.

The behavior of farmer suggests that they view sorghum hybrids and local varieties not as two different types of cultivars but rather as two different species. Sorghum hybrids have a high yield potential and harvest index and are short-statured, photoperiod insensitive, and early maturing. A contrasting set of adjectives describes local varieties. Sorghum hybrids and local varieties are readily differentiated in the market and fetch different prices for grain and fodder. When phenotypic change is so complete, risk analysis among alternative cropping systems may offer a more informative perspective on relative stability. Sorghum hybrids may be notably more stable than

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local varieties, but returns in sole-cropped hybrid sorghum may be markedly more variable than what is obtained in competing intercropping systems in which local sorghum occupies a proportionately small area and hence plays a minor role in conditioning revenue variability.

The economic stability of sole-cropped hybrid sorghum vis-a-vis two common intercropping systems in the Akola region of Maharashtra is the central theme of this paper. The study is based on farm-level data from Kanzara, one of the sites for the ICRISAT Village Level Studies (VLS). The VLS are conceptually described in Binswanger and Ryan (1980) and data collection instruments are documented in Binswanger and Jodha (1978). Agronomic and socioeconomic information is gathered from 30 cultivator and 10 landless labor households at approximately monthly intervals by a resident investigator in each village. For cropping systems analysis, the unit of observation is the plot, and we use field data over six cropping years from 1975-76 to 1980-81.

The study builds on and extends our descriptive research (Walker and Subba Rao 1982) on yields and net return distributions for the cropping systems most commonly practiced by farmers in the VLS. The technical and economic features of the common dryland rainy season cropping systems in Kanzara are discussed more thoroughly in that work, and some highlights are presented in Table 1.

A farmer with adequate resources in Kanzara can choose from four common dryland cropping systems for planting in the rainy season. These include two cotton intercropping systems, sole-cropped hybrid sorghum, and sole-cropped hybrid cotton. The most traditional and most common option (cotton intercrop 1) is to row intercrop desi or local cotton with pigeonpea and sorghum. A typical row ratio for the three crops is 12:2:1 local cotton dominates the system. Use of purchased inputs is minimal, and returns are low but extremely stable (Table 1). The second alternative (cotton intercropping 2) for the farmer is to invest more in this system by applying more purchased inputs particularly inorganic fertilizer, by planting with the more labor intensive 'dibbling method' for improved weed control, and by substituting more profitable cotton for local sorghum in the cropping system. Hybrid sorghum is another step towards commercial cropping, and it is more intensive in its demand for purchased inputs particularly pesticide and fertilizer.[1] Farmers spray hybrid sorghum in Kanzara to control stem borer and midge.

1. In years of abundant rainfall farmers sowing hybrid sorghum in the rainy season can plant a second crop in lower lying fields or in those that are located near wells. Dryland chickpea and irrigated wheat are the most popular choices for sequential cropping. About 30% of the area and plots planted to hybrid sorghum were cropped sequentially in Kanzara from 1975-76 to 1980-81. Because sequential cropping is less common and is restricted to site specific field conditions, we focus on the sole cropping of hybrid sorghum during the rainy season in this paper.

Table 1. Salient features of common cropping systems in Kanzara[a]

Description	Cropping system		Hybrid
	Cotton Intercrop 1	Cotton Intercrop 2	sorghum
Type of cropping	Row intercropping; cotton:pigeonpea: sorghum (12:2:1)	Row intercropping; cotton:pigeonpea (12:2)	Sole cropping
Input use			
Inorganic fertilizer (% plots)	14	37	60
Pesticide (% plots)	0	8	46
Yield			
Mean yield[b] (kg/ha)	135	178	871
C.V.	44	55	68
Skewness[e]	0.31*	1.24**	0.16
Economic			
Total variable cost[b,c] (Rs./ha)	345	444	525
Mean net returns[b,d] (Rs./ha)	368	421	505
C.V. of net returns	74	99	115
Skewness of net returns[e]	0.51**	1.97**	0.41
Number of observations from 1975-76 to 1980-81			
Plots	190	98	78
Cultivator households	32	25	23

a. Source: Constructed from Walker and Subba Rao (1982).

b. Simple average (across plots) of data adjusted for individual farmers effects. The adjustment procedure is described in Walker and Subba Rao. Yield data refer to cotton in the two intercropping systems.

c. Total variable cost is estimated on the opportunity and monetary costs of all inputs including family labor and owned draft power.

d. Net returns to management, land, and capital and is equivalent to the value of production of all components of the cropping system minus total variable cost discussed in note c.

e. ** and * denote statistically significant differences from corresponding values for the normal distribution at the .01 and .05 levels respectively

Sole-cropped hybrid cotton relies more heavily on purchased inputs than hybrid sorghum, but unfortunately we do not have enough field-level observations to include it in the analysis.

Switching from the traditional cotton intercrop 1 to the semi-improved cotton intercrop 2 to sole-cropped hybrid sorghum implies acceptance of more risk - the coefficient of variation increases from 74 to 99 to 115 - in exchange for higher profits. It is this tradeoff in risk and profits that is the central theme of the paper.

The conflict between risk and expected profitability is introduced with a mean variance analysis in the next section. The simple mean variance framework is applied in a portfolio approach in the second section to explore this tradeoff in a more realistic setting. The area response to changes in yield stability in hybrid sorghum production is evaluated in the same section. Consequences of skewness in net return distributions are discussed in the third section. The paper concludes with implications for the development of improved sorghum hybrids and varieties and for risk assessment in cropping systems.

THE TRADEOFF BETWEEN RISK AND NET CROP INCOME

Returning to Table 1, we see that if a representative farmer in Kanzara would substitute hybrid sorghum for local cotton in the first intercropping system he could expect an increase in net crop income per hectare from about 370 Rs. to 500 Rs.; however, he would also have to accept more risk the estimated coefficient of variation on net returns rises from 74 to 115%. If farmers were neutral to risk and maximized profits, the gain to society would be about Rs. 130 or about 145 (kgs/ha) of hybrid sorghum provided input supplies and output demands were perfectly elastic and markets were perfect.[2] In other words, 145 kilos of sorghum per hectare is the benefit that we would assign to a program designed to reduce the financial risk accompanied by increasing the area under HYV sorghum production.

The conflict between risk and expected profitability in shifting from less profitable and less risky common cropping systems to those that are more remunerative and less assured is fairly sharp in Kanzara. Optimal choice of cropping systems hinges on farmer risk preferences that are analyzed with a standard mean-variance approach.

The mean variance framework allows us to quantify tradeoffs between expected profitability and risk. Net returns are assumed to be normally distributed, and risk is therefore synonymous with variance. Farmers are supposed to maximize a weighting or utility function that depends on the mean level of net returns and variance in each cropping system. Graphically, this is equivalent to plotting the mean level of net return on the Y axis and standard deviation on the X axis in Figure 1.

2. Valued in late 1970s prices.

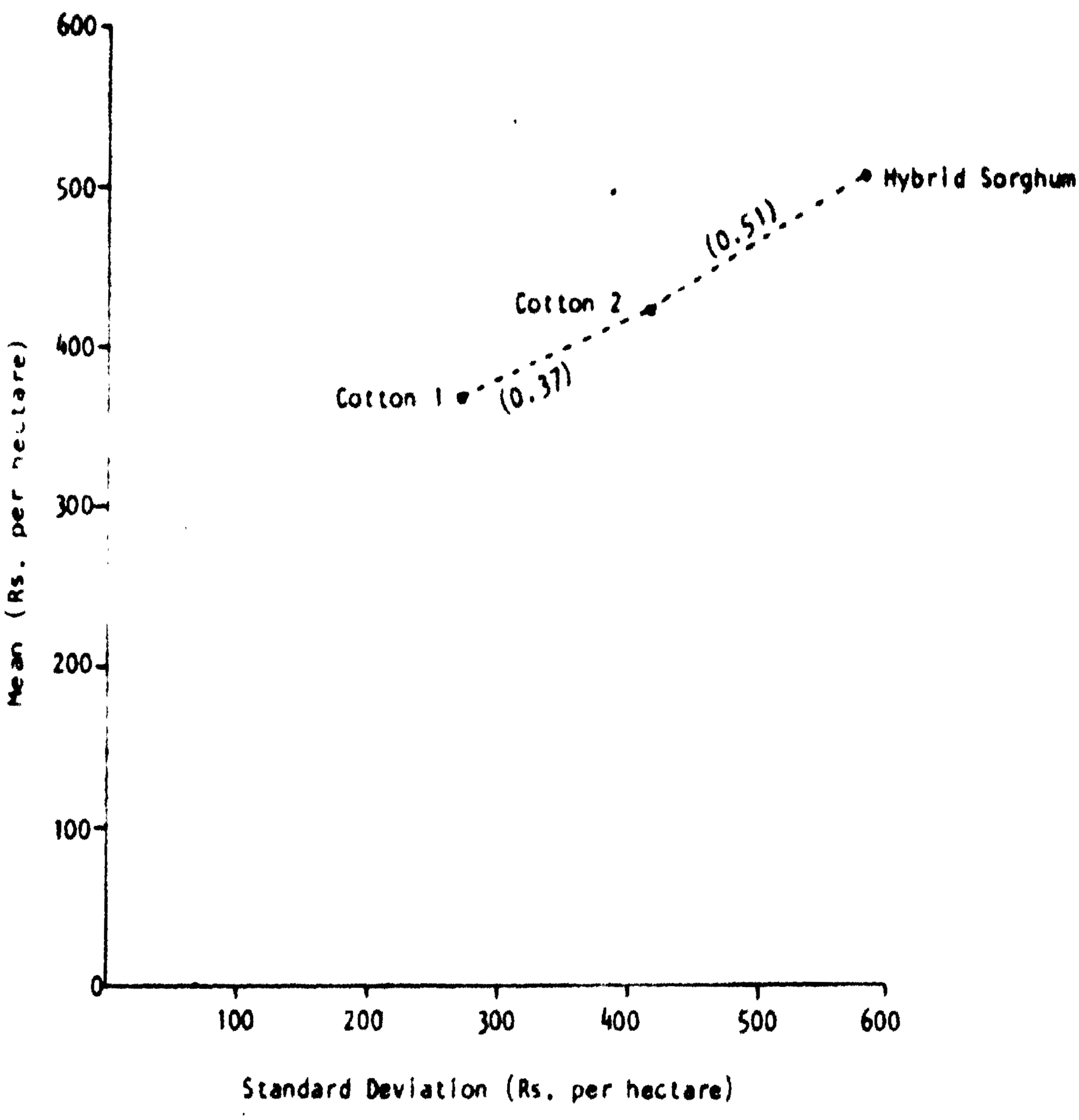

Figure 1. Mean-variance analysis of risk in common cropping systems in Kanzara.

Coordinates with respect to mean and standard deviation are taken from the net return data presented in Table 1. The key statistic in the analysis is the risk tradeoff coefficient θ that is defined as the change in expected mean return divided by the change in expected standard deviation as our average farmer substitutes one cropping system for another. In Figure 1, we also assume that returns between different cropping systems are perfectly correlated.

The first point to observe in Figure 1 is the moderate tradeoff in risk implied by switching from cotton intercrop 1 to cotton intercrop 2 to hybrid sorghum in Kanzara. A tradeoff coefficient of 0.51 between cotton intercrop 2 and hybrid sorghum says that a farmer prefers to plant hybrid sorghum if he is willing to accept a one Rs. or less increase in expected returns for a two Rs. rise in standard deviation. Farmers who desire a higher increase in expected return to compensate for a two unit increase in standard deviation prefer to plant more cotton intercrop 2.

Binswanger (1978) with a series of experimental games has estimated values for θ for farmers in Kanzara. From the results of the largest game where farmers could select various alternatives between a sure bet of Rs. 50 to a risky alternative of Rs. 200 for a good outcome and zero for an unfavorable outcome, Binswanger found that most cultivators in Kanzara were intermediately to moderately risk averse. Their choices implied the following distribution of values for θ (Table 2).

Table 2. Distribution of risk attitudes in the Rs. 50 game for 29 cultivator households in Kanzara.

Risk attitude category	Value for θ	% of respondents
Severely or extremely risk averse	Greater than 0.66	0
Intermediately risk averse	0.50 to 0.66	40
Moderately risk averse	0.33 to 0.50	46
Slightly risk averse or risk neutral	Less than 0.33	14

Source: Constructed from Binswanger (1978).

On comparing the estimates in Table 2 with the tradeoff values implied in Figure 1, we see that the choice of cropping systems is extremely sensitive to the level of farmer risk aversion. Fourteen percent of the farmers are clearly willing to accept the risk in going from a cotton intercrop system to hybrid sorghum, but for the other cultivators the decision is not as clear. The tradeoff values of 0.51 in Figure 11 approaches the modal value of 0.50 estimated for farmers' risk attitudes in the experimental games. Clearly, risk does make a difference for many farmers, and the size of the difference can be more accurately measured with a portfolio analysis.

THE CHOICE OF CROPPING SYSTEM

Portfolio Analysis

We have implicitly assumed that the farmer planted all his land to one cropping system. We know that this is a strong assumption because land is divisible among cropping systems, and there may also be a need to rotate cropping systems across space and time. A more realistic approximation to the farmer's decision and hence a sounder empirical base for measuring the cost of risk aversion is contained in (1).

$$\max_{z} EU[(p_1\pi_1 + p_2\pi_2 + (1-p_1-p_2)\pi_3)A] \qquad (1)$$

where p_1 = proportion of land planted to cotton intercrop 1;

p_2 = proportion of land planted to cotton intercrop 2;

$1-p_1-p_2$ = proportion of land planted to hybrid sorghum;

EU = a weighting or utility function;

A = area to be planted;

z^i = a portfolio of different proportions of the three cropping systems. For example $z^1=(1,0,0)$; $z^2=(0,1,0)$; $z^3=(0,0,1)$ etc.

The portfolio approach simply says that the farmer allocates his land to the three cropping systems in such a way that maximizes his expected utility. Expected utility depends on the expected mean level of return and standard deviation of each portfolio allocation. In order to make equation (1) operational, we again assume that net returns are normally distributed and that $\emptyset$ equals 0.5. We select the portfolio allocation in (2) that maximizes weighted net returns after an allowance for risk has been deducted.

$$\max_{z} \sum_{k=1}^{3} p_k\bar{\pi}_k - \emptyset s_z \qquad (2)$$

where $\bar{\pi}_k$ = estimated net returns of the k^{th} cropping system $k=1, \ldots 3$;

s_z = estimated standard deviation of portfolio z^i;

p_k = proportion of area planted to each cropping system in portfolio z^i.

The estimated standard deviation s_z for each portfolio is calculated from (3) where the variance of each portfolio is the weighted sum of the variances and covariance in net returns for the three cropping systems.

$$s_z^2 = p_{1z}^2 s_1^2(\bar{\pi}_1) + p_{2z}^2 s_2^2(\bar{\pi}_2) + p_{3z}^2 s_3^2(\bar{\pi}_3) + 2p_{1z}p_{2z}s_{12} + 2p_{1z}p_{3z}s_{13} + 2p_{2z}p_{3z}s_{23} \quad (3)$$

Returns from the two intercropping systems are assumed to be perfectly correlated because cotton is such a dominant crop in either system. Returns from either cotton cropping system are expected to be uncorrelated with those from hybrid sorghum. Estimated correlation coefficients for the six cropping-year averages support these two assumptions.

Based on these estimates, the optimal allocation for our representative farmer is an area allocation in proportions of 0.40, 0.30 and 0.30 to cotton intercrop 1, cotton intercrop 2, and hybrid sorghum. The optimal portfolio results in a net return of about Rs. 425 that departs from a profit maximizing portfolio planting only hybrid sorghum by about Rs. 80. The size of the underinvestment in hybrid sorghum due to risk aversion is equivalent to about 90 kilograms of sorghum per hectare. This output corresponds to 10% of the value of production and 16% of net farm income per hectare. Again this is a partial estimate as other factors such as access to credit are not considered.

Farm Level Supply Response and Yield Stability

The portfolio analysis suggests that the choice of cropping system is sensitive to variability in sorghum yield. A reduction in yield variability does not translate on a one-to-one basis into a decrease in crop income variability. Price variability also conditions fluctuations in net returns, and price and yield are inversely correlated for most crops. For nonirrigated SAT districts, Barah and Binswanger (1982) found that yield variability contributed about 80% to variation in the monetary value of production, while price by yield interactions were negatively covariate and explained an additional 30% of gross return variability. When we adopt their estimates, and ignore the negative coveriance between price and yield, a 10% reduction in the CV of yield is equivalent to an 8% decrease in the standard deviation of net revenue for hybrid sorghum. The solid line in Figure 2 is based on this assumption. The broken line is calculated on the assumption that prices are inversely covariate with yields. In this case a 10% decrease in the CV of yield corresponds to a 5.6% decline in the standard deviation of net revenue.

When we parametrically reduce the CV of hybrid sorghum yield from 10 to 90%,[3] we find that the proportional portfolio allocation to hybrid sorghum rises gradually and then steeply. A 30% reduction in the CV of yield results in a 46% increase in the area planted to HYV sorghum; the proportional area depicted by the broken line in Figure 2 rises from 0.28 to 0.41. There appears to be ample scope in the Akola Region to increase supply response of hybrid sorghum by maintaining the same average yield but by reducing its variance. This could be achieved by developing cultivars that yield slightly less in good years and more in unfavorable years.[4]

IMPLICATIONS OF SKEWNESS IN NET CROP INCOME

The mean variance and portfolio approaches to risk assessment assume that net returns are normally distributed, and we have seen that net returns for the two cotton intercrop systems are positvely skewed (Table 1). One intuitive way to understand the implications of skewness is to contrast the observed probability densities with what would obtain under the normal distribution for the two cotton intercrop systems. Normal distributions are estimated using the mean and variance estimates in Table 1. For cotton intercrop 1, the observed is slightly more peaked but does not depart significantly from the normal with respect to downside risk (Figure 3). In contrast, the observed cotton intercrop 2 distribution is severely skewed (Figure 3). For the three lowest net return frequencies (-600, -300, and 0), the probability mass under the normal is greater than under the empirical distribution.

Because we do not have information of farmers' preferences for skewness - a case can be made that farmers prefer positively skewed net return distributions (Anderson et al. 1977) - we cannot precisely determine how the skewness observed in the net returns from cotton

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3. Mean yield is held constant and standard deviation of yield is decreased corresponding to the reductions in the CV.

4. This result begs the question how more stable cultivars with slightly inferior yield potential would fare in multilocational testing where yield potential is an overriding criterion for selection.

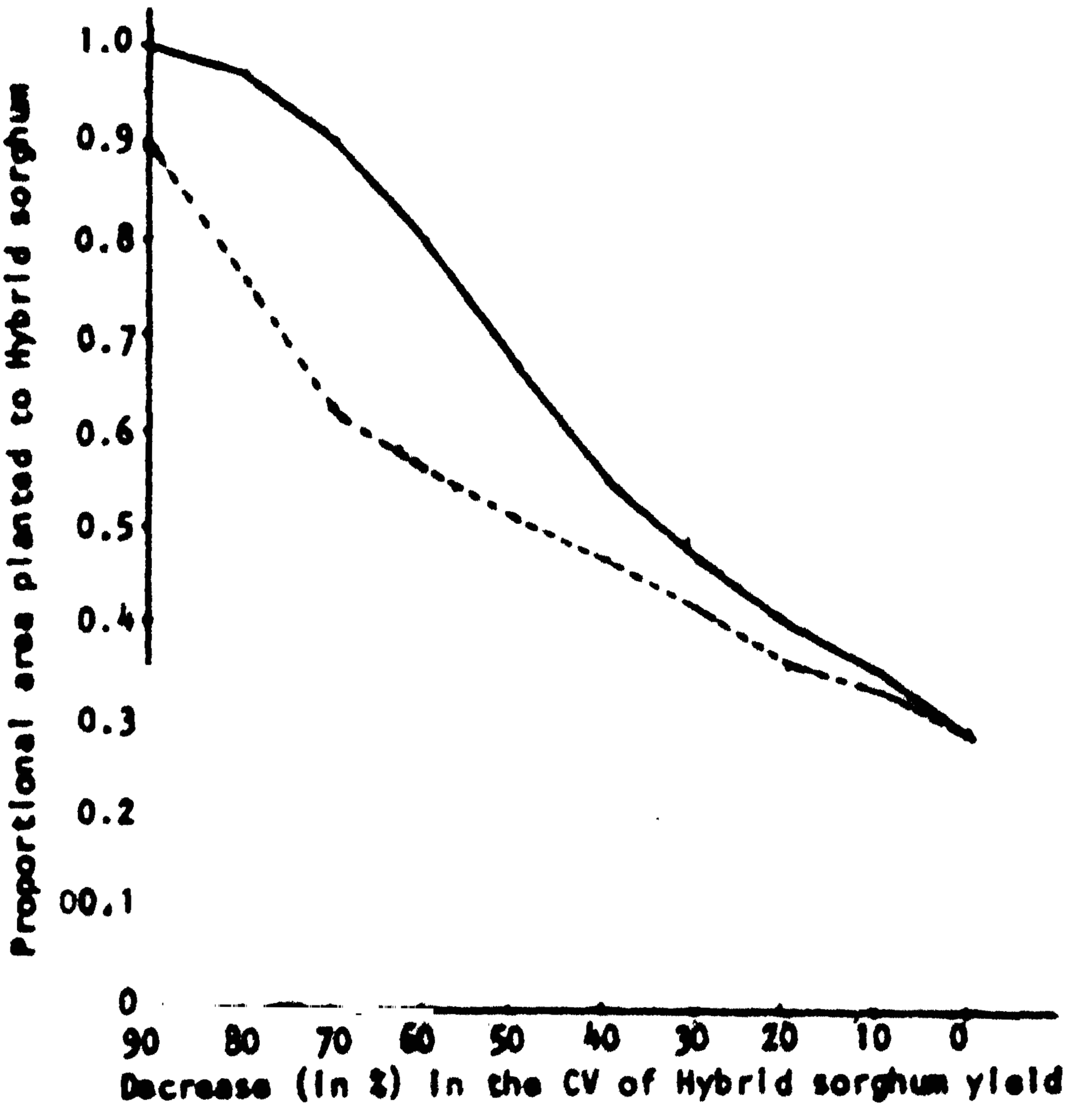

Fig. 2. Supply response and yield stability of hybrid sorghum.

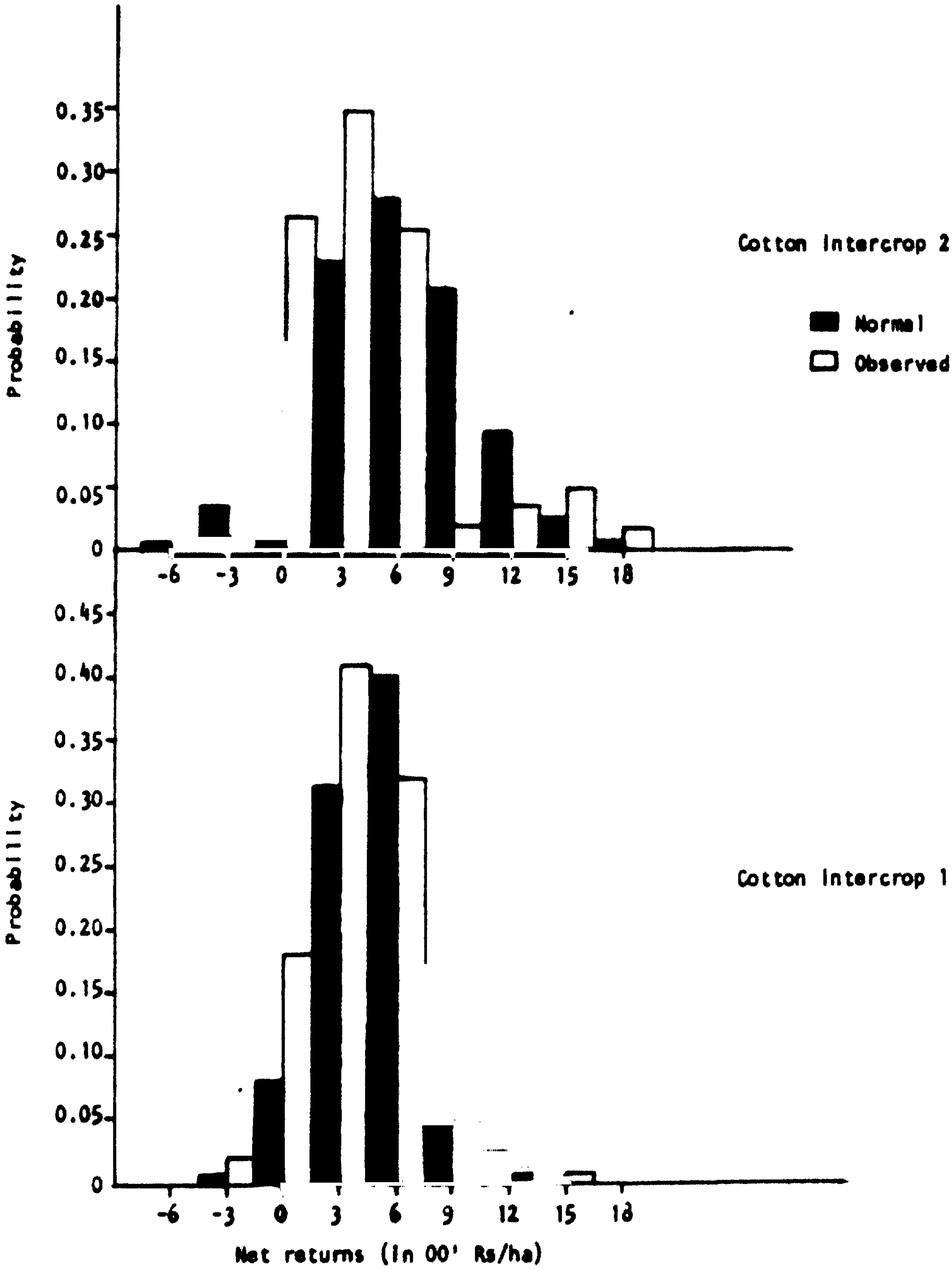

Fig. 3. Normal and observed net return frequency distributions for cotton intercropping systems in Kanzara.

intercrop 2 affects the choice of cropping system. Nevertheless, we can draw some tentative conclusions through a comparative analysis of what the observed and normal cumulative density functions imply for the choice of cropping system.

The cumulative density function indexes the summed probability that net returns fall below a given level. On comparing the choice between cotton intercrops 1 and 2, we observe that the conflict between risk and expected profitability is negligible under the observed distributions and is fairly sharp when normal distributions are assumed. The cumulative probability that returns are less than -300 Rs. is about 0.007 for cotton 1 and 0.04 for cotton 2 when net returns are assumed to be normally distributed (lower part, Figure 4). The probability gap is not nearly as wide under the observed distributions.

Repeating the same comparison, the choice between cotton intercrop 2 and hybrid sorghum leads to the opposite conclusion. Downside risk is considerably larger under the observed compared with what is implied by normal distributions. Under normal cumulative density functions, the probability of having net returns less than or equal to -300 Rs. is about 0.04 and 0.08 for cotton intercrop 2 and hybrid sorghum, respectively (lower part, Figure 5). Comparable probabilities are 0.01 and 0.08 under the observed distributions (upper part, Figure 5).

Because observed net returns under hybrid sorghum are normally distributed and those under cotton intercrop 1 are not as acutely skewed as net returns under cotton intercrop 2, we see that the normal and observed cumulative distributions would give approximately the same results on decisions on the choice of optimal cropping system. The area between the two curves to the left of where they cross is about the same size for comparisons based on observed or normal distributions for cotton intercrop 1 and hybrid sorghum (Figure 6).

Summing up, the assumption of normal distributions in the mean-variance and portfolio analyses overestimates the size of risk between cotton intercrop 1 and 2, understates the risk in switching from cotton intercrop 2 to hybrid sorghum, and gives similar results in comparing cotton intercrop 1 and hybrid sorghum that are characterized by net revenue distributions that are less skewed.

CONCLUSIONS

Based on historical, nonexperimental on-farm data, we find that risk is a potential deterrent to the planting of hybrid sorghum on a wider scale in the black-soil, cotton-growing region of Maharashtra. When farmers in Kanzara substitute hybrid sorghum for competing local cotton intercropping systems, they can increase net crop income per hectare by 17 to 27% but th[illegible] rise in the CV of inc[illegible] from 16 to 40%. We estimate

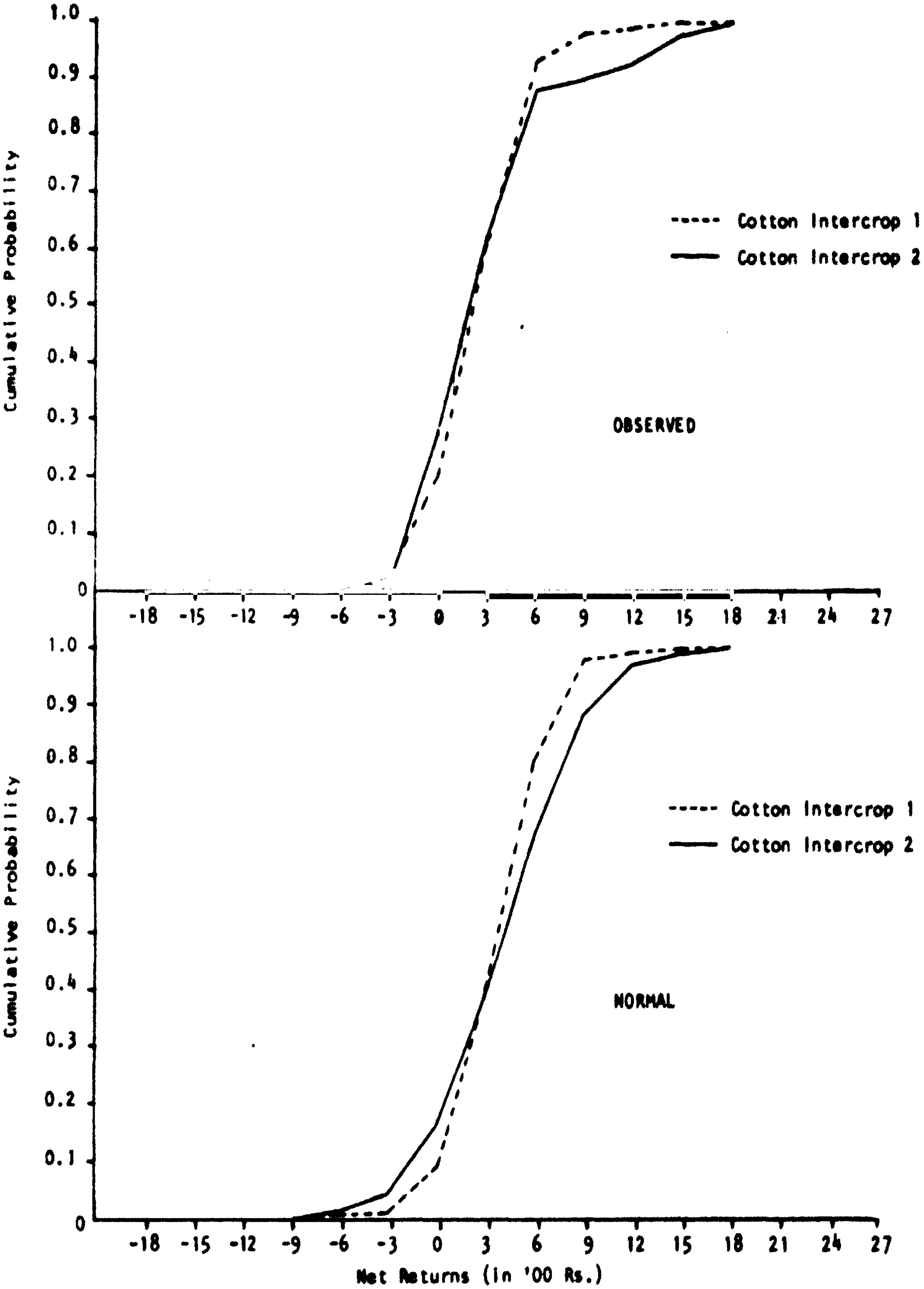

Fig. 4: Evaluation of the choice between Cotton Intercrops 1 and 2 based on observed and normal net return distributions.

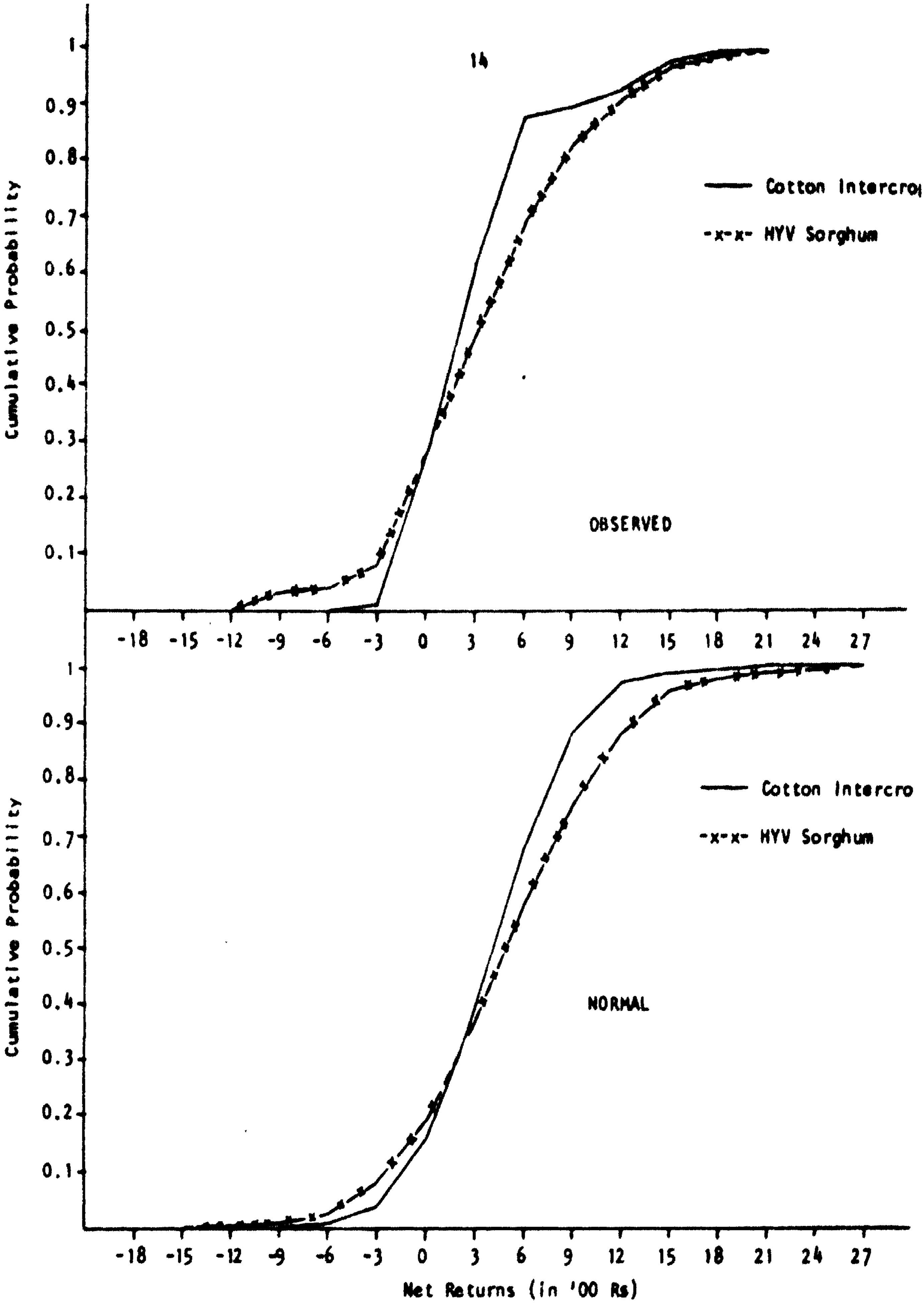

Fig. 5. Evaluation of the choice between cotton, intercrop 2 and hybrid sorghum based on observed and normal net return distributions.

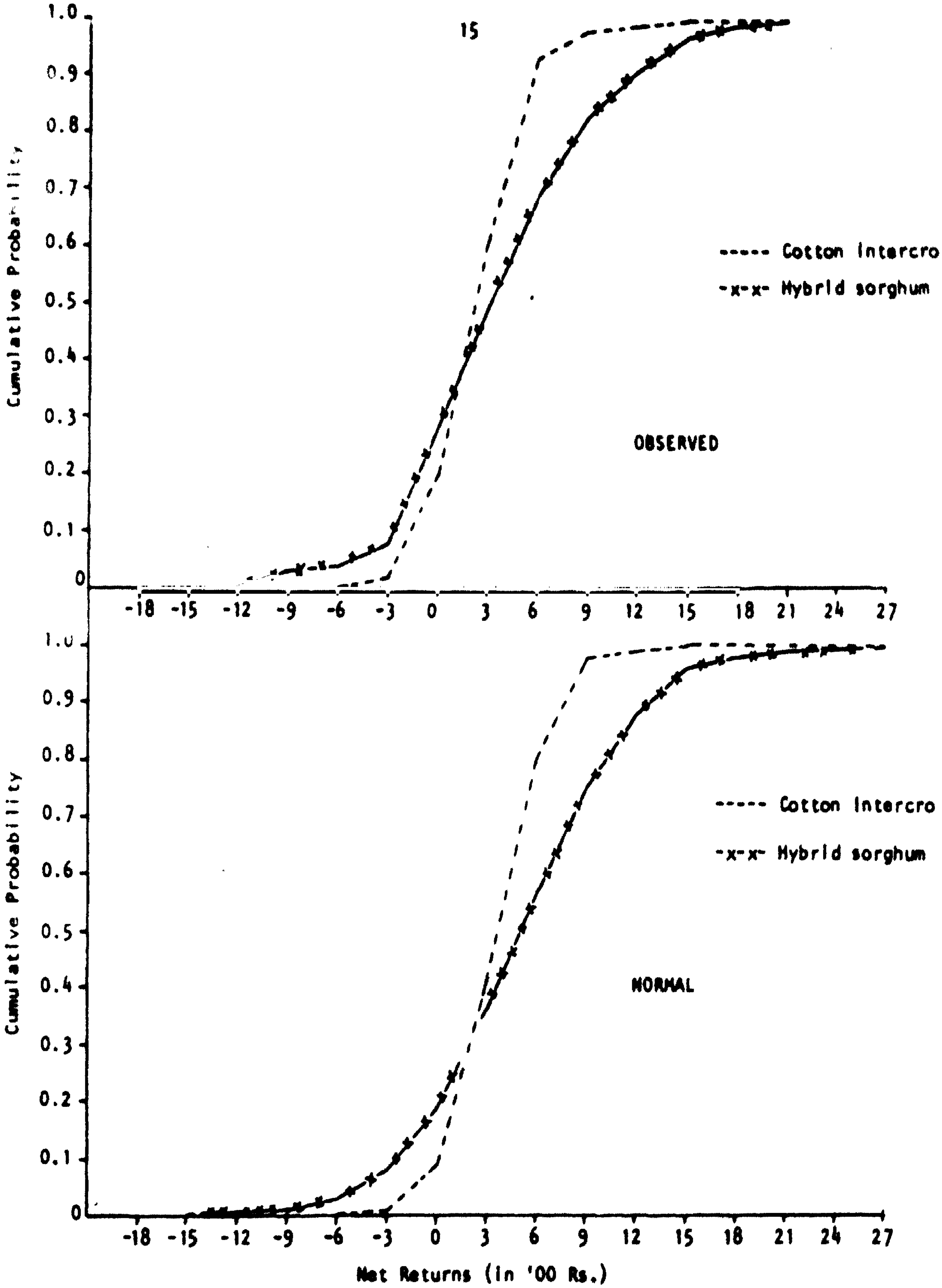

Fig. 6: Evaluation of the choice between Cotton intercrop 1 and Hybrid sorghum based on observed and normal net return distributions

that the underinvestment in hybrid sorghum caused by farmer risk aversion costs society the equivalent of about 80 kilos (equivalent to 10% of average yield) of hybrid sorghum per hectare valued in late 1970s prices.

These results should be interpreted with caution because they apply to one representative village over six cropping years from 1975-76 to 1980-81. They are derived from by a microscopic decision analysis and hence are very partial; they need to be integrated into a whole farm planning framework (Ghodake and Hardaker 1981) and into a market scenario analysis (Behrman and Murty 1981).

If these results are valid, they provide some "good news" and "bad news" for sorghum improvement scientists. The "good news" is that breeding for stability in and of itself has the potential to yield handsome dividends. We calculate that a 30% reduction in the CV of sorghum yield holding mean yield constant would lead to a 46% increase in the area planted to HYV sorghum. This note of encouragement applies particularly well to sorghum hybrids which have a fairly high yield potential. The "bad news" is that the local cotton intercropping systems are remarkably stable performers. Cotton yields were more resistant to agroclimatic variability during the six cropping years than any other component crops in the nine cropping systems analyzed in Walker and Subba Rao (1982). Moreover, net return distributions from both cotton intercropping systems are positively skewed while that of hybrid sorghum is normally distributed. The contrasting shapes of the net revenue distributions likely reinforces the tendency of risk averse farmers to choose cotton intercropping systems over hybrid sorghum.

Our results suggest that skewness matters when the estimated skewness coefficient on net returns exceeds 2.00. In any case, technology risk assessment is an intuitive exercise, and simple techniques like a comparative evaluation of the cumulative net return densities may generate more insight than a more formal rigorous analysis. The foundations for a more sophisticated risk assessment are shaky because we have little descriptive information on farmer preferences for skewness.

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REFERENCES

Anderson, J.R., Dillon, J.C., and Hardaker, B. 1977. Agricultural decision analysis. Ames, Iowa: Iowa State University Press.

Barah, B.C., Binswanger, H.P., Rana, H.S., and Rao, N.G.P. 1981. The use of risk aversion in plant breeding. Concept and application. Euphytica 30(2): 451-58.

Barah, B.C., and Binswanger, H.P. 1982. Regional effects of national stabilization policies: the case of India. American Journal of Agricultural Economics (forthcoming).

Behrman, J.R. and Murty, K.N. 1981. SAT crop markets: Scenario analysis of impacts of changes in technology, fertilizer prices, highways, labor markets, consumption expenditure, rainfall and price policy. ICRISAT Economics Program progress report 39, Patancheru, A.P. 502 324, India.

Binswanger, H.P. 1978. Attitudes toward risk: experimental measurement in rural India. Economic Growth Center Discussion Paper No. 285. Yale University, New Haven, Connecticut.

Binswanger, H.P. and Jodha, N.S. 1978. Manual of instructions for economic investigators in ICRISAT's village level studies. Vol. II, ICRISAT Economics Program, Patancheru, A.P. 502 324, India.

Binswanger, H.P. and Ryan, J.G. 1980. Village level studies as a locus for research and technology adoption. Pages 121-129 In Proceedings of the International Symposium on Development and Transfer of Technology for Rainfed Agriculture for the SAT Farmer, ICRISAT, 28 Aug-1 Sept 1979, Patancheru, A.P. 502 324, India.

Ghodake, R.D. and Hardaker, J.B. 1981. Whole farm modeling for assessment of dryland technology. ICRISAT Economics Program progress report 29, Patancheru, A.P. 502 324, India.

Walker, T.S., and Subba Rao, K.V. 1982. Yield and net return distributions in common village cropping systems in the Semi-Arid Tropics of India. ICRISAT Economics Program progress report 41, Patancheru, A.P. 502 324, India.

Willey, R.W., Rao, M.R., and Natarajan, M. 1980. Traditional cropping systems with pigeonpea and their improvement. Pages 11-25 In Proceedings of the International Workshop on Pigeonpeas, Vol. I ICRISAT, 15-19 December, Patancheru, A.P. 502 324, India.