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APAARI PUBLICATION : 2004/3

SUSTAINING THE GREEN REVOLUTION IN INDIA

A Success Story of Wheat

Cover picture: Seed Production plot, creating variability, and Grain rain

S. NAGARAJAN

FOR COPIES WRITE TO

The Executive Secretary

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FOREWORD

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) is playing a facilitator's role in catalyzing both agricultural research and development activities through active collaboration with the national agricultural research systems (NARS). Since its inception, as an active regional forum, it has facilitated collaboration in the region among NARS, CGIAR/IARCs, FAO of the United Nations, GFAR, nongovernmental organizations and other stakeholders to develop and strengthen networking, so as to achieve through prioritized R&D activities, common goals of poverty alleviation, food security and sustainable livelihood.

APAARI activities are well reflected in several of its publications such as, proceedings of symposia/workshops/meetings, special thematic publications, newsletter, and the success stories (crop based, commodity group based etc.) produced each year on specific topics signifying R&D achievements of the national programmes. These are meant to share research results and for technology transfer, information dissemination among NARS, particularly in the Asia-Pacific region.

The success story on 'Sustaining the Green Revolution in India' briefly highlights the achievements of the Indian national programme. It narrates well the activities of over four decades, starting as a well structured programme of the Indian Agricultural Research Institute and later emerging as a national network under the All India Coordinated Wheat Improvement Project, with active multi-disciplinary research centres located at the various State Agricultural Universities (SAUs). Through these concerted efforts, High Yielding Varieties (HYVs) were developed to meet specific needs of diverse agro-climatic zones in India. The annual production now has stabilized at around 70+ mt per year. India has now become the second largest producer of wheat in the world, which has stabilized the food grain price and improved per capita consumption despite three fold increase in population since independence.

The above successes were possible through an effective international collaboration, particularly with CIMMYT. Overall, the Green Revolution happened in India because there was adequate infrastructure to catalyze the change, and to adopt to technological innovations. With the result, presently several Indian wheat varieties are being grown in different countries in Asia.

I congratulate Dr S. Nagarajan for his very timely effort in putting all relevant information together. I am sure, this success story will be of much use to all concerned with wheat production in the Asia-Pacific region.



R.S. Paroda
Executive Secretary

INTRODUCTION

The President of India in his address to the nation on the 50th year of India's independence mentioned of few landmark scientific achievements. The near self-sufficiency in food and the agricultural transformation was one amongst them. Slow growth in total wheat production up to 1965 necessitated a large-scale food grain import by India under the soft (Public Law) PL480 system (Figure 1). The series of agricultural changes that happened after 1965 in cereal production was called "Green Revolution". Many underestimated the impact of change and rated green revolution as just an increase in the food grain production. But it was the decision of the scientists, extension functionaries, policy makers, political system and above all the Indian farmer to go in for major changes, alterations and improvements in his way of farming. By 1970 the impact of the green revolution made many visionaries predict that India will become self sufficient in food grain production. The 80s made us believe that India will be able to

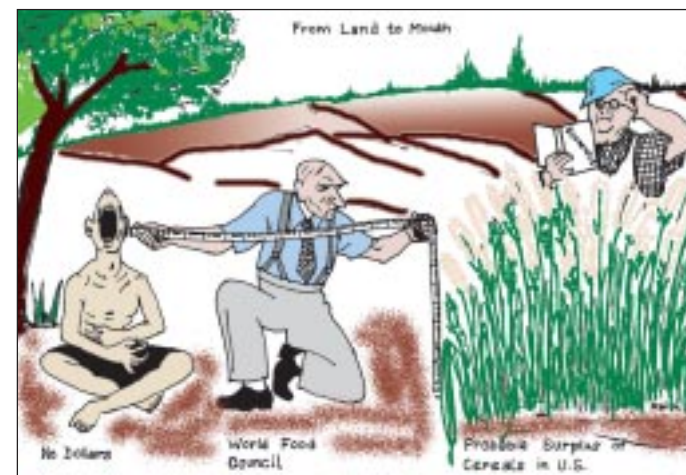


Figure 1: Lord Boyd Orr, the first Director General of the FAO, measures the distance between supply lines and purchasing power of the consumer

construct adequate buffer stock to thwart the adverse weather and other calamities. The 1990s made us dream that we must be able to export some quantity of wheat. During crop year 2000, India harvested 76 million tonnes (MT) of wheat, an unsurpassed record. India continues to remain the second largest producer of wheat in the world. Despite the last few years of drought and terminal heat stress, the total annual wheat production remained at 70 MT. There is a need to keep the wheat price and supply affordable for the 240 million people below the poverty line. That apart, India will have 1.4 billion people to be cared and protected against food shortages by 2025. The last few years of decline in total production and the concern about the factor of productivity has necessitated an examination of the present stalemate. Wheat (*Triticum* spp.) is the most important winter cereal of India and is grown during November to mid-April. Wheat is grown during the non-monsoon months, demands less water and it is less vulnerable to yield variation. Since the monsoon season crop remains at the mercy of rainfall, and that for having a reliable and robust food security system, winter season crop of wheat was chosen (Figure 2).

India now has about 40 million tonnes of surplus grain mainly wheat (> 25 MT) and this has stabilized the food grain price and improved the per capita consumption of the grain. If the wheat revolution would not have happened then the old technology would have demanded an additional area of 40 million hectares under wheat to produce the level of 70 + MT of harvest. Therefore, the new

Figure 2: Total wheat production during different years

technology has saved considerable amount of land from being under wheat that has now been diverted to varied uses.

Cereal availability increased over the last forty years and has reached 180 kg/person/year. This has happened despite reduced consumption of millets and pulses (Figure 3). Since overall food calorie position improved, many people moved above the poverty line. States such as Punjab and Haryana accelerated their economic development because of the wheat revolution.

Excavations of the Indus valley civilization period show several charred grains of wheat and barley indicating the antiquity of their cultivation in the subcontinent. By 1886 AD, in British India over 11 million hectare (mh) wheat was sown that yielded 8 MT. After the division of India in 1947–48, wheat production accounted for 6.4 MT and reached 12.26 MT by 1964-65 due to increase in area under irrigation, fertilizer usage and cultivation of tall rust resistant varieties. Despite all this, the food availability remained under concern for the nation as wheat import in 1965 through PL480 programme touched an all time high of 10 MT. In view of the serious drought in the state of Bihar and failing food front, there was an urgency to substantially increase wheat production.

In the farm of the Indian Agricultural Research Institute (IARI), New Delhi, amongst others, Dr B.P. Pal and Dr M.S. Swaminathan

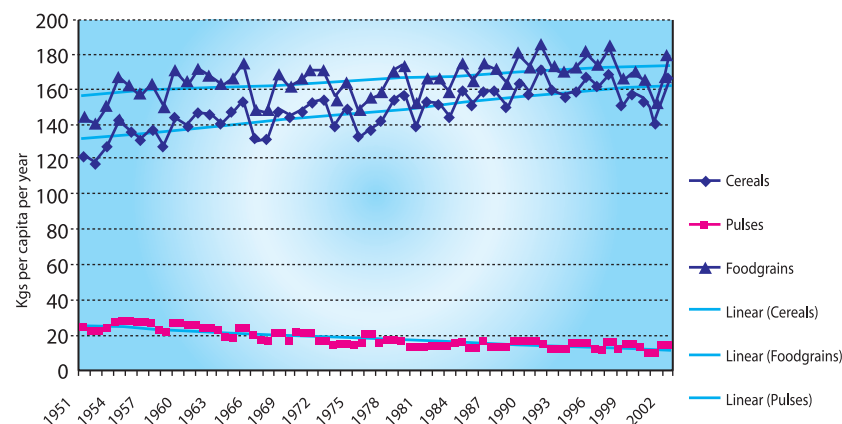


Figure 3: Net availability of foodgrains (per annum) in India from 1951 to 2002

noticed in 1962 the photo-thermo insensitive, dwarf, input responsive new wheat lines in the nursery supplied by the United States Department of Agriculture (USDA). They realized that extended cultivation of these new genotypes may enable India quickly increase its wheat production and come out of the food shortages. In 1963, IARI received one-quintal seed of Lerma Rojo 64, Sonora 63, Sonora 64, and Mayo 64 from Dr Norman E. Borlaug of CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) to conduct multilocation test and assess the yield potential. In 1964, IARI initiated the National Demonstration Programme and through that it became evident that the new non-lodging, semi-dwarf wheat has clear yield supremacy. Following this, in 1966 the Ministry of Agriculture, Government of India, decided to import 18,000 metric tonnes of seed of these varieties from Mexico. In 1969, Dr M.S. Swaminathan wrote “Brimming with enthusiasm, hard working, skilled and determined, the Punjab farmer has been the backbone of the wheat revolution”. Since the new High Yielding Varieties (HYVs) performed very well, plant breeders quickly improved the grain quality for chapati (non fermented leavened bread) making. From the early generation material supplied by CIMMYT superior disease resistant good grain type varieties such as PV 18, Kalyan Sona and Sonalika etc were identified for cultivation in different zones.

The Indian tall wheat is sown deep (5 to 6 cm) during late October/early November using native wooden plough with an iron share. The long coleoptile of the native wheat permits good germination. But for the mid November sown dwarf HYV of wheat having short coleoptile, the seed rate, row distance, time of seeding, fertilizer dose and the entire good agronomic practices were to be worked out afresh and popularized.

By 1970, these dwarf HYVs, occupied four million hectares and wheat production touched 20 MT. This created a problem of warehousing and storage of the grain. Therefore, agencies such as the National Seed Corporation (NSC), State Farms Corporation (SFC), State level agencies, Food Corporation of India (FCI), expanded to do business on seed and grain handling. Following this success several new activities got triggered and this in turn brought confidence amongst the rural populace. To mark the beginning of the new era

triggered by “Wheat Revolution”, the then Prime Minister of India, Madam Indira Gandhi released a commemorative stamp. But for the political wisdom, scientific support, hard work of the farmers and the associated decision-making processes, this huge transformation would not have happened.

There was considerable amount of policy support and the government extended subsidy on fertilizers particularly the nitrogenous one. There was also subsidy incentive to electricity charges of the irrigation pump, pesticides, in some cases on the cost of seed, selectively for some farm implements with the sole objective to produce more wheat. Many of these steps stimulated the farmers to take to wheat farming and the assured procurement price ensured that there is profit in farming.

The IARI, New Delhi established in 1905 conducts research on several aspects of wheat crop improvement. The IARI played a key role in conceptualizing the wheat revolution, in providing viable technological support, in developing working models and experience in village level seed production system (Jawahar Jyoti seed village concept). Extension models as the national demonstration; farm demonstrations like Lab-to-Land, Operational Research Projects were started by IARI. The various State Agricultural Universities (SAUs) perfected village link up activities. The land grant universities had huge farms where seed of various crops were multiplied and made available to the farmers. Thus Pusa (IARI), Pantnagar (GB Pant University of Agriculture and Technology) and PAU (Punjab Agriculture University) became trusted names amongst the farming community for inputs as seed and technological advances.

The green revolution did happen in India because there was adequate infrastructure to catalyze the change. By mid 1960s adequate agricultural graduates were available as staff in the Department of Agriculture, agriculture colleges and the various research establishments. To ensure availability of good quality seed, the Government of India established the NSC and the SFC. By extending the minimum support price, the surplus food grains were procured by the FCI and they built large warehouses at several places to store the grain. The Public Distribution System (PDS) served as mechanism

to make available the foodgrains to the people through reach-out, ration shops. Subsequently, these surpluses were also used for the food for work programme during drought years, to construct/maintain civic amenities as canal, roads etc. Thus green revolution in the initial stages enabled address several social issues and infrastructure development.

ALL INDIA COORDINATED RESEARCH PROJECT (AICRP) – THE WIN-WIN STRATEGY

Strengthening National Programme

The IARI has a number of regional stations in diverse agro-ecological areas. The plant breeders advance/test/evaluate their material at these stations and generate voluminous information on the performance and stability of the material. Out of this experience the AICRP was designed to share between centres the elite breeding material, conduct identical yield trials to assess the best and stable genotypes and their suitability for release as variety. On the strength of this working model in 1965, the All India Coordinated Wheat Improvement Project (AICWIP) was started to accelerate the process of varietal development. The project has active multidisciplinary research centres housed in the various SAUs and these centres get financial support to meet 75 % of the annual expenditure from the federal government and the remaining from the state. This cost sharing brought about a cohesive, purpose and result oriented network to develop varieties and at the annual meeting all the AICWIP researchers exchange the trial data, results. Figure 4 shows the location of various cooperating centres and sites where yield trials are conducted under the AICWIP. In the AICWIP annual meeting breeders share the material and plan collectively the activity for the next season. The unifying force between various centres and conflicting personalities is the urge to come together, share the expertise, breeding material and in taking collective decision. These strong points and the cherished vision ensured the success of the wheat programme.

Each wheat-breeding centre enters their best material in the National Initial Varietal Trial (NIVT). In these multilocation tests the superior performer or the ones at par with the check, but having some special trait is promoted to a two year multilocation Advanced



Figure 4: Wheat Research and Testing Centres
(All India Coordinated Wheat Improvement Project, ICAR)

Varietal Test (AVT). Trials are constituted at zonal level and based on three years of field data and other ancillary information the variety identification committee identifies the best performer. On the strength of this, the Central Varietal Release Committee (CVRC), a statutory body examines and notifies the variety in the Gazette of India. This then entitles the variety for breeder seed production and further multiplication in adequate quantities to sell to farmers. This whole process of starting a cross to release of a variety takes about ten years (Figure 5a & b).

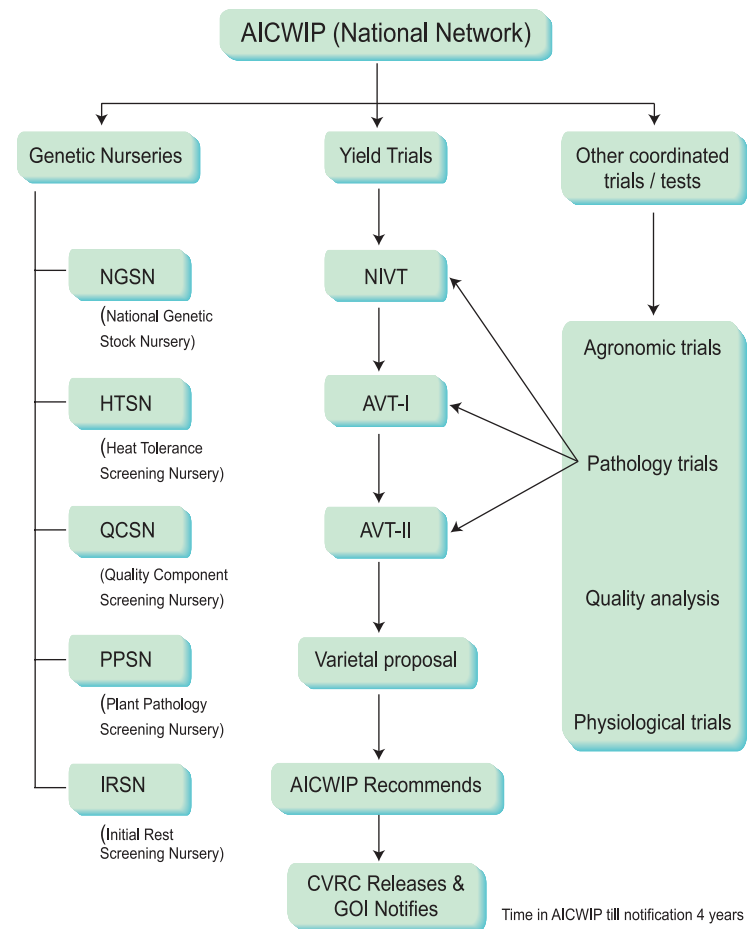


Figure 5a: Structure of AICWIP

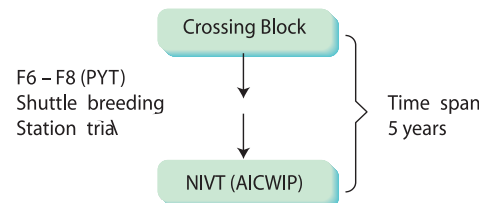


Figure 5b: Effort at the Breeding Station Level

All together the various wheat breeding centres in India attempt about five thousand to seven thousand cross combinations in a year. The various nurseries received from CIMMYT and the International Centre for Agricultural Research in Dry Areas (ICARDA), have provided useful donor lines. In addition the AICWIP also dispatches various nurseries and elite material to the plant breeding centres for crop improvement purposes. The summer nursery facility at Wellington and Lahaul and Spiti are used during May to October to advance the generation, make corrective crosses, screen for rust resistance etc. Following the pedigree system of selection thousands of single plants are selected, fixed and later the best are entered in their station trial.

Wheat Growing Zones of India

Since the country is large and has 27 mh under wheat, based on environmental and growing conditions, the wheat growing areas are divided into six mega environments (Figure 6), namely, as Northern

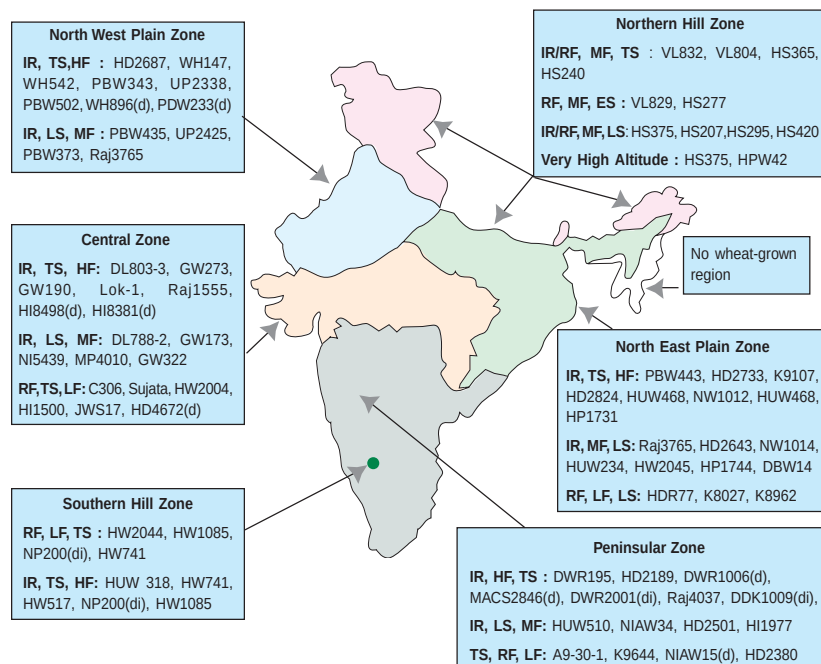


Figure 6: Wheat Growing Zones of India and the recommended varieties

Hill Zone (NHZ), North West Plain Zone (NWPZ), North East Plain Zone (NEPZ), Central Zone (CZ), Peninsular Zone (PZ) and Southern Hill Zone (SHZ). The NHZ has ~ 1.2 mh under wheat and is grown under varying elevations; on slopes it is un-irrigated and along the river flow irrigation is feasible. The NWPZ is the fertile, canal and tube well irrigated (>90%), gangetic alluvial soil with even topography where wheat is cultivated over >9.0 mh. The wheat season is cold and for several days the minimum temperature may reach 5 °C. In NWPZ wheat matures in 140 days, is most productive and yet is vulnerable to terminal heat and suffers from severe crop loss to rusts and Karnal bunt. The NEPZ has a network of rivers and drains, with high humidity, high soil pH, uneven topography and poor access to irrigation. The wheat season is damp and encounters for several days thick ground fog. Condensation of dew on the leaf for several hours happens routinely. In the NEPZ wheat occupies >9.0 mh and gets adjusted in various annual crop sequences. The CZ and PZ are predominantly highland areas with deep black soil and have >5.0 mh and 1.0 mh under wheat, respectively. Wheat is grown under retreating soil moisture conditions and at best in some areas farmers give two irrigations. Wheat is always exposed to high temperature and so tillering is very poor. The crop matures in 100 to 110 days with hard lustrous grain, with high protein and flour recovery. The SHZ has few hundred hectares under wheat and is the main source of inoculum for stem and leaf rust to both PZ and CZ. Hence, containing the inoculum of the rust pathogen here is an important objective. Till now, more than 200 wheat varieties have been released for cultivation in the six-mega wheat growing environments. Some of the most promising and currently cultivated wheat varieties in different zones and conditions have been given in Figure 6. These materials cover the well-fertilized, irrigated timely or late sown situation and account for over nearly 75% of the total area sown to wheat. The rainfed wheat may account for 15 % of the net area sown to wheat and the tetraploid wheat namely Durum and Khapli account for the remaining area. Several of them are from out of the crosses attempted in India involving exotic donors (Table 1). Many of these varieties became popular in different parts of India and the world and were cultivated over several million hectares.

Table 1. Pedigree of some major wheat varieties

S.No.	Variety	Pedigree
1.	HD 2329	HD 1962/E 4870/K 65/ 3/HD 1663/UP 262
2.	HD 2285	249/HD 2160/ HD 2186
3.	WH 147	E 4870/C 303/S 339/ PV-18
4.	Lok-1	S-308/S 331
5.	WH 542	JUP/BJY 'S'/URES
6.	K 7410	K 812/KAL
7.	HUW 234	HUW 12*2/CPAN 1666
8.	HUW 206	KVZ/Buho//KAL/Bb
9.	PBW 343	ND/VG 1944//KAL// BB/3/YACO'S'/4/ VEE # 5
10.	C 306	REGENT 1974/CSK 3 / 2* C 591/3/P19/C 281
11.	K 8027	HD 1969/2* K 852
12.	K 8804	VEE 'S'/WL 711
13.	Sonali	KL 6010/6* Ska
14.	MACS 2496	SERI
15.	HD 2189	HD 1963/HD 1931
16.	NI 5439	REMP 80/4*NP 710
17.	DWR 162	KVZ/Buho//KAL/Bb
18.	GW 190	VEE 'S'/VA-6
19.	VL 616	Ska/CPAN 1507
20.	HS 240	Au/KAL/Bb/WobS'/ PVN'S'
21.	Raj 1555(d)	Cocorit'S'/Raj 911
22.	UP 262	S 308/Bajio-66
23.	DL 803-3	HUW 302/K 7537/ HD 2160 M
24.	UP 2338	UP 368/VL 421// UP 262
25.	PDW 233(d,I)	YAV 'S'/TEN 'S'

Note: d = *durum*, I = Identified

TECHNOLOGICAL INNOVATIONS AND IMPROVEMENT

Search for New Plant Type

There has been a gradual shift in the plant morphology and other features due to plant breeding. The old wheat varieties of the New Pusa series of the 1950s were looking different. Native improved wheat was sown in October/November, had long coleoptile, tall (120 + cm) with few tillers, small ear head and less seeds per panicle. However, the grain size was large and the quality of the grain met the native food requirements. Most of them were vulnerable to the three rust diseases and suffered heavily.

The new HYV released since 1965 are about 90 cm tall, have 1.3 to 1.4 productive tillers and the main tiller has >50 grain with 40 g/1000 g wt. Over the years there has been a marginal increase in the number of grain produced/m² of area. The marginal increase in the number of productive tiller and grains per ear head have also contributed to yield increase. But the grain weight still remains much below that of land races or NP wheat. The flour recovery of the HYVs and also the quality of the flour for bread making and chapati needs have scope to improve. The Indian wheat programme focused for quantity and despite all our efforts in the last decade no tangible advancement has happened in quality and nutrient improvement of the wheat grain. There is a dearth of qualified manpower in cereal chemistry and product development. Furthermore, the wheat-breeding laboratories are poorly equipped, advanced equipments and trained manpower are needed to interpret the data.

For the NWPZ focused programme to develop, wheat varieties with 8-tonne/h yield should be taken up. This can be achieved by enlarging the sink-source relationship. Robust seedlings should produce large ear head having at least 80 well-filled grains yet non-lodging and

amenable to combine harvest. These materials should have deep and functionally efficient root system and the genotype must mature in 145-150 days. This superior wheat should have tolerance to yellow rust and terminal heat tolerance. Additional advantage would be if the grain has the quality for flat non-fermented bread or chapati making characteristics. The new plant type if developed soon can give a distinct yield advantage. Such material will increase the yield per hectare and will relieve land for diversification purposes (Figure 7).

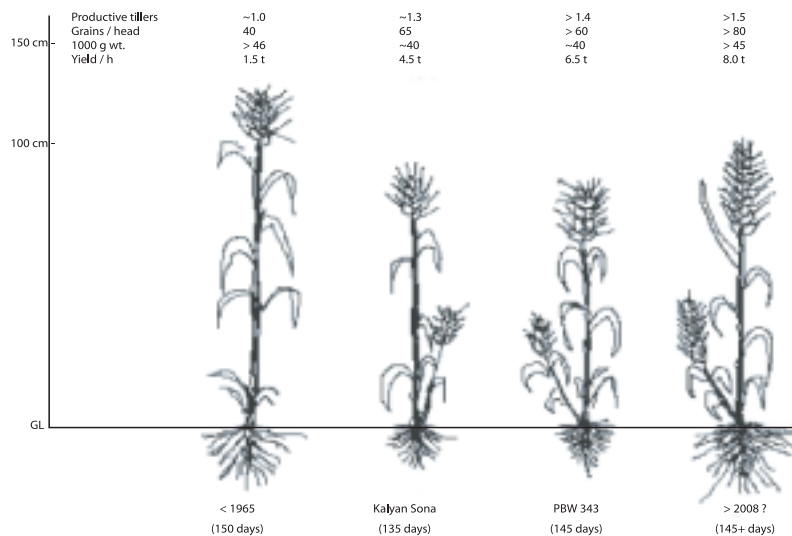


Figure 7: Gradual improvement in plant ideotype

Quality Seed Production

Availability of good quality seed of the recent variety is an important factor in production increase. The seed source is invariably the carry over seed of the farmers, horizontal purchase from farmer to farmer and replacement with certified/truthfully labeled seed produced by the federal or state agencies. In order to keep the purity of the seed it is advised to replace the retained seed with better ones after every four to five years. During 2003, ~617 tonnes of breeder seed of 68 varieties were produced by the public system. The varietal mosaic is kept dynamic between years as new varieties gradually replace the old. Of the breeder seed produced by the public system during 2000,

PBW 343 and Lok 1 topped the list; and in 2003 the situation changed and seed production in UP 2338 and Raj 3077 was greater (Figure 8). The variety mosaic in all the wheat-growing zones is kept dynamic and this keeps the terminal severity of the rust diseases below the economic threshold and the total production stable. The amount of certified seed produced has increased over the last several years indicating that the varietal mosaic of no two years is identical.

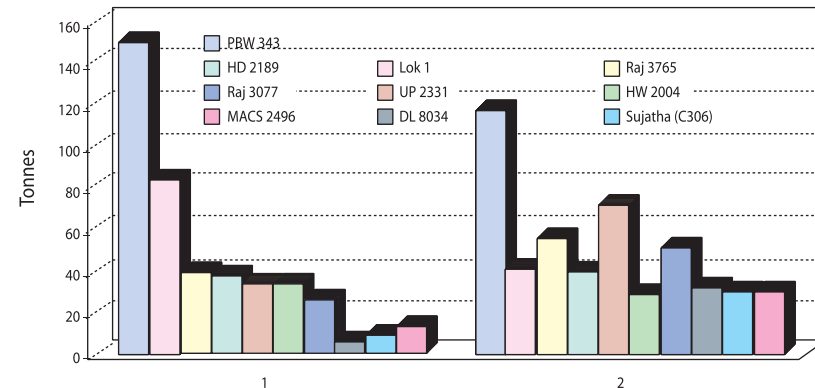


Figure 8: Actual Breeder Seed Production during 2000(1) and 2003 (2)

Between 1990 and 2002 the volume of certified wheat seed produced doubled and there is a growing demand for good quality seeds. Many varieties developed by the AICWIP occupied vast area. Varieties like HD 2329, PBW 343, Kalyan Sona and Sonalika covered more than four mh and WL 711 occupied ~ 2 mh. And several varieties such as Arjun (HD 2009), HD 2285, UP 262, HUW 234, Lok 1, WH 147, C 306, Raj 1555 etc occupied significant area for a number of years.

Based on the breeder seed demand placed by the Ministry of Agriculture, the ICAR/SAU system produces the mutually agreed quantity of seed and supplies to various private seed companies and state agencies. The spread of new varieties between farmers happen quickly as the smart farmers get the seed of the latest variety, multiply and sell it in their neighbourhood. Thus it can be confidently said that in states like Punjab where 3.4 mh is under wheat complete varietal replacement can be achieved in about four annual crop cycles.

Varietal Improvement *vis-à-vis* Growth in Wheat Yield

Of the total quantity of certified seed produced by the public system, that of wheat is the largest. Since the seed rate of wheat is 100-to150-kg/h, bulk material is to be stocked, transported and marketed. This deters the large seed companies in venturing into wheat seed business. Establishment of the NSC and other enabling institutions by the Government facilitated the growth of seed industry in India. The Indian seed industry is growing very fast and now has a turnover of Rs. 10,000 million (1\$ = 45 Indian Rs). Many of the companies have established their own good R & D facilities complementing the efforts of the public funded institutions. There has been periodic technological innovation and improvement in plant breeding methods leading towards the development of varieties with better per hectare productivity. Over the last four decades genetic ability of wheat to yield more has been increasing on an average by 1.0 % per year (Figure 9). The last yield gain came through some of the 1990s CIMMYT germplasm such as Atilla, Veery, Kauz, Bavicora, Baccanora, Chriya and Bobwhite series etc. And the current yield stagnation can be overcome by introgression with new diverse materials such as the synthetic derivatives, Chinese sub-compactoid class of germplasm and Buitre material distributed by CIMMYT. By selecting for multiple

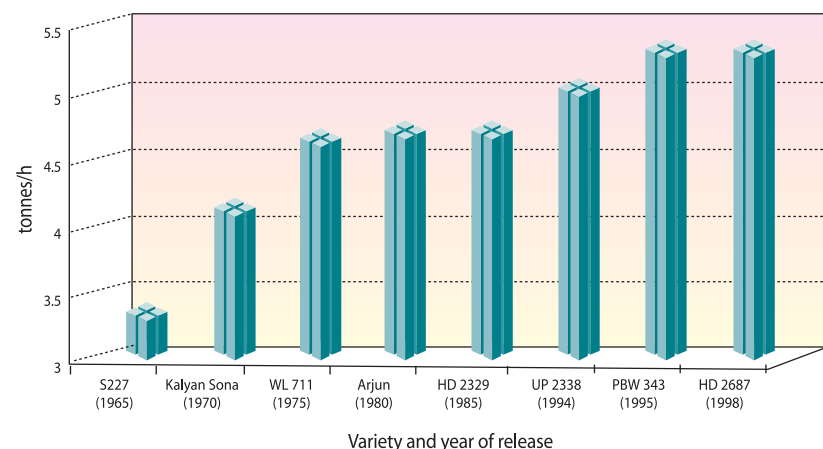


Figure 9: Genetic gain in wheat yield due to varietal improvement efforts

yield components as higher productive tillers/plant, more spikelet per head, more grain/head, higher thousand grain weight, tolerance to abiotic and biotic stresses etc, further yield gain can be achieved.

Hybrid wheat offers unconventional opportunity to break the yield barrier and this offers year and again uniform grain quality. Many countries have hybrid wheat under cultivation such as South Africa, Australia etc. In India experimental hybrids have been produced using chemical hybridizing agent (CHA) and many of them have viable yield jump. And some cytoplasmic male sterile system (CMS) based wheat hybrids are being marketed by private seed companies like MAHYCO. Indications are that like in rice, in wheat also the hybrid technology would offer new opportunities.

Fertilizers – A Key to Increase in Production

With the intensive cultivation and area expansion under HYVs of rice and wheat there was a sudden demand for chemical fertilizers and farm machinery. Of the various sources of N, in the northern states urea is the most preferred being the cheapest. During the Green Revolution period the cropping intensity also increased due to the availability of seeds of several crop varieties of varying maturity period. Coupled with this the liberal access to irrigation further created a market for different types of fertilizers. In the NWPZ the recommended fertilizer dose for wheat is 150 N, 60 P and 40 K. Half of the N and the entire P and K are applied as basal dose and following the first irrigation that is around 35 days after seeding and the remaining fertilizer is top-dressed.

There has been a steep increase in the use of nitrogenous and phosphate fertilizers (Figure 10) and this significantly contributed towards production increase. Application of potash is very less and the inappropriate blend of fertilizers apart from reducing the nutrient use efficiency also increase the Zn and sulphur deficiency.

Micronutrient level in the grain and protein content of C 306, C 591, K 68, UP 262 and WH 712 are high compared to HD 2329 and PBW 343. The micronutrient content in the first bunch of varieties and the good chapati making quality make them candidate as biofortified grains (Table 2).

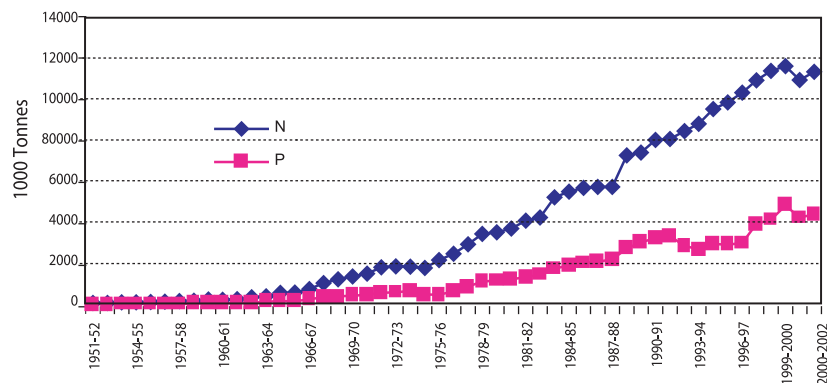


Figure 10: Use of fertilizers in India in terms of nutrients (N & P) from 1951-52 to 2001- 02

Table 2. Levels of micronutrient, sedimentation value and HMW banding on quality

Variety	Fe	Zn	Cu	Sed Value	Protein	HMW	Glu Score	Chapati Rating
C 306	77	80	36.5	53	12.4	N,20,2+12	4	9.2
C 591	41	49	31	38	10.4	N,20,2+12	4	8.4
N P4	41	107	7.6	58	13.9	2,17+18,5+10	10	8.2
K 68	61	57	32.3	70	13.2	2,17+18,5+10	10	9.2
UP 262	52	95	30.6	60	12.3	2,7+8,2+12	8	8.4
HI 977	31	67	16.8	65	12.9	2,17+18.5+10	10	7.5
HI 1077	37	78	30	71	12.9	2,17+18,2+12	8	6.7
WH 712	85	105	23.2	64	12.1	2,17+18,5+10	10	8
PBW 343	44	53	7.7	36	11.6	1,7+9,5+10	9	7.5
HD 2329	44	49	9.1	46	13.2	2,7+9,2+12	7	6.7

The pre-green revolution era tall Indian wheats as NP 4, C 306, C 591, K 68 etc have higher amount of micronutrients in the grain compared to the recent varieties. Since the NWPZ is in general Zn deficient, Zinc sulphate is recommended as basal dose @ 25 kg/h, if not already applied to the previous crop of rice. Increased cropping intensity and mono-cropping of wheat/rice or wheat/cotton deplete the micronutrient status in the topsoil. As a result, there is response to sulphur application in the NWPZ and that also improves the protein content of the grain. A ten tonne cereal harvest following the

rice/ wheat annual sequence removes 250 g of zinc, 190 g of copper and 3.4 kg of iron from the soil under recommended fertilizer dose. The urea that is invariably used in the NWPZ contains very low levels of micro and trace elements. Over a period of time using only urea depletes the soil of the micronutrients and this creates a yield decline syndrome. Balanced use of fertilizer, use of ammonium sulphate, integrated nutrient management and green manuring to increase the soil carbon content lead to better soil fertility and crop response.

The over tillage done in the rice/ wheat system has reduced the soil organic matter status affecting the mineralization process. Since legumes have been replaced from out of the cropping sequence in the NWPZ there has been a rapid fall in the soil organic carbon status. Crop diversification and changing to farming systems practices are encouraged to rejuvenate the soil health and nutritional status.

SUSTAINING THE WHEAT REVOLUTION

The wheat revolution era is characterized by a growth phase of more than 2 percent annual increase in production of wheat without area increase. This is required so as to make available wheat to the population growing at about 1.8 percent per year. Also there should be adequate surplus stocks to thwart the shortages caused by weather aberrations and cyclic changes in surplus status. Hence there should be continuing efforts to sustain the wheat revolution.

Bridging the Yield Gap

“Yield gap” is the difference between what is technically attainable under a given farm situation and what is really harvested by the farmer following his cultivation practices. Very often the farmer does not accept the entire package of practices recommended by the R&D system. He adopts a major part of the technology leaving a few steps for reasons known to him. This partial technology adoption reduces the yield level. Therefore, the Ministry of Agriculture funds a series of on-farm research operations called the “front line demonstration” (FLD). Under this activity the recently released varieties are field evaluated in lead farmer’s field, to enable the community of farmers to continuously assess the advantages of the full cultivation technology. The neighbouring farmers interact all through the crop-growing season sharing views in their own dialect and at harvest time having got convinced of the advantages, invariably procure the seed from the leader farmer and soon they also adopt the full technology. The slippage in knowledge with each passage of information transfer is corrected through ‘farm mela’ or farm show, radio and TV programmes and by printed media. Several programmes such as the Farmers Science Centres, Krishi Vigyan Kendras (KVK) and Front Line Demonstrations (FLD) extend support to technology spread. This massive network of extension functionaries contributed to the success of the wheat revolution (Figure 11).



Figure 11: On-farm education of the farmers during FLD Wheat Day

Evidences are that there is still potential to increase the wheat production by reducing the yield gap between what is attained in the demonstration farm and in farmers field (Figure 12). Even in Punjab there is considerable difference in the per hectare yield between districts. Ludhiana and Hoshiarpur have between them more than one-tonne/h yield difference due to reasons of knowledge gap and poor crop husbandry. In India, Punjab enjoys cool weather, good

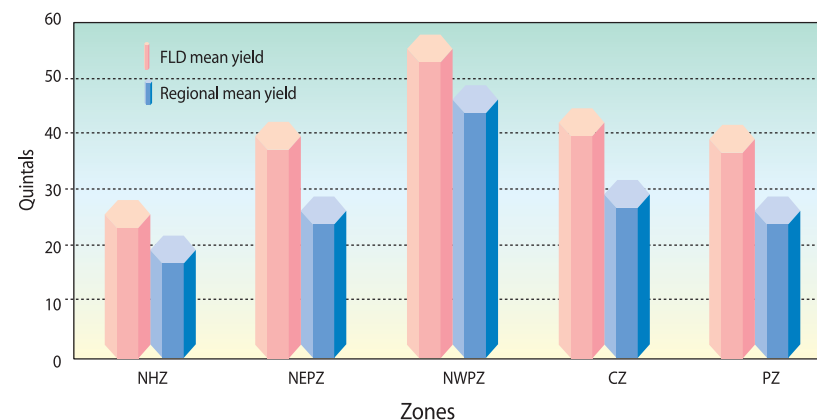


Figure 12: Yield Gap in Wheat as assessed during 2000

water resources, consolidated land holdings, well-connected roads, greater input usage and even topography. Punjab is ideally suited for cereal farming and thus is the food grain bowl of India. Between Punjab and the adjoining states there is a yield difference of about 1.2 tonne / h. As one moves from Amritsar in Punjab to Jalpaiguri in north West Bengal, the productivity reduces by ~100 kg / h for every 100 km. Empowering the farmers with knowledge, creating an enabling environment, implementing farmer centric policies and understanding the market forces can all contribute towards reducing the yield gap.

Green Revolution Induced Changes

Rice / wheat annual sequence has emerged as a major cropping system over the NWPZ. The rice variety chosen by the farmers is of longer duration and disposal of the rice straw, vacating the field and preparing it to sow wheat has become a major agronomic problem. The delayed sowing of wheat affects the productivity. Farmers after harvesting rice by combine burn the straw to quickly vacate the field and sow wheat (Figure 13). To address this issue Zero tillage or direct



Figure 13: Straw left behind by combine is burnt to quickly sow wheat

seeding machines were developed. This machine has an inverted T-shaped chisel as tine, which slits the wet soil surface about 2 to 3 cm deep, making a 1 to 1.5 cm wide channel and places both the seed and the fertilizer. The slit depth does not permit the germinating seed getting picked by birds. Wheat sowing is done immediately after the harvest of rice (Figure 14) with the rice straw still remaining anchored. Zero tillage saves about ten days time that is otherwise lost in



Figure 14: Zero tillage cum fertilizer drill in operation in a field vacated by rice. Next is the wheat crop in the same field after 25 days

irrigating the field vacated by rice, in preparing the seed bed and sowing wheat. This timely sowing promotes better crop stand and good harvest. That apart, substantial amount of fossil fuel spent on the farm machinery in preparing the field also gets saved and reduces the cost of cultivation and maximizes the profit margin.

One of the main reasons for the increase of cropping intensity in NWPZ is the extent of farm mechanization. Using tractor power >95 % of the area under wheat is seeded and >50% of the area is mechanically harvested. During harvest time combine move from CZ to NWPZ, harvesting the smallholdings at a negotiated per hectare price (Figure 15). Farmers who care for the straw mechanically thresh the material and the biomass is used as cattle feed (forage) and if sold, fetches a price equal to the cost of cultivation. Wet weather when the crop is mature affects the grain quality and lodges the crop.

Water is a crucial input in semi-arid areas and where there is a fall in water table. Furrow Irrigated Raised Bed Planting System (FIRBS) is a seeding and management strategy for wheat in areas where water is scarce (Figure 16). In FIRBS three rows of wheat are sown on the top of the ridge and simultaneously basal dose of



Figure 15: Roving combines from CZ to NWPZ harvest wheat quickly to vacate the field for rice

fertilizer is also drilled on the top of the bed. The long furrow enable efficient irrigation and better control of water even though it needs to be irrigated more frequently in comparison to flood irrigation. Succeeding wheat, by reshaping the furrow the next crop of rice can be planted in the furrow or any other crop can be sown. Better light penetration, fertilizer usage efficiency and effective water usage promotes good crop growth. Since the cost of cultivation gets reduced FIRBS usage increases the profit margin. The succeeding crop of rice / cotton / vegetables are sown by reshaping the ridge and furrow. Over the years, FIRBS increases soil organic matter status and improves the sustainability of the cropping system.



Figure 16: Raised bed system (FIRBS) of planting wheat has become popular in north Rajasthan where irrigation water is a limitation

Shift towards Cropping System

Availability of high yielding varieties of varying duration and time saved on field preparation by farm mechanization promoted an increase in cropping intensity. The systems productivity was dependent on the per day productivity and was the basis for increasing the income of the farmer. This necessitated diversification in agricultural systems and vegetable farming and animal husbandry further added to farmers' income. Several annual crop sequences as the rice- wheat: cotton – wheat and pearl millet – wheat / berseem became dominant in NW India (Table 3). During the monsoon or *kharif* season crops that withstand high temperature are taken up and following their harvest in October/ November field become ready for seeding wheat. In the CZ if the monsoon is normal, after the harvest of pearl millet/ sorghum /soybean or cotton, under retreating moisture regime wheat is sown either as a rainfed crop or at best with the support of one irrigation.

In NWPZ, the rice-wheat system covers about 4 mh, cotton / wheat another 3 mh and such intensive mono-cropping has caused sustainability problem. The corrugated FIRBS planting procedure is now widely adopted in northern Rajasthan and this has optimized the irrigation water use efficiency both for wheat and the succeeding crop of cotton. Choice of appropriate variety of cotton and wheat is necessary to plant these crops in time and at the same time maximize the productivity of the cropping system. The reduced tillage that occurs due to successive years of FIRBS improves soil organic matter content and promotes soil living organisms. The FIRBS also increases

Table 3. Area under different wheat based cropping systems in India

Crop sequence	Rabi	Kharif	Million ha (system area)
Wheat / Rice	Wheat	Rice	10.0
Wheat / Cotton	Wheat	Cotton	3.0
Wheat / Soybean	Wheat	Soybean	2.0
Wheat / Pearl millet or Sorghum	Wheat	Millet or Sorghum	5.0
Other systems			5.0
Total			~ 25.0

the termite damage in wheat and the wheat powdery mildew severity increases. The new tillage options after few years of continuous adoption may skew the weed flora composition. Therefore changes in the tillage system influence other subsystems as the pest dynamics. This calls for sustained research to understand the systems behaviour and the role of stabilizing tendencies.

Gene Deployment Against Wheat Rusts

The alternate hosts for *Puccinia graminis tritici* and *P. recondita tritici* that cause stem rust and leaf rust disease respectively, are non functional in India and the pathogen survives during the hot summer months on the off-season crops (plants) available in the Nilgiri and Palni hills (SHZ). From the SHZ urediospores of both the rust get wind borne and travel north under the influence of the cyclonic wind circulations formed in the Bay of Bengal. When the spore-ridden currents reach the CZ and PZ the accompanying rain-washes them down on wheat crop that is 15 to 20 days old. Subsequently, before harvest the disease severity reaches a level of concern and causes severe crop losses. This annual travel route of the rusts (Figure 17) is called “*Puccinia* path”. During years when such weather conditions do not occur at the correct time then no epidemic develops and so there occurs hardly any crop loss. Stem rust is not at all a serious problem for the NWPZ as the pathogen does not over summer in adequate number in the Himachal Himalayas to glide down to the plains of Punjab to cause infection in November. Nor do new virulence of stem rust reach India from western borders. Hence, the *Puccinia graminis tritici* urediospore dispersal is unidirectional from southern hills to PZ and CZ and seldom do the virulence that get established in the target areas return back to the source (SHZ). It is because of these reasons that the disease has been very effectively contained for the last 35 years and there has been no epidemic of stem and leaf rust diseases in the PZ and CZ.

Mapping the pathogen virulence on isogenic lines indicate the avirulence and virulence genes the pathogen isolate possess. By challenging the appropriate virulences on the test wheat variety, the probable rust resistance genes it possesses is inferred. The AICWIP uses this technique for the advanced wheat lines to infer the probable

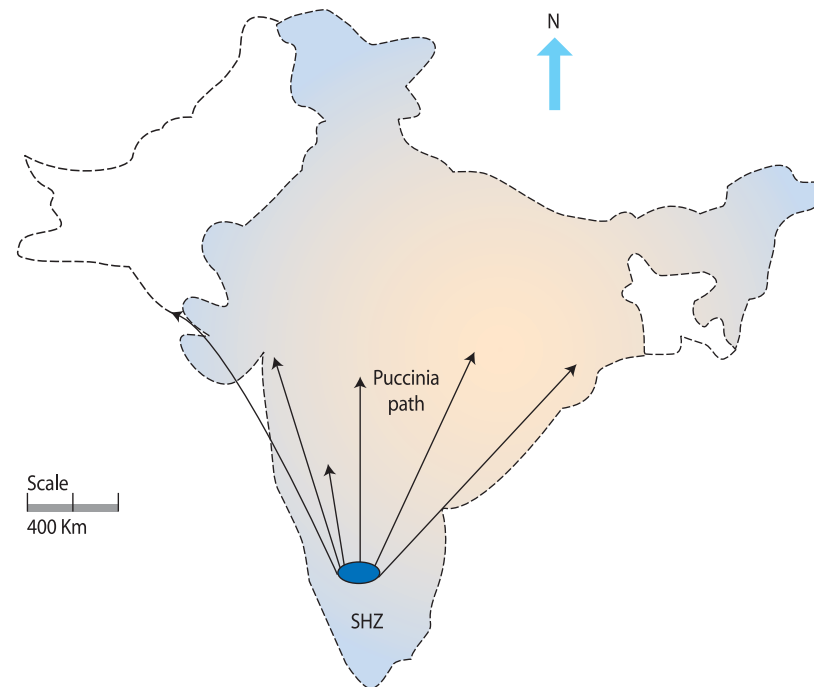


Figure 17: The “*Puccinia* path” shows the dispersal route of stem and leaf rusts from SHZ to PZ and CZ

stem rust/leaf rust resistance genes they possess. Using this information and the rust virulence distribution pattern they design a “gene deployment” strategy by placing varieties of different resistance gene combinations in the SHZ, PZ and CZ. By growing varieties with different resistant gene(s) along the *Puccinia* path, it has been made difficult for the pathogen to sweep across all zones, overcoming the genetic barrier. Over the last two decades through this approach several million tonnes of wheat that was otherwise lost earlier due to the stem and leaf rust epidemics have been saved and stability in wheat production has been achieved.

Combating the Shifting Enemy

Wheat sowings are done in November in the NEPZ in small-undulated terrain with inadequate nutrient application and irrigation water. The

hot summer, following the wheat harvest eliminates the urediospores of *P. recondita tritici* and *P. striiformis*. The over summering urediospores of *P. recondita tritici* on self-sown/off season crop/collateral hosts in hills of Central Nepal become wind borne and during January get deposited over the NEPZ and also spread from the hills of western Himalayas to the foot hills of NWPZ (Figure 18). In two months time the leaf rust spreads all over the Gangetic Plain and by harvest time the terminal disease severity reaches ~50 to 80% on susceptible varieties and causes 15 to 30 % yield reduction.

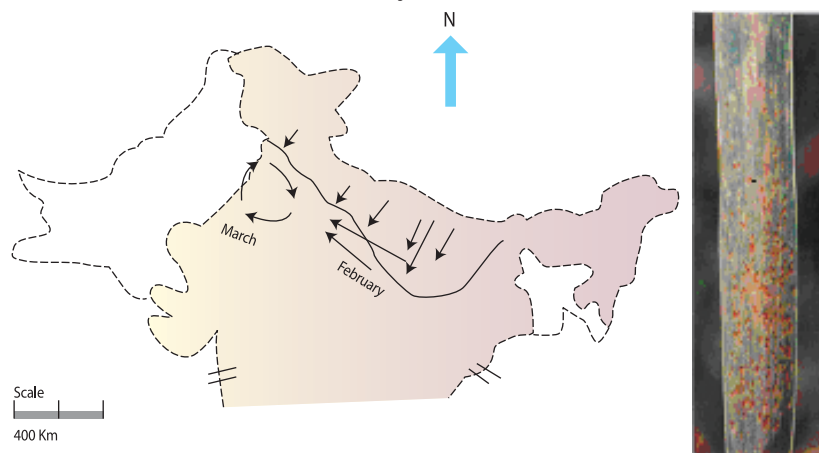


Figure 18: Leaf rust (photo insert) over the Gangetic Plain spreads from Central Nepal to the NEPZ and then to the NWPZ

During such years the urediospores of *P. striiformis* that over summers in the interior Himalayan valleys also spread to the Himalayan foot hills and adjoining NWPZ. The cool and moist spells that occur during winter provide the microclimate needed for the development of leaf and yellow rust epidemics. The nearly 9 m in the NWPZ with an average yield > 4 tonnes/h is vulnerable to severe yellow rust epidemic. Quick varietal reshuffle with varying resistance combinations is recommended as the strategy to contain the damage. The regular wind flow from West Asia to India invariably brings along with it urediospores of new virulence of *P. striiformis* (Figure 19). Once new virulence of yellow rust gets recruited into the Indian flora they multiply and create epidemic in the NWPZ if the host is vulnerable and weather is congenial. This calls for pro-active research to know

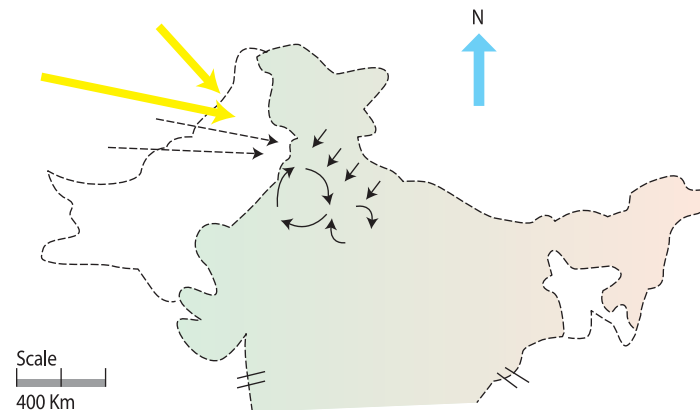


Figure 19: Yellow rust arrives from the Western Himalaya to NWPZ by January. New virulence (yellow arrow) may reach under the influence of weather conditions called “western disturbance”

the yellow rust virulence pattern in this region and follow it with an action plan.

Based on the reaction of the pathogen isolate on the isogenic lines the avirulence/virulence pattern of the yellow rust flora is mapped. Using the information on the leaf rust gene/yellow rust gene postulation, genetically diverse material are released for the NHZ, NEPZ and the NWPZ to avoid the spread of the pathogen over large area. The gene deployment thus brought yield stability and stopped the quick varietal breakdown.

There are several locations in India where every year severe development of the rust disease takes place, known as “hot spots”. The early generation materials and other germplasm in the breeding programme are evaluated under artificial epiphytotic conditions and in the hot spots. Based on several years of testing number of donor lines for various diseases have been identified and through the National Genetic Stock Nursery (NGSN) are made available to the wheat breeders for usage in variety development.

The NWPZ is endemic to Karnal bunt disease caused by *Tellitia indica* and the epidemiology; disease management and risk analysis for this disease have been worked out. The pathogen cycle inherently

has several vulnerable stages and by modifying the cultivation practices disease potential has been minimized. Artificial screening and hot spot testing by plant breeders of the NWPZ enabled the development of wheat varieties with high level of tolerance to Karnal bunt.

Marker Aided Wheat Improvement

Post harvest seed dormancy is an important agronomic trait as lack of dormancy will lead to vivipary under wet weather conditions and the damaged kernels will become unfit for any use. Indian researchers have identified on chromosome 3DS fifteen different Quantitative Trait Loci (QTL) interval maps. Seed dormancy in wheat seems to be a complex trait controlled by number of QTLs. Therefore Marker Aided Selection (MAS) is an efficient plant breeding tool in developing wheat varieties tolerant to moisture/rain that damages the quality of the wheat grain. These molecular markers associated with seed dormancy can then be used for MAS along with the other ones reported from different parts of the world. In order to make gene pyramiding and deployment effective, many reliable molecular markers have been identified for leaf rust resistance genes Lr19, Lr24, Lr28 etc and have been put to use in the varietal breeding programme (Figure 20). The MAS is a reliable tool in the hands of plant breeder to effectively assess the incorporation of resgene combinations that are otherwise difficult to infer based on disease expression alone.

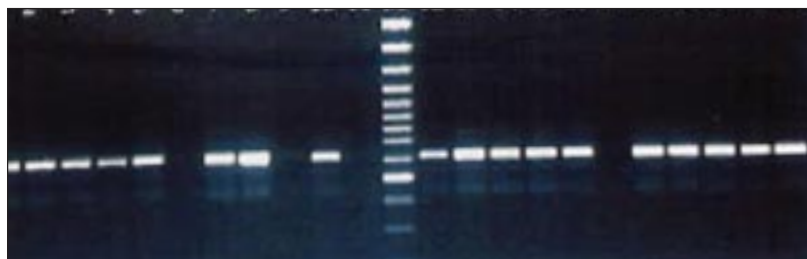


Figure 20: Validations of lines possessing Lr32 and Lr28 using SCAR marker SCS421₆₄₀. Lines 1 – 10 for Lr32 and 12 – 22 for Lr 28 presence of band shows presence of the resgene

SUCCESS OF THE WHEAT REVOLUTION

Policy Support

Convincingly superior technologies arouse farmer's interest to adapt to new and innovative practices. Also the availability of number of well-trained people for taking up mission mode research, extension and seed production activities made the wheat revolution happen. Diverse, dwarf, photo insensitive, high yielding genotypes from the CIMMYT wheat improvement programme was used to develop superior varieties suited to Indian conditions. A band of committed Indian wheat scientists used these materials to introgress with native types and continuously developed better varieties and technologies. Varietal development programme integrated the plant breeding activities with disease resistance breeding and plant disease control approaches. Release of number of wheat varieties of different duration increased cropping intensity and placed wheat in different sequences. This helped in increasing the area sown to wheat. Easy access to inputs such as seed, fertilizer, farm power etc, through the credit line extended by the banks and other financial institutions catalyzed change. Reach out to the farmers by the extension functionaries through mass contact programme, media and field demonstrations. Minimum support price (MSP) that was declared well in advance by the government ensured a price guarantee for the produce and administrative and political will at all levels, to increase agricultural production in general and wheat production in particular.

The Government of India introduced the MSP to ensure that the increased arrival of wheat grain in the market does not lead to a price collapse and to ensure that farmers produce more food grain to feed the population. By this the Government ensured that the surplus grain produced by the farmers is procured by the governmental system (FCI etc) at the mandi (grain markets). The MSP price has been static for quite some time compared to the earlier increases (Figure 21). The MSP induced farmers to produce more as market was assured and

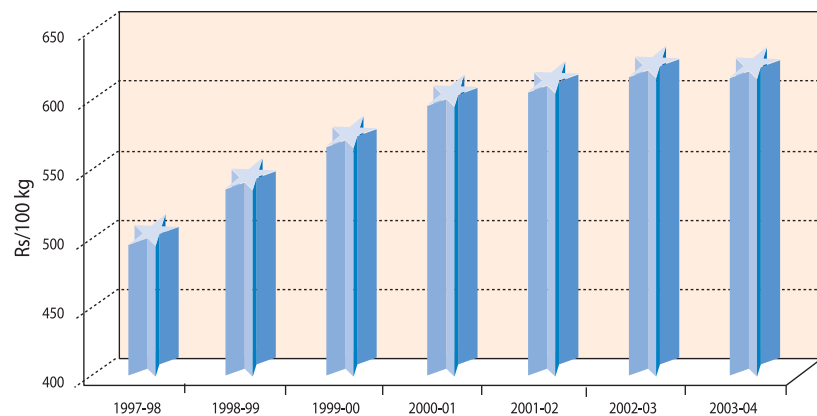


Figure 21: Minimum support price for wheat over years

also the MSP discouraged the function of the “Law of demand and supply”. Since the MSP had only the Fair Average Quality (FAQ) as the basis of procurement there was no price difference for better quality grain. The mounting grain surplus and the cost involved in maintaining a huge grain stock became a point of public debate.

Wheat procurement has steadily improved over the years and contribution of Punjab and Haryana increased very impressively. These states account for more than 85% of the total procurement of wheat done during the last ten years and wheat has retained its position as a major contributor to the economy of these states. The level of procurement each year has been consistently growing in both Punjab and Haryana. But Uttar Pradesh that has more area under wheat than both the above states put together contributes very less to the surplus pool. In both NEPZ and CZ potential exists to increase the total wheat production and to make it happen that, provided enabling policies are in place (Figure 22). Over the last few years the MSP price has stabilized. The PDS system now covers only the population below the poverty line and the amount of grain used by this system has substantially reduced. This has reduced the economic burden on the exchequer and good part of the middle class is now paying a premium price for better grain quality. Since the grain procurement now is open to both public and private grain traders and

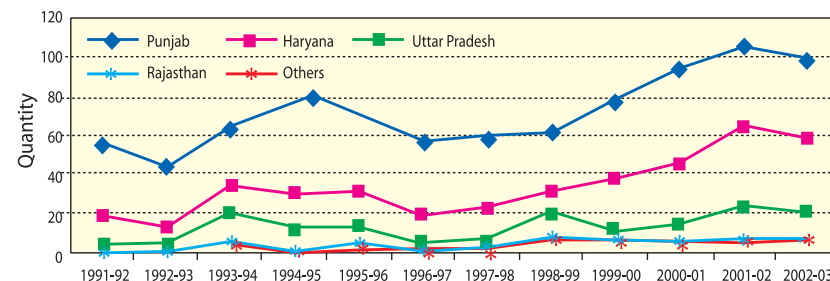


Figure 22: Procurement of wheat from different states (in 1,00,000 tonnes)

movers there is a perceptible shift towards better grain quality and market price.

Economic Benefit

In the pre-wheat revolution period of 1950 to 1965 production gain came mainly due to increase in area sown to wheat, increased area under irrigation and use of agrochemicals. There is a very good linear fit between increasing years and production increase (Figure 23).

The R^2 value for productivity growth during the pre-wheat revolution era is 0.77 and extending the curve shows that in 2004 about 23.7 MT of wheat would have been produced under that given technology. A conservative estimate of the 2004 wheat production is

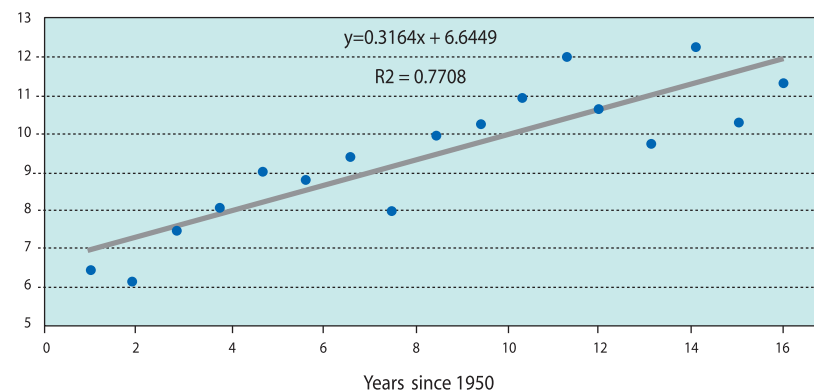


Figure 23: Linear growth in total wheat production (mt) in the pre-green revolution period (1950 to 1967)

71+ MT. Hence during 1965 to 2004 the benefit of wheat revolution accounted for more than 1,100 MT of additional wheat production and the economic benefit that accrued to India will be worth several trillion rupees. The wheat revolution is environmentally friendly, as in the absence of it huge forestlands would have been diverted to agriculture. Wheat revolution also created village level employment, and strengthened the infrastructure, more so in the grain surplus NWPZ.

POTENTIAL THREATS

Global Warming

The global climatic changes have become the focus of scientific and social attention. Even though there are no convincing indicators to show that global warming is happening, if it happens then wheat-growing areas of India will come under heat stress. Such a heat stress if coincides with the early/mid dough stage of crop growth, then substantial yield reduction occurs. Even one degree centigrade increase in mean winter temperature will put several million hectares under severe physiological stress and will increase the demand for irrigation water. Heat tolerant wheat varieties have been developed and some of them require very less chilling temperatures to have a good crop. These wheat varieties are now cultivated at locations 10°N of the equator at elevations of 300 m amsl. These are heat tolerant and mature in 90 days and give 2 to 2.5 t/h yield if backed by five irrigations. Global warming may alter the rainfall pattern and precipitation during March/April over NWPZ. Such pre-harvest precipitations would increase the seed moisture, decrease seed viability and will increase the severity and damage by head scab disease caused by *Fusarium* spp. The changed aflatoxin status of the grain may affect the value of the harvest and prudence demands action by way of anticipatory research.

Demand and Supply can Change

Population growth in India has remained high in 1950s and 1960s. In 1990s the increased life expectancy and per capita income slowed down the rate of population growth. Low inflation promoted greater rural saving, and the savings were partly invested by the farmers to increase the infrastructure needed for better farming. Also it provided the venture capital to diversify to animal farming activities. Both these complemented well and further improved the living standards in

Punjab and Haryana, but such a development to a large extent did not happen in NEPZ and CZ. The population of India will be 1.4 billion by 2020 and will need ~105 MT of wheat to meet the changing kitchen needs of the middle class population and any unforeseen food shortages. A record 76 MT of wheat production was achieved during 2000, and in the next fifteen years it should increase to 105 MT. Extrapolating the current growth rate of wheat shows that achieving this target seems to be possible provided necessary instruments of change are brought about to promote further growth in agriculture.

During 1980s, annual wheat production grew at 3.57%. Area increase was just marginal and most of the gain came through productivity increase. This productivity increase declined to 2.11 % during 1990s and for the three-year period ending 2003, it has further declined to 0.73 %. The present growth in the productivity of wheat is far below the annual rate of growth of the population and if not corrected, would lead to a wheat grain deficit situation (Figure 24). The deceleration in wheat production is also due to reduction in area sown to wheat due to reasons of poor monsoon. Only the marginal areas in CZ/PZ depend on receding monsoon moisture for raising a wheat crop. These are areas of low productivity and if wheat was not sown here due to drought, even then the growth in productivity should not have reduced. The decline in productivity recorded during this decade is real and is of concern.

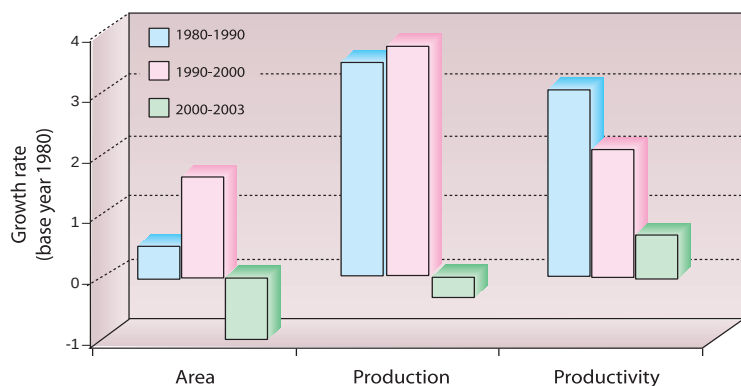


Figure 24: Compound growth rate of area, production and per hectare yield of wheat in India

Value Addition

With better quality products in the market at affordable prices, the choice before the consumer increases and so does the level of consumption. This will promote the growth of food industries and the movement of wheat in the value addition chain. The growth of biscuit industry and product diversification is an example of the growth of wheat-based industries. The value of the processed food industry by 2005 will be US\$ 50,000 million (1\$=Rs.45) and a number of companies are integrating the agri-supply chain creating a network of service providers offering credit, inputs, information on market prices, crop-weather details etc. The global food companies on their part have also joined the rapidly growing food business making wheat move in the value addition chain. Consumer preferences indicate that per capita consumption of cereals from 154 kg/year in 1993-94 has come down to 147 kg in 1999-2000. A mixed food basket has evolved, moving away from the predominantly cereal based food diet to milk, meat, vegetables and fruits (Figure 25). Within the cereal grains there is a clear shift to processed food. The food manufacturing industry grew at 28 % in 1993 and it increased to 37 % in 2000. There is a considerable opportunity for the food sector to grow further.

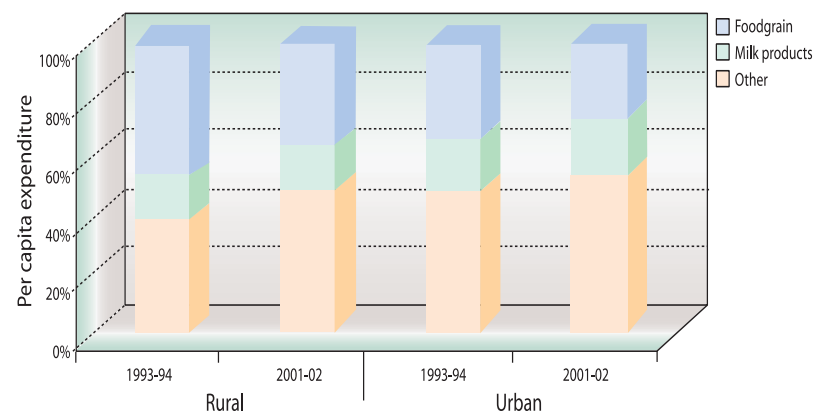


Figure 25: Changing food habits in India
(Monthly per capita expenditure on food in rural India is Rs.276/ and that of urban India is Rs. 402)

Consumer Needs

With the rising income levels farming has to undergo a change and crop diversification through vegetable and fruit farming is essential since they have greater consumer demand. So states such as Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and West Bengal have moved to horticultural crops. Over the last decade there has been considerable area expansion under these high value crops. But in the wheat/rice system dominated Punjab and Haryana there has been hardly any diversification despite the best of efforts (Figure 26). This being the producer of surplus grain, it further indicates that

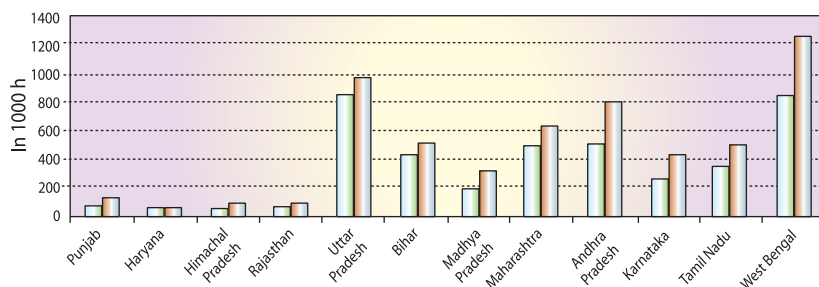


Figure 26: Area under vegetables and fruits (1990 and 2000)

cereal farming continues to be profitable in the NWPZ and the labour-intensive horticultural crops are not emerging as the real alternative.

GOODWILL THROUGH WHEAT – REGIONAL IMPACT

Indian wheat varieties are grown in several countries of the world such as Nepal, Bangladesh, Sudan, and Afghanistan etc. India shares several of the nurseries and trial materials with Nepal and many Indian wheat varieties have been released for cultivation to supplement the efforts of the national programme. Years ago India supplied the seed of WL 711 to Pakistan. The currently most popular Pakistan wheat variety “Inqalab” has WL 711 in its pedigree. Indonesia grows no wheat but imports each year several million tonnes to meet the domestic bakery needs. During 2000, Indonesia imported seeds of Indian wheat variety DWR 162 released for the PZ. It was evaluated at elevations ~540 m amsl, and it matured in 120 days yielding >3 tonnes/h. During 2004, Indonesia has sown more than 150 h under this variety and have intentions of taking wheat cultivation seriously. In view of that, India extended training to a number of young Indonesian wheat scientists to carry on their national programme. These are a few examples of south-south cooperation in wheat research (Figure 27).



Figure 27: Indian Wheat DWR 162, is a run-away success in Indonesia

The primary inoculum of leaf rust for the NEPZ comes from the adjoining central Nepal and occasionally new virulence of yellow rust enters Punjab from the western frontiers enriching the virulence spectrum of the pathogen. This calls for closer cooperation between India and the WASA (West Asia-South Asia) nations to combat the epidemic of leaf and yellow rusts of wheat.

WHEAT FUTURISTIC

Commodity Exchange Procedure

Since India has also emerged as a reliable supplier of wheat, a Commodity Exchange to cover cereals like wheat has been put in place as NCDEX trading system-having Delhi as the auction centre. Two delivery units and two classes (with specifications) of Indian wheat have been finalized as the first step to get integrated with the global grain trading practices. This shows the development of huge confidence in the trade that there will be stock each year for shipment. To enable good trading and to enable global comparison Indian wheat is put in to the following clusters and grades.

Classes of Indian Wheat

The Indian wheat grain broadly falls into six classes and as of now the commodity trade has accepted the first two classes.

Indian Medium Hard Bread Wheat (Standard Mill Quality Wheat)

Medium grain size and appearance, medium hard, dry gluten 9%, protein >10%, hectoliter weight 76 (HLW), seed moisture 11%, and flour suited for non-fermented flat breads.

Indian Hard Bread Wheat (Premium Wheat)

Bold and lustrous grain, dry gluten 9%, protein >12%, HLW 78, seed moisture 11%, flour recovery is better and suited for a variety of fermented and non-fermented breads.

Indian Soft Bread Wheat (Biscuit Wheat)

Yellowish/white grain, soft textured, dry gluten 7%, protein <9.5%, HLW 75, seed moisture 11 %, and fit for eastern food habits, biscuits etc.

Indian Durum Wheat

Hard, lustrous, beta-carotene >5%, protein >12%, HLW >78, seed moisture 11%, and suited for noodles, pasta and extruded products, semolina etc.

Indian Dicoccum Wheat

Hard, bold, beta- carotene 5%, HLW >78, protein >13%, seed moisture 11%, suited as breakfast cereal, semolina and porridge, extruded products and high protein foods.

Other Wheat

Wheat that does not fall under any of the class.

These classes are based on chemical quality, physical purity of the grain and can be up and down regulated by + or – symbol as suffix to the class to give price clarity. Thus the Indian grain classes (and grades) can be compared with that of other countries for auctioning and pricing purposes. This will further facilitate the promotion of wheat export from India.

LESSONS LEARNT

The initiatives taken / successes achieved by the national programme point out that:

- Having a shared vision and bringing together various national institutions and agencies in a transparent manner with well-defined programme and objectives is necessary to achieve the “impossible”.
- Cooperative research in field crop improvement has several advantages and accelerates the process of developing variety with greater adaptation.
- Germplasm exchange, indexing them and using it for diverse crop improvement activities accelerates varietal development efforts.
- The new technology should be robust, simple, easy to adopt and must get backdrop support from dedicated R&D system.
- A core of qualified, committed staff for project execution and a bunch of critical and analytical board room experts to monitor the course of development, with trust and confidence of the political and economic system is essential.
- Enabling government policies, incentives to produce more, a system to handle the marketable surplus and reaching out the benefit to the poor are vital.
- Interaction at grass-root level/farm level, collecting feed back data / issues to refine the technology to the level of the stakeholder's satisfaction are essential.
- Perception of the farmer to adopt new technologies / R&D findings. Once the farmer changes his varieties and practices for a betterment and gets convinced of the robustness of the technology, then he gains confidence to make such changes in other crops, diversifies his farming system, invests to scale up the productivity of his farm, promotes development of infrastructure and manufacturing of items and through all this endeavour a new market emerges.

EPILOGUE

India has a long history of wheat cultivation spanning over 4000 years. Wheat growing farm families identified and maintained a variety of genetic resources of wheat varying for several economic traits. Dr Howard and Mrs Howard in 1905 collected and characterized several of them during their stay in India. From out of these bulks they purified several lines and released them as varieties. By mid 1930s in India crossing between wheat lines to develop superior wheat varieties started. Since area with assured irrigation was less and the fertilizer use was insignificant yields were very low. Soon the population growth overtook production advances and food shortages and food import became a regular feature. During 1960s India was regularly importing about 10 MT of wheat and had a 'shift to mouth' living. Subsequently, a well integrated rational R&D programme helped change this scenario. With the advent of wheat revolution things changed for betterment and from the year 2000 onwards India produced regularly 70 MT of wheat grain per year. This amount was more than the annual domestic requirement and enabled the creation of adequate buffer stocks to thwart the drought and other calamities. The surplus grain stocks prompted India during the years 2000 to 2004 to export 19.87 MT of wheat. The highest volume of export of 7.07 MT of grain was in 2003–04.

Following their experience in wheat, farmers changed their farming practices in other crops and allied animal husbandry activities. Agriculture contributed substantially to the fast growing economy and the resultant stable food prices promoted savings and opened a huge consumer market with a demand on variety of quality consumer and other products. In my opinion the growth in Indian agriculture was the launching vehicle for a strong and robust economic order in India. With all laurels to its credit, wheat revolution in India can rightly be called a 'success story'.

ACKNOWLEDGEMENTS

I wish to acknowledge the assistance rendered by my colleague Dr Jagshoran and Dr J. Kumar, Directorate of Wheat Research, Karnal, India, in providing some of the photographs and Dr R.K. Arora, Former Director, NBPGR, and presently Hon. Research Fellow, IPGRI Office for South Asia, New Delhi for the editorial skills and other important advices.

India's wheat revolution is indebted to Drs B.P. Pal, M.S. Swaminathan, A.B. Joshi, M.V. Rao and L.M. Joshi; CIMMYT team – Drs Norman Borlaug, Glen Andersen and Gene Saari; policy makers and to the dexterous poor Indian farmers.

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