Ind. Jn. of Agri. Econ.
Vol. 50, No. 2, April-June 1995

Technological Change in Sorghum Production: An Econometric Study of Dharwad Farms in Karnataka

INTRODUCTION

Sorghum stands third in respect of area and production in the country after rice and wheat, accounting for nearly 12 per cent and 6 per cent of the country's area (128.3 million hectares) and production (170.3 million tonnes) of foodgrains respectively. It is grown extensively in the states of Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan, Gujarat, Tamil Nadu and Uttar Pradesh. Karnataka State ranks second in both area and production of sorghum next only to Maharashtra.

Since the inception of the High-Yielding Varieties (HYVs) Programme the sorghum area in the state of Karnataka has decreased from 27.73 lakh ha in 1966-67 to 21.06 lakh ha in 1988-89, while the sorghum production during the same period stepped up from 13.09 lakh tonnes to 15.46 lakh tonnes. Obviously, this could be possible due to the rapid increase in the sorghum productivity levels from 497 kg/ha to 773 kg/ha during this period.

With the introduction of improved varieties of sorghum into the farming system, there arose a wide gap in the productivity levels between the traditional and modern technologies. The present paper attempts to examine the nature of technological change in sorghum production through the measurement of productivity difference between modern varietal technology (MT) and traditional varietal technology (TT) and thereafter to analyse and evaluate the constituent sources of such a difference.

DATA AND METHODOLOGY

The primary data required for the study were collected through a survey of 180 farmers from 12 villages spread across four talukas of Dharwad district during the agricultural year 1988-89. The sample respondents were selected using the multi-stage random sampling technique. The production function and decomposition models were used for processing the data.

To test whether there existed any significant difference in the mean productivity levels of the two technologies, the student 't' test was first used. To sort out the contributions of technology and resource use differentials to the total productivity difference between MT and TT, the log-linear production function (Cobb-Douglas version) of the following specification was then considered for both the technologies:

$$Y = a_0 L^{a_1} N^{a_2} S^{a_3} M^{a_4} F^{a_5} K^{a_6} \text{Exp}(U) \quad ....(1)$$

where, Y, N, S, M, F and K are the total values of output, human labour, seed, manure, fertiliser and capital services (including the value of bullock services used, expenditure on plant protection chemicals, depreciation and other incidental charges not covered by other aforesaid variables) respectively; L is the area under the crop; a_0 and a_j (j = 1,....,6), are the scale and slope parameters (production elasticities) of the regression function respectively; and U is the random disturbance term.

To examine whether the parameters of the production function of MT were different from those of TT, equation (1) was estimated separately from MT, TT and pooled sample data sets and Chow test was applied (Chow, 1960; see also Rao, 1952, pp. 112-115). Since the Chow's F-statistic was found significant, an attempt was made to test whether the structural difference in production relationships was due to intercept or slope or both. This was done by introducing respectively in equation (1) dummy variables for intercept, slope and for both, and then testing the significance levels of the dummy variables so obtained from the equations estimated separately.

To decompose the total productivity differential between MT and TT into its constituent sources, Bisaliah's (1976, 1977) output decomposition model was used. The model requires the production function to be specified on unit area basis. Hence with the help of the functional form specified in equation (1), the Cobb-Douglas production functions on per hectare basis, as specified below in log-linear form, were estimated:

$$\ln Y_m = \ln a_0 + a_1 \ln N_m + a_2 \ln S_m + a_3 \ln M_m + a_4 \ln F_m + a_5 \ln K_m + e_m \quad ....(2)$$

$$\ln Y_t = \ln b_0 + b_1 \ln N_t + b_2 \ln S_t + b_3 \ln M_t + b_4 \ln F_t + b_5 \ln K_t + e_t \quad ....(3)$$

where all the variables are as defined in equation (1) except that they are on per hectare basis and that the term 'e' is the random variable and the subscripts 'm' and 't' stand for MT and TT respectively. The specified equations were estimated using Ordinary Least Squares (OLS) technique. A zero-order correlation suggested that multicollinearity was not a problem for the data set and the model specification. Taking the difference between the equations (2) and (3) and performing a slight algebraic manipulation and re-arrangement of some terms, the following decomposition model was arrived at:

$$\begin{aligned} \ln Y_m - \ln Y_t = {} & [\ln a_0 - \ln b_0] + [(a_1-b_1)\ln N_t + (a_2-b_2)\ln S_t + \\ & (a_3-b_3)\ln M_t + (a_4-b_4)\ln F_t + (a_5-b_5)\ln K_t] + \\ & [a_1(\ln N_m - \ln N_t) + a_2(\ln S_m - \ln S_t) + a_3(\ln M_m - \ln M_t) + \\ & a_4(\ln F_m - \ln F_t) + a_5(\ln K_m - \ln K_t)] + [U_m - U_t] \quad ....(4) \end{aligned}$$

The left hand side of the equation (4) gives the total difference in productivity expressed as percentage over traditional technology. The first bold bracketed term on the right hand side, the natural logarithm of constant terms, is the gap attributable to the neutral component of technology. It is a measure of neutral technological gap. The second bold bracketed term is the gap attributable to the non-neutral component of technology weighed by input use for TT. The third bold bracketed term refers to the gap attributable to differences in the input use weighed by the slope coefficients of the productivity function fitted for MT. And of course, the last component is a random term, which the model could not take into account.

RESULTS AND DISCUSSION

Production Response for Modern and Traditional Technologies

All the estimated production functions were significant as evidenced by the significance of F-values at 1 per cent level (Table I). The adjusted coefficient of multiple determination ($\bar{R}^2$) was also high, ranging from 73 per cent in the case of TT to 76 per cent in the case of MT, and indicated thereby a fairly high degree of 'goodness of fit'.

A perusal of the production function estimates reveals that the coefficients of land (L) and capital (K) variables were invariably positive and significant in all the functions, with the only exception of land variable in the TT function which was positive but not significant. Apart from these, manure (M) and human labour (N) were found significant in the 'pooled' function whereas only manure (M) turned out to be significant in the TT function. In a few cases, the regression coefficients were negative, but none of them was significant at any acceptable level of significance. It may be recalled that in the Cobb-Douglas production function, regression coefficients are equivalent to production elasticities. It could be noticed

TABLE I. ESTIMATES OF PER FARM PRODUCTION FUNCTIONS

Sr. No.	Explanatory variables	MT (Eq. 2)	TT (Eq. 3)	Pooled (Eq. 4)	Pooled with intercept dummy (Eq. 5)
(1)	(2)	(3)	(4)	(5)	(6)
1.	Intercept$	5.2070*	5.1023**	4.6996*	4.9887*
		(0.7440)	(2.2981)	(0.6015)	(0.6076)
2.	Intercept dummy$				0.2809**
					(0.1299)
3.	Land (L)	0.4434*	0.3183	0.3311*	0.4331*
		(0.1304)	(0.2643)	(0.0895)	(0.1000)
4.	Human labour (N)	0.1495	-0.1764	0.2133**	0.1538
		(0.1066)	(0.5138)	(0.1043)	(0.1064)
5.	Seed (S)	-0.0444	-0.2617	0.0358	-0.0460
		(0.0763)	(0.1695)	(0.0503)	(0.0624)
6.	Manure (M)	-0.0004	0.0803**	0.0286***	0.0160
		(0.0179)	(0.0343)	(0.0147)	(0.0156)
7.	Fertiliser (F)	0.0630	-0.0099	0.0224	0.0197
		(0.0463)	(0.0442)	(0.0275)	(0.0271)
8.	Capital (K)	0.2795*	0.7130**	0.2472*	0.2928*
		(0.0948)	(0.3103)	(0.0898)	(0.0910)
9.	$\overline{R}^2$	0.7601	0.7325	0.7370	0.7454
10.	F-value	56.9656*	10.5819*	60.9927*	54.5212*
11.	Sample size (n)	107	22	129	129

Notes: Figures in parentheses are the standard errors.
*, ** and *** indicate significance at 1, 5 and 10 per cent probability levels respectively.
$ - in natural logarithmic form.

that the production elasticities of all the inputs were invariably less than unity, thus implying diminishing marginal productivity with respect to each of the inputs. As between the MT and TT functions, the production elasticities of all the inputs were relatively higher in the case of MT when compared to the TT, except for manure and capital. The higher production elasticities of manure and capital in the case of TT could be perhaps due to the lower use of these inputs on TT farms as compared to MT farms, resulting in higher efficiency levels, owing to the 'diminishing marginal productivity' property of the production function.

Structural Break and Nature of Technological Change

The existence of structural break in question was examined by conducting tests for the equality of regression equations. Chow's F-statistic computed for the equality of regression coefficients including the intercept term was obtained as 2.35, which at 7 and 115 d.f was significant at 5 per cent level. This implied that the introduction of the MT in sorghum caused structural break in the production response and shifted the sorghum production function in the process of technological change.

The nature of technological change was examined by testing the homogeneity of regression coefficients of various inputs while the constant terms (intercepts) in the two production functions were allowed to differ (Rao, 1952; Alshi *et al.*, 1983; Kiresur, 1992). The computed F-ratio of 1.96 at 6 and 117 d.f turned out insignificant, implying that the shift in production function was in the intercept and not in the slope. It could be seen that the intercept for MT sorghum was higher by 28.09 per cent as compared to TT sorghum as indicated by the intercept dummy (Table I). Thus it was concluded from the foregoing discussion that the technological change as a result of the introduction of MT of sorghum was of neutral type.

The analysis of covariance test revealed that the structural break (shift in production function) was due to a significant change in the intercept rather than in the slope. However, it could not be ascertained from the above test whether the slope coefficients of all the explanatory variables were equal as between the MT and TT or some of them were different. In order to test the complete structural relationship in the parameters of the production functions for the two technologies, the log-linear transform of equation (1) was estimated with both the intercept and slope dummies. The regression estimates are presented in Table II.

TABLE II. TESTING OF COMPLETE STRUCTURAL RELATIONSHIP BETWEEN PRODUCTION FUNCTIONS OF MT AND TT

Sr. No. (1)	Explanatory variables (2)	Regression coefficient (3)	Standard error (4)
1.	Intercept	5.1023**	2.0053
2.	Land (L)	0.3183	0.2306
3.	Human labour (N)	-0.1764	0.4483
4.	Seed (S)	-0.2617***	0.1479
5.	Manure (M)	0.0803*	0.0299
6.	Fertiliser (F)	-0.0099	0.0385
7.	Capital (K)	0.7130*	0.2707
8.	Intercept dummy	0.1047	2.1563
9.	Slope dummy for		
	(a) Land (L)	0.1252	0.2665
	(b) Human labour (N)	0.3259	0.4615
	(c) Seed (S)	0.2174	0.1673
	(d) Manure (M)	-0.0806**	0.0351
	(e) Fertiliser (F)	0.0729	0.0611
	(f) Capital (K)	-0.4335	0.2876
10.	$\overline{R}^2$	0.7565	
11.	F-value	31.5894*	

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

The estimated equation was a good fit as indicated by the F-ratio and adjusted R^2 respectively. It could also be noticed that none of the slope dummies was significant with the only exception of the dummy variable for manure. Thus the hypothesis of homogeneity in the regression coefficients of manure between the two production functions was rejected whereas the same hypothesis was accepted in the case of all other inputs. The positive signs of the dummies for land, human labour, seed and chemical fertiliser suggest that the production elasticities and hence the productivities of these inputs were probably higher in the case of MT sorghum when compared to TT sorghum. On the other hand, the productivities of manure and capital inputs turned out to be relatively higher on the TT farms, probably due to the relatively lower use levels of these inputs on the TT farms as implied by the diminishing marginal productivity assumption of the Cobb-Douglas production functions.

Decomposition of Productivity Difference

The per hectare log-linear production functions as specified in equations (2) and (3) and the geometric mean levels of input use for the two technologies were used for decomposition analysis. The estimated functions are presented in Table III.

TABLE III. ESTIMATES OF PER HECTARE PRODUCTION FUNCTIONS

Sr. No.	Explanatory variables	Regression coefficients		
		MT	TT	Pooled
(1)	(2)	(3)	(4)	(5)
1.	Human labour (N)	0.2852*	0.6446	0.3729*
		(0.1009)	(0.4075)	(0.0935)
2.	Seed (S)	-0.0565	-0.0978	0.0573
		(0.0791)	(0.1704)	(0.0519)
3.	Manure (M)	0.0011	0.0258	0.0127**
		(0.0073)	(0.0152)	(0.0060)
4.	Fertiliser (F)	0.0090	-0.0166	-0.0020
		(0.0226)	(0.0180)	(0.0120)
5.	Capital (K)	0.2074**	0.2929	0.1735***
		(0.0957)	(0.2866)	(0.0891)
6.	Intercept$	5.1800*	2.3338	4.2970
		(0.7453)	(2.0835)	(0.5980)
7.	R^2	0.25	0.47	0.35
8.	F-value	6.7212*	2.8898**	13.4914*
9.	Sample size (n)	107	22	129
10.	Chow's F-value	2.4129**		

Notes: Figures in parentheses are the standard errors.
*, ** and *** indicate significance at 1, 5 and 10 per cent probability levels respectively.
$ - in natural logarithmic form.

As regards the estimates of per hectare production functions, the constant term (intercept) in the case of MT was significant and much higher than that for the TT. This virtually signifies the upward shift in production function due to technological change. The response coefficient of human labour was positive and significant at one per cent level in the case of MT whereas it was relatively high and positive but non-significant in the case of TT. The positive but less than unit production elasticities with respect to human labour indicate that the labour use levels stood in the rational zone of the production surface.

The regression coefficients of capital and manure were positive and less than unity for both the technologies. However, only for capital in the case of MT, the coefficient was significant at 5 per cent level. It is interesting to note that the output elasticity coefficients of human labour, capital and manure in the case of MT were relatively lower as compared to those for the TT. All these foregoing observations reinforce the fact that the MT is more input or cost intensive than the TT.

Table III also provides the estimates of pooled production function. The pooled function was significant and the distinct feature of this function was that the variable manure had significant positive impact on the productivity. The Chow's F-test was carried out to ascertain whether there existed any significant difference between the two production functions of MT and TT in terms of their parameters. The Chow's F-value was found to be significant at 5 per cent probability level, thus indicating the significance of the difference in parameters between the MT and TT production functions.

Levels of Output and Input Use on Sorghum Farms

In addition to the estimates of per hectare production functions, the decomposition analysis requires the geometric mean values of different inputs used. Table IV presents the geometric mean values of various inputs and output on per hectare basis in both the technologies. It could be revealed from the table that the average levels of inputs used on the MT farms were higher as compared to those on the TT farms. Also, the gross value of output of MT scored over that of the TT by an appreciable margin. The observed difference in gross value of output between the two technologies was 44.85 per cent (Table V).

TABLE IV. GEOMETRIC MEAN LEVELS OF INPUTS AND OUTPUT

(Rs./ha)

Sr. No. (1)	Input/Output (2)	MT (3)	TT (4)	Pooled (5)
1.	Human labour (N)	819.26	546.59	764.64
2.	Seed (S)	95.84	26.58	77.01
3.	Manure (M)	68.33	0.01	15.59
4.	Fertiliser (F)	402.50	25.66	251.69
5.	Capital (K)	755.36	683.35	742.56
6.	Output (Y)	3,897.93	2,489.16	3,610.86

Sources of Productivity Difference

A perusal of the results of decomposition analysis (Table V) reveals that there was a slight discrepancy between the observed (44.85 per cent) and the estimated (45.31 per cent) differences in the productivities of MT and TT. This discrepancy was attributed to the random error term which, among others, accounts for variables that could not be included in the model such as management input. Such discrepancies of varying degree in decomposition analysis were also encountered in several earlier studies including those by Umesh and Bisaliah (1986), Ballabh and Sharma (1989) and Lalwani (1990). In a majority of these studies, such discrepancies were attributed to random errors and exclusion of one of the important variables from the model, namely, the management input. However, in the present study, since the discrepancy in question was of a very low order the results of the decomposition analysis were considered to be satisfactory.

TABLE V. DECOMPOSITION OF TOTAL PRODUCTIVITY DIFFERENCE BETWEEN MT AND TT

Source of productivity difference	Percentage contribution	
	Sub-total	Total
(1)	(2)	(3)
A. Total observed difference in productivity		44.85
B. Due to difference in technology		35.49
(1) Neutral technological difference	284.62	
(2) Non-neutral technological difference	-249.13	
(a) Human labour (N)	-226.55	
(b) Seed (S)	13.55	
(c) Manure (M)	11.37	
(d) Fertiliser (F)	8.31	
(e) Capital (K)	-55.81	
C. Due to difference in input use level		9.82
(a) Human labour (N)	11.54	
(b) Seed (S)	-7.25	
(c) Manure (M)	0.97	
(d) Fertiliser (F)	2.48	
(e) Capital (K)	2.08	
D. Total estimated difference in productivity (due to all sources)		45.31

The technological and input use differentials between the two technologies together contributed to form the total productivity difference of the order of 45.31 per cent, whereas the technological component alone accounted for 35.49 per cent. This implies that with the present level of resource used by the TT growers the productivity could be increased by about 35 per cent if the farmers could just switch over from TT to MT. In other words, with no additional units of inputs, the existing level of sorghum yield could be increased to a great extent by the adoption of MT. Such an increase in productivity exclusively due to technological improvement is brought about through a shift in the scale and/or slope parameters of the production function. If, however, the farmers could simultaneously raise the input use level to the same level as on the MT farms, the productivity could be further raised by another 10 percentage points from 35.49 per cent to 45.31 per cent.

The contribution of the neutral technological component in the productivity difference was positive and it was of a very high order (285 per cent) whereas the non-neutral technological component contributed negatively to the total difference in the gross value of output. This was to the tune of -249 per cent. The high positive neutral technological component signifies that with the present level of input used on the TT farms, the farmers could have trebled the productivity level by adopting the MT provided the efficiency levels of input use were held constant. But the reduction in net efficiency level of various inputs together narrowed down the productivity gap by two and a half times (-249 per cent) while shifting from TT to MT, as signified by the negative non-neutral technological component.

The main factors responsible for the negative non-neutral technological component of a very high order were human labour and capital contributing negatively and significantly to the total productivity difference. The negative contribution of human labour and capital to the productivity gap indicates that the productivity gap was drastically reduced due to the decrease in the use efficiency of these two inputs. Thus while shifting from TT to MT, had the efficiency levels of human labour and capital increased or even remained constant, there would have been a drastic jump in the productivity of MT resulting in the enhanced productivity gap.

At the present level of input use, a given increase in the use of these two inputs on both MT and TT farms could increase the productivity on the TT farms more rapidly than that on the MT farms. Therefore, the resource use efficiency on the MT farms should be increased by way of adopting the recommended package of cultivation practices in order to fully exploit the potential of the MT.

On the other hand, the elasticities of seed, manure and chemical fertiliser had positive contribution to the productivity difference which was estimated to be nearly 33 per cent. These inputs together could substantially widen the productivity gap between the two technologies, as was quite expected.

The total contribution of differences in the levels of input use to the productivity gap accounted for 9.82 per cent, indicating that the productivity on TT farms could be increased by about 10 per cent, if the per hectare input use levels on these farms could be increased to the same level as on the MT farms. As explained earlier, there was a large gap in the per hectare input use levels between the TT and MT. Therefore, it might not be possible for the TT farmers to completely adopt the input use package of the MT growers due to their poor resource base. But perhaps, they could adopt the modern cultivars with the existing or, possibly, higher level of input use, which could earn them better returns.

CONCLUSION

The estimated farm level production response functions were significant and a good fit for both the MT and TT. There was a structural break between the two production functions which was of neutral type. In other words, the upward shift in the production function due to technological improvement was through a shift in the intercept to the extent of 28 per cent, i.e., improvement in genetic quality of seed, rather than a shift in the slope, i.e., output elasticity with respect to various inputs.

The total difference in the productivity per hectare between MT and TT sorghum was estimated to be about 45 per cent. The major component of this productivity gap was the difference in varietal technology contributing nearly 35 per cent, while the remaining 10 per cent was shared by different inputs, namely, human labour, seed, manure, chemical fertiliser and capital, in terms of differences in their use levels between the modern and traditional sorghum production technologies.

V. Kiresur, R.K. Pandey and Mruthyunjaya*

Received November 1994. *Revision accepted June 1995.*

REFERENCES

Alshi, M.R.; P. Kumar and V.C. Mathur (1983), "Technological Change and Factor Shares in Cotton Production: A Case Study of Akola Cotton Farms", *Indian Journal of Agricultural Economics*, Vol. 38, No. 3, July-September, pp. 407-415.

Ballabh, V. and B.M. Sharma (1989), "HYV Adoption, Productivity Gaps and Production Adjustment Mechanisms in Flood-Prone Areas of Uttar Pradesh: A Synthesis", Research Paper No. 5, Institute of Rural Management (IRMA), Anand, Gujarat, India.

Bisaliah, S. (1976), *Effects of Technological Change on Output, Employment and Functional Income Distribution in Indian Agriculture: A Case Study of the Punjab Wheat Economy*, Ph.D Dissertation, University Microfilms International, Ann Arbour, Michigan, U.S.A.

Bisaliah, S. (1977), "Decomposition Analysis of Output Change under New Production Technology in Wheat Farming: Some Implications to Returns on Research Investment", *Indian Journal of Agricultural Economics*, Vol. 32, No. 3, July-September, pp. 193-201.

Chow, G.C. (1960), "Tests of Equality Between Sets of Coefficients in Two Regressions", *Econometrica*, Vol. 28, No. 3, July, pp. 591-605.

Kiresur, V. (1992), *Technological Dualism in Agriculture: An Econometric Analysis of Diffusion of Technology of Jowar Production in Karnataka*, Ph.D Thesis (Unpublished), Post-Graduate School, Indian Agricultural Research Institute, New Delhi.

Lalwani, M. (1990), "Human Labour Absorption in Dairying: Evidence from Karnal Villages of Haryana", *Indian Journal of Agricultural Economics*, Vol. 45, No. 2, April-June, pp. 150-158.

Rao, C. Radhakrishna (1952), *Advanced Statistical Methods in Biometric Research*, John Wiley and Sons, Inc., New York.

Umesh, K.B. and S. Bisaliah (1986), "Productivity Differential Between Small and Large Farms: An Econometric Study", *Asian Economic Review*, Vol. 28, No. 3, pp. 17-33.

---

* Scientist, Directorate of Oilseeds Research, Hyderabad-500 030, Principal Scientist, Indian Agricultural Statistics Research Institute, New Delhi-110 012 and Assistant Director General (Economics, Statistics and Marketing), Indian Council of Agricultural Research, New Delhi-110 012, respectively.

This paper forms a part of the senior author's Ph.D thesis submitted, under the guidance of the second author, to the Faculty of Post-Graduate School, Indian Agricultural Research Institute, New Delhi in 1992.

The authors are grateful to the anonymous referee of the Journal for useful comments on the paper.