EFFECT OF GREEN REVOLUTION IN WHEAT ON PRODUCTION OF PULSES AND NUTRIENTS IN INDIA

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Concern is sometimes expressed about the decline in acreage, production, and per capita availability of pulses in India as a consequence of the green revolution in wheat which commenced in the mid-1960s.[1] Pulses provide the high protein component of the predominantly cereal-based diets of people living in the major wheat growing States of India, so (it is felt) the substitution of wheat for them in cropping patterns has led to an inferior dietary position for foodgrain consumers.

Recently Ryan *et. al.* (12, 13) suggested that a predominantly yield-oriented strategy is more appropriate than improvement of grain protein percentage and other cryptic qualities in breeding improved foodgrain varieties for the nutritional well-being of people living in the semi-arid tropics (SAT), particularly for people regarded as nutritionally vulnerable.[2] The issue of yield versus protein quality/quantity in plant breeding becomes relevant if there is some trade-off involved in the pursuit of one at the expense of the other, and/or if pursuit of both together reduces the probability of success of enhancing either in a given period of time. Ryan, *et al.* (12, 13) argued there was some evidence of such a trade-off, but many plant breeders would not agree. Bhatia and Robson (2, p.8) conclude: "It is apparent that increase in protein or lysine in most cereals would demand additional production of photosynthates which alternatively could also be channelled by plant breeding towards increased grain yield with normal or even lower protein concentration. Hence improved protein cultivars are likely to slightly lag the top yield cultivars in grain yield."

One major attribute of the new high-yielding wheat varieties (HYVs) introduced into India in the mid-1960s was a vastly increased yield potential. An examination of the actual nutritional impact of these wheats can test whether or not such a breeding strategy did improve aggregate nutritional status.

NET NUTRIENT PRODUCTION TRENDS

To measure the impact of the HYVs of wheat on total nutrient production, data from six major wheat growing States—Uttar Pradesh, Punjab,

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1. For recent examples see the Joint FAO/WHO Expert Committee on Nutrition (6, p. 32), the United Nations Economic and Social Council (17), Dharm Narain (7), Singh (14), and Anonymous (1).

2. Those most nutritionally vulnerable include pre-school children, infants, pregnant and lactating women.

Haryana, Bihar, Rajasthan, and Madhya Pradesh—were selected. According to Dharm Narain (7), expansion of wheat hectareage sown in these States has primarily been at the expense of chickpea, pigeonpea, other pulses, winter rice, and barley.

Using nutritive values presented by Gopalan, *et al.* (5), the production of these crops was converted into units of protein, calories, and the essential amino-acids—lysine, methionine+cystine, tryptophan, leucine, and isoleucine.[3] Data were divided into two periods—the pre-green revolution period 1954-55 to 1964-65, and the post-green revolution period 1964-65 to 1974-75. Separate linear trend lines were fitted to the combined nutrient production figures of all crops in the six States for these two periods. The pre-green revolution trend lines were projected up to 1974-75 to represent the nutrient picture which might have emerged in the absence of HYVs of wheat. These were compared with the actual trend lines from 1964-65 to 1974-75. (Figures 1-8).

The projections reveal that for all the selected nutrients except lysine, actual trends were significantly higher than that which would have been produced had the green revolution not occurred. If the HYVs of wheat had not been introduced annual trend production of these six commodities in the six States would have been 13.4 per cent less than it actually was during the year 1974-75. Annual production of the other nutrients would have been reduced by the following percentages had HYVs of wheat not been introduced:[4]

Protein	:	10.0
Energy	:	~~13.5~~
Methionine+Cystine	:	15.5
Tryptophan	:	11.3
Leucine	:	5.9
Isoleucine	:	2.0

There would have been about 6.4 per cent more lysine produced in 1974-75 had HYVs of wheat not been introduced and pre-green revolution trends continued to that time. However, it should be noted (Figure 3) that the trend growth in lysine production after the HYVs of wheat were introduced is in fact slightly higher than before. The current per caput trend level of lysine production from these five crops alone is already 65 per cent higher than the recommended daily per caput allowance based on the age distribution of the Indian population. Using World Health Organization (18) allowances, this current lysine trend production level of 2.381 grams per caput per day

3. Production data were derived from Government of India, Directorate of Economics and Statistics (4). Space does not permit discussion of the detailed results or procedures used. The interested reader is referred to the forthcoming paper by the authors (11).

4. The reductions in per caput production of these nutrients had there been no HYVs of wheat amount to figures of between one and two percentage points below these total figures.

FIGURE 1. TOTAL PRODUCTION OF WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

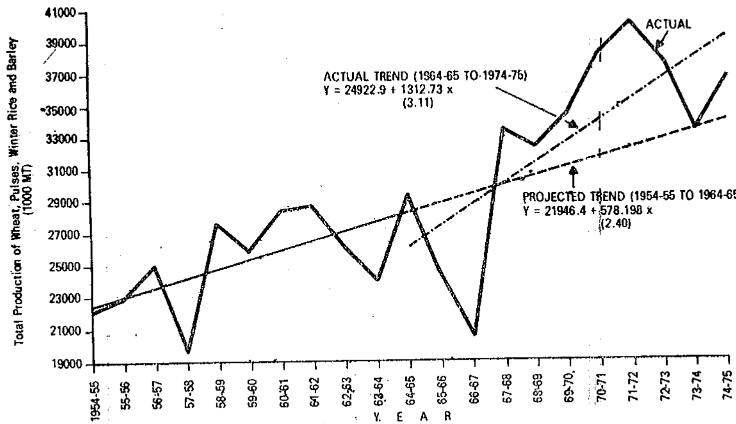


FIGURE 2. TOTAL PRODUCTION OF PROTEIN FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

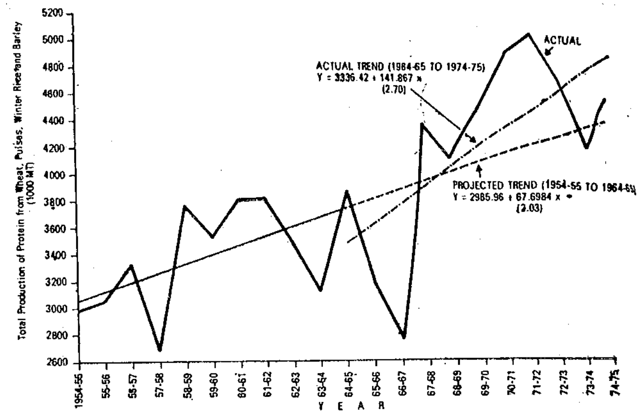


FIGURE 3. TOTAL PRODUCTION OF ENERGY FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

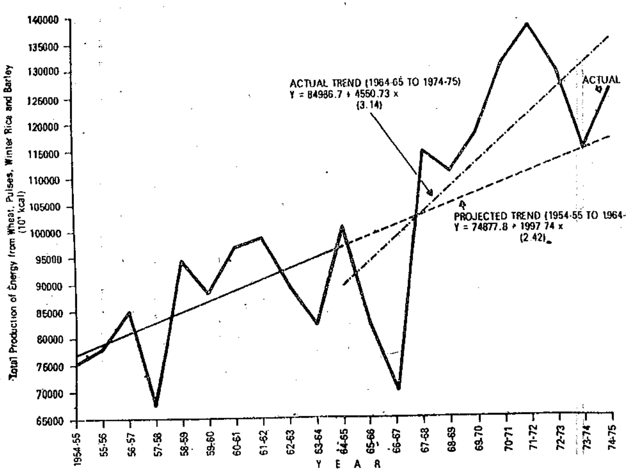
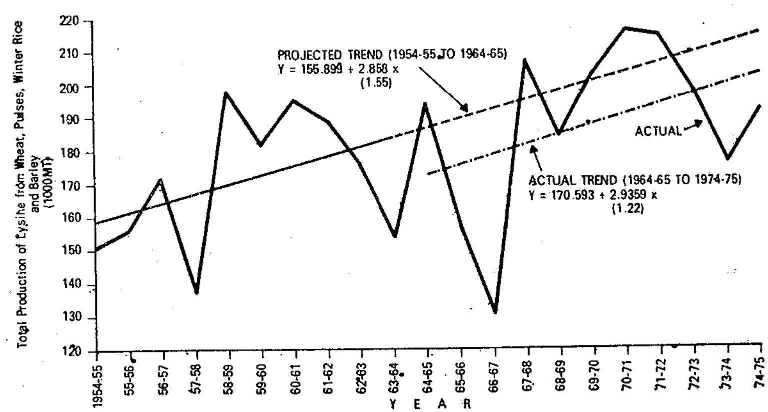


FIGURE 4. TOTAL PRODUCTION OF LYSINE FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA



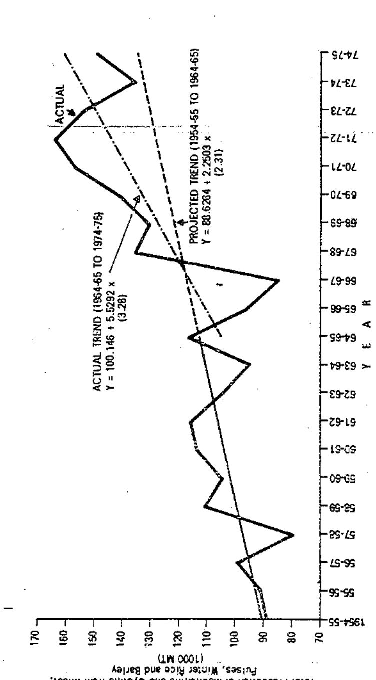


FIGURE 5. TOTAL PRODUCTION OF METHIONINE AND CYSTINE FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

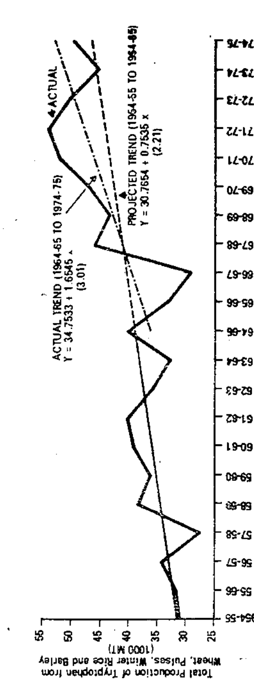


FIGURE 6. TOTAL PRODUCTION OF TRYPTOPHAN FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

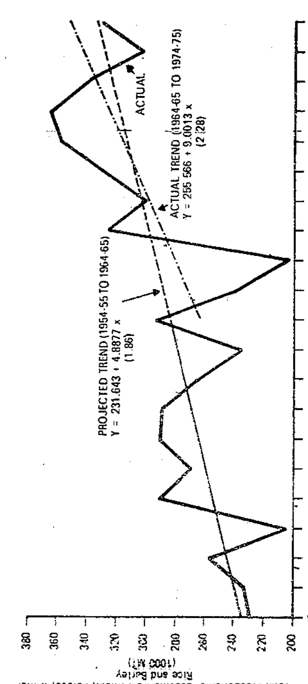


FIGURE 7 TOTAL PRODUCTION OF LEUCINE FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

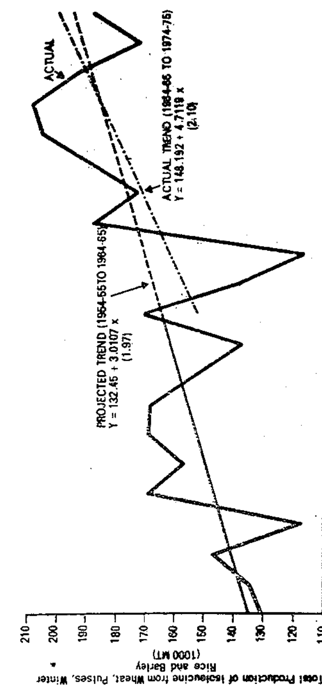


FIGURE 8. TOTAL PRODUCTION OF ISOLEUCINE FROM WHEAT, PULSES, WINTER RICE AND BARLEY IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA

is also 60 per cent more than the allowance for lactating mothers, 90 per cent more than that for pregnant women and pre-school children, and about equal to the recommended daily allowance of lysine for children 10 to 12 years of age. Furthermore, as Ryan, *et al.* (12) have shown, lysine is far from being limiting in the existing diets of even the lowest income families in rural and urban India.[5]

Under these circumstances the small reduction in lysine resulting from the shift to wheat would appear to be of little, if any, nutritional consequence. This small reduction in lysine production is a minor and acceptable price to pay for the substantial increases in production of energy and protein provided by the HYVs of wheat. As shown by Sukhatme (16), Ryan, *et al.* (12, 13) and others, calories are generally the first limiting nutrient in diets of people living in India and other parts of the SAT, even those people in the least affluent socio-economic groups. In helping to significantly alleviate this constraint in Indian diets, the new HYVs of wheat have allowed the existing (and HYV wheat-augmented) proteins and amino-acids being eaten to be utilized more fully and effectively for essential body functions other than energy production. Under a calorie deficient regime, proteins themselves are utilized for energy production.

The above figures, it should be noted, exclude the record production year of 1975-76. Data for this year became available only after the trend analyses were completed. What the 1975-76 data do show is that, compared to values obtained in projecting the pre-green revolution trends to 1975-76, the *actual* production of nutrients in the six major wheat growing States in 1975-76 was higher by the following percentages: total production 22, protein 20, energy 22, lysine 7, methionine and cystine 21, tryptophan 33, leucine 16, and isoleucine 12. We can confidently conclude that today the production status of protein, energy, and essential amino-acids would have been far inferior had it not been for the HYVs of wheat. This is not to say anything about how these added nutrients were distributed amongst the nutritionally affluent and the nutritionally vulnerable population groups in the country. This is largely a function of the basic distribution of wealth and income, and Government policies, as shown recently by Reutlinger and Selowsky (10). *Per se* the green revolution in wheat *did not* result in an inferior overall level of total or per caput production of the primary nutrients—protein, energy, and the major amino-acids—in the aggregate diets of people in the major wheat growing States in India. It, in fact, brought about a vast improvement.

ECONOMICS OF GREEN REVOLUTION NUTRIENT CHANGES

In 1965-66 the price of chickpea was approximately 10 per cent higher than that of wheat in Hapur, one of the major markets for foodgrains in

5. Diets contained from two to four times the recommended daily allowances of lysine per consumption unit in a 1974 National Institute of Nutrition survey of rural and urban areas in nine Indian States (8).

northern India. Chickpea was about Rs. 82 and wheat about Rs. 75 per quintal.[6] At these prices, the cost of 100 grams of protein from wheat was 32 per cent higher at Re. 0.633 compared with Re. 0.479 from chickpea (Table I). Chickpea in April-June, 1977 was priced some 30 per cent higher than wheat at Rs. 140 per quintal compared to Rs. 108 for wheat. At these prices, the cost of 100 grams of protein from wheat was Re. 0.919, 12 per cent higher than the Re. 0.819 for 100 grams from chickpea. What is more significant is the comparison of the 1965-66 cost of protein from the two sources inflated by the Consumer Price Index for Industrial Workers, with the present April-June, 1977 prices. Here we see that for wheat the *real price of protein* in April-June, 1977 is 34 per cent lower than its real price in 1965-66. In real terms, protein from chickpea costs 23 per cent less in April-June, 1977 than it was in 1965-66. Hence, while it is true that the relative price of protein from chickpea has risen vis-a-vis wheat, the real cost of protein from both sources has fallen considerably in the last ten years. The cost of energy from chickpea and wheat was approximately the same in 1965-66 (Table I). In April-June, 1977, energy from wheat was about 20 per cent cheaper than that from chickpea. As was the case with protein, the real price of energy from wheat was 34 per cent less in April-June, 1977 than in 1965-66, and 22 per cent less for chickpea.

TABLE I—RELATIVE COSTS OF PROTEIN AND ENERGY FROM WHEAT AND GRAM IN 1965-66 AND 1977*

Crop	Cost per 100 grams of protein in			Cost per 1000 kcal. of energy in		
	1965-66		April-June, 1977 actual	1965-66		April-June, 1977 actual
	Nominal terms	Real 1977 terms		Nominal terms	Real 1977 terms	
Wheat ..	0.633	1.398	0.919	0.216	0.477	0.313
Gram ..	0.479	1.06	0.819	0.227	0.501	0.389

**Source:* Government of India, Directorate of Economics and Statistics (3) for wholesale prices of Hapur wheat and gram in 1965-66 and the Consumer Price Index for Industrial Workers, *The Economic Times,* for April-June, 1977 grain prices. *Records and Statistics* (9) used for Consumer Price Index for Industrial Workers in 1976-77. Nutritive contents taken from Gopalan, *et al.* (5).

Production of protein and energy from a hectare of land sown to wheat or chickpea in 1964-65 and 1974-75 is presented in Table II. At trend yield levels existing in 1964-65, a hectare of wheat produced one and 41 per cent more protein and energy, respectively, than did a hectare of chickpea. With the large yield increases in wheat in the late 1960s and early 1970s, a hectare of wheat produced 49 and 106 per cent more protein and energy, respectively, than did chickpea.

6. See Government of India, Directorate of Economics and Statistics (3).

TABLE II—TREND LEVELS OF PRODUCTION OF PROTEIN AND ENERGY PER HECTARE FROM WHEAT AND GRAM IN THE SIX MAJOR WHEAT GROWING STATES OF INDIA IN 1964-65 AND 1974-75*

Crop	Yield (kg./ha.)		Protein (kg./ha.)		Energy ('000 kcal./ha.)	
	1964-65	1974-75	1964-65	1974-75	1964-65	1974-75
Wheat ..	900	1414	106	167	3114	4892
Gram ..	615	657	105	112	2214	2365

* Trend lines are contained in Ryan and Asokan (11).

From a nutritional angle, the substitution that did occur of wheat for chickpea after the green revolution resulted not only in a vast increase in the production of energy from each hectare, but also of protein. The 1974-75 chickpea hectare gave 112 kg. of protein and 2,365,000 kilo-calories of energy on an average in the six major wheat growing States of India. Each hectare of 1974-75 wheat which substituted for a hectare of chickpea added a further 35 kg. of protein and 2,527,000 kilo-calories of energy to what the chickpea would have produced. This is further evidence that the new wheats have resulted in a vast improvement in nutrient production on a hectare-for-hectare basis with chickpea, the crop primarily affected by the expansion in wheat hectareage. Elsewhere (11), the authors have shown that about 22 per cent of the increase in the area of wheat which occurred between 1964-65 and 1974-75 could be accounted for by a reduction in the area planted to pulses. About eight per cent came at the expense of winter rice and barley. The bulk of the growth in wheat hectareage in the six States was a result of increases in cropping intensities resulting from the HYVs, expansion in irrigation, and an increase in net sown areas. Hence it seems once again clear that the net nutritional impact of the new wheats was both positive and substantial.

CONCLUSIONS

The nutritional success of the HYVs of wheat in India illustrates how a sufficiently large increase in production of a cereal, primarily as a result of a yield-oriented plant breeding strategy, can produce a significant improvement in aggregate nutritional well-being. That this could occur even though the cereal itself has certain imbalances in protein and amino-acids, and its area was increased at the expense of some area of pulses and other crops, is testimony to the value of yield-oriented plant breeding strategies as a means of achieving nutritional gains. As has been shown elsewhere by Ryan, *et al.* (12, 13), yield increases also provide a mechanism for enhancing real incomes of low income consumers of foodgrains via the effects on prices. In this way, the yield increases provide the wherewithall for the purchase of additional nutrients by the nutritionally most vulnerable.

In having said all this, a final and extremely important point needs to be made. The yield increases in wheat occurred at a time when yields of pulses were relatively stagnant. Indeed, this is one of the reasons for the expansion of the area sown to wheat, about one-fifth of which was at the expense of pulses according to the authors (11). The need now is to increase the yield potential of the pulses to ensure that their prices do not rise to a point beyond the means of the nutritionally vulnerable and economically poor. The nutrient composition of pulses generally complements that of the cereals, and provides desirable variety in the dietary sense. For these reasons, a predominantly yield-oriented breeding strategy in the pulses is called for, as it is for the cereals (particularly the coarse grains—sorghum, millets, and maize). Evidence cited in this paper offers convincing proof of the nutritional benefits possible with this type of approach.

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