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High-Yielding Varieties and Correlated Response of Yields of Wheat and Rice in Uttar Pradesh

The advent of the new agricultural technology in the sixties and its impact on production in many developing countries have received considerable attention. Countries like India, which have had a long history of serious food shortages, are now virtually self-sufficient in meeting their food needs at least at the current levels of purchasing power of their people. More recently, it has been suggested that the new agricultural technology based on the high-yielding varieties (HYVs), while helping to increase production substantially, may have brought in its wake greater production and yield variability (Mehra, 1981; Hazell, 1982 and 1984; Walker, 1984).

NATURE OF THE STUDY

The purpose of this paper is to determine whether yields and yield variability of wheat and rice have become more positively correlated across districts and regions over time with the introduction of the HYVs. For this purpose data of yields of wheat and rice for 44 districts in the State of Uttar Pradesh have been examined for the two periods - the pre-HYVs period and the HYVs period. The pre-HYVs period corresponds to 1954-55 to 1965-66 while the HYVs period corresponds to 1966-67 to 1980-81. District level analysis has been undertaken as analysis at this level may be more instructive than at a more aggregate level. This is because the variability in the production of a crop at an aggregate level will depend on the mutually offsetting pattern of variability across States and regions. Thus production at the aggregate level may appear stable even if there is high but mutually offsetting variability in the component regions. Table I gives the districts of Uttar Pradesh which have been studied. The sources of data used in the study are given in the Appendix.

TABLE 1. LIST OF DISTRICTS IN VARIOUS REGIONS OF UTTAR PRADESH

Western region	Central region	Bundelkhand region	Eastern region
(1)	(2)	(3)	(4)
1. Saharanpur	17. Fatehpur	26. Jhansi	30. Allahabad
2. Muzzafarnagar	18. Kanpur	27. Jalaun	31. Varanasi
3. Meerut	19. Lucknow	28. Hamirpur	32. Mirzapur
4. Bullandshahar	20. Unnao	29. Banda	33. Jaunpur
5. Aligarh	21. Rae-Bareilly		34. Ghazipur
6. Mathura	22. Sitapur		35. Ballia
7. Agra	23. Hardoi		36. Basti
8. Mainpuri	24. Kheri		37. Gorakhpur
9. Etah	25. Barabanki		38. Deoria
10. Badaun			39. Azamgarh
11. Moradabad			40. Faizabad
12. Shahjahanpur			41. Gonda
13. Pilibhit			42. Bahraich
14. Rampur			43. Sultanpur
15. Farukhabad			44. Pratapgarh
16. Etawah			

Although Uttar Pradesh is by no means representative of the whole of India, this State was selected for study because it can be divided into broad agro-climatic zones, which differ significantly from one another in terms of climatic factors like the amount and pattern of rainfall, input use and in terms of the development of agricultural infrastructure like irrigation facilities as well as the diffusion of the new agricultural technology. The plains of Uttar

Pradesh can be divided into distinct regions according to their soil-climatic conditions. These are the Western, the Central, the Bundelkhand and the Eastern regions.

In the medium rainfall districts of the Western region substantial investment has been made in irrigation mainly due to the large scale commercial cultivation of sugarcane. As a result, crop cultivation particularly that of wheat and sugarcane has developed under more controlled conditions of water management. The spread of HYVs of wheat as well as rice has also been most rapid in the districts of the Western region although districts in the other regions of Uttar Pradesh are also fast catching up. The Central and Bundelkhand regions fall in the dry belt of the State with low rainfall. In these regions little investment was made to develop irrigation and infrastructure because of the difficult terrain and low yield of crops. The Eastern region of the State comprises mainly the high rainfall districts and the main source of irrigation here is canal irrigation. In Uttar Pradesh, the crop-wise spread of HYVs of wheat has been more than any other crop, though a significant proportion of the rice area is also planted to HYVs.

METHODOLOGY

To determine whether yields have become more positively correlated across districts over time, different measures of yield and yield variability could be used. These are either actual yields or the yields which have first been detrended to remove the effect of systematic factors like technology which vary with time. Actual yield correlations would be expected to be higher in the second period because of the positive effects of technology on yields. However, to determine whether the different districts show an increasingly similar pattern of yield variability with the introduction of the new technology, it is more important to determine the joint behaviour of yields given the two technologies (see French and Headley, 1985). Accordingly, actual yields as well as yields detrended over time become the appropriate basis for determining yield correlations across districts for the two time periods. Another measure of yield variability is the variability in yield attributable to rainfall. A comparison of correlations of weather variability over the two time periods would indicate if climatic factors like rainfall lead to a higher proportion of significantly positive correlations during the HYV period.

The variability in yields of wheat and rice for the different districts has been measured around a linear trend. This trend has been estimated separately for the two time periods. On examining the raw data for wheat, one finds that in the year 1973-74, the districts of the Western region experienced particularly low yields of wheat. These low yields were probably the result of a severe stripe and leaf rust epidemic, which affected large areas of the Western region planted to wheat. To take care of this outlier value, a dummy variable was included in the trend estimation, which takes the value one in the year 1973-74 and zero in all other years for the districts of the Western region.

In the case of rice, yields were extremely low in the year 1979-80 because of a very severe drought in large parts of the country. Rainfall was particularly deficient in the *kharif* season when the sowing of rice is done. Accordingly, a dummy variable has been included in the trend estimation for the rice crop, which takes the value one in 1979-80 and zero in all other years.

Dummy variables have been used for the year 1973-74 and 1979-80 for wheat and rice respectively as these were years of particularly low yields for both these crops because of abnormal factors. If these exceptional years are not treated in an exceptional manner, one may gain overall variability but lose on account of avoidable imprecision which creeps into the analysis.

To determine the contribution of weather towards yield variability, a weather component (rainfall) has been added to the linear time trend. (The dummy variable for the year 1979-80 for rice has not been used in the weather-trend model.) For each district a rainfall index is used which expresses the annual rainfall received in each district as a percentage of the long-term normal rainfall for the district.

$$Y = a + bT + cRI + e$$

where Y is the yield in the district,
T is time,
RI is the rainfall index for the district,
e is the error term.

The effect of weather on yield variability can then be estimated by normalising the rainfall index for both the periods. The difference between the yield estimated with normalised weather and the yield estimated with actual weather gives the variability in yield due to weather.

As the correlations are being estimated for different regions, they could be classified as within region correlations and across region correlations. It is expected that yield correlations between districts from within one region would be higher than those between districts from different regions as each region is likely to be agriculturally more homogeneous.

In order to examine whether yields have, indeed, become more positively correlated over districts, the number of significantly positive correlations for the districts within each of the four regions as well as the inter-district correlations across regions will be reported to see if this number has increased during the second time period.

The results of the correlation analysis for wheat are given in Table II while Table III gives similar results of similar analysis for rice.

OBSERVATIONS FROM CORRELATION ANALYSIS

Correlations between Actual Yields

It will be seen that there are rather different results for correlations calculated from actual yields for both wheat and rice and those calculated from the yields after detrending. Looking at the analysis for actual yield of wheat, it is found that the number of significantly positive correlations has gone up in all cases. This increase is greatest in the Western region where the percentage of significantly positive correlations has increased from 53.4 per cent to 92 per cent. The inter-region districts also show a greater number of significantly positive correlations during the period of the modern technology. Actual yields of rice also show an increased number of significantly positive correlations in all cases except one. It can also be observed that between the districts of the Eastern and Bundelkhand regions, actual yield correlations of rice have become less significant during the second period.

Correlations between Yield Variability

However, quite a different picture emerges, when the inter-district correlations for yield variability (measured around the trend) are considered. Looking at the results for both wheat and rice, it is found that the number of significantly positive correlations between districts has in fact decreased during the second period. This is true for all the four regions. The inter-district correlations between the districts of the different regions also show fewer significantly positive correlations during the HYVs period compared to the first. In fact, the number of negative correlations between the districts of these regions is greater during the period of HYVs as compared to the first period of traditional varieties. This result holds for both wheat and rice.

TABLE II. PERCENTAGE OF STATISTICALLY SIGNIFICANT POSITIVE INTER-DISTRICT YIELD CORRELATIONS FOR WHEAT, 1954-55 TO 1965-66 AND 1966-67 TO 1980-81

Regions and periods	Actual yield	De-trended yield	Weather variability
(1)	(2)	(3)	(4)
Western region			
1954-55 to 1965-66	53.4	58.0	33.3
1966-67 to 1980-81	92.0	11.7	66.7
Eastern region			
1954-55 to 1965-66	59.0	85.0	34.3
1966-67 to 1980-81	62.0	24.7	76.1
Central region			
1954-55 to 1965-66	58.0	90.0	38.9
1966-67 to 1980-81	67.0	36.0	64.3
Bundelkhand region			
1954-55 to 1965-66	67.0	100.0	100.0
1966-67 to 1980-81	83.0	83.3	100.0
Western-East			
1957-58 to 1965-66	37.5	44.0	12.9
1966-67 to 1980-81	63.0	25.7	34.2
Western-Central			
1957-58 to 1965-66	46.0	55.4	28.9
1966-67 to 1980-81	67.0	9.6	46.1
Western-Bundelkhand			
1954-55 to 1965-66	30.0	64.0	35.9
1966-67 to 1980-81	9.4	32.8	20.3
Eastern-Central			
1954-55 to 1965-66	18.0	28.6	19.3
1966-67 to 1980-81	47.0	7.4	42.5
Easten-Bundelkhand			
1954-55 to 1965-66	8.3	18.3	25.0
1966-67 to 1980-81	15.0	6.7	76.7
Central-Bundelkhand			
1954-55 to 1965-66	33.0	60.7	55.5
1966-67 to 1980-81	8.3	11.1	78.0

TABLE III. PERCENTAGE OF STATISTICALLY SIGNIFICANT POSITIVE INTER-DISTRICT YIELD CORRELATIONS FOR RICE, 1954-55 TO 1965-66 AND 1966-67 TO 1980-81

Regions and periods	Actual yield	De-trended yield	Weather variability
(1)	(2)	(3)	(4)
Western region			
1954-55 to 1965-66	41.7	40.8	66.7
1966-67 to 1980-81	72.5	21.7	96.7
Eastern region			
1954-55 to 1965-66	13.0	30.0	80.0
1966-67 to 1980-81	48.6	10.5	80.0
Central region			
1954-55 to 1965-66	38.9	30.6	55.6
1966-67 to 1980-81	47.2	8.3	50.0
Bundelkhand region			
1954-55 to 1965-66	50.0	83.3	100.0
1966-67 to 1980-81	83.3	100.0	50.0
Western-East			
1957-58 to 1965-66	27.5	22.0	39.2
1966-67 to 1980-81	65.0	9.6	48.8
Western-Central			
1957-58 to 1965-66	20.7	55.4	48.0
1966-67 to 1980-81	36.3	9.6	46.5
Western-Bundelkhand			
1954-55 to 1965-66	53.1	32.8	51.6
1966-67 to 1980-81	23.4	20.3	34.4
Eastern-Central			
1954-55 to 1965-66	5.9	23.7	56.3
1966-67 to 1980-81	53.3	9.6	54.8
Easten-Bundelkhand			
1954-55 to 1965-66	30.0	46.6	83.3
1966-67 to 1980-81	36.7	16.7	75.0
Central-Bundelkhand			
1954-55 to 1965-66	22.2	58.3	61.0
1966-67 to 1980-81	33.0	11.1	58.3

From the above analysis, it would seem that the introduction of the new HYV technology has not resulted in a more uniform pattern of yield variability across districts. It is true that with the new technology, farmers had to rely more on the use of modem farm inputs, and that similar adjustments in the use of these inputs in response to price policies or availability of these inputs, could lead to a more correlated yield variability across districts. However, the results indicate that either the factors discussed above do not induce correlated yield variability, or that the districts differ significantly from one another in other respects so that with the introduction of the HYV technology, there has not been an increase in the number of significantly correlated yield variations across districts.

Correlations between Weather-Induced Variability in Yields

Looking at the variability in yields due to weather, it is found that there are different results for the two crops, wheat and rice. From Table II it would appear that the response of yields of wheat to rainfall has become more uniform across districts during the period of the HYVs. In the case of rice, on the other hand, the results are not so clear and while in some regions the effect of rainfall on variability of yields of rice has become more uniform across districts with the introduction of the HYVs, in others it has become more varied. Table III shows that within the districts of the Western region, rainfall seems to be inducing similar patterns of yield variability across districts. This is also true for the correlations between districts of the Western and Eastern regions. The number of positive correlations between districts of the Eastern region has remained unchanged over the two periods. In all other cases, the number of positive correlations between weather induced yield variability has decreased in the second period.

The increased correlation in weather-induced variability in yields of wheat in the second period is perhaps due to the much greater genetic uniformity in crop plants, which has resulted from the introduction of a limited number of widely adapted HYVs. Indian farmers have traditionally grown hundreds of genetically diverse varieties which show a much more varied response to factors like rainfall and serious disease and pest epidemics. Many of the local cultivars have now been replaced by a few HYVs often covering very large areas. The HYVs are much more sensitive to rainfall and given the greater genetic uniformity of these varieties, they show a much more correlated response to rainfall compared to the traditional varieties.

In the case of rice, on the other hand, the spread of the HYVs has not been as rapid as that for wheat so that in the second period substantial areas continue to be planted with traditional varieties. This perhaps is responsible for the decrease in inter-district correlations of weather-induced variability in the HYV period. The growth of area under HYVs of rice has been most rapid in the districts of the Western region followed by the Eastern region. That is probably the reason why correlations between the districts of the Western region and the districts of the Western and Eastern region show increased number of positive correlations between weather-induced variability.

CONCLUSIONS

On the basis of the above analysis, a number of conclusions can be reached:

For both wheat and rice there has been an increase in the number of significantly positive correlations between actual yields across districts with the introduction of HYVs. However, this increase in correlations between actual yields is due to the systematic trend in yield. With the introduction and adoption of the HYVs, most districts experienced simultaneous increase in yields. As a result of this positive trend in yields, yields across districts tended to move together.

When the trend is removed, it is seen that for wheat as well as for rice, there is a reduction in the number of significantly positive correlations between yield variability across districts in the HYV period. This means that the introduction of the HYVs has not resulted in increasingly similar patterns of yield variability across districts, which could lead to greater yield variability at a more aggregate level. This finding is at variance from the one which Hazell (1982) obtained for his State level analysis of India using de-trended yields, where he concludes that increased correlations in yield variability across States have been the major factor contributing to increased variability in the production of cereal crops in India during the HYV period. Hazell has maintained that the new agricultural technology of wheat and rice, built around a limited number of HYVs, which have been widely distributed and their associated agronomic practices in terms of input use, have created the potential for a more correlated response in terms of yield variability in the different regions of the country. It is, of course, possible that Hazell's results differ from those of the present study because of the difference in levels at which the analysis has been performed. Hazell used data from the different States of India for his analysis. However, the findings of the present study would suggest that the HYVs of wheat and rice and the genetic uniformity which they have introduced in the different regions (it is common to find the same set of varieties widely cultivated in more than one region) have been a factor in making agriculture of the different regions more uniform in terms of yield increases. It does not follow, however, that all the regions have managed the new technology equally effectively as far as the stability of production is concerned. A large number of agro-ecological and institutional factors account for this kind of differential inter-regional response. It follows, however, that as the process of modernisation is accelerated, the institutional support improved, and the role of environmental factors reduced through more intensive agronomic management, the different regions would tend to become more uniform not only in terms of yields but also in respect of yield variability over a longer period of years.

The response of yields to rainfall has become more uniform across districts, as far as the wheat crop is concerned during the second period of HYVs. In the case of rice, correlations between weather induced variability have increased in the districts of the Western region while showing a decrease in other regions. This observation shows that the increased correlated response in the case of wheat is obviously a function of the greater sensitivity of HYVs generally to water management and the extensive coverage of HYVs.

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APPENDIX

SOURCES OF DATA

All-India production, area and yield data for cereal crops are collected for the 34 years from 1949-50 to 1982-83 from "Area and Production of Principal Crops in India" published by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi. At the State level, the data for production, area and yields of wheat and rice from 1957-58 to 1980-81 are taken from various issues of the "Season and Crop Report" of Uttar Pradesh, which is published by the Directorate of Economics and Statistics of Uttar Pradesh, Lucknow. Data for annual rainfall, gross cropped area in the districts and irrigated area under wheat and rice are also obtained from the same publication. The area under HYVs of wheat and rice is collected directly from the Directorate of Economics and Statistics, Lucknow. Unfortunately, no crop-wise figures are available for fertiliser consumption. As there are only rough estimates of the percentage of total fertiliser applied to different crops, it was decided to use figures for total fertiliser consumption in each district. These figures are obtained from the "Season and Crop Report" of Uttar Pradesh as well as from various issues of Fertiliser Statistics, which is published by the Fertiliser Association of India.

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REFERENCES

French, J.B. and J.C. Headley (1985). "Inter-Area Maize Yield Correlations as Influenced by Technology", Paper presented at the IFPRI/DSE Workshop on Sources of Increased Variability in Cereal Yields, Feldafing, Germany, November 26-29.

Hazell, P.B.R. (1982). Instability in Indian Foodgrain Production, Report No. 30, International Food Policy Research Institute, Washington, D.C., U.S.A.

Hazell, P.B.R. (1984). "Sources of Increased Instability in Indian and U.S. Cereal Production", *American Journal of Agricultural Economics*, Vol. 66, No. 3, August.

Mehra, S. (1981). Instability in Indian Agriculture in the Context of the New Technology, Research Report No. 25, International Food Policy Research Institute, Washington, D.C., U.S.A.

Ray, S.K. (1983). Growth and Instability in Indian Agriculture, Institute of Economic Growth, University of Delhi, Delhi.

Walker, T.S. (1984). HYVs and Instability in Sorghum and Pearl Millet Production in India, International Crops Research Institute for the Semi-Arid Tropics, Hyderabad (mimeo.).