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Ryan,J.G.; Asokan,M.

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9. ABSTRACT

Evaluates the effect of high-yielding varieties (HYV) of wheat introduced in India in the mid-1960's on the production of pulses and major nutrients. Linear trend lines were fitted to date from the 6 major wheat-growing states of India for the 10-year period preceding 1964-65 and separately for the subsequent 10-year period. Twenty-two percent of the expansion in wheat hectarage occurring in the latter period could be accounted for by the reduction in the area of pulses and 8% came at the expense of winter rice and barley. The growth in the area sown to wheat was largely a result of increases in cropping intensities resulting from the HYV's and the expansion in irrigation and an increase in net sown areas. The net nutritional impact of the new HYV's of wheat was both positive and substantial. Total annual trend foodgrain production in 1974-75 would have been 13.4% less had HYV's of wheat not been introduced. The success of these wheats clearly illustrates how a plant-breeding strategy which emphasizes increased yield potential can result in significant improvements in aggregate nutritional well-being. Every hectare of 1974-75 wheat which substitutes for a hectare of chickpea adds a further 55 kg of protein and 2,527,000 kilo-calories of energy to what the chickpea would have produced. If the nutritionally most vulnerable groups are to be made better off, substantial increases in yields of coarse grains and pulses, primarily crops of the rainfed semi-arid tropics, are required.

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

James G. Ryan and M. Asokan

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1-11-256 Begumpet, Hyderabad 500016, (A. P.) India

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

*James G. Ryan and M. Asokan**

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

Recently Ryan *et al.* [21, 22] suggested that a predominantly yield-oriented strategy in breeding improved foodgrain varieties is a more appropriate mechanism than one which emphasises improvement of grain protein percentage and other cryptic qualities for enhancing the nutritional well-being of people living in the semi-arid tropics, particularly the nutritional well-being of those regarded as nutritionally vulnerable.[2] The issue of yield versus protein quality/quantity becomes relevant if

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* The authors are Economist and Research Technician, respectively, at the International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India. They are grateful to N.S. Jodha for useful discussions throughout the course of this work and to G. Bengtson for editorial expertise.

1 For recent examples see the Joint FAO/WHO Expert Committee on Nutrition [16, p.32], the United Nations Economic and Social Council [28], Narain [17], Singh [25], and Anonymous [2].

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

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 both attributes in a given period of time. Ryan *et al.* [21, 22] argued there was some evidence of such a trade-off, but many plant breeders would not agree. Bhatia and Robson [6, 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 (HYV's) introduced into India in the mid-1960's 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.

HISTORICAL PRODUCTION TRENDS IN WHEAT, PULSES, WINTER RICE AND BARLEY[3]

In the years following the introduction in the mid-1960's of the new HYV's of wheat into India, areas sown to wheat expanded substantially. A large part of this expansion came at the expense of the area sown to pulses, and to a lesser extent that sown to winter rice and barley.

The total trend area under all pulses in India from 1954-55 to 1964-65, the years before the green revolution in HYV wheat commenced,

increased by 1.74 million hectares, or by 7.7 percent. Trend production increased in the same period by 0.67 million tonnes, or by 6 percent. In spite of this, during the same period the trend net per-caput availability of pulses fell from 70.5 to 59.5 grams per day. From 1964-65 to 1974-75, the period after the introduction of HYV wheats, total pulse area fell by 2.8 percent, trend production fell by 4.8 percent, and the net per-caput trend availability fell from 54.9 to 42.1 grams per day.

In the 10 years prior to 1964-65, the trend area under wheat in India increased by 1.78 million hectares (14.8%), while production increased by 3.07 million tonnes (36%). During the same period, the net per-caput trend availability of wheat increased from 54.9 to 58.9 grams per day. In the 10 years following the start of the HYV green revolution in wheat, the trend wheat hectarage increased by a mammoth figure of 7.08 million hectares (55%) with a 136 percent trend increase in production amounting to 15.5 million tonnes. This contributed to an increase in net per-caput availability of wheat from 58.9 grams per day in 1964-65 to 111.1 in 1974-75.[4]

These figures lend support to the contention that a significant portion of the post-1964-65 increase in wheat area and production was at the expense of pulses. To examine this in more detail, we have selected the six major wheat-growing states -- Uttar Pradesh, Punjab and Haryana (combined), Bihar, Rajasthan, and Madhya Pradesh. These states produce

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4 *Source :* Directorate of Economics and Statistics [9, 10]. These trends were evident even in 1970-71 as reported by Bansil [5], Singh and Gangawar [26], Dikshit and Singh [8], and Sidhu and Sankhayan [23].

87 percent of India's wheat production and grow 78 percent of the new HYV's of wheat.[5] We will proceed to discuss production trends in these states for the six crop groups of wheat, chickpea (gram), pigeonpea (tur), other pulses, winter rice, and barley.

WHEAT

These six states are involved in the bulk of India's HYV wheat-production program (Table 1). A rather unexpected observation is that the percentage of adoption of HYV's of wheat in Bihar in 1971-72 and 1975-76, along with the rate of growth of wheat yields, were higher than in the Punjab and Haryana. These latter two states are traditionally thought of as being the vanguard of the HYV wheat program in India. In 1971-72 Bihar had almost 87 percent of its wheat area sown to HYV's whereas in the Punjab the figure was 73 percent. In 1975-76, the respective figures were 96 and 86 percent. The average yields of wheat in Bihar rose from 657 kg/ha in 1964-65 to 1353 kg/ha in 1974-75, representing a compound annual growth rate between these two periods of 9 percent (Table 2). This compares with a growth rate of only 5.1 percent in Punjab and Haryana, 4.1 percent in Madhya Pradesh, 4 percent in Rajasthan, and 1.6 percent in Uttar Pradesh. Of course the initial hectarage and yield levels in Bihar in 1964-65 were less than half those in the Punjab, so the base on which Bihar's growth occurred was much lower than that in the Punjab.

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5 *Source* : Agricultural Prices Commission [1]. Data refer to 1973-74.

Table 1 : Area ('000 ha) under high yielding varieties of wheat in India.

	Bihar	Gujarat	Haryana	Himachal Pradesh	Jammu & Kashmir	Madhya Pradesh	Maharashtra	Mysore (Karnataka)	Punjab	Rajasthan	Uttar Pradesh	West Bengal	All India
1966-67													
Total Area	809	461	738	269	161	2,130	876	298	1,615	9[illegible]	4,394	55	12,838
Area under HYV	25	1	13	1	1	16	43	1	59	9	363(200)[a]	8	541
Percentage	3.1	0.2	1.8	0.4	0.6	0.8	4.9	0.3	3.7	0.9	8.3(4.6)[a]	14.5	4.2
1967-68													
Total Area	1,054	553	846	311	187	2,661	891	306	1,804	1,265	4,970	79	14,998
Area under HYV	182	161	101	11	28	45	14	11	639	126	1,587(888)[a]	28	2,942
Percentage	17.3	29.1	11.9	3.5	15.0	1.7	1.6	0.4	35.4	10.0	31.9(17.9)[a]	35.4	19.6
1968-69													
Total area	1,095	503	895	313	200	3,056	873	310	2,086	1,162	5,239	150	15,958
Area under HYV	301	167	259	23	36	81	63	26	1,012	190	2,515 (1,367)[a]	62	4,793
Percentage	27.5	33.2	28.9	7.3	18.0	2.7	7.2	0.8	48.5	16.4	48.0 (25.9)[a]	54.7	30.0
1969-70													
Total area	1,145	433	1,017	330	210	3,176	865	327	2,162	1,254	5,378	240	16,625
Area under HYV	437	17[b]	440	69	40	150	152	36	1,502	288	1,640	174	5,005
Percentage	38.2	3.9	43.3	20.9	19.0	4.7	17.6	11.0	69.5	23.0	30.5	72.5	30.1
1970-71													
Total Area	1,316	577	1,129	302	184	3,403	882	306	2,299	1,478	5,907	360	18,241
Area under HYV	880	101[b]	630	109	57	201	211	47	1,589	366	1,938[b]	357	6,542
Percentage	66.9	17.5	55.8	36.1	31.0	5.9	23.9	15.4	69.1	24.9	32.8	99.2	35.9
1971-72													
Total area	1,397	574	1,177	333	180	3,665	1,009	347	2,335	1,514	6,046	422	19,139
Area under HYV	1,213	261	796	125	60	291	207	49	1,695	467	2,200[b]	385	7,858
Percentage	86.8	45.5	67.6	37.5	33.3	7.9	20.5	14.1	72.6	30.8	36.4	91.2	41.1
1972-73													
Total Area	2,509	371	1,270	315	189	3,277	691	299	2,404	1,399	6,135	368	19,464
Area under HYV	1,640	130	800	175	101	536	400	67	1,880	600	3,200[b]	360	10,237
Percentage	65.4	35.0	63.0	55.6	53.4	16.4	57.9	22.4	78.2	42.9	52.2	97.8	52.6
1973-74													
Total Area	1,334	521	1,178	303	190	3,273	923	346	2,338	1,673	6,009	330	18,583
Area under HYV	1,128	315	1,018	200	112	632	377	60	1,970	669	3,400[b]	298	10,912
Percentage	84.6	60.5	86.4	66.0	59.0	19.3	40.9	17.3	84.3	40.0	56.6	90.3	58.7
1974-75													
Total Area	1,478	496	1,117	319	191	2,788	942	365	2,213	1,421	6,152	422	18,010
Area under HYV	890	329	990	190	124	725	403	112	1,956	726	4,152	411	11,216
Percentage	60.2	81.0	88.6	59.6	64.9	26.0	42.8	30.7	88.4	51.1	67.5	97.4	62.3
1975-76(est.)													
Total Area	1,815	686	1,231	319	191	3,248	1,183	407	2,402	1,760	6,102	565	20,112
Area under HYV	1,750	320	1,050	240	140	850	1,100	80	2,060	780	4,500	550	13,665
Percentage	96.4	46.7	85.3	75.2	73.3	26.2	93.0	19.7	85.8	44.3	73.8	97.4	67.9

a Figures in parentheses are estimates of the areas of HYV's only; The other figures refer to local improved varieties also. Minor states have been left out and hence the All India figure does not equal the sum of the entries in the table. Agricultural Prices Commission [1], Vyas [29], and private communication with Dr. Bhatnagar, Joint Commissioner, Food Crops, Ministry of Agriculture, New Delhi, February 1977.

b Excluding local improved varieties.

Table 2 : Annual compound growth rates of area, production and yield of wheat in six major wheat-growing states in India, 1964-65 to 1974-75.

(%)

State	Area	Production	Yield
Bihar	11.3	21.4	9.0
Punjab and Haryana	5.5	10.9	5.1
Madhya Pradesh	2.8	7.0	4.1
Rajasthan	4.5	8.6	4.0
Uttar Pradesh	4.9	6.5	1.6

Source : Directorate of Economics and Statistics [10].

Appendix Figures 1 to 5 present detailed breakdowns of area and yield trends in wheat from 1954-55 to 1974-75 for the six states.[6] In all six states, the trend in the area sown to wheat after 1964-65 is markedly steeper than the trend prior to the year. In Uttar Pradesh, the area of wheat trended upwards by about 242,000 hectares per year after 1964-65 while prior to that period the trend was only 12,000 hectares. For Punjab and Haryana (combined), the corresponding figures were 157,000 and 51,000 hectares. In Bihar the area sown had little trend prior to 1964-65, but increased at a trend of 126,000 per annum after that. Rajasthan's wheat area grew 18,000 hectares per year before 1964-65 and 56,000 hectares afterwards, while in Madhya Pradesh the corresponding figures were 68,000 and 77,000. In the latter two states, wheat hectarage seemed to suffer a large decrease in the drought years of the mid-1960's. In spite of this, the trend after the drought years was much higher than before.

As expected, yield trends in wheat in all six states were steeper after 1964-65 than before. The difference in the two yield trends was greatest for Bihar, where trend wheat yields rose by 65 kg/ha *more* per annum after 1964-65 than before. For Punjab and Haryana the difference was approximately 52 kg/ha, for Rajasthan 47, Madhya Pradesh 19, and Uttar Pradesh 5 kg/ha.[7]

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6 In all figures in this paper, linear regression equations are shown for the various trend lines. The variable x refers to time in years and the numbers in parentheses refer to the t-values of the estimated regression coefficients. Unfortunately, the 1975-76 production estimates became available only after all the trend lines were fitted; they could not be included.

7 Rajasthan was the only one of these six states where wheat yield trends were negative prior to 1964-65.

CHICKPEA

Appendix Figures 6 to 10 contain trends in area and yields of chickpea (gram) from 1954-55 to 1974-75 in the six selected states. The most dramatic change in the trends of area sown to chickpea after 1964-65 occurred in Uttar Pradesh. Before 1964-65 the Uttar Pradesh chickpea area was falling by some 8,000 hectares annually, whereas after it began to fall at a rate of 79,000 hectares per year. In the Punjab and Haryana the trend in chickpea area was distinctly negative prior to the introduction of the HYV's of wheat in 1964-65, to the extent of a reduction of 36,000 hectares per year. After 1964-65 this negative trend intensified to 68,000 hectares per year. The trend area of chickpea had been relatively stable in Bihar to 1964-65 but then it changed, generating an annual reduction of 19,000 hectares. In spite of a sharp depression in chickpea hectarage in the mid-1960's in Rajasthan, since then the trend has been positive at 31,000 hectares per year, which compares to an upward trend of 20,000 hectares prior to 1964-65. However, the actual hectarage of chickpea in Rajasthan is yet to reach the levels of the early 1960's. Madhya Pradesh is the only state where the area of chickpea has continued to expand throughout the whole 1954-55 to 1974-75 period. This upward trend increased from 8,000 hectares annually before 1964-65 to 26,000 hectares afterwards.

Yield trends of chickpea (gram) in Uttar Pradesh were almost constant prior to 1964-65 and remained so after that time. Before 1964-65, chickpea yields in the Punjab and Haryana were trending down by some 7 kg/ha per year. After that time, yields began an even steeper decline to the extent of about 12 kg/ha per year. Bihar chickpea yields changed from an upward trend of 18 kg/ha per year before 1964-65 to a downward

trend of 7 kg/ha per year afterwards. In Rajasthan yield trends improved by some 30 kg/ha annually after 1964-65. The reduced areas of chickpea sown there during the late 1960's were thus probably on the better quality lands, the poorer lands being diverted to wheat and other crops. The same was probably true in Madhya Pradesh, where there was a slight increase in trend yields of 13 kg/ha per year after 1964-65, whereas prior to that yields were virtually stable. This occurred while the area sown to chickpea was rising by 21,000 hectares per year. In the other four states (Uttar Pradesh, Punjab, Haryana, and Bihar), it is likely that the areas taken out of chickpea after 1964-65 may have been the better quality lands, as generally yield trends of chickpeas declined in these states subsequently.

PIGEONPEA

Yield and area trends for pigeonpea (tur) for the six states are shown in Appendix Figures 11 to 15. Only three of the six -- Uttar Pradesh, and Bihar -- are significant pigeonpea producing states. Area sown in the other three states is relatively small.

In Uttar Pradesh, the total area sown to pigeonpea was relatively constant at some 634,000 hectares before 1964-65, after which it then began to decline by some 17,000 hectares per year. In Madhya Pradesh the area sown was also relatively constant at around 380,000 hectares prior to 1964-65 but, contrary to Uttar Pradesh, after that it began to increase by 8,000 hectares per year. In Bihar the pigeonpea area, following 10 years of relative stability, began a downward trend of 7,000 hectares per year after 1964-65.

In both Uttar Pradesh and Madhya Pradesh, the post-1964-65 yield trends in pigeonpea were more positive than the ante-1964-65 trends. However, in Uttar Pradesh the yield trend still remained virtually constant in this latter period, whereas in Madhya Pradesh it rose substantially to a trend increase of 18 kg/ha per year. In Bihar, pigeonpea yields began to fall at a rate of 5 kg/ha per year after 1964-65; they were recording an annual increase of 33 kg/ha before this. This suggests that the pigeonpea land diverted to wheat in Uttar Pradesh and Madhya Pradesh following 1964-65 tended to be in the more marginal areas, whereas in Bihar it was in the higher-quality soil areas.

OTHER PULSES[8]

Appendix Figures 16 to 20 show that the area sown to "other pulses" fell substantially after 1964-65 in two of the four major producing states. In Uttar Pradesh, the area was increasing by some 27,000 hectares per annum before 1964-65 and then it began to decline at an annual rate of 36,000 hectares. In Bihar, annual area trends went from an increase of 47,000 hectares to a decrease of 42,000 hectares during the same periods. In the major producing states of Madhya Pradesh and Rajasthan on the other hand, the area of other pulses continued to trend upward at virtually the same rate as before 1964-65.

Coincident with the area reduction in Uttar Pradesh and Bihar after 1964-65, the annual reduction in yields were about 16 kg/ha and 10 kg/ha respectively. This was in contrast to annual trend yield increases of 18 kg/ha and 28 kg/ha prior to 1964-65. It hence appears

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8 Included in this category are black gram, cowpea, green gram, horse gram, lentils, field beans, etc.

that in these two states the more-fertile land might have been taken out of production of "other pulses" and put into wheat and other crops. In Madhya Pradesh and Rajasthan, yield trends remained almost the same in the two periods, although yields fell during the drought period the mid-1960's. In these states, the increase in area sown to "other pulses" thus did not appear to entail yield sacrifices, as it did in the case of Uttar Pradesh and Bihar which both reduced the area sown to "other pulses".

WINTER RICE

Only two of the six major wheat growing states -- Uttar Pradesh and Bihar -- grow winter rice. As shown in Appendix Figures 21 and 22, areas sown in these two states decreased substantially after 1964-65. Prior to that year, the area of winter rice was increasing annually in Uttar Pradesh by 39,000 hectares in Bihar by about 55,000 hectares. Subsequently, the winter rice areas began to decline by 16,000 and 18,000 hectares, respectively, per annum.

In spite of the reduction of the areas sown in Uttar Pradesh, the upward yield trends in winter rice remained about the same after 1964-65 as before. However, in Bihar the upward trends of 35 kg/ha prior to 1964-65 were cut in half in the 10-year period following. This implies that, as with the other substitute crops for wheat in Bihar, the land diverted from winter rice to wheat was of a higher average quality than was the case in Uttar Pradesh.

BARLEY

Trends in barley area and yield during the 20-year period under study are shown in Appendix Figures 23 to 27. In every state except

Bihar, trends in barley area were significantly more positive after introduction of the new HYV wheats. Hence there would not appear to be support for the contention that HYV wheat land substituted for barley land, except perhaps in the case of Bihar.

Prior to 1964-65, a distinct downward trend was reflected in the areas sown to barley in Uttar Pradesh (-42,000 hectares), Punjab and Haryana (-10,000 hectares), and Rajasthan (-13,000 hectares). In Madhya Pradesh, no trend was apparent, while Bihar had a slight upward trend of 2,000 hectares per annum during the same period. After 1964-65, the area trend remained negative in Uttar Pradesh at 30,000 hectares per year, but much less so than before. In Punjab and Haryana, the area trend rose to 7,000 hectares per year after 1964-65, in Rajasthan it rose to 16,000 hectares and in Madhya Pradesh to 6,000 hectares per year. In Bihar, barley area declined at a trend rate of 18,000 hectares per year after 1964-65.

Yield trends for barley in Uttar Pradesh and Bihar continued upward movement after 1964-65 at about double the prior rate. In Madhya Pradesh there was no change in the positive yields trend of 15 kg/ha per year after introduction of HYV wheats. In Rajasthan barley began to rise at some 8 kg/ha per year after being stagnant prior to 1964-65. The Punjab and Haryana were the only two states to record yield decreases in barley (13 kg/ha per year) after 1964-65, whereas prior to that yields rose by some 6 kg/ha per year.

OVERALL TRENDS

If we combine the trend lines for the areas of chickpea, pigeonpea, and other pulses sown from 1964-65 to 1974-75 in the [illegible], we

can see how the total change in pulse area compared with that of wheat between the two periods (Table 3). The largest reduction in trend hectarage between these two periods was in chickpea, where the reduction of 1,100,000 hectares amounted to 14.7 percent. Next was the "other pulses" category with a 200,000-hectare reduction over the 10 years, although this represented only 3.1 percent of the area sown to these crops in 1964-65. The trend area of pigeonpea fell by a total of about 150,000 hectares, or by 11.4 percent. Overall, the trend area of pulses in these six states fell in the 10-year period by some 1,450,000 hectares, which represented a 9.4 percent reduction. The trend area of winter rice and barley during the same 10-year period fell by 310,000 and 200,000 hectares (5 and 7.2 percent), respectively. Compared to this the trend wheat area expanded by 6,580,000 hectares, an increase of 61.9 percent.

The significant point is that the net reduction in the total pulse area after 10 years of the HYV wheat program was only 22 percent of the increase in the area sown to wheat during the same period. When we also include the reduction in areas sown to winter rice and barley to that of the pulses, we can account for no more than 30 percent of the increase in the area sown to wheat in these six states. Obviously the expansion in wheat was not only at the expense of pulses, winter rice, and barley.[9] The vast majority of it was due to the substantial increase in cropping intensity which followed the introduction of the HYV's of wheat. Tubewell irrigation allowed two crops to be taken where only rainy-season (kharif) crops were grown previously. Excluding Bihar, for which data were not available, the area of irrigated wheat

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9 According to Narain [17], the shift from chickpea to wheat was occurring before the advent of the HYV's due to the expansion of irrigation. The greater profitability of the HYV's of wheat compared to local varieties, especially under irrigation, accentuated the shift ou[illegible] pea.

Table 3 : Net changes in trend areas of wheat, pulses, winter rice and barley in six major wheat-growing states of India, 1964-65 to 1974-75.

Crop	Area of crop from trend line ('000 ha)			Difference as percentage of 1974-65 (%)
	1964-65	1974-75	Difference	
Wheat	10,630	17,208	+6,578	+61.88
Chickpea	7,457	6,362	-1,095	-14.68
Pigeonpea	1,320	1,169	- 151	-11.44
Other pulses	6,587	6,386	- 201	- 3.05
Total pulses	15,364	13,917	-1,447	- 9.42
Winter rice	6,764	6,426	- 338	- 5.00
Barley	2,703	2,508	- 195	- 7.21

Source : Trend lines from 1964-65 to 1974-75 contained in Appendix Figures 1 to 27 drawn from data in Directorate of Economics and Statistics [10].

rose in the other five states by more than 70 percent, or by some 3,800,000 hectares from 1967-68 to 1973-74, according to the Agricultural Prices Commission [1, p 22]. During the 8 years from 1964-65 the trends in total gross cropped area in these six states rose by 6,350,000 hectares. Most of this increase would have been sown to wheat. The trend net sown area rose during the same period by 2,750,000 hectares.[10] Apparently cash crops were not much affected by the expansion in wheat.[11]

PRODUCTION OF MAJOR NUTRIENTS FROM WHEAT, PULSES, WINTER RICE AND BARLEY

Area, yield, and production data for each of the six states described in the previous section were amalgamated to obtain the total production of food from these six commodity groups for each year (Fig 1). The annual increase trend in food production from these six sources combined more than doubled after the advant of the HYV's of wheat. Prior to this time, production was rising by some 580,000 metric tonnes per year. Afterwards this rose to more than 1,300,000 metric tonnes. Had pre-green revolution trends in area and production continued, 1974-75 production of these six foodgrains would have been 13.4 percent less than actually occurred (Table 4). Pre- and post-green revolution trends on a per-caput basis using the combined population of the six states in the various years are presented in Table 5.

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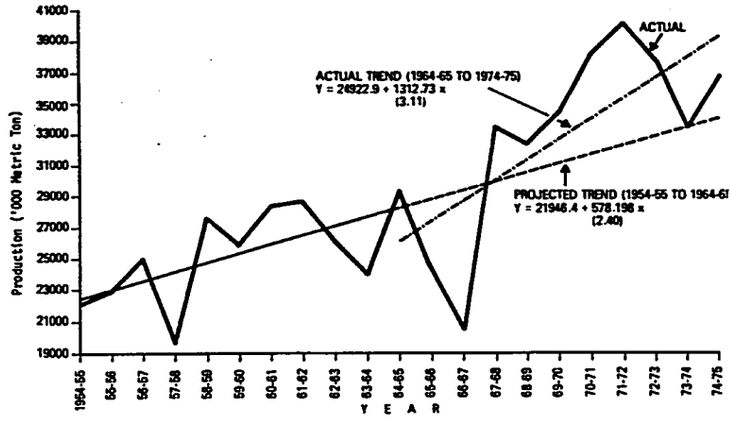
10 *Source :* Directorate of Economics and Statistics [11, 12]. Data up to 1973-74 were not available for total cropped and net sown area.

11 See Narain [17]. He points out that expansion in the areas of sorghum and pearl millet during this period did affect the areas sown to cash crops.

STATES OF INDIA.



MAJOR WHEAT-GROWING STATES OF INDIA.

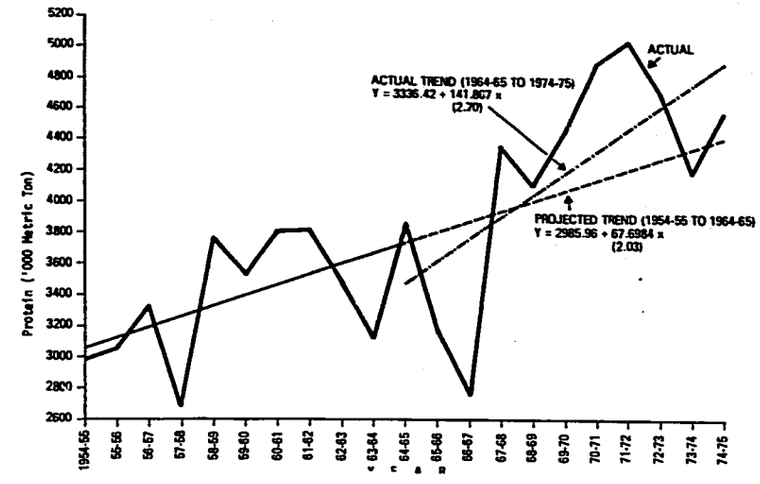


FIGURE 3. TOTAL PRODUCTION OF ENERGY FROM WHEAT, PULSES, WINTER RICE, AND BARLEY IN THE SIX MAJOR WHEAT-GROWING STATES OF INDIA.

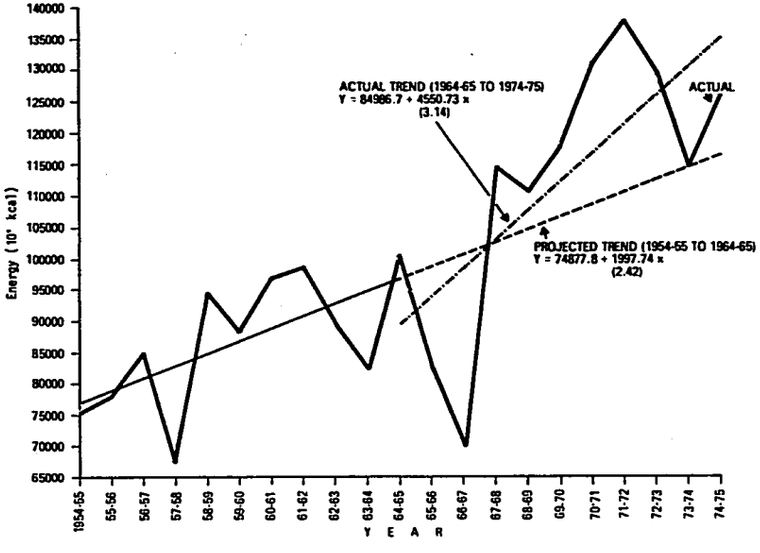


FIGURE 4. TOTAL PRODUCTION OF LYSINE FROM WHEAT, PULSES, WINTER RICE, AND BARLEY IN THE SIX MAJOR WHEAT-GROWING STATES OF INDIA.

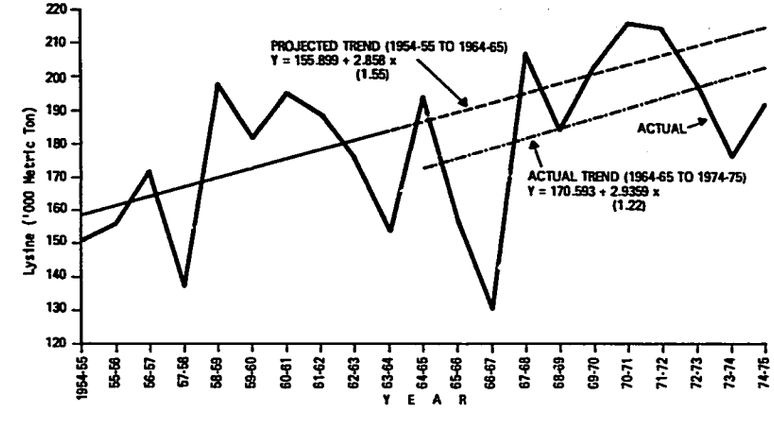


Table 4 : Average 1974-75 total production of nutrients from wheat, pulses, winter rice, and barley in the six major wheat-growing states of India with and without the wheat "Green Revolution".

Nutrient	Unit	Average total production in 1974-75 from linear trend lines fitted through : Actual production from 1964-65 to 1974-75 (i.e."With Green Revolution")	Actual production from 1954-55 to 1964-65 and then projected to 1974-75 (i.e. "Without Green Revolution")	Percentage change in total trend production in 1974-75 had Green Revolution not occurred (%)
Total weight of six food-grains	'000 MT	39,363	34,089	-13.4
Protein	'000 MT	4,897 (5,060)[a]	4,408	-10.0 (-12.9)
Energy	10^9 Kcal	135,045	116,830	-13.5
Lysine	'000 MT	203 (207)	216	+ 6.4 (+ 4.3)
Methionine + Cystine	'000 MT	161	136	-15.5
Tryptophan	'000 MT	53	47	-11.3
Leucine	'000 MT	355	334	- 5.9
Isoleucine	'000 MT	200	196	- 2.0

a Figures in parentheses include an allowance for the estimated additional protein percentage of the HYV's.

Table 5 : Average 1974-75 per-caput production of nutrients per day from wheat, pulses, winter rice, and barley in the six major wheat growing states of India with and without the wheat "Green Revolution".[a]

Nutrient	Unit	Average per-caput production in 1974-75 from linear trend lines fitted through : Actual production from 1964-65 to 1974-75 (i.e. "With Green Revolution")	Actual production from 1954-55 to 1964-65 and then projected to 1974-75 (i.e. "Without Green Revolution")	Percentage change in production trend in 1974-75 per caput had Green Revolution not occurred (%)
Total weight of six food-grains	g/day	429.6	382.4	-11.0
Proteins	g/day	53.4 [55.2][b]	49.08 (42.7)[c]	- 8.0 [-12.5]
Energy	Kcal/day	1,474	1,312 (2373)	-11.0
Lysine	g/day	2.199 [2.247]	2.381 (1.36)	+ 8.3 [+ 6.0]
Methionine + Cystine	g/day	1.759	1.523 (0.87)	-13.4
Tryptophan	g/day	0.578	0.520 (0.18)	-10.0
Leucine	g/day	3.860	3.708 (1.23)	- 3.9
Isoleucine	g/day	2.175	2.182 (0.80)	+ 0.3

a Figures are expressed per-caput of the combined populations of the six major wheat-growing states of India,namely Punjab, Haryana, Uttar Pradesh, Rajasthan, Madhya Pradesh, and Bihar.

b Figures in square brackets include an allowance for the estimated additional protein percentage in the HYV's.

c Figures in the parentheses are recommended daily allowances for an average Indian. See Ryan *et al.* [21].

Whilst of course the effect of the green revolution on per-caput production of the six foodgrains is not as large as the effect on aggregate production due to population increases, the percentage decrease in annual per-caput production in 1974-75 (if the green revolution had not occurred) would have been of the order of 11 percent. It is clear from this the *net impact* of the HYV's of wheat on overall foodgrain production was substantial.

Curves in Figure 2 show how the above foodgrain production trends look when converted into units of protein. The conversion was effected by applying the protein-content values contained in Gopalan *et al.* [13] for the various crops to their production each year and then summing across crops.[12]

The figure shows that despite replacement of a large area of high-protein-content pulses by low-protein-content wheat, the combined production of protein in the six states increased about 142,000 metric tonnes per year after 1964-65. The annual trend protein increase of 68,000 metric tonnes prior to the 1964-65 period was much smaller.

It is likely that the above post-1964-65 trend in protein is in fact an underestimate. This is because we used the same protein-content figure for wheat (11.8 g/100 g of whole grain) for the entire period examined. In fact, after 1964-65 levels of application of nitrogen fertilizers on wheat increased substantially. There is a strong positive association between protein content and nitrogen fertilizer applications, which would have contributed to a significant increase in the protein content

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12 The nutritive values of the 12 other pulses besides chickpea and pigeonpea contained in Gopalan *et al.* were averaged to derive the nutrient factors for the category of other pulses. The same procedure was used for the other nutrients.

of wheat after 1964-65. Austin *et al.* [3] conducted experiments to compare the effect of various levels of nitrogen fertilizers on 10 newly evolved wheat varieties and three standard varieties. When 80 kg N was applied per hectare, HYV's showed a significant gain in protein content (2.29 percentage points) from the base level of 9.77 percent. For the standard varieties examined, protein content rose even more. When 80 kg N/ha was applied, protein content increased by 2.94 percentage points from the initial level of 9.19 percent. Dalrymple [7] cites other evidence in support of the contention that increased nitrogen levels have appreciably increased protein contents of wheat. According to Austin and Ram [4, pp 41,52], chapati-making qualities (water-absorption, puffing, texture, sweetness) of the HYV's are not much different from from those of standard varieties. However, in tasting-test with consumer panels, the HYV's in general were comparable or even superior to the local varieties for chapati quality.

To adjust post-1964-65 trends in protein production to allow for the effect of increased protein percentage in wheat, we assumed an increase of one percentage point in protein content of all HYV's produced. This estimate, provided by Dr. S.V. Pingale, previously Manager (Quality Control) of the Food Corporation of India (FCI)[13], was derived from numerous analyses performed by FCI on market samples over recent years. Judging by the experimental results cited earlier, it may be a conservative estimate.

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13 Private communication, July 31, 1976. Data from wheat grain samples taken from households in six villages in Maharashtra and Andhra Pradesh suggest a protein content of 13.8 percent. This is two points higher than the standard protein content used here.

When we add (to the 1974-75 actual trend value of protein of the six foodgrains) the estimated additional protein resulting from the higher content of the HYV's, it increases it by 163,000 metric tonnes (3.3 percent). If this is included, about 652,000 metric tonnes more trend protein were produced in 1974-75 after the green revolution in wheat than would have been the case had pre-green revolution trends continued unabaded into the late 1960's and early 1970's (Table 4). This represents an increase of nearly 15 percent.[14] When translated into protein per-caput (Table 5), without the green revolution in wheat, the production of trend protein per-caput in 1974-75 would have been reduced by more than 6 g. This would mean 12.5 percent less protein per-caput.[15]

The total production of energy from the six foodgrains substantially increased after 1964-65 (Figure 3). Prior to that year, the trend was increasing by almost 2000 x 10^9 kilocalories per year (2.5 kilocalories per-caput per day). Now the trend is an increase of more than twice that figure, or 4550 x 10^9 kilocalories per year (28.5 kilocalories per-caput per day). The actual trend production of energy from these sources in 1974-75 was about 135,000 x 10^9 kilocalories (Table 4). Had the pre-green revolution trends continued to 1974-75, production of energy from these foodgrains would have been only 117,000 x 10^9 kilo-

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14 To put it another way, there would have been about 13 percent *less* production of protein from these six foodgrains combined, compared to what was actually produced (in trend values), had the HYV's of wheats not been introduced.

15 There was virtually zero trend in the per-caput production of protein prior to 1964-65. Thereafter it began to increase by 0.73 grams per-caput per day.

calories, or some 13.5 percent less. In per-caput terms, the reduction would have been 11 percent -- from 1,474 to 1,312 kilocalories per-caput per day (Table 5) -- had there been no HYV wheats introduced. In view of the predominance of calorie deficiencies in the diets of the Indian population [Sukhatme (27) and Ryan *et al.* (21,22)], it would appear that the green revolution in wheat made a significant impact on the production of this critical nutrient and presumably on overall nutritional well-being.[16]

The amino-acid balance is an important component of the nutritional picture, especially when one is considering cereals and pulses. Generally cereals are considered to be relatively deficient in lysine, while the pulses are considered to be relatively deficient in methionine+ cystine. The concern with the advent of the HYV wheat green revolution was that the displacement of lysine-adequate pulses with lysine-deficient wheat would lead to an inferior overall quality of protein, as well as less total protein, in the diet.

Primarily due to the 1965-66 drought, the post-green revolution trend line of total lysine production from all six foodgrains fell slightly below (about 6.5 percent) the pre-green revolution trend line (Figure 4). However, the annual trend rate of increase in lysine of 2940 metric tonnes per year after 1964-65 was slightly larger than the pre-green revolution trend rate of increase of 2860 metric tonnes. In per-caput terms lysine production from these six foodgrains was falling by 0.0107 grams

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16 This, of course, assumes that the nutritionally vulnerable part of the population participated in the increased consumption of the additional production. More will be said on this later in the paper.

per day before 1964-65. Subsequently the rate of decline was less at 0.0088 grams per-caput per day.

There was about 4.3 percent less lysine produced in 1974-75 than there would have been had pre-green revolution trends continued to that time (Table 4). This represents a loss of some 9000 metric tonnes of lysine. The per-caput production in 1974-75, using post-green revolution trends, was 2.247 g per day, whereas had pre-green revolution trends continued to 1974-75, there would have been 2.381 grams of lysine produced per caput per day, or 6 percent more. Lysine is the only one of the seven nutrients examined whose production fell as a result of the introduction of the HYV's of wheat, and even then the reduction was minor. As Table 5 shows, the current per-caput trend level of lysine production from these six foodgrains alone is already 65 percent higher than the recommended daily allowance for an average Indian. Using the World Health Organization allowances [30], this current lysine trend production level of 2.381 grams per-caput per day is also 60 percent more than the allowance for lactating mothers, 90 percent 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.* [21] have shown, lysine is far from being limiting in the existing diets of even the lowest income families in rural and urban India.[17] Under these circumstances, the small reduction in lysine resulting from the shift to wheat would appear to be of little if any nutritional consequence.

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17 Diets were shown by Ryan *et al.* to contain from two to four times the recommended daily allowances of lysine per consumption unit in a 1974 survey of rural and urban areas in nine Indian states conducted by the National Institute of Nutrition [18].

Production of methionine and cystine, another essential amino-acid complex, would have been 15.5 percent less (Table 4) than the actual recorded trend level in 1974-75, had pre-green revolution trends shown in Figure 5 continued their rise of 2250 metric tonnes per year (representing a zero annual per-caput rise). After the introduction of HYV's of wheat in 1964-65, the trend rate of increase in total production of these two amino-acids rose to 5530 metric tonnes per year (an increase of 0.036 grams per-caput per day each year). Per-caput trend production in 1974-75 was 1.759 grams per day, whereas had pre-1964-65 trends continued it would have been more than 13 percent less at 1.523 grams (Table 5).

Tryptophan production registered an increase in annual trend production after 1964-65, more than double that prior to then (Figure 6). Per-caput trend production of tryptophan was virtually stable before 1964-65, but afterwards recorded an annual increase of 0.009 grams per day. In 1974-75, had it not been for the HYV wheats, total tryptophan production would have been reduced by about 11 percent, whereas per-caput production would have been reduced by 10 percent.

The trend rate of increase in production of leucine rose after 1964-65 to 9000 metric tonnes per year, nearly double the previous trend of about 4900 (Figure 7). During corresponding periods per-caput production trends were 0.036 and -0.008 grams per day, respectively. By 1974-75 this meant there would have been about 6 percent less total leucine and 4 percent less leucine per capita produced had the HYV wheats not been introduced (Tables 4, 5).

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

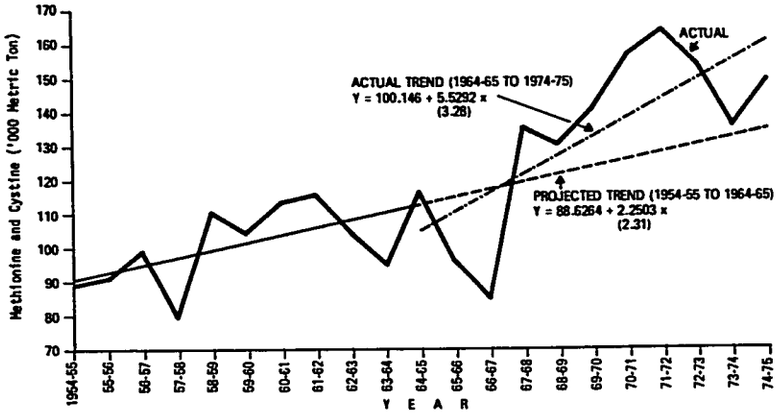


FIGURE 6. TOTAL PRODUCTION OF TRYPTOPHAN FROM WHEAT, PULSES, WINTER RICE, AND BARLEY IN THE SIX MAJOR WHEAT-GROWING STATES OF INDIA.

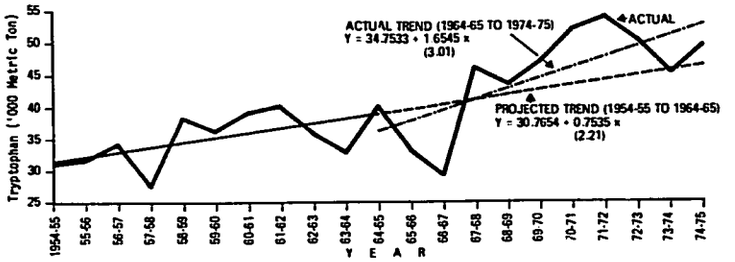


FIGURE 7. TOTAL PRODUCTION OF LEUCINE FROM WHEAT, PULSES, WINTER RICE, AND BARLEY IN THE SIX MAJOR WHEAT-GROWING STATES OF INDIA.

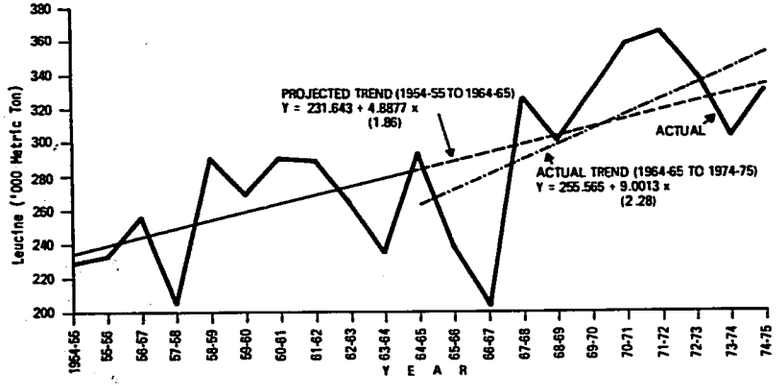
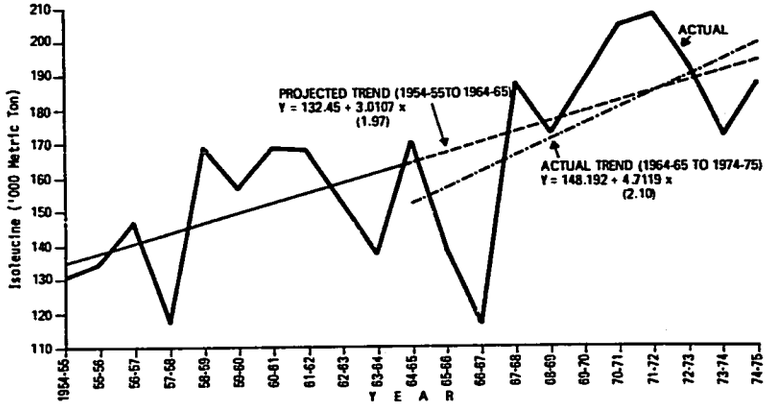


FIGURE 8. TOTAL PRODUCTION OF ISOLEUCINE FROM WHEAT, PULSES, WINTER RICE, AND BARLEY IN THE SIX MAJOR WHEAT-GROWING STATES OF INDIA.



For isoleucine, Figure 8 shows an improved trend after 1964-65, to the extent that production trended upwards by an additional 1700 metric tonnes per year when compared with the previous trend. The annual per-caput change in trend production of isoleucine before 1964-65 was slightly negative at -0.0018 grams per day. Subsequently this became positive at a 0.036 grams per day increase each year. In 1974-75 this meant total production without the green revolution would have been less by 2 percent and about the same on a per-caput basis.

ECONOMICS OF NUTRIENT CHANGES ENGENDERED BY HYV'S OF WHEAT

The above results demonstrate that the net effect of the introduction of the new HYV's of wheat and the changes in area and production of wheat, pulses, winter rice, and barley which it engendered was a substantial enhancement in both the total and per-caput production available of protein, energy, and the major essential amino-acids -- except perhaps lysine, which registered a very marginal reduction. In the process though, as Narain [17] points out, the relative prices of pulses, especially chickpea, have risen compared to wheat. This has had the apparent effect of making it more difficult for people to purchase sufficient quality protein to ensure a proper diet. This is examined in Table 6.

In 1965-66 the price of chickpea was approximately 10 percent higher than wheat in Hapur market, one of the major markets for foodgrains in northern India. Chickpea was about Rs 82 and wheat about Rs 75 per quintal.[18] At these prices, the cost of 100 grams of protein from wheat

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18 See Directorate of Economics and Statistics [9].

Table 6 : Relative costs of protein and energy from wheat and gram in 1965-66 and 1977.

Crop	Cost of protein in: (Rs/100 g)			Cost of energy in: (Rs/'000 Kcals)		
	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
Chickpea	0.479	1.06	0.819	0.227	0.501	0.389

Source : Directorate of Economics and Statistics [9] for wholesale prices of Hapur wheat and chickpea in 1965-66 and the Consumer Price Index for Industrial Workers; *Economic Times*, for April-June 1977 grain prices. *Records and Statistics* [19] used for Consumer Price Index for Industrial Workers in 1976-77. Nutritive contents taken from Gopalan *et al.* [13].

was 32 percent higher at Rs 0.633, compared with Rs 0.479 from chickpea. In April-June, 1977, chickpea was priced some 30 percent 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 Rs 0.919, only 12 percent higher than the current price of 100 grams from chickpea of Rs 0.819. What is more significant is the 1965-66 cost of protein from the two sources inflated by the Consumer Price Index for Industrial Workers, compared with the present April-June 1977 prices. Here we see that, for wheat, the real price of protein in April-June 1977 is 34 percent lower than the real price in 1965-66. Protein from chickpea is 23 percent cheaper per 100 grams in April-June 1977 than it was in 1965-66 in real terms. Hence, while it is true that the relative price of protein from chickpea has risen vis-á-vis wheat, the real cost of protein from both sources has fallen considerably in the last 10 years.

The cost of energy per 1000 kilo calories in 1965-66 from chickpea and from wheat was approximately the same (Table 6). In April-June 1977, energy was about 20 percent cheaper when it came from wheat compared with chickpea. As was the case with protein, the real price of energy from wheat was 34 percent lower in April-June 1977 than in 1965-66; From chickpea it was 22 percent lower.

Table 7 compares production, in terms of protein and energy, on a hectare of land sown to wheat with that on a hectare sown to chickpea in 1964-65 and 1974-75. At trend yield levels existing in 1964-65, a hectare of wheat produced 1 and 41 percent more protein and energy, respectively, than did a hectare of chickpea. After the large yield increases

Table 7 : Trend levels of production per hectare of protein and energy from wheat and chickpea 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
Chickpea	615	657	105	112	2214	2365

Source : Trend lines in Appendix Figures drawn from data in Directorate of Economics and Statistics [10].

in wheat in the late 1960's and early 1970's, a hectare of wheat produced 49 and 106 percent more protein and energy respectively, than did chickpea.

From a nutritional angle, the substitution of wheat for chickpea that did occur 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 protein and 2,365,000 kilocalories of energy on 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 55 kg of protein and 2,527,000 kilocalories of energy to what the chickpea would have produced. This itself is evidence enough that the new wheats have brought about a vast improvement in nutrient production on a hectare basis with chickpea, the crop which was primarily affected by the expansion in wheat hectarage. When it is further recalled (from Table 3) that no more than one-third 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 areas of pulses, winter rice, and barley, it seems once again clear that the net nutritional impact of the new wheats was both positive and substantial.

CONCLUSION

It is apparent from the foregoing analyses that the new HYV's of wheat introduced into India in 1964-65 had, by 1974-75, resulted in a substantial improvement in the production of total food, protein, energy, and all of the essential amino-acids except lysine. There was some indication of a very minor reduction in the total production of

lysine -- caused by the substitution of wheat for pulses in cropping patterns. However, the trend growth in lysine production after HYV's of wheat were introduced was in fact higher than before. The trend level, though, had not quite caught up with the projected level due to the effect of the 1965-66 drought. This small reduction in lysine production is a minor and acceptable price to pay for the substantial increases in production of energy and protein realized from the HYV's of wheat. As shown by Sukhatme [27], Ryan *et al.* [21, 22] and others, calories are generally the first limiting nutrient in the diets of people in India and other parts of the semi-arid tropics, even for those in the lower socio-economic groups. In helping to significantly alleviate this constraint in Indian diets, the new HYV's of wheat have allowed the existing (and HYV wheat-augmented) proteins and amino-acids consumed to be utilized more fully and effectively for essential body functions other than supplying of energy. Under a calorie-deficient regime proteins themselves are utilized for energy production. It should be noted the above results exclude the record production year of 1975-76. Data for this year became available only after the trend analyses were computed. What 1975-76 shows is that, compared to the values obtained by projecting the pre-green revolution trends to 1975-76, the actual production of nutrients in the six major wheat-growing states during 1975-76 was higher by the following percentages: protein 22, energy 20, lysine 7, methionine and cystine 21, tryptophan 33, leucine 16, and isoleucine 12. This permits us to confidently conclude that today the production status of protein, energy, and all the essential amino-acids would have been far inferior had it not been for the

HYV's of wheat. This is not to say anything about how these added nutrients were distributed amongst the nutritionally affluent and the nutrionally vulnerable population groups in India. This is largely a function of the basic distribution of wealth and income, and government policies as shown recently by Rutlinger and Selowsky [20]. What can be said though is that *per se* the green revolution in wheat did not create 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, made possible a vast improvement.

The success of the HYV's 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 was increased in hectarage at the expense of some hectarage 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.* [21, 22], yield increases also provide the mechanism for enhancing real incomes of the low-income consumers of foodgrains via the effects on prices. In this way, the wherewithall is provided to the nutritionally most vulnerable to purchase the added nutrients which the yield increases provide.

In having said all this, a final and extremely important point needs to be made. The yield increases in wheat occurred at the same time as 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. The need now is to increase the yield potential of the pulses so that prices for these do not rise to an extent beyond the means of the nutritionally vulnerable and economically poor. The nutrient composition of pulses generally complements that of the cereals, as well as providing desirable variety in the dietary sense. For these reasons a predominantly yield-oriented breeding strategy in the pulses is also called for, as it is for the cereals, particularly the coarse grains -- sorghum, millets, and maize. The evidence cited in this paper offers convincing proof of the nutritional benefits that are possible with this type of approach.

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SUMMARY

The effect of high-yielding varieties (HYV) of wheat, introduced in India in the mid-1960's, on the production of pulses and major nutrients was evaluated. Linear trend lines were fitted to data from the six major wheat-growing states of India (Punjab, Haryana, Uttar Pradesh, Bihar, Rajasthan, and Madhya Pradesh) for the 10-year period preceding 1964-65 and separately for the subsequent 10-year period. It is apparent that 22 percent of the expansion in wheat hectarage occurring in the latter period could be accounted for by the reduction in the area of pulses and 8 percent came at the expense of winter rice and barley. The vast majority of the growth in the area sown to wheat was a result of increases in cropping intensities resulting from the HYV's and the expansion in irrigation and an increase in net sown areas.

Total annual trend foodgrain production in 1974-75 would have been 13.4 percent less had HYV's of wheat not been introduced. This takes into account the reduction in production of pulses, winter rice, and barley, as well as the increased wheat production. The following percentage reductions would have occurred in total annual 1974-75 production of various nutrients:

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

Per-caput production of foodgrains and the above nutrients would also have been less had the HYV's of wheat not been introduced. Generally, the per-caput reductions percentages would amount to between

one to two points less than the above figures. Total lysine production would have been about 6.4 percent more had HYV's not been introduced. Calories, (as well as certain minerals and vitamins) rather than protein or amino-acids, seem to be the first limiting nutrient in the diets of most Indians -- including those in the least affluent socio-economic categories -- so this small reduction in lysine is an acceptable price to pay for the substantial increases in production of foodgrains, energy, and protein which resulted. When the record production year of 1975-76 is included in the analysis, production of all nutrients, including lysine, shows a substantial increase over what would have occurred had pre-green revolution conditions continued.

Even though prices of chickpea relative to wheat have risen since 1964-65, the real prices of protein and energy from both sources has substantially fallen. For chickpea, the real prices of protein and energy have fallen more than 20 percent between 1964-65 and 1974-75. For wheat the reduction has been more than 33 percent. Every hectare of 1974-75 wheat which substitutes for a hectare of chickpea adds a further 55 kg of protein and 2,527,000 kilo-calories of energy to what the chickpea would have produced.

Hence, it is clear that the net nutritional impact of the new HYV's of wheat was both positive and substantial. The success of these wheats clearly illustrates how a plant-breeding strategy which emphasizes increased yield potential can result in significant improvements in aggregate nutritional well-being. Substantial increases in yields of coarse grains and pulses, primarily crops of the rainfed semi-arid tropics, are required if the nutritionally most vulnerable groups are to be made better off.

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JGR.MApurna

Appendix Table 1 : Nutritive values of foodgrains

Crops	Protein[a]	Energy[a]	Essential Amino Acids[b]					
			Lysine	Trypto-phan	Methio-nine	Cystine	Leucine	Isoleu-cine
Barley	11.5	336	0.23	0.10	0.10	0.10	0.42	0.24
Rice, raw, milled	6.8	345	0.23	0.08	0.15	0.09	0.50	0.30
Wheat (whole)	11.8	346	0.17	0.07	0.09	0.14	0.41	0.22
Chickpea (whole)	17.1	360	0.44	0.05	0.08	0.08	0.58	0.32
Pigeonpea dal	22.3	335	0.48	0.04	0.06	0.06	0.45	0.25
Other pulses								
Black gram dal (Urid or Phaseolus)	24.0	347	0.40	0.07	0.09	0.08	0.50	0.34
Cowpea	24.1	323	0.43	0.07	0.09	0.08	0.48	0.28
Field Bean, Dry	24.9	347	0.50	0.03	0.04	0.08	0.55	0.36
Green gram (whole) (Mung bean)	24.0	334	0.46	0.06	0.08	0.06	0.51	0.35
Horse gram	22.0	321	0.52	0.07	0.07	0.13	0.54	0.37
Kesari dal	28.2	345	0.47	0.05	0.03	0.07	0.41	0.41
Lentil	25.1	343	0.44	0.06	0.05	0.07	0.47	0.27
Moth beans	23.6	330	0.34	0.04	0.06	0.03	0.42	0.31
Peas, dry	19.7	315	0.44	0.06	0.05	0.07	0.43	0.28
Rajmah	22.9	346	0.46	0.06	0.06	0.04	0.47	0.30
Soya bean	43.2	432	0.40	0.08	0.08	0.10	0.48	0.32
Sutari	21.5	332	--	--	--------Not available----------			

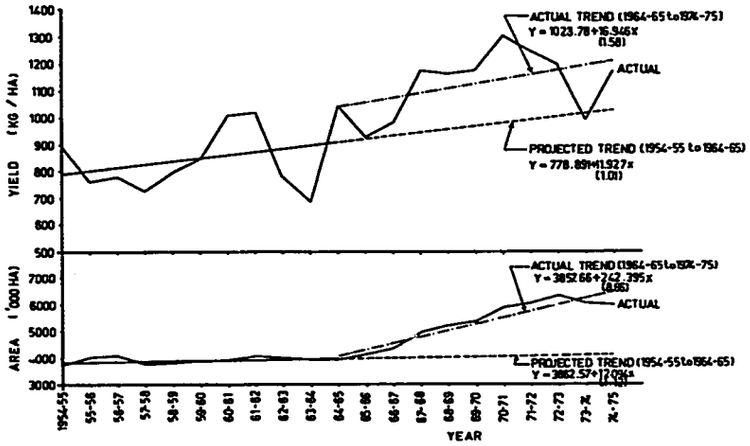
Source : Gopalan, C. [13].

a Values given are per 100 g of edible portion.

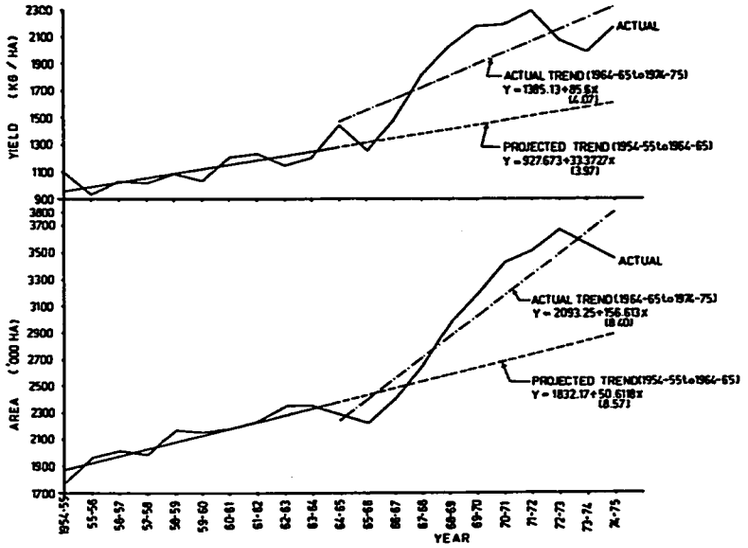
b Values given are g per g N.

Note: Conversion rate from dal to whole grain is taken as 75% for pigeonpea dal and Kesari dal; 71% for black gram (Urid or Phaseolus) dal. These were taken from Siegel and Faweett [24, pp 28, 78].

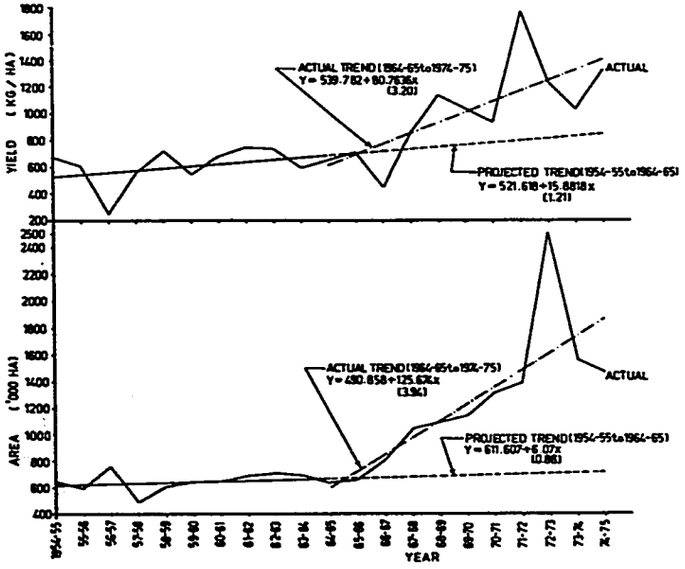
APPENDIX FIGURE 1. AREA AND YIELD TRENDS IN WHEAT IN UTTAR PRADESH.



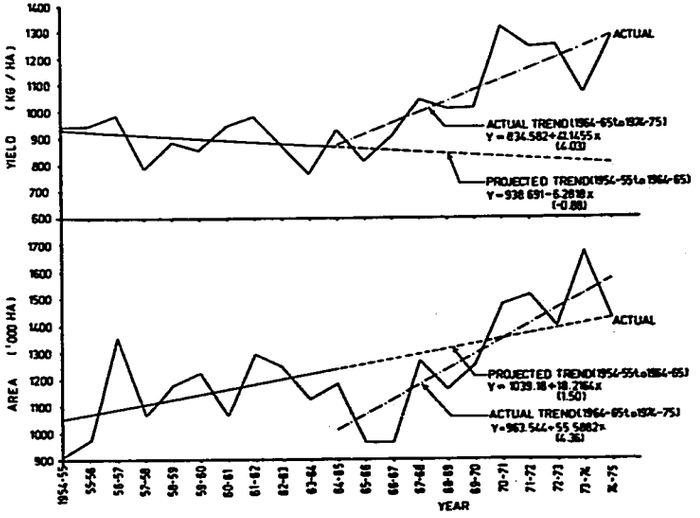
APPENDIX FIGURE 2. AREA AND YIELD TRENDS IN WHEAT IN PUNJAB AND HARYANA.



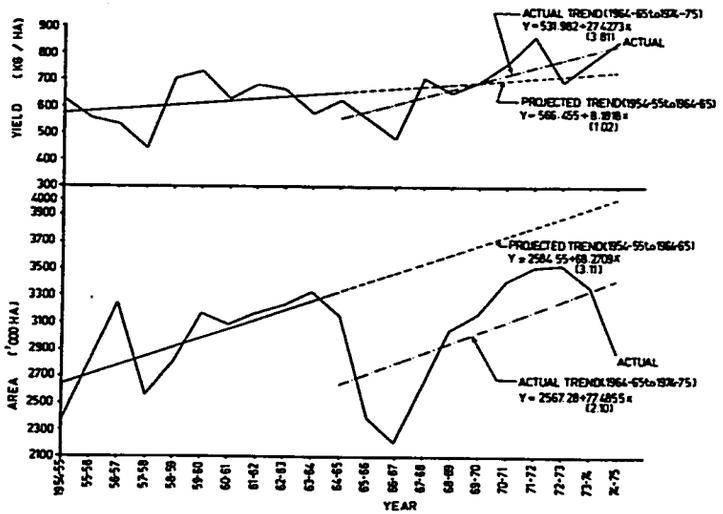
APPENDIX FIGURE 3. AREA AND YIELD TRENDS IN WHEAT IN BIHAR.



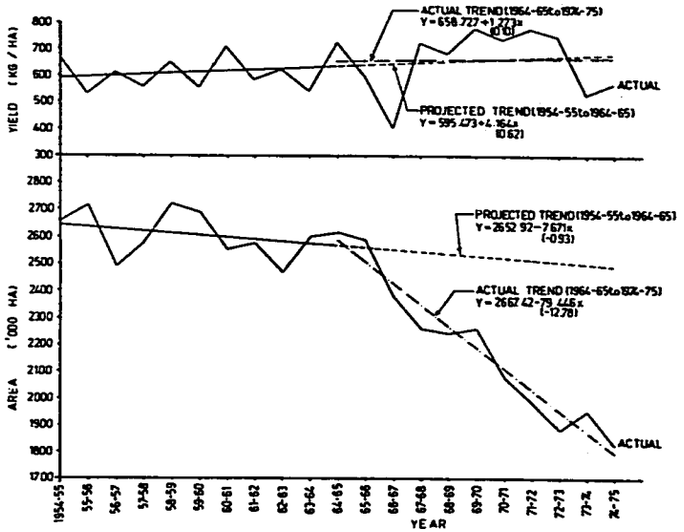
APPENDIX FIGURE 4. AREA AND YIELD TRENDS IN WHEAT IN RAJASTHAN.



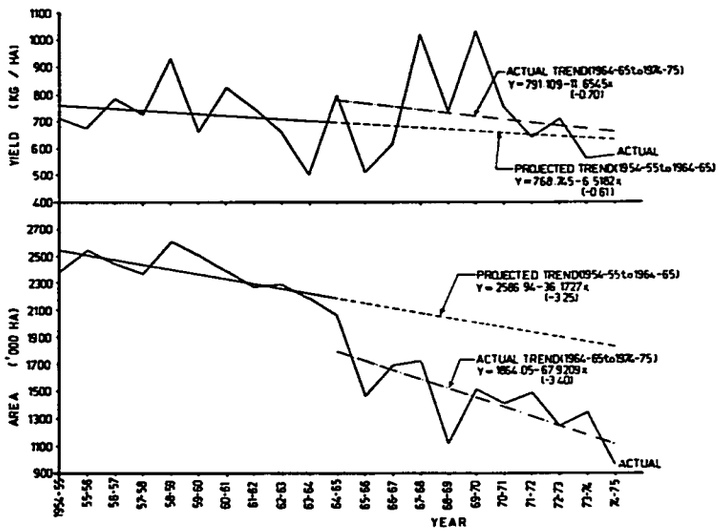
APPENDIX FIGURE 5. AREA AND YIELD TRENDS IN WHEAT IN MADHYA PRADESH.



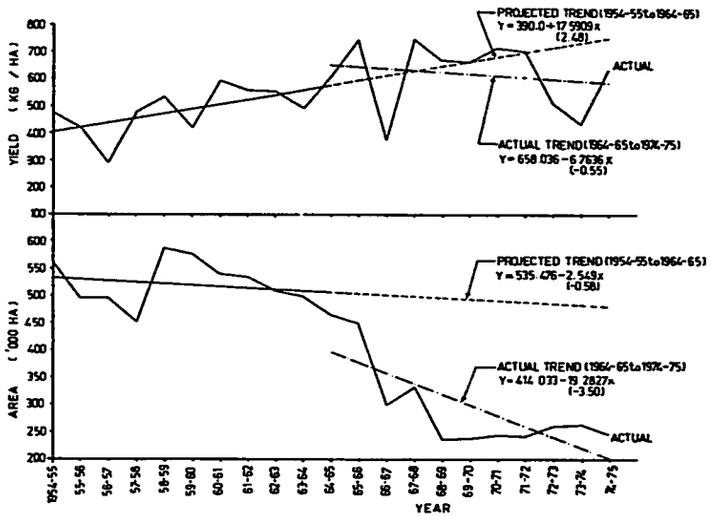
APPENDIX FIGURE 6. AREA AND YIELD TRENDS IN CHICKPEA IN UTTAR PRADESH.



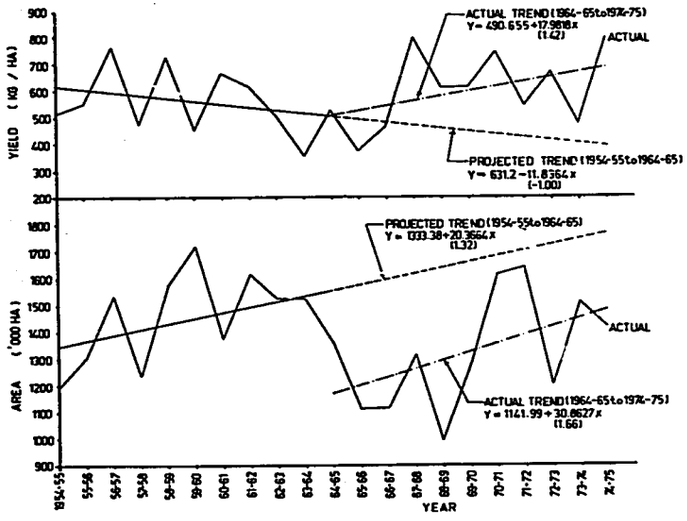
APPENDIX FIGURE 7. AREA AND YIELD TRENDS IN CHICKPEA IN PUNJAB AND HARYANA.



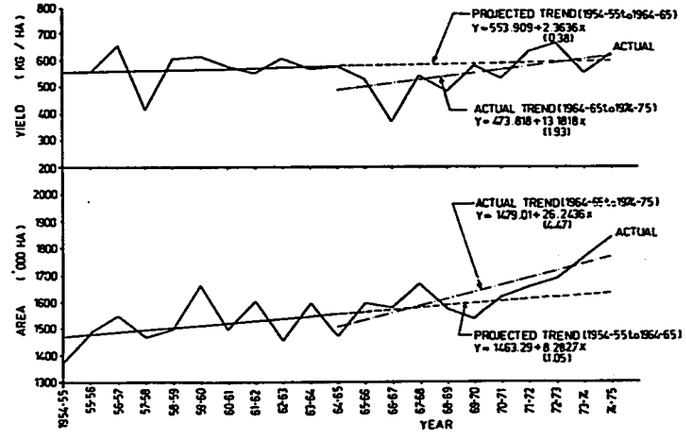
APPENDIX FIGURE 8. AREA AND YIELD TRENDS IN CHICKPEA IN BIHAR.



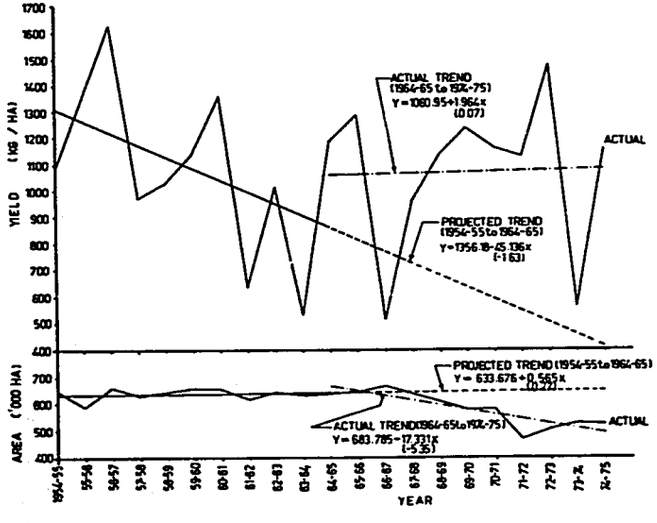
APPENDIX FIGURE 9. AREA AND YIELD TRENDS IN CHICKPEA IN RAJASTHAN.



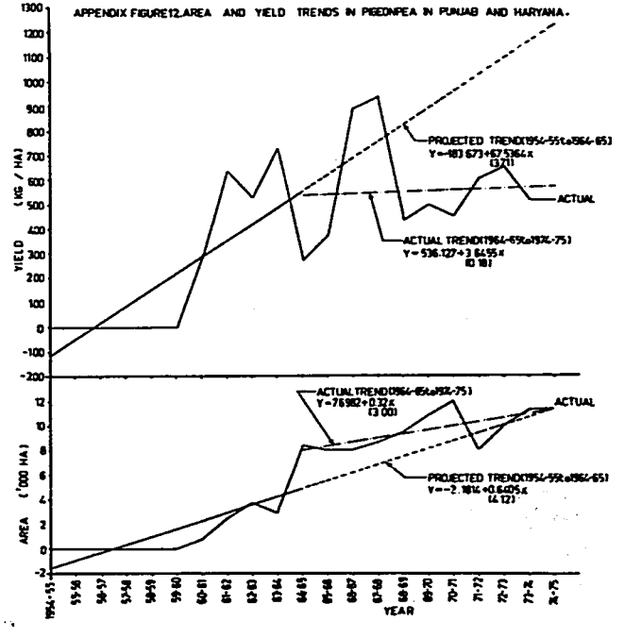
APPENDIX FIGURE 10. AREA AND YIELD TRENDS IN CHICKPEA IN MADHYAPRADESH.



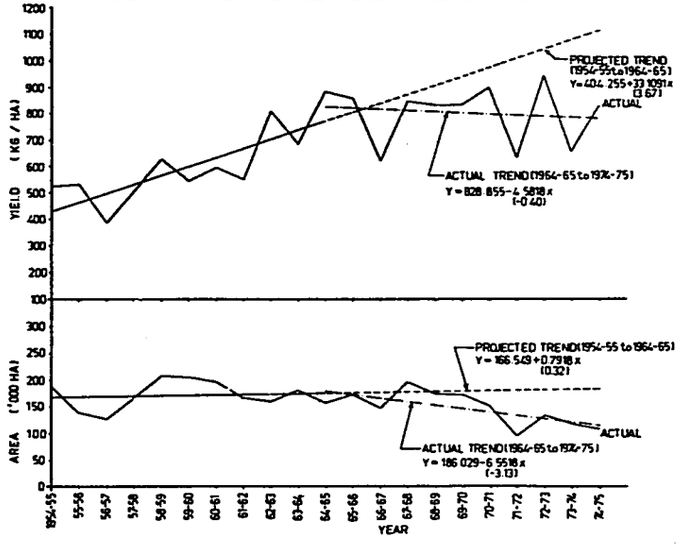
APPENDIX FIGURE 11. AREA AND YIELD TRENDS IN PIGEONPEA IN UTTARPRADESH.



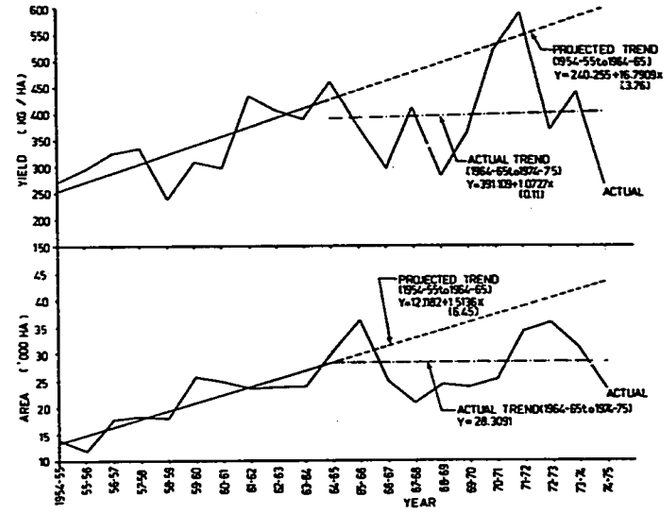
APPENDIX FIGURE 12. AREA AND YIELD TRENDS IN PIGEONPEA IN PUNJAB AND HARYANA.



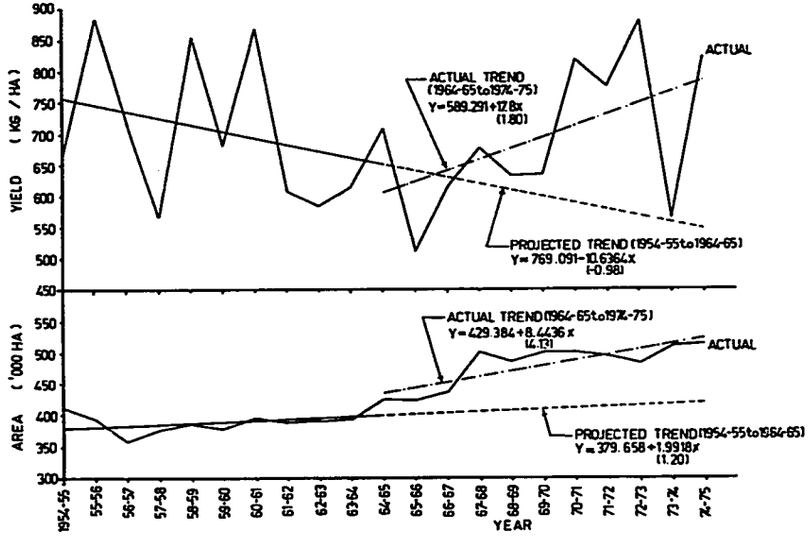
APPENDIX FIGURE 13. AREA AND YIELD TRENDS IN PIGEONPEA IN BIHAR.



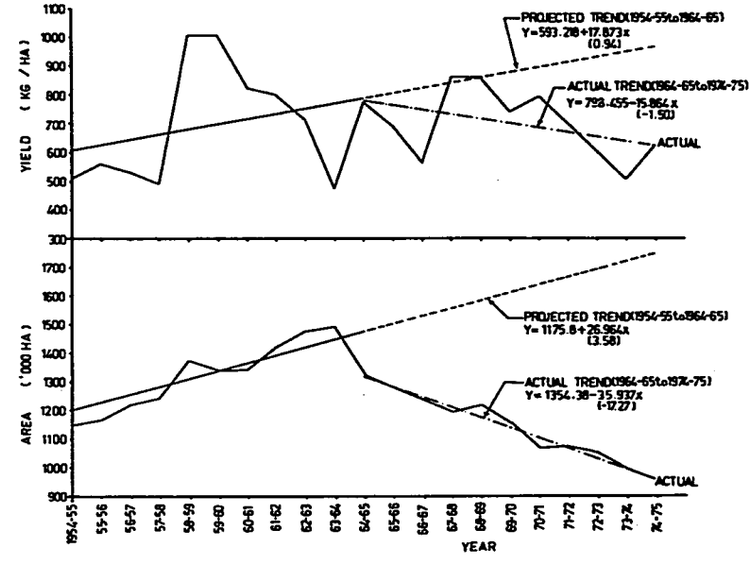
APPENDIX FIGURE 14. AREA AND YIELD TRENDS IN PIGEONPEA IN RAJASTHAN.



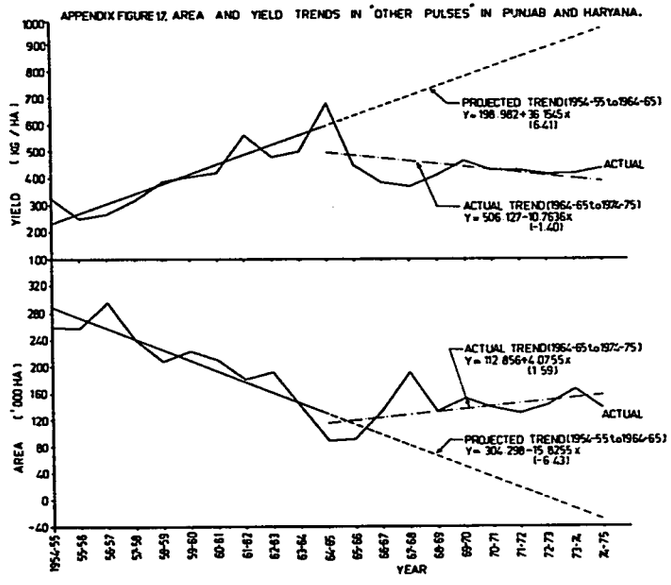
APPENDIX FIGURE 15. AREA AND YIELD TRENDS IN PIGEONPEA IN MADHYA PRADESH.



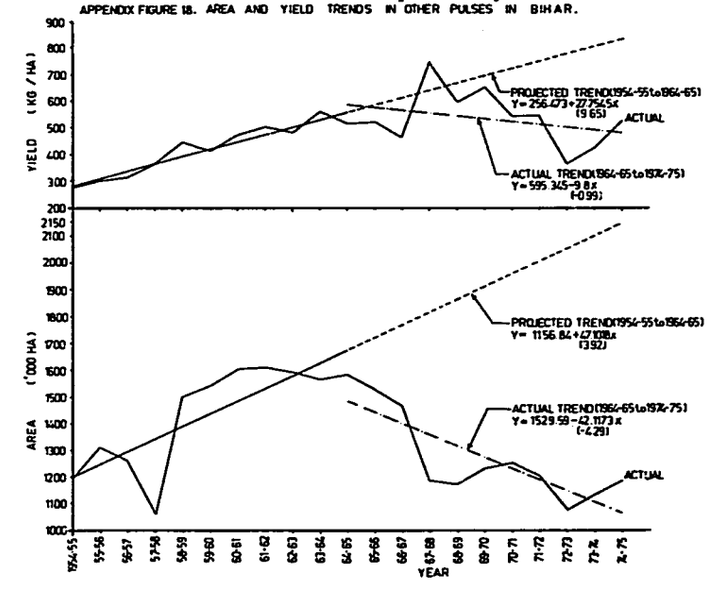
APPENDIX FIGURE 16. AREA AND YIELD TRENDS IN "OTHER PULSES" IN UTTAR PRADESH.



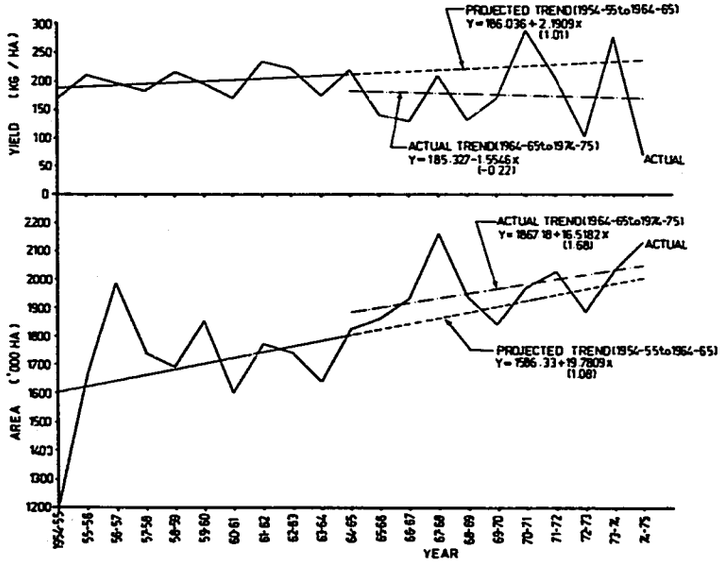
APPENDIX FIGURE 17. AREA AND YIELD TRENDS IN "OTHER PULSES" IN PUNJAB AND HARYANA.



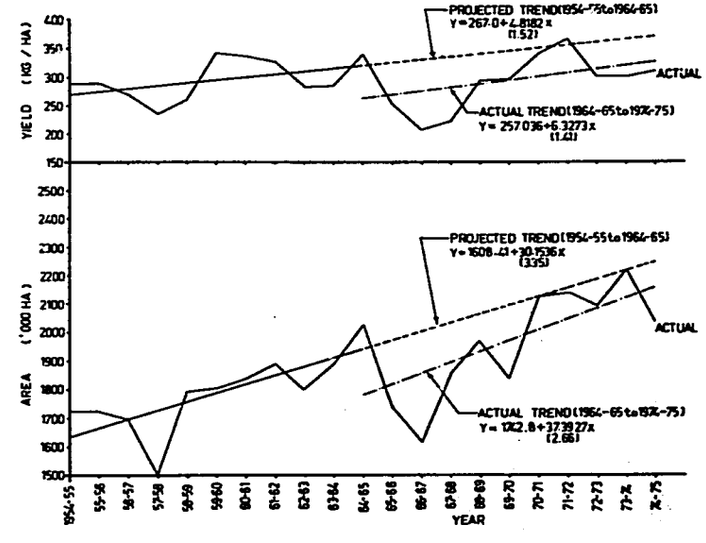
APPENDIX FIGURE 18. AREA AND YIELD TRENDS IN "OTHER PULSES" IN BIHAR.



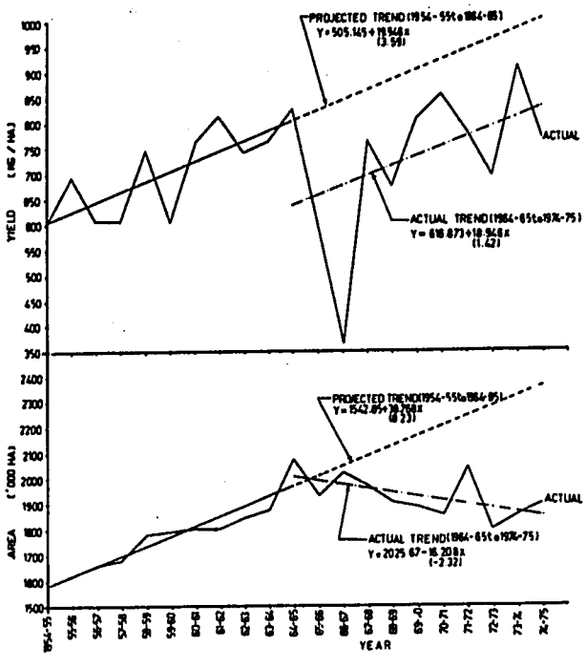
APPENDIX FIGURE 19. AREA AND YIELD TRENDS IN "OTHER PULSES" IN RAJASTHAN.



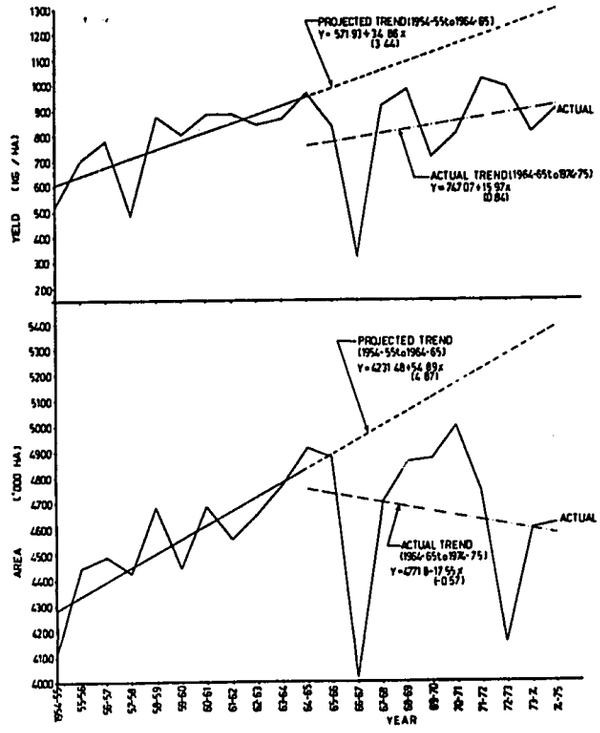
APPENDIX FIGURE 20. AREA AND YIELD TRENDS IN "OTHER PULSES" IN MADHYA PRADESH.



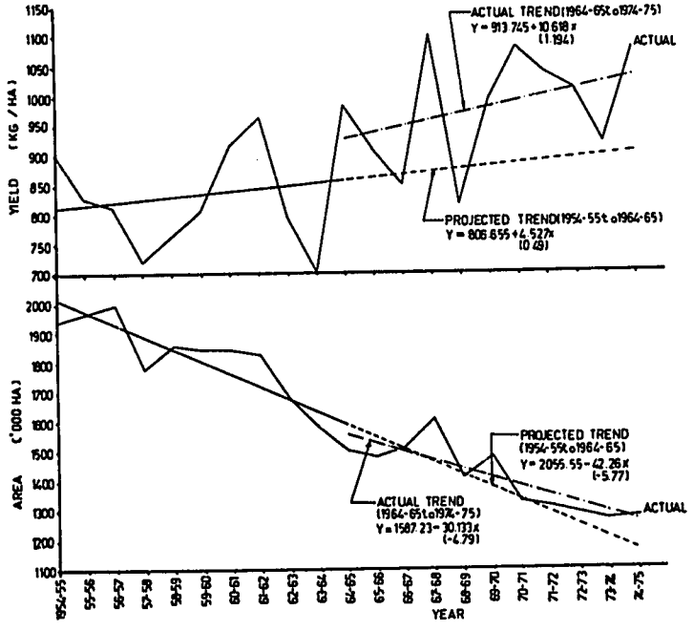
APPENDIX FIGURE 21. AREA AND YIELD TRENDS IN WINTER RICE IN UTTAR PRADESH.



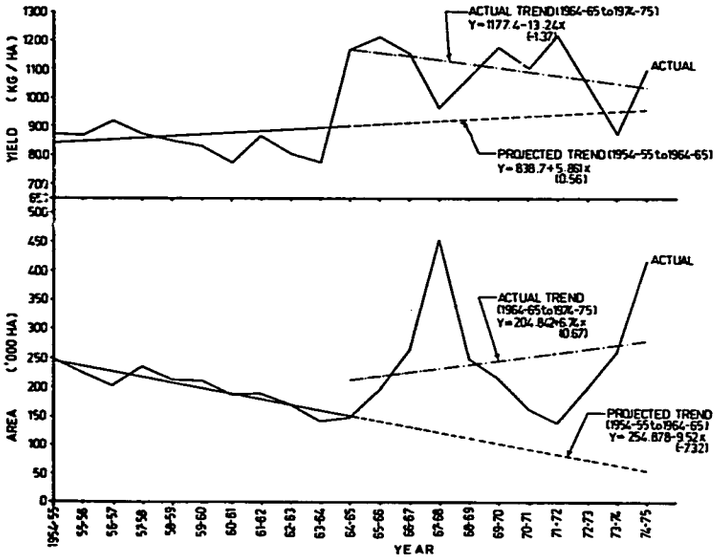
APPENDIX FIGURE 22. AREA AND YIELD TRENDS IN WINTER RICE IN BIHAR.



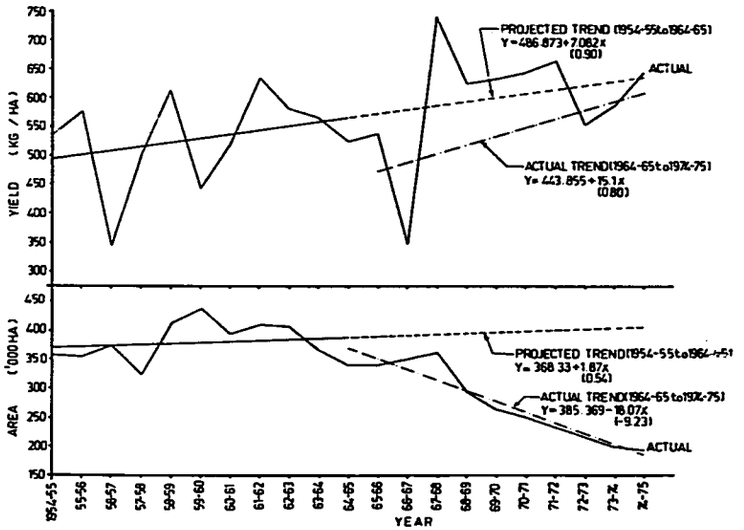
APPENDIX FIGURE 23. AREA AND YIELD TRENDS IN BARLEY IN UTTAR PRADESH.



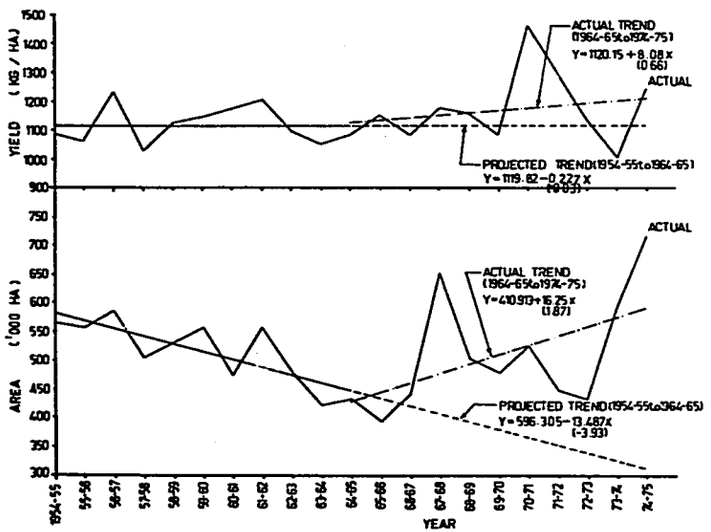
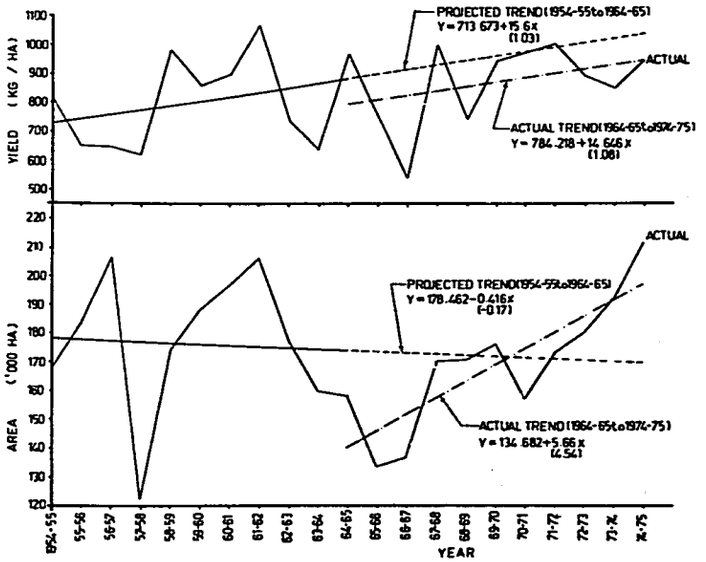
APPENDIX FIGURE 24. AREA AND YIELD TRENDS IN BARLEY IN PUNJAB AND HARYANA.



APPENDIX FIGURE 25. AREA AND YIELD TRENDS IN BARLEY IN BIHAR.



APPENDIX FIGURE 26. AREA AND YIELD TRENDS IN BARLEY IN RAJASTHAN.



APPENDIX FIGURE 27. AREA AND YIELD TRENDS IN BARLEY IN MADHYA PRADESH.