VISION-2025

Directorate of Wheat Research

Indian Council of Agricultural Research
Karnal-132001 (INDIA)

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Dr. B. Mishra
Project Director
Directorate of Wheat Research, Agrasain Marg
Karnal-132001, Haryana, India

Telephone : +91-184-2267490

Fax : +91-184-2267390

Email : dwr@vsnl.com

Compiled & Edited by:

B. Mishra, R. Chatrath, D. Mohan, M.S. Saharan and B.S. Tyagi

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FOREWORD

Indian agriculture must continuously evolve to remain ever responsive to manage the change and to meet the growing and diversified needs of different stakeholders in the entire production to consumption chain. In order to capitalize on the opportunities and to convert weaknesses into opportunities, we at the ICAR attempted to visualize an alternate agricultural scenario from present to twenty years hence. In this endeavour, an in-depth analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) was undertaken to place our research and technology development efforts in perspective so that we succeed in our pursuit of doing better than the best. Accordingly, the researchable issues *are* identified, strategies drawn and programmes indicated to have commensurate projects and relevant activities coinciding with the launch of the 11th Five Year Plan.

Wheat is the second most important foodgrain in India after rice. The Directorate of Wheat Research (DWR), Karnal through its national network of research centres has developed large number of improved wheat and barley varieties and their production-protection technologies for different agro-climatic zones in the country. Despite the last few years of adverse climatic conditions like drought and terminal heat stress, the total annual wheat production still hovers around 72 MT, hereby posing a challenge to the wheat scientists for breaking this stalemate. The choice before the consumer increases with better quality products in the market at affordable prices 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. Therefore, development of modern genotypes suitable for intensive agriculture is going to become a prime concern. Exploiting hybrid vigour, developing super wheat and innovations through molecular tools are some of the possible approaches to further increase the yield potential of wheat. Managing the natural resources is an important challenge in the highly productive rice-wheat cropping system (RWCS) which is predominant in the Indo-Gangetic plains. It is essential that the factor productivity be improved and needful steps taken to reverse the deteriorating soil health, nutrient deficiencies and falling C/N ratio.

It is expected that realizing the Vision embodied in the document would further ensure that the DWR, Karnal continues to fulfill its mandate to make Indian agriculture locally, regionally and globally competitive. The efforts and valuable inputs provided by my colleagues at the ICAR Headquarters and by the Director and his team at the Institute level for over an year to develop Vision 2025 deserve appreciation.

March, 2007

(MANGALA RAI)

Secretary, Department of Agricultural Research & Education
and
Director General, Indian Council of Agricultural Research
Dr. Rajendra Prasad Road, Krishi Bhawan, New Delhi 110001, India

PREFACE

Slow growth in total wheat production up to 1965 necessitated a large-scale food grain import by India under the PL480 system. The series of agricultural changes following the utilization and exploitation of Norin 10 dwarfing gene in wheat after 1965 was called "Green revolution". The impact of green revolution made India self sufficient in food grain production. The 80s witnessed quantum jump of wheat production making India worth of stockpiling 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. This success story of wheat production is now seeking a turning point towards keeping the wheat price and supply affordable for more than 240 million people below the poverty line. Also, changing food habits with preference for pasta and noodle category of foods would demand shift in breeding for quality traits other than those associated with conventional chapati and biscuit making. In a quest to produce more and more food, the cropping sequences in this country changed fast in the near past to promote intensive farming. As a result, rice - wheat rotation has emerged as the most important cropping sequence of last two decades in the main wheat belt of north western India. Maintaining highest standards of quality and purity of our agricultural produce and encountering stiff international competition in view of GATT agreement is the biggest challenge towering before the scientific and policy making fronts.

The All India Coordinated Project on Wheat and Barley has a number of centres in diverse agro ecological areas. The plant breeders develop, advance and evaluate their materials at these centres and generate voluminous information on the performance and stability of their breeding accessions before channeling those into the national system of varietal identification and release for their respective zones. The project has active multidisciplinary research centers housed in the various State Agricultural Universities (SAUs) and these centers get financial support to meet 75 % of the annual expenditure from the federal government and the remaining from their own states. This cost sharing brought about a cohesive, purposeful and result oriented network to develop varieties and appropriate production and protection technologies.

The present document is focused on a research program which envisages developing 'super wheats' - varieties with 8-ton/h yield particularly in NWPZ, the wheat bowl of India. 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 20 - 25 days earlier than the average duration of present day cultivars. These superior wheat varieties should have tolerance to rusts, Karnal bunt, foliar blights as well as abiotic stresses of salinity and terminal heat. Advantage would be more if the grain has the quality for new kinds of food such as pasta, noodle, bread etc. in addition to the conventional flat non-fermented bread or chapati making characteristics. The flour recovery of the HYVs and also the quality of the flour for bread making and biscuit needs improvement.

The wheat-breeding laboratories in general, are inadequately equipped as far as the present methodologies based on the techniques of molecular biology are concerned. At the same time, trained manpower is needed to pursue the research projects devised with the modern biotechnological objectives. Many reliable molecular markers have been identified to facilitate breeding for disease resistance, physiological traits and quality characteristics. In order to make gene pyramiding and deployment effective, many more reliable molecular markers have been proposed to be identified and put to use in the varietal breeding programme. The marker aided selection (MAS) will be promoted as reliable and output efficient tools in the hands of breeders, pathologists, physiologists and agronomists to effectively asses the incorporation of yield, resistance and quality genes, that are otherwise difficult to infer based on phenotypic observations alone. The adoption of furrow irrigated raised bed system (FIRBS) system of planting wheat will be projected to increase the water and nutrient use efficiency while the reduction in tillage operations will reduce the cost of cultivation and maximize profitability to the farmers.

The frontline demonstrations have clearly revealed that there is a considerable gap between the possible and actual yield in farmers' field which varies from state to state. However, with the available technologies, it seems possible to bridge this gap, especially under irrigated conditions. It is possible to harvest additional 24.8 mt by reorienting government policies and extensive extension approach at the grass root level. Several programs as the Krishi Vigyan Kendra (KVK) and FLD need strengthening to extend support to technology spread. There is a possibility of getting additional production more than 7.5 million ton from the rainfed areas of MP, Bihar, UP and Rajasthan. The real cost of cultivation is lowest in Punjab, Haryana and Rajasthan and needs to be reduced more to deal effectively with the stringent requirements of global market. The states of UP, MP are above national average in this regard and efforts will be diverted for reducing cost of cultivation in these states sharing the largest wheat cultivable area in the country. The advanced and efficient farm machinery needs to be fine tuned to address the needs and capabilities of average Indian farmers.

The research work on barley has geared to develop better malt type barley for industrial application in brewing, distillation and high energy foods/drinks. Due to increased industrial demand the barley crop will be known as cash crop in the coming years. Some industries are adopting contractual farming and giving premium on better malt producing varieties. Besides this, barley is also an important crop for feed and fodder purposes and therefore emphasis will be given to develop dual purpose varieties.

The Indian Council of Agricultural Research (ICAR) having taken into cognizance the previous efforts, struggle to increase the productivity, concern to augment and sustain what has been achieved, issued the directives and guidance to develop the vision for research mandate to be adopted in the forthcoming decades.

It had been a pleasure opportunity for the Scientists of Directorate of Wheat Research to take up this task of developing the present document that may serve as guideline for attaining 109.0 mt. wheat production by 2025 AD. As Project Director, I extend my sincere thanks to all the scientists of DWR and coordinated system for their valuable inputs to bring this document in the present shape. I am sincerely thankful to Dr. Mangala Rai, Secretary, DARE and DG, ICAR for his enumerable guidance imparted during the process of drafting up this document. I take it a privilege to acknowledge contributions of Dr. Gautam Kalloo, former DDG (CS and H) for giving valuable advice in finalizing this document. Thanks are also due to Dr. S. N. Shukla, ADG (FFC) for his help.

(B. Mishra)
Project Director

EXPLANATION TO ABBREVIATIONS

ACIAR	: Australian Council of International Agricultural Research
AICW&BIP	: All India Coordinated Wheat and Barley Improvement Project
AMIS	: Agricultural Market Intelligence System
APR	: Adult Plant Resistance
CFTRI	: Central Food Technological Research Institute
CHA	: Chemical Hybridizing Agent
CIMMYT	: International Maize and Wheat Improvement Centre
CMS	: Cytoplasmic Male Sterility
CSIR	: Council of Scientific and Industrial Research
CVRC	: Central Variety Release Committee
CZ	: Central Zone
DHTSN	: Drought and Heat Tolerance Screening Nursery
DST	: Department of Science and Technology
DWR	: Directorate of Wheat Research
EIGN	: Elite International Germplasm Nursery
FIRBS	: Furrow Irrigated Raised Bed System
FLD	: Front Line Demonstration
GATT	: General Agreement on Tariffs and Trade
GFDL	: Geophysical Fluid Dynamics Laboratory
GIS	: Geographic Information System
GRI	: Global Rust Initiative
HMW	: High Molecular Weight
IARI	: Indian Agricultural Research Institute
ICAR	: Indian Council of Agricultural Research
ICARDA	: International Centre for Agricultural Research in Dry Areas
IGP	: Indo Gangetic Plains
IPM	: Integrated Pest Management
IPR	: Intellectual Property Right

ISCB	: Indo Swiss Collaboration in Biotechnology
LAN	: Local Area Network
LMW	: Low Molecular Weight
MAS	: Marker Assisted Selection
MEASA	: Middle East and South Asia
NBPGR	: National Bureau of Plant Genetic Resources
NEPZ	: North Eastern Plains Zone
NGSN	: National Genetic Stock Nursery
NHZ	: Northern Hills Zone
NIL	: Near Isogenic Line
NIVT	: National Initial Varietal Trial
NWPZ	: North Western Plains Zone
PAU	: Punjab Agricultural University
PGPR	: Plant Growth Promoting Rhizobacteria
PIN	: Puro Indolines
PRA	: Pest Risk Analysis
PVR	: Plant Variety Right
PZ	: Peninsular Zone
QCSN	: Quality Component Screening Nursery
RCT	: Resource Conservation Technology
RIL	: Recombinant Inbred Line
RWCS	: Rice Wheat Cropping System
SDN	: Short Duration Nursery
SHZ	: Southern Hills Zone
SSN	: Segregating Screening Nursery
SVRC	: State Variety Release Committee
USDA	: United States Department of Agriculture
WTO	: World Trade Organisation
YCSN	: Yield Component Screening Nursery

EXECUTIVE SUMMARY

Directorate of Wheat Research (DWR) through All India Coordinated Wheat and Barley Improvement Project (AICW&BIP) in its 42nd year of service, is coordinating the multidisciplinary and multilocational activities of varietal improvement, resource management and crop protection technologies across the diverse ecosystems for increasing and stabilizing the wheat and barley production. As a nodal institute, DWR facilitates planning, exchange of experimental material, monitoring the trials/activities, data compilation and documentation. At present 120 scientists from 30 funded centres and 174 scientists from 123 non-funded co-operating centres are carrying out the planned activities. In addition to this, as a key component of National Steering Committee, the DWR plays a crucial role in formulating strategies to ensure sustainable improvement in the productivity of Rice-Wheat System. Adoption of molecular approach to complement conventional wheat improvement programme is one of the recent initiatives taken up by DWR through a research network project. Research capabilities and facilities are being strengthened through various network projects to enhance output of competent research centres under AICW&BIP.

The area, productivity and production of wheat have increased 119%, 236 % and 634%, respectively by the year 2005 as compared with 1965-66 (base year). During 1999-2000, the wheat production in the country touched the highest peak of 76.37 million tonnes. For the last ten years, India is maintaining its second position in the world next to only China. The "rate of return analysis" largely explains the success of wheat improvement programme and this is evident from the fact that the investment made in wheat research has been repaid through increased productivity and production. Since the inception of the All India Coordinated Project in 1965, the wheat programme has released 312 wheat and triticale varieties, comprising bread wheat (262), durum (43), dicocccum (4) and triticale (3), for cultivation under different production conditions in all the wheat growing zones. Similarly, over 70 improved varieties of barley have also been developed for commercial cultivation. Through concerted research efforts in the form of protection technologies, a check has been kept on various insects, pests and diseases. As a result of this, no outbreak of any diseases or pests has been witnessed during the last three and a half decades.

Nevertheless, this progress should not make us complacent as we face a myriad of challenges in the years to come. The population is increasing in a geometric progression leading to an increased demand of wheat but there is no possibility of further increase in area due to growing urbanization, diversification, dwindling water resources, micro-nutrient deficiencies and soil health deterioration. Therefore, the need to produce more wheat has to be met with fewer resources in a sustainable and cost effective manner. The wheat production, currently, is hovering around 70 to 72 mt and recent estimates have shown that India will need nearly 80 mt of wheat by the end of XI-Five Year Plan and more than 109 mt by 2025.

It is a matter of great concern that for the last several years, plateau in wheat productivity is being observed. There is a very little scope for increasing the area under wheat cultivation, so the major challenge is to break the yield barriers. Since a yield jump as observed in 60s does not appear to be possible now, there is need to follow an approach for gradual gain in yield in the breeding populations in order to break the yield plateau. For this purpose, already known high yielding diverse lines need to be used as base material for incorporating some useful traits from other un-adapted cultivars or lines. In this direction, the winter x spring wheat hybridization, interspecific/wide hybridization for introgression of useful genes from related wheat species may be highly effective. In addition, other unexploited germplasms such as *buitre* germplasm for grain number and spike size, synthetic hexaploids for thousand kernel weight, resistance to heat stress, Karnal bunt, rusts and waterlogging and Chinese sub compactoid germplasm for lodging resistance, noodle quality and high yield potential may also be utilized. The development of hybrids in wheat is another promising approach to break the yield barriers. A basic research to re-address hybrid wheat development through CMS and CHA approach was initiated in 1995 in a network mode. Though initially hybrids were developed using the CHA approach, these could not be commercially exploited due to non-sterile late tillers, residual effect of the chemicals as well as unstable and low heterotic levels over locations. Hence the emphasis has now been shifted to development of hybrids through CMS system. Biotechnological interventions such as marker assisted selection are now being used in the gene pyramiding programme for developing wheat varieties resistant to rusts as well as for superior quality. PCR based markers linked to disease resistance genes are being used for marker assisted pyramiding for improving the most popular varieties such as LOK 1, HUW 234, PBW 343, HD 2687, HD 2733 and WH 147. Development of Recombinant Inbred Lines (RILs) for important traits are in progress. Transgenic approach has been attempted to address many of the stresses else where though the progress in successful demonstration of the products is not impressive. Protocols for developing transgenic wheat will be standardised at DWR and will be used in developing transgenic wheat for biotic and abiotic stresses. Identification of useful genes from diverse sources and their introgression through molecular approach, developing doubled haploids through interspecific hybridization etc. may also supplement in this process. There is also a need to develop new genotypes involving super wheats that are responsive to high nutrient and water use efficiency and capable of yielding beyond 7t/ha.

The research work on barley has been reviewed and priorities is being given on to develop better malt type barley for industrial application in brewing, distillation and high energy foods/drinks. Due to increased industrial demand, the barley crop will be known as cash crop in the coming years. Some industries are adopting contractual farming and giving premium on better malt producing varieties. Besides this, barley is also an important crop for feed and fodder purposes and therefore emphasis will be given to develop dual purpose varieties.

Managing the natural resources is an important challenge in the highly productive rice-wheat cropping system (RWCS) which is predominant in the Indo-Gangetic plains (IGP). Further more, the intensive cultivation of rice and wheat for more than three and half decades continuously has put a tremendous pressure on the land thereby creating a complex situation. Problems of stagnating yields at levels far below the potential productivity and even yield declines are occurring in many areas in the rice-wheat systems of India. The total factor productivity of this system is declining due to intensive tillage leading to the depletion of soil organic carbon. The declined soil organic carbon is directly responsible for the decreased nutrient and water holding capacity of the soil thereby adversely affecting the native soil fertility. The problem is further aggravated by burning crop residues by farmers especially that of rice under rice-wheat system in north western parts. Nutrient mining, imbalanced fertilisation and over-exploitation of water resources are the other factors responsible for decline in total factor productivity. Addition of organic matter to soil through green manuring and crop residue recycling, balanced fertilisation, integrated nutrient management, diversification/intensification of rice-wheat system by including pulses, oilseeds and vegetables crops are some of the possible remedial measures to improve soil productivity and hence, total factor productivity. The time has also come for an integrated rice-wheat research towards development of varieties with efficient input use and complete compatibility with each other. There is also a need to develop specific wheat varieties suitable for the different tillage options that are increasingly becoming popular in the RWCS. To address these issues, research efforts are initiated by the NARS to evaluate and develop genotypes suitable for the rice-wheat system of IGP. For sustaining the R-W system in IGP, there is urgent need to economise on the use of natural resources as well as enhance the organic carbon content in the soil. The zero-tillage technology has been a fore-runner in IGP and currently occupies more than 2.0 mh area. The farmer can save nearly Rs 2,000 to 3,000 per hectare by saving the use of diesel, since there is no need of ploughing for wheat sowing by zero till machine after the harvest of rice. The other RCTs which is being adopted by the farmers is FIRB (furrow irrigated raised bed) which saves 25% nitrogen as well as seed and 15-30% irrigation water depending upon soil type.

The most serious constraints to wheat production are biotic stresses. Among the major biotic stresses, rusts and foliar blight are more critical for achieving higher yields. India in particular has not faced any rust epidemic since last three and half decades because of proper deployment of rust resistance genes. However, the threat of a new black rust race (*Ug99*) looms large as most of the wheat lines available in India carrying the *Sr31* gene are susceptible to this race. Fortunately, timely steps have been initiated by the Council and also through the launching of ‘Global Rust Initiative’ (GRI) to combat this impending problem. For this purpose, 22 genetic stocks were screened in Kenya in the year 2005 out of which three genetic stocks, FLW 2, FLW 6 and FLW 8 carrying *Sr24 and Sr25* were found to possess good level of resistance to this new race. Directorate of Wheat Research, Karnal, in coordination with its cooperating centres, has already initiated the breeding programme for incorporation of resistance to stem rust by utilizing the resistant genetic stocks. Besides this, a new race of yellow rust, *78S84*, has been observed on the most widely grown variety PBW 343. A new wheat variety DBW 17 which has been developed and released recently, possesses adult plant resistance to this new race with superiority in yield also. The Directorate and its cooperating centres have initiated breeding programmes for using new and more effective rust resistance genes like *Yr5*, *Yr10*, *Yr15* for yellow rust; *Lr24*, *Lr28*, *Lr35*, *Lr37* for leaf rust and *Sr24*, *Sr25*, *Sr26* for stem rust. The problem of leaf blight is more prominent in the north eastern region and is being addressed through our linkages with CIMMYT-South Asia and cooperators located in the region. Other problems like Karnal bunt, powdery mildew, and pests (aphids, termites, etc.) are also receiving due attention in the wheat improvement programme. The entire plant protection strategy will move towards the integrated pest management mode and focus on surveillance, biological control and other eco-friendly methods. Pest Risk Analysis (PRA) for global trade and use of Plant Growth Promoting Rhizobacterium (PGPR) will be dealt in the years to come. Among other biotic stresses, weeds also play an important role in deciding the productivity of wheat crop. In the past, weed control measures were developed in individual crops and very little work has been done to control weeds in a cropping sequence. Therefore, there is a need to focus on integrated weed management and succession of weeds in a cropping sequence.

Wheat is the main source of energy and nutrition in human diet. Wheat is unique in the sense that large numbers of diverse end-products such as chapati, biscuit, bread, noodles, macaroni and other pasta products are made from it. Though major quantity of wheat in India is consumed in the form of chapati, the baking industry is getting boost and the demand for various baking products is increasing @ 5%. India is the second largest producer of wheat as well as biscuits in the world and biscuit industry is the largest constituent of food processing industry in the country. Millions of people are involved in biscuit industry directly or indirectly in India. The projected demand by the end of next Five-Year Plan is 2.7 mt for bread, 3.5 mt for biscuits and 0.25 mt for pasta. The demand for these products will continue to increase in future with globalization and liberalization on economy. Therefore, it will be necessary to develop wheat genotypes that are better suited for the processing industries and export. Also, India has to compete with major exporters of wheat such as Australia and North America in international market. This calls for fine-tuning of the breeding programme not only to meet the quality requirements and demands of the household consumer and indigenous industry but also qualify the needs of international trade. This will have large impact on farmer’s profit, industrial efficiency, consumer acceptance and improve the competitiveness of Indian wheat varieties under liberalized global economy. Similarly, durum wheat which nearly occupies about 2 million ha area has a good potential for export. Increasing global demand, value addition potential, better price in market and resistance to Karnal bunt are the factors, which make durum an export commodity. Nutritional quality is becoming major concern because of prevalence of malnutrition especially among poor families having cereals as their sole diet. Therefore, increasing the levels of micronutrients (such as Fe and Zn) in grains through bio-fortification and their enhanced bioavailability will have impact on human health especially children and pregnant women. Work has been initiated on understanding genetic aspects related to gluten strength and extensibility, noodle quality, dough and pasta colour, beta-carotene content, anti-nutritional factors in the grain and genes related to starch biosynthetic pathway to manipulate starch properties for improving quality and yield. Subsequently identified genetic components and genotypes for specific quality traits will be utilized in the improvement of wheat for industrial and nutritional quality. This will need specific breeding strategy utilizing molecular approach and phenotypic approach simultaneously. Therefore keeping the above facts in mind, following thrusts areas have been identified:

Thrust Areas of Research

Breaking yield barriers

- Exploitation of heterosis for developing hybrids based on CMS system
- Broadening of genetic base of varieties
  - Through use of winter x spring hybridization
  - Use of synthetics, Buitre and Chinese germplasm
  - Use of alien species for biotic and abiotic stresses
- Biotechnological interventions
  - Gene pyramiding
  - Marker aided selection for biotic, abiotic and quality traits
  - Transgenics
  - Structural and functions genomics

Sustainability of rice-wheat system

- Resource conservation technologies
  - Refinement and indigenization of machines
  - Developing tillage specific varieties
  - Diversification/intensification
  - Water and nutrient use efficiency
  - Tackling weeds and pests under new tillage practices
  - Residue management
  - Land levelling through laser leveler

Improving soil health

- Increasing carbon content
- Correction of micro-nutrient deficiency/toxicity
- Balance use of fertilizers

Combating diseases and insect pests

- Integrated pest management
- Survey and surveillance for new races
- Combating rusts through durable resistance
  - New race of yellow rust – 78S84
  - New race of black rust – Ug99
- Creating effective resistance against leaf blight and Karnal bunt
- Emerging problems of termites and aphids

Improving quality

- Developing product specific varieties with desired quality traits.
- Characterization of genes associated with different quality traits and their manipulation using molecular approach.
- Improving protein content, gluten strength and extensibility to enhance bread making quality.
- Improving protein content, gluten strength, beta-carotene content and semolina recovery in durums.
- Improving nutritional quality by manipulating starch composition, lysine content and biofortification of micronutrients (specially Zn, Fe,) and their enhanced bioavailability and reducing anti-nutritional factors.

On-farm demonstration and validation of new technologies

The Indian wheat programme has a strong multi-disciplinary team across the country in the form of 30 funded and an equal number of voluntary centres belonging to ICAR institutes and SAUs. With a strong research and policy support that Indian Council of Agricultural Research is providing to DWR, the goals of higher wheat production seems achievable.

1. PREAMBLE

In India, the wheat research started in an organized manner a hundred years ago during British rule after the joining of Sir Howards as the Imperial Botanist at Pusa (Bihar) in 1905. Later on, with the establishment of the Indian/Imperial Council of Agricultural Research in 1929, it became the main funding agency and promoter of wheat research in India. An important milestone in this process was establishment of the All India Coordinated Wheat Improvement Project (AICWIP) in 1965 by the ICAR with its headquarters at IARI, New Delhi. The AICWIP was raised to the status of a Directorate in 1978. Later on it was moved to the present location at Karnal as Directorate of Wheat Research in 1990, and with the merging of barley it was named AICW&BIP.

Through coordinated research efforts nearly 312 wheat varieties suited to different agro-ecological conditions and growing situations have been released. These genotypes helped in increasing the wheat production from a mere 12.5 million tons in 1964 to around 75 million tons in 2007. Development of such genotypes also resulted in intensive cropping and created additional need for fertilizer and water. It is now realized that sustaining the productivity of the Indo-Gangetic plains is essential to provide food security to the population of India. In the field of crop improvement, efforts would be to develop new genotypes that are responsive to high input management and capable of yielding beyond 7 t/ha. At the same time, the new genotypes must be nutrient and water use efficient. With holding the strong base of rust resistance, emphasis will be to develop short duration genotypes resistant to leaf blight especially for eastern India. Innovative approaches to produce hybrid wheat that will have at least one tonne yield advantage over the commercial varieties will draw attention. There is need to highlight importance of abiotic stresses viz., heat, drought, salinity and water logging. Due emphasis is to be given for developing genotypes efficient in utilizing the micronutrients so as to make the wheat flour more nutritive. Wheat suitable for chapati making, which ruled the domestic market, may have to accommodate other types of wheat that are suited for product development. It will be necessary to develop wheat genotypes that are better suited for export and the processing industries. Also, the quality of Indian wheat is to match that of Australian and North American wheat in bread making. This calls for fine-tuning of the breeding programme not only to meet the quality requirements and demands of the household consumer and indigenous industry but also satisfy the needs of international trade.

Efforts in the form of time bound projects are a necessity if we have to provide a competitive edge to Indian wheat growers and traders. These projects are to be taken up not only by the DWR but also by the partners of AICW&BIP and also by all those involved in wheat and barley improvement work in SAU's as well as traditional universities. For this purpose, country has been divided into six wheat growing zones based on agro-climatic conditions, disease spectrum and soil status. The irrigated and rainfed trials under timely, early and late sown conditions of bread and durum wheats are conducted in these zones. Special trials on *dicoccum* wheat in peninsular India, summer trials in very high altitude, triticales and salinity-alkalinity trials are also conducted to address specific needs. The project draws support from six zonal coordinators who are entrusted to incorporate zonal mandates/ problems to be handled under the AICW&BIP. The 30 funded centres located in different SAU's support multidisciplinary research on wheat and barley. Another 30 locations are knitted with the project as voluntary centres for providing help in evaluation work. In addition, some other testing sites are also provided by non-government organizations and State Agriculture Departments. These locations have been identified in such a way that all the agro-climatic zones of the country are covered.

2. MANDATE

- Organize, coordinate and monitor multi-locational and multidisciplinary research for developing and identifying superior wheat and barley varieties having better quality and tolerant to biotic and abiotic stresses under varied agro-climatic zones.
- Collect, acquire, evaluate, catalogue, maintain and share working germplasm collections of wheat and barley with focused attention on identifying suitable donors for yield components, biotic and abiotic stresses and quality traits.
- Undertake basic and strategic research for a major advance in genetic yield potential, quality, and durable disease resistance through the utilisation of genetic resources and genetic enhancement.
- Mobilise genetic diversity from national and international sources for developing new genetic stocks for distribution to the cooperating centres in different zones.
- Develop strategic research, which will lead into precision farming, enhance input use efficiency, optimal use of renewable resources and enhance the sustainability of wheat based cropping systems.
- Monitor the obligate parasites e.g. rust pathogen dynamics and develop strategies to mitigate crop losses due to pests and diseases.
- Establish national and international linkages for strengthening wheat and barley improvement programmes.
- Provide off-season nursery facility for rapid generation advancement and seed multiplication.
- Serve as a core facility for data analysis, documentation and information management, so that DWR becomes the national repository for all wheat and barley databases.
- Coordinate and organise nucleus and breeder seed production.
- Impart training/education related to wheat and barley improvement, production, protection, utilisation and trade.

The Mission

Ensuring food security of India by enhancing the productivity and profitability of wheat and barley on an ecologically and economically sustainable basis and making India the world leader in wheat production.

3. GROWTH

The All India Coordinated Wheat Improvement Project (AICWIP) was established in 1965 by the ICAR with its headquarters at IARI, New Delhi. The AICWIP was raised to the status of a Directorate in 1978. Later on it was moved to the present location at Karnal as Directorate of Wheat Research in 1990. The project draws support from six zonal coordinators who are entrusted to incorporate zonal mandates/ problems to be handled under the AICW&BIP. The 30 funded centres located in different SAU's support multidisciplinary research on wheat and barley. Another 30 locations are knitted with the project as voluntary centres for providing help in evaluation work. In addition, some other testing sites are also provided by non-government organizations and State Agriculture Departments. These locations have been identified in such a way that all the agro-climatic zones of the country are covered.

3.1 Infrastructure

The Indian Council of Agricultural Research invested over Rs. 100 millions initially for the establishment of a modernized research complex in form of the Directorate of Wheat Research at Karnal. The Directorate of Wheat Research has a three storied building comprising two blocks. The western block accommodates laboratories and is centrally air-conditioned. The building accommodates five specialized disciplines namely Crop Improvement, Resource Management, Crop Protection, Quality and Basic Sciences and Statistics and Social Sciences.

3.1.1 Laboratory and field equipments

The Directorate of Wheat Research has well equipped laboratories in the disciplines of Crop Improvement, Resource Management, Quality, Biotechnology, Crop Protection, Malt Barley and Germplasm Unit.

Crop Improvement: Infra red thermometer, Chlorophyll meter, Grain counters, SPAD meter, Canopy analyser, Weather station, Nitrogen analyzer, Falling Number (for amylase enzyme analysis)

Biotechnology: Thermal cyclers, Centrifuges, Gel documentation, Lypholizer, Refrigerator, Deep freezes, Liquid Nitrogen containers, Vortex, Water bath etc.

Germplasm Unit: Two germplasm modules for conserving wheat and barley active collection for medium duration. Storage facilities also created at Dalang Maidan for conserving germplasm under natural conditions.

Crop Protection: BOD's, Refrigerators, Deep freeze, Gel documentation, Thermal cycler, Water purification system, Spectrophotometer, Shaker, Laminar flow, Centrifuges, Microscopes, Bio-fermentor, Poly houses and glass houses.

Quality: State of art facilities developed for quality testing includes NIR System (for quick and non-destructive analysis of protein content), Semolina mill, Semolina purifier, Pasta making unit, Gel Electrophoreses system, Alveograph, Mixograph, Farinograph, Rapid-Visco Analyzer, Glutomate, SKCS, Refrigerated centrifuge, Brabander senior mill, Cyclotec, Baking units for bread and biscuit making etc.

Resource Management: Atomic absorption spectrophotometer, Nitrogen analyzer, UV Spectrophotometer, Flame photometer, CHNS analyzer, Soil moisture meter, Green seeker, Leaf canopy analyser, Infra red thermometer and recording penetrometer *etc*.

Malt Barley: Micro-Malting System for barley (for malting the small size samples of 50 g from early generation breeding programme).

Field Facilities: The Directorate of Wheat Research has a well-developed experimental farm of 100 acres. The farm has well laid approach and underground irrigation system.

3.1.2 Library

The DWR Library at Karnal has now built up a large collection of books, journals, etc. to meet the immediate needs of information management and up gradation. The Library has more than 550 books and subscribes to over 40 periodicals including 7 abstracts, 19 foreign journals, 11 Indian periodicals and 3 bulletins. Procurement of dual facility mirror and storage server has helped on-line LAN users of the Directorate. Number of newsletters/ reports/ bulletins/ research highlights/ newspapers and other reading material from other organizations are also received. The DWR has been coming out with a number of publications including research/ technical bulletins, news letters, annual reports with ISSN and ISBN numbers which are mailed to all the wheat workers, research workers, scientists, universities and other institutions within the country and abroad.

3.1.3 Regional stations

The Regional Station of DWR at Flowerdale, Shimla was established in 1930 to serve as a national facility for monitoring wheat rust pathotypes, evaluating advanced generation material, postulating rust resistance genes in the tester lines and as a repository for maintenance of the wheat rust pathogens. A number of glass and poly-houses along with the guest-house facility have helped wheat rust workers to utilize this station in a very effective way for identification of resistant sources. A small biotech laboratory set-up is also created to study molecular biology aspects of the rust pathogen.

The Regional Station at Dalang Maidan lies in the district of Lahaul & Spiti, Himachal Pradesh. It is a summer nursery facility located at an altitude of 10,000 feet with twelve hectares of land, of which six hectares is cultivable. The office cum laboratory and guest-house facilities has been created for the benefit of research workers. Many AICW&BIP centres use this facility for raising wheat between May to October. Facilities of this station are utilized for advancing the generation, conservation of germplasm, making crosses during off-season and screening against yellow rust resistance.

3.2 Budget (Rs. in Lakhs)

3.2.1 Plan (DWR, Karnal and AICW&BIP)

	Year	DWR		AICW&BIP		Total	
		Allocation	Expenditure	Allocation	Expenditure	Allocation	Expenditure
IXPlan	**1997-98**	173.0	172.9	199.7	199.4	372.7	372.3
	1998-99	140.0	139.7	291.7	291.6	431.7	431.3
	1999-2000	175.0	174.9	328.5	328.4	503.5	503.3
	2000-01	120.0	120.0	371.0	371.0	491.0	491.0
	2001-02	131.0	131.0	404.0	404.0	535.0	535.0
Total		**739.0**	**738.5**	**1594.9**	**1594.4**	**2333.9**	**2332.9**
XPlan	**2002-03**	80.0	79.8	900.0	899.6	980.0	979.4
	2003-04	90.0	89.7	732.0	732.0	822.0	821.7
	2004-05	180.0	180.0	500.0	500.0	680.0	680.0
	2005-06	96.5	96.5	524.0	524.0	620.5	620.5
	2006-07	84.0	60.6	501.3	385.9	585.3	446.5
Total		**530.5**	**506.5**	**3157.3**	**3041.5**	**3687.8**	**3548.1**

3.2.2 Non-Plan

	Year	Allocation	Expenditure
VIII Plan	1992-93	78.0	77.9
	1993-94	85.0	84.9
	1994-95	90.0	90.0
	1995-96	101.0	99.2
	1996-97	133.5	133.5
Total		**487.5**	**485.4**
IX Plan	1997-98	168.0	164.6
	1998-99	246.0	239.1
	1999-2000	238.6	238.6
	2000-01	264.9	264.9
	2001-02	295.2	294.8
Total		**1212.7**	**1202.0**
X Plan	2002-03	309.0	308.4
	2003-04	350.0	350.0
	2004-05	384.0	384.0
	2005-06	444.0	441.3
	2006-07	432.0	333.2
Total		**1919.0**	**1816.9**

3.3 Manpower (As on Jan., 2007)

S. No	Manpower	Sanctioned Strength	In position	DWR Karnal	DWR R.S. Shimla	DWR R.S. Lahaul Spiti
1	Scientific	50+1*	40+1	36+1	4	0
2	Administrative	23	23	20	2	1
3	Technical	5	49	42	5	2
4	Supporting	34	33	19	12	2
Grand Total		163+1	145+1	117+1	23	5

**RMP*

4. SALIENT RESEARCH ACHIEVEMENTS

4.1 Crop Improvement

4.1.1 Development of improved varieties

The All India Coordinated Wheat and Barley Improvement Project conducts a number of well-organized multilocation yield trials for different production conditions. This testing has contributed in release of 312 wheat varieties suited to different environments and growing situations. The prominent ones are Kalyansona, Sonalika, Lerma Rojo, Chhoti Lerma, Arjun, C 306, WL 711, UP 262, LOK 1, HUW 206, HUW 234, HD 2189, HD 2329, HD 2285, Raj 3077, PBW 34, WH 147, Sujata, VL 421, VL 616, HS 240, HS 295, UP 2338, PBW 343, PBW 502, GW 322, GW 496, Raj 3765 in bread wheat and Raj 1555, PBW 34, HI 8381, HI 8498, PDW 233 and PDW 291 in durum wheat. Varieties have been developed and released for high altitude areas, suppressive (salt affected) soils, harsh conditions (central India), and hot and humid environments prevailing in north east. Varieties have also been released for moisture stress conditions, both in bread and durum wheats. Many varieties developed by the project are also under cultivation in many of the foreign countries.

Wheat and triticale varieties released in India during 1965-2006

Species	Released by		Total
	CVRC	SVRC	
Bread wheat (*Triticum aestivum*)	175	95	270
Durum wheat (*Triticum durum*)	17	18	35
Dicoccum wheat (*Triticum dicoccum*)	04	-	04
Triticale	01	02	03

4.1.2 National efforts in churning the gene pool

Every year, near about 10,000 crosses are made as part of a massive national effort in increasing productivity of *Triticum* spp. Nearly 18 thousand lines of bread wheat and 8 thousand in durum wheat are maintained by different centres, with inevitable duplicates. About 75% of the co-ordinated efforts are focused on irrigated wheat. Improvement of bread wheat draws highest attention i.e. 82 percent, while durum and other spp. including triticale draw 15 and 3 percent of the total efforts, respectively. About 450 varietal trials are conducted every year to evaluate around 500 test entries under various environmental conditions. Another 200 trials/nurseries are organized to develop improved crop production and protection technologies. The international nurseries/trials include various material received from CIMMYT, ICARDA and other international programmes.

4.1.3 Up grading of the evaluation system

The system of varietal evaluation was restructured through incorporation of National Initial Varietal Trials (NIVTs). It has been useful in disseminating the elite germplasm across the zones and many varieties have already been released across the zones within few years of adopting this system. PBW 443 from PAU, Ludhiana, DBW 14 from DWR, Karnal and HW 2045 from IARI, Wellington were released for NEPZ. Similarly varieties developed at Kanpur (K 9644), Durgapura (Raj 4037), Varanasi (HUW 510), Ludhiana (PBW 533) and Vijapur (GW 322) have been found suitable for the Penninsular Zone.

Some important wheat varieties released during 1990-2006

Zone	Production conditions		
	Normal sown	Late sown	Rainfed
North Western Plains Zone			
Bread wheat	WH 542, PBW 343, PBW 502, UP 2338, HD 2687, DBW 17, Raj 3077*, KRL-19*	DBW 16, PBW 373 UP 2338, UP 2425, RAJ 3765	PBW 299 PBW 396, WH 533
Durum	PDW 291, PBW 34, PDW 215, PDW 233, WH 896		
North Eastern Plains Zone			
Bread wheat	K 8804, K 9107, HUW 468, PBW 443, DL 784-3, K 0307, HP 1731, HP 1761, HD 2733, NW 1012, HD 2824, Raj 3077*, KRL-19*	DL 784-3, HD 2643, HP 1633,HP 1744, NW 1014, HW 2045, DBW 14, NW 2036	K 8962, K 9465, K 8027, HD 2888
Central Zone			
Bread wheat	GW 190, GW 273, GW 322, GW 366, Raj 3077*, KRL-19*	GW 173, DL 788-2 MP 4010, HD 2864	HW 2004, JWS 17, HI 1500, HI 1531
Durum	HI 8381, HI 8498	-	HD 4672, HI 8627
Dicoccum	DDK 1001, DDK 1025, DDK 1009	-	-
Peninsular Zone			
Bread wheat	HD 2189, DWR 162, GW 322, MACS 2496, RAJ 4037, NIAW 917	DWR 195, HD 2501, NIAW 34, HD 2833, HUW 510, PBW 533	K 9644, HD 2781
Durum	MACS 2846	-	AKDW 2997-16
Dicoccum	DDK 1001, DDK 1009, DDK 1025	-	-
Northern Hills Zone			
Bread wheat	VL 738, VL 804, HS 240	HS 295, HS 420	VL 738, HPW 42, HS 365, VL829, VL832, SKW 196 HS 375 (summer)
Triticale	-	-	DT 46
Southern Hills Zone			
Bread wheat	HUW 318, HW 1085, HW 2044	-	-

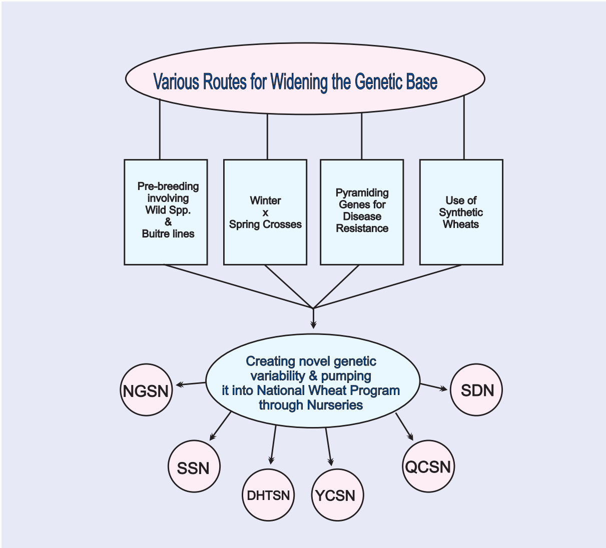
*: Sodic soils

4.1.4 Biodiversity and genetic resources

The Germplasm Resource Unit at the Directorate maintains local collections, identified donors from trials and nurseries, genetic and cyto-genetic stocks, wild species and close relatives, and exotic selections for their utilization in the breeding programme. Twenty species each of *Triticum* and *Aegilops* are also being maintained at DWR Karnal, PAU Ludhiana, ARI Pune and IARI, New Delhi. In total, 84 genetic stocks of wheat have been registered with NBPGR for various traits. DWR, Karnal has been instrumental in registration of Hindi 62, Halna, Kharchia Local, HD 29, HD 30, Bawaji, Giant 3, MBL 2, MBL 5, Harit-1, DW1001, DBP-01-06, Nap Hal, FKW 1, FKW 3 and FKW 4 for various useful traits, while DWR Research Station, Shimla developed and registered six stocks viz. FLW 1, FLW 2, FLW 3, FLW 4, FLW 6 and FLW 8 for various rust resistant genes.

4.1.5 Germplasm enrichment and sharing

The diverse material coming out of different programmes, including genetic stocks, yield components and quality component lines etc.are shared with wheat breeding centres in the country. The nurseries constituted each year have also helped in registration of genetic stocks. Besides these national nurseries, two more nurseries EIGN I and EIGN II are also constituted which involve selected exotic *aestivum* and *durum* material.



DWR is creating and sharing the germplasm across the country

4.1.6 Hybrid wheat programme

The approach to develop hybrid in wheat was executed at the Directorate and various other centres through a network project and the role of CHA and CMS was envisaged for the futuristic approach, especially for a quantum jump in the wheat bowl of the country i.e. NWPZ. Achievements and the opportunities through this approach are listed below.

CHA Approach

1. The highest pooled standard heterosis over the best check in NWPZ and PZ was 10.2% and 29.2%, respectively and it was 27.4% over all zones. 23 hybrids were shortlisted with high standard heterosis over the best check and superior quality parameters.
2. Technology standardized for inducing sterility like “Improved DWR CHA Spray System” and fabrication of a seed drill for simultaneous sowing of male and female parents.
3. Among 96 CHA molecules evaluated since 1995, five of them viz. CH9701, CH9702, CH9708, CH9831 and CH9832 exhibited acceptable levels of male sterility.
4. Most suitable stage for CHA spray was 10-15mm of spike length, which is attained 50-60 days after germination in most of the genotypes.
5. Patent application for CHA used in hybrid wheat seed production has been submitted for an Indian (Date of Application: 16.9.2002, Application Serial No.: 0939/DEL/2002) and US patent (Date of Application: 28.3.2002, Application Serial No.: 10/113215).

CMS Approach

1. Cytoplasm from at least 4 sources (*Triticum timopheevi, T. araraticum, Ae. caudata* and *Ae. speltoides*) is in use to develop hybrid wheat at PAU and IARI. In addition, IARI also utilized *T. zhukovskyi* in the programme.

2. Ten cytoplasmic male sterile lines were developed at IARI and 50 lines are at various levels of backcrossing at PAU, Ludhiana. In addition, 25 CMS lines have been received from CIMMYT, Mexico. Fertility restoration was near complete (above 80%) with *T. timopheevi*.
3. No apparent adverse effect was observed on plant morphology by *T. araraticum* and *Ae. speltoides* based CMS lines.

4.1.7 Strategy to deploy new genes for rust resistance

The AICW&BIP has strategy of replacing the rust susceptible varieties with new improved types. As an alternative to the ruling variety of 90's, alternate varieties for the NWPZ like UP 2338, WH 542, PBW 343, PBW 502 and DBW 17 have been released. These varieties have inbuilt resistance to rust and other wheat diseases with superior quality and agronomic traits. To replace HD 2285 for irrigated late sown condition, the varieties like UP 2338, PBW 373, DBW 16, UP 2425 and Raj 3765 have been released. These genotypes possess adequate levels of rust resistance under late sown situations. Many new wheat varieties viz. Sonali, NW 1014, K 9107, HW 2045, PBW 343, HD 2824, K 9107, HD 2733, HD 2643, HUW 468, DBW 14 and NW 2036 have been recommended for the NEPZ region. New varieties like GW 273, GW 322, GW 496, HD 2864 and MP 4010 etc. have been developed and recommended as an alternate to popular but susceptible variety Lok 1 of central India.

4.1.8 Molecular mapping and molecular assisted selection

The recent developments in plant biotechnology including molecular mapping and marker-assisted selection (MAS), offer a choice of options for targeted utilization of traits/ genes. The most important activity for any molecular biology work is the availability of mapping populations for various traits of agronomic /economic importance. Indian wheat programme visualized this and several mapping populations for various traits are either already available or are under process. Some of them are listed below.

Bread quality	HI 977 (good) x HD 2329 (poor)
Grain hardness	NP 4 (hard) X HB 208 (soft)
Grain hardness	Chinese spring (soft) x PBW 343 (hard)
Chapati quality	C 306 (good) x WH 157 (poor)
Gluten strength	HD 4676 (high) x NIDW 15 (low)
KB resistance	HD 29 (resistant) x HD 2009 (susceptible)
FHB resistant	Toronit (tolerant) x Lona (susceptible)
Yr16 gene tagging	Cappelle Desprez (source) x PBW 343 (susceptible)
Lr34 gene tagging	HD 2189 (carrier) x Agra Local (non-carrier)
Thermal tolerance	HUW 510 (susceptible) x WH 730 (tolerant)
Leaf blight resistance	Sonalika (susceptible) x BH 1146 (resistant)
Leaf blight resistance	Kanchan (suceptible) x Chiriya 1 (resistant)
Leaf blight resistance	HUW 234 (susceptible) x YM#6 (resistant)
Beta-glucan content	UB 466 (low) x ICARDA 54 (high)
Beta-glucan content	UB 466 (low) x K 647 (high)
Aphid resistance	EB 921 (resistant) x Alfa 93(susceptible)
Aphid resistance	BCU 390 (resistant) x Alfa 93(susceptible)

Two diagnostic markers, one for stripe rust resistance gene *Yr10* and one for *HMW glue 8* subunits were developed by the molecular biology programme at the DWR. Two genotypes MBL-2 and MBL-5, selected out of the RILs showing high grain protein (approximately 14%) have been registered as Genetic Stocks by the NBPGR.

A research programme in form of a "Network project on gene pyramiding for resistance to multiple biotic stresses in crops" has been initiated with the objective of improving existing cultivars. Some of the genes that are targeted to be pyramided are *Lr24*, *Lr28*, *Lr35* and *Lr37* for leaf rust and *Yr10* and *Yr15* for stripe rust resistance. The varieties which have been taken as recipients are LOK 1, HUW 234, PBW 343, HD 2687, HD 2733 and WH 147. MAS was found quite effective in segregating the genotypes with and without these genes for further selection/backcrossing. BC_1F_1 plants with *Lr24*, *Lr28*, *Lr37* and *Yr10* in different background were selected and backcrossed with the recipient parents. Similarly parental lines C 306, VL 421, NI 5439 and the donor lines *viz.*, WH 542/* *Yr*Moro(*Yr10*), WH 542/ **Yr15* (*Yr15*), PBW 343/*Tc *Lr37* (*Lr37*) and for *Lr34* gene,

BW 11 and HS 240 were used for crossing. The individual BC_1F_1 plants selected through marker assisted selection were utilized for further backcrossing. About 50 genotypes postulated to carry *Lr34* and non-carriers of this gene were screened with 7 micro satellite and 3 EST based markers (reported to be on 7DS and in close vicinity of *Lr34* gene). Marker-gene analysis was also performed. A population has also been developed out of the cross HD 2189 x Agra Local for complimenting the *Lr34* fine mapping work.

With an objective to prepare Indian wheat programme to fight back the possible menace of Ug99 pathotype of stem rust, effort was made to identify lines with more than one effective stem rust resistant gene (*Sr24* and *Sr26)* for utilization by the breeders. A set of parental lines along with their respective Near Isogenic Lines (NILs) having *Sr26* and *Sr24* developed at the IARI Regional Station, Wellington, Tamil Nadu were subjected to marker assisted screening with separate markers, linked to *Sr24* and *Sr26.* When tested with marker linked to *Lr24*, results confirmed tight linkage between *Lr24* and *Sr24* as none of the NILs and other 145 genotypes having *Lr24* tested, showed breakage of linkage between these genes.

4.1.9 Tolerance against abiotic stresses

4.1.9.1 Heat stress

Wheat is sown late on considerable area in north-western and north-eastern plains of India due to high cropping intensity and delayed harvest of previous crop. As a result, the crop gets exposed to higher ambient temperatures at the time of grain filling, which cause significant reduction in productivity. Studies conducted with advanced wheat genotypes have helped in characterizing the environments in terms of weather parameters and also in terms of plant responses.

- It has been conclusively shown that biomass production is a key factor in high grain yield performance under late sown high temperature environments.
- KI induced leaf senescence can be used to assess variability in stem reserve utilization if used in low concentration and avoiding spikes during spray.
- Efficient partitioning of assimilates, more number of tillers and number of grains/spike contribute to superiority of Raj 3765, Halna, NIAW 34, NW 1014, Tepoka, WH 730, CBW 12,that can be used as source of heat tolerance.

4.1.9.2 Water logging

Water logging situations arise in northern India due to incessant rains of high intensity and short duration at early stages of wheat growth and development. The intensity of water logging is high when rain occurs immediately after irrigation. In northern India alone, appox. 2.5 m ha of wheat is affected by irregular water logging which is more pronounced in sodic soils. Hence, efforts are being made to identify wheat genotypes with increased tolerance to transient flood or water logging at initial stages of crop growth.

- Studies revealed considerable genetic variation in response to water logging and the genotypes showing yield reduction up to 15% have been noted as tolerant types.
- HD 2329 showed relatively high tolerance to water logging
- Some of the doubled haploid lines generated by using water logging tolerant Ducula-4 and Brootton (Australian genotype) have been found tolerant to water logging.
- Sodium and potassium ratio is important factor in determining water logging tolerance in sodic soils.

4.1.10 Seed dynamics

The identification of wheat varieties originating from identical/ similar parentage have been discouraged to ensure genetic diversity in Indian wheat varieties. The genetic diversity among wheat varieties under commercial cultivation will serve as a safeguard from any possible pathogenic hazard. Cultivation of a large number of varieties with diverse pedigree in breeder seed programme, will hinder any disease epidemic. During 1967 to 1977, there were only two varieties namely Sonalika and Kalyansona which occupied largest area in the country. In 1984-85 there were 62 wheat varieties under breeder seed programme out of which indents of 11 varieties were higher than 50 quintals. By 1994-95, many of the varieties like HUW 234, HD 2285, WH 542 and HD 2329 were added in the list to further increase in diversity in wheat varieties. Now many new varieties like PBW 502, UP 2338, Raj 3765, HI 8498, K 9107, HS 295, VL 804, GW 322, PBW 373, PBW 343, HUW 468, HW 2045, HD 2733, DBW 14, DBW 16, DBW 17 and NW 2036 have been added in the seed production chain. For quicker replacement of old, disease susceptible or otherwise uneconomical varieties, the central research institutes, state agricultural universities and state departments of agriculture should develop a strategy to distribute small quantity of newly identified varieties.

4.2 Resource Management

When the dwarf wheat varieties were introduced in late 60’s, it was perceived that the agronomic practices have to undergo a change since the practices followed earlier were found to be inappropriate. Package of practices for growing dwarf wheats and harvesting procedures were then reinvestigated and standardized.

4.2.1 Irrigation management

Area under irrigated wheat has increased with popularization of the Mexican wheat’s. At present, nearly 95% of the area sown to wheat in Punjab and Haryana has assured irrigation. The agronomy group has demonstrated that irrigating wheat at crown root initiation stage (CRI) which is approximately 21days after sowing is most crucial. If water is available subsequently, it was advised to utilise the irrigation during tillering and at flowering stages. Using the FIRB technology, it had been demonstrated that water saving to the extent of about 30 percent could be achieved for wheat cultivation.

4.2.2 Fertilizer management

The time and placement of fertilizer is another area where significant progress was made. It was demonstrated that 120 kg nitrogen, 60 kg phosphorus and 30 kg potash per hectare were required for optimum productivity. The N was to be applied in two split doses of 60 kg as basal and the remaining 60 kg at first irrigation and full phosphorus and potash to be applied as basal. Recently, the new wheat varieties have responded up to 180 kg N/ha with optima dose around 150 kg/ha. In the Indo-Gangetic plains, application of zinc @ 25kg/ha in rice-wheat system was found to increase the yield substantially. Recently, the use of sulphur has been found beneficial for enhancing the productivity as well as the grain protein content of wheat. Response to Mn (pockets in the Indo-Gangetic plains) and boron (eastern and far eastern region) has also been realized.

4.2.3 Weed management

The high cost of inputs brought to light the importance of weed management since weeds remove both soil moisture and nutrients. The AICW&BIP developed suitable chemical weed control strategy, and standardized the dosage and the time of application. Isoproturon recommended in early eighties provided broad spectrum weed control for more than a decade. However, sole dependence on this herbicide resulted in the evolution of isoproturon resistance in *Phalaris minor.* To curtail the yield reduction caused by isoproturon resistant *P. minor*, clodinafop, fenoxaprop and sulfosulfuron have been recommended.

4.2.4 New resource conservation technologies

For sustaining the R/W system in the Indo-Gangetic plains, there was an urgent need to economise the use of natural resources as well as enhance the organic carbon content in the soil. The Zero-Tillage technology emerged as cost effective measure and farmers responded to it in many parts of NWPZ and NEPZ. More than 3000 rupees per ha can be saved through reduced ploughing cost and zero till sowing after the harvest of rice. The other RCTs which can be adopted by the farmers in near future are FIRB, Rotary Till Drill, Strip Till Drill and Laser Leveling. For seeding into surface retained loose crop residues, second generation machines like rotary disc drill and happy seeder can be found useful. Adopting conservation agriculture (seeding into surface retained residues) will help in improving the sustainability of soil and water resources by avoiding burning crop residue.

4.2.5 Diversification/intensification of Rice-Wheat system

Rice-wheat is a major cropping sequence and due to the exhaustive nature of these crops, soil fertility is depleting leading to declining factor productivity. Therefore, need was felt to replace one crop by a short duration legume. Some of the remunerative alternate cropping systems tuned to new tillage options were rice-vegetable pea-winter maize, rice-wheat-moong, rice-vegetable pea (FIRBS)-wheat (FIRBS), pigeon pea (FIRBS)-wheat (FIRBS)-rice-wheat (FIRBS) and, rice-mustard (FIRBS)-green gram (FIRBS)-rice-wheat (FIRBS).

4.3 Crop Protection

As a part of the wheat improvement programme, a continuous monitoring has been done to map the prevalence and distribution of the black (*Puccinia graminis tritici*), brown (*P. recondita tritici*) and yellow rust (*P. striiformis*) virulence. The avirulence/ virulence genes present in the pathogen are characterized by analyzing more than 2000 rust samples per year and by inoculating them on differentials possessing different resistance genes. During crop season, Wheat Crop Health Newsletter is issued every month. Information over years shows that there is a difference in the brown rust and yellow rust virulence pattern between the wheat growing zones arising mainly due to gene deployment and the varietal diversification programme.

There is a strong association between distribution pattern of brown rust and the type of host varieties grown. During the past few years, there is a quick appearance of new pathotypes able to match gene *Lr* 26. Various genetic stocks and other wheat lines have been identified possessing resistance to the three wheat rusts and minor diseases such as foliar blight, loose smut and Karnal bunt. Brown rust race distribution frequency at national level shows that pathotypes of race groups 104 and 12 have reduced whereas race 77 has increased steeply. The distribution pattern of the virulences gives the much needed indications for executing the resistant gene deployment.

Addition of new pathotypes in Indian rust flora over years

Time Span	Black rust	Brown rust	Yellow rust
Till 1975	11, 11A, 14, 15, 17, 21, 24, 24A, 34, 34-1, 40, 42	10, 11, 12, 12A, 17, 20, 63, 77, 106, 107, 108, 162	13, 14, 19, 20, 31, 38A
1976-80	21-1, 40A, 21A-2	77-A, 104	14A, 20A, 38A, I
1981-85	117A-1	77-A, 114-A, 104B, 12-2	K
1986-90	40-1, 117-1	77-1, 77-2, 77-3, 12-1, 12-3, 12-4, 107-1, 108-1	L, N, P
1991-95	117-2, 117-3, 117-4, 117-5, 117-6	77-4, 77-5, 104-2, 104-3	T, U, CI, CII, CIII
1996-2K	-	77-6, 77-7	46S 119
2001-06	184-1, 58G13	77-8,12-5, 12-6, 162-1 162-2, 162-3, 5R9-7	78S84

4.3.1 Creating artificial epiphytotic conditions for rust screening

The Regional Station at Flowerdale, Shimla. supplies the nucleus inoculum to various active breeding programmes for proper evaluation of the material and also acts as a custodian for maintenance of all the pathotypes of *Puccinia* infecting wheat, barley and oats. Centre has cryopreserved reference seed of all useful lines possessing seedling resistance to wheat rust.

4.3.2 Karnal bunt

In mid 1970's, Karnal bunt became a major production constraint and the programme quickly developed a procedure for the rapid isolation of *Neovossia indica.* Technology for mass production of the pathogen spores and procedure for field inoculation and the post-inoculation was developed for creating disease. It facilitated in conducting multi-location trials to screen the wheat material and develop lines which are tolerant to KB. Among improved varieties, PDW 215, PDW 233, WH 896 in durum, TL 1210 in triticale, and WL 1562, PBW 154 and HD 2281 in bread wheat possess high degree of KB tolerance. Three variants of *Tilletia indica* causing Karnal bunt infection have been identified with the help of polymorphism in mycelial proteins.

4.3.3 Head scab

Six *Fusarium* spp. viz., *graminearum*, *moniliforme*, *oxysporum*, *equiseti*, *semitectum* and *solani* were found associated with the head scab in Punjab, Tamil Nadu and Himachal Pradesh. Inter and intra species specific variation could also be noticed. *F. graminearum* isolates of Dalang Maidan (HP) and Wellington were found more aggressive than that of Punjab (Ludhiana & Gurdaspur). RAPD was used to study genetic variation in natural pathogen populations of *F. graminearum* and other *Fusarium* spp. associated with the disease. This study has shown that there is a considerable genotypic variability among *F. graminearum* isolates obtained from infected wheat earheads from different geographic regions of India.

4.3.4 Leaf blight complex

Rating scale and techniques for the rapid evaluation of wheat genotypes against *B. sorokiniana* and its toxin 'Helminthosporol' were developed. 13 distinct isolates of *B. sorokiniana* have been characterized in India. RAPD was used to study the genetic variation among *Bipolaris sorokiniana* isolates of different geographic regions of India.

4.3.5 Nematode resistance

A large number of lines now under evaluation possess multiple disease resistance and this is a complement to the interdisciplinary approach being adopted in breeding program. Wheat variety AUS15854 has been identified to be immune to the *Heterodera avenae* and the Durgapura centre has initiated efforts to utilize it.

4.3.6 Insect pest resistance

Major insect pest problems in wheat are the termites, shootfly, mite, aphids, root aphids and storage pests. Resistant lines have been identified for shootfly (PDW 215, Raj 1555, Raj 3190, HUW 234, PDW 213, HD 2307, UPD 8, HI 8381) and brown mite (A-9-30-1, C 306, DT 18, HDR 132, HPW 42, WH 589, WH 610, WH 629).

4.3.7 Integrated pest management

The IPM in wheat was applied at DWR Farm and the adjoining two villages (Taraori and Darar). The yield advantage in different villages and different varieties has been in the range of 9 to 15 per cent consistently over the years, which has encouraged the farmers to take up this technology on large scale.

4.3.8 Chemical control as emergency measure

The programme has identified several fungicides for the control of rusts, loose smut, Karnal bunt and foot rots. Though use of pesticides in wheat is low, but when seen as a wheat based cropping system, nearly 12% of the pesticides sold in India are meant for Rice-Wheat system, while 30% go to cotton-wheat system.

4.4 Wheat Quality

The main emphasis has been in understanding biochemical/genetic basis of grain quality traits and evaluating quality of the entries tested in the coordinated system. Based on several years of quality analyses, several varieties have been identified for different wheat products. Promising varieties have also been identified for individual quality parameters like protein content, sedimentation value, extraction rate, wet/dry gluten, gluten index, beta-carotene, iron, zinc, copper and manganese etc., which can be used in the breeding programme for the improvement of wheat quality. The prospects of combining quality with yield components has been critically examined.

Chapati	C 306, Raj 3765, HD 2285, PBW 226, PBW 175, PBW 373, K 8027, LOK 1, MACS 6145, K 9107, UP 262, NW 1014, HUW 234, HUW 533, HD 2833, Sujata, HI 1500, HW 2004, DL-788-2, GW 173, GW 273, GW 322, GW 496
Bread	HS 240, VL 738, PBW 396, HD 277, HD 2733, NW 2036, LOK 1, GW 173, GW 190, GW 496, HI977, HD 2189, HD 2501, DWR 162, DWR 195, PBW 533
Biscuit	Sonalika, UP 2425
Pasta	PDW 233, WH 896, PBW 34, HI 8498, HD 4672, MACS 2846, Raj 1555, A-9-30-1, DDK 1009, NP 200

The quality requirements for each end-product have been defined and grain hardness, protein content and gluten strength have been noted as key components in wheat quality. Molecular markers associated with gluten strength in durum wheat have been identified using recombinant inbred lines. Microlevel tests useful in breeding for evaluating early segregating generations such as solvent retention capacities and sedimentation tests have been developed for improving wheat quality. Germplasm lines with desirable quality traits have been identified and being used in breeding programme. Nap Hal, the unique Indian land race of wheat has been well characterized at molecular and rheological level and registered at National Gene bank for use in biscuit making quality.

4.5 Statistical Processing and Computer Applications

Advancement of computer technology has been utilized for entire analysis of data being processed at the Directorate. New softwares have been developed for the statistical processing of data. To maintain data and the results on electronic media for easy and fast retrieval of information, database structures along with their friendly menu based packages like WHIP, WREMP, Qual Bas have been developed.

New Softwares

Software	Design	Purpose
LATT	Lattice	Analysis of NIVTs data
AUG	Augmented	Analysis of Nurseries data
SPLIT	Split Plot	Analysis of data for Resource Management programme
AGRB	R.B.D.	Analysis of data for Resource Management programme
TCM1	CRBD	Centre-wise analysis of AVTs data
WOUT	Pooling	To pool the results and generate the report

4.6 Extension Activities and Frontline Demonstrations (FLDs)

New technologies have been taken to the farmers through FLDs to demonstrate the worth of new varieties and highlighting the role of new RCTs, balanced use of fertilizers, combined use of organic and inorganic fertilizers etc. Besides helping in the spread of new varieties among the farmers, the FLDs have clearly brought out the existing yield gap in different wheat growing zones in the country. By bridging the existing yield gap, an additional production equal to 24.7 m t can be added to raise the total production of wheat to 95 m t.

Technologies demonstrated in FLD's	
Wheat	**Barley**
• Improved varieties	• Improved varieties
• Production of quality seed	• Production and use of quality seed
• Optimising irrigation schedule and efficient water usage	• Irrigation management
• Fertilizer dose and method of application	• Fertiliser application
• Effective weed control (e.g. *Phalaris minor*)	• Seed treatment
• Plant Protection measures for loose smut	• Plant protection measures
• Zero tillage sowing by Pantnagar Zero-Till-Seed Drill to minimize the cost of cultivation	• Line Sowing
• Production under suppressive environments (salinity, rainfed, cold tolerance)	• Production under suppressive environments (salinity, rainfed, cold tolerance etc.)

4.6.1 Cost of cultivation

Utilizing economic data for frontline demonstrations conducted by various coordinating centres during 2005-06, cost of cultivation was estimated for different zones and it was noted that raising wheat in NWPZ and NEPZ is resource intensive but still it is more remunerative since the cost of production per Kg wheat is less.

Cost of cultivation across zones (Rs./ha)

Head	CZ	SHZ	NHZ	PZ	NEPZ	NWPZ
Working cost	9252	4521	9011	10536	15125	16025
Cost of cultivation	11546	5642	11245	13147	18876	19998
Total Returns	26638	10918	15451	29071	31152	38219

4.6.2 Adoption of new technologies

Feed back received through FLD's has helped a great deal in realizing constraints in rapid adoption of new production technologies. The study has revealed the following points:

- Even though majority of the farmers use their own seed without any treatment but purchase of good quality seed has also started gaining momentum.
- Zero tillage has been adopted by a significant number of farmers and they are inclined towards adoption of new RCTs also.
- Grain yield followed by disease resistance and crop duration were the main parameters selected by the farmers to select a variety.
- All the farmers in Haryana and Punjab have adopted the high yielding wheat varieties; however, the rate of varietal adoption was slow in other wheat growing areas.
- FIRBS planting saved 25-30% water as compared to conventional tillage.
- To draw maximum advantage of high yielding varieties, farmers are getting interested in use of pesticides, herbicides, sprinklers and farm machinery.
- MSP policy has prompted farmers to bring maximum produce in grain market and contribute in national food security.
- Contract farming and value addition has attracted lot of farmers to raise cash benefit from wheat and barley crops.

4.7 Barley Improvement

4.7.1 New semi-dwarf plant type

Traditionally, barley is seen as low input crop for stress conditions and the tall native plant types were common earlier. The barley network programme has been successful in developing semi dwarf, management responsive, lodging resistant cultivars with improved plant type, like erect leaves, compact plant with thick stem and stiff straw. The varieties like PL 426, RD 2035, RD 2052, RD 2552, RD 2592, K 508, K 551, BCU 73, BH 393, DWR 28 and DWRUB 52 are examples for such plant type. Besides, thirteen genetic stocks have also been registered for different useful attributes.

4.7.2 Resistance to diseases/ pests

A number of varieties with built in resistance to stripe rust and leaf blights have been developed viz., DL 88, ALFA 93, HBL 113, RD 2503, RD 2508, RD 2552, NDB 1173, Gopi, DWR 28 and DWRUB 52. High yielding varieties RD 2035 and RD 2052 (nematode resistant) demonstrate the success achieved in such efforts. A number of genetic stocks having superior resistance to rusts and leaf blights have also been registered, which can be utilized for barley improvement.

4.7.3 Rainfed ecosystem

For the Indo-Gangatic plains, varieties like K 560, K 603, RD 2508, RD 2624 and RD 2660 give good yields (3.0 to 3.5 t/ha). For northern hills, both hulled and hulless varieties like BHS 169, BHS 352, VLB-1, VLB56, HBL 113, HBL 276 and VLB 56 are resistant to rusts and can give about 2.5 t/ha grain yield in nutritionally poor soils. Similarly JB 58 has been released in MP for low fertility rainfed cultivation in central zone.

Malt barley varieties for irrigated timely sown conditions for different zones

Objectives	Variety	Year	Area of Adaptation
Two-row barley	Alfa 93	1994	NWPZ
	BCU 73	1997	NWP, NEPZ, PZ
	DWR 28	2002	NWPZ
	DWRUB 52	2006	NWPZ
Six-row barley	RD 2503	1997	NWPZ
	K 551	1997	NEPZ
	DL 88	1997	PZ

4.7.4 Dual purpose barley

The potential of barely as dual purpose crop (one cut for green fodder and regenerated crop for grain) in dry areas of northern plains has been realized through joint efforts of AICRP on forage crops, Jhansi and DWR Karnal. Varieties RD 2035 and RD 2552 can be utilized with about 200 q/ha green fodder as well as 2.5 to 3.0 ton of grain yield in northern plains. Similarly, barley can be grown for dual purpose in higher hills and varieties BH 169 and HBL 276 are recommended for such type of cultivation under rainfed conditions.

4.7.5 Value addition

Earlier introduced barley varieties, ALFA 93, BCU 73 and newly improved varieties like RD 2503 (NWPZ), K 551 (NEPZ/NWPZ) and DL 88 (PZ) are good in malt quality. New varieties like DWR 28, developed through 2x6 row type hybridization, DWRUB 52 and RD 2668 are new ventures in this direction. Under the first private-public collaboration programme DWRUB 52, two-row malt barley with equivalent yield levels to that of six-row, has been developed for NWPZ.

Barley varieties released during 1990-2006

Major objectives	Variety
Malt barley, irrigated	Alfa 93*, BCU 73*, RD 2503, K 551, DL 88, DWR 28*, DWRUB 52, RD 2668
Feed/ fodder, irrigated	RD 2035, RD 2503, RD 2552, BH 393, K 329,K 409, K 508, Marinara Barley-2, RD 2592, PL 426
Feed/ fodder, rainfed	RD 2508, K 560, K 603, PL 419, JB 58, RD 2624, RD 2660
Salt tolerance, irrigated	DL 88, RD 2552, Marinara Barley-1, Narendra Barley-3, NDB 1173
Cyst nematode resistance	RD 2035, RD 2052
Tolerance to rust, cold and moisture stress (hills)	HBL 113*, HBL 276**, BHS 352**, HBL 316, VLB 56
Food/ huskless, rainfed	Geetanjali (K 1149)**

*2R barley, ** huskless barley

5. IMPACT ASSESSMENT

A major impact of wheat production technology developed through wheat research in India can be realized by working out the farm area saved for other land uses. During 1965, India was producing 12.3 m t of wheat from an area of 13.4 m ha with the productivity level of 0.91 t/ha but during 2002 we produced 71.8 m t of wheat from an area of only 25.9 m ha. This was possible by increasing the productivity level up to 2.77 t/ha. If there had not been any increase in the productivity after 1965, we would have needed 78 million hectares of area for producing 71.8 m t of wheat. In this way, over 50 m ha of area has been saved due to enhancing the productivity of wheat varieties.

5.1 Wheat for Robust National Economy

The impact of wheat research can be judged from the fact that the country could produce extra wheat to the tune of 1159 m t till 2003-04 over the base year of 1964-65. The extra wheat so produced has generated extra money equal to 3, 91,152 million of rupees. As a result, the financial position of wheat growers has improved tremendously and an era of prosperity was ushered. Large number of industries providing fertilizers, weedicides, pesticides, agricultural machinery, and seed producing agencies were set up in the country which created new jobs and business opportunities in rural and urban sectors. Above all, it has brought in a sense of self- respect, pride and honour to India and Indian nationals.

5.2 More Income to the Farmers

Resource conservation and zero tillage technologies have contributed in lowering the input cost. Adding high productivity gains over it have proved instrumental in raising farmer's income. Adoption of mechanized farming, increase in tractors and tube wells can be rated good indicators of increased income. The cropping system based varieties have increased cropping intensity roping in additional income. The importance of global trade has also been realized by the farmers and there is enough signal of growing interest of industry to involve farming community in contract farming.

5.3 More Wheat and Product Range

Even though the Indian wheat is traditionally known for *chapati*, there are now varieties suitable for various products like bread, biscuit, semolina, pasta, macaroni, etc. India is rated as the second largest biscuit industry in the world. The millers, fast food parlours, bakers, even the transporters have gained tremendously from efforts in value addition.

The process of social and economic development has developed a sense of competitiveness among the people at large and urbanites in particular. These days earning by each and every one in a family has become a way of thinking. This arduous exercise leaves very little time for the working class to get their meals with traditional approach. More and more people are therefore, now going for instant foods. Preference for low calorie foods is slowly developing among the urbanites that are health conscious. Demand for baby foods and pasta products as well as baked foods are on the rise in the cities. Affluent people are finding convenient food as easy source of their daily meals. Therefore, there is a big scope for converting the wheat grain into value addition.

5.4 Wheat Nutrition and Human Health

There lies good scope of targeting wheat not only for nutrition security but also a commodity to impart good health. *T. dicoccum* has already established itself as a good cereal crop for diabetic patients. Change in bran proportion in flour makes it more suitable for patients with chronic constipation. Wheat being the basic ingredient of daily diets has enough scope to be manipulated for making different instant foods by supplementing with nutrients/ vitamins/ phospholipids etc. to contain various syndromes likes hypertension, diabetes, bone and skin abnormalities. Since a large section of people now prefer local or herbal products to cure various ailments, it may prove quite rewarding to explore the possibilities of any threat or benefits that wheat can cause for human health.

6. SCENARIO AND SWOT ANALYSIS

6.1 Wheat

6.1.1 Global ranking in wheat production

India ranks the second largest wheat-producing nation in the world and contributes approximately 11.7% to the world wheat production from 12% global area. China is the largest producer of wheat with 11 % and 15% contribution respectively, in area and production.

Major wheat growing countries and their production (mt)

Country	1993-94	1994-95	1995-96	2000-01	2002-05
Algeria	1.10	0.75	1.25	2.01	2.97
Argentina	9.70	11.30	8.60	15.50	13.50
Australia	16.48	8.90	7.00	24.29	24.92
Brazil	2.11	2.19	1.51	3.25	5.85
Canada	27.23	23.12	25.43	20.56	23.55
China	106.39	99.30	102.00	93.87	86.49
India	59.84	65.77	62.10	69.68	65.10
Mexico	3.60	4.15	3.46	3.27	2.90
Morocco	1.57	5.52	1.10	3.32	5.15
Pakistan	16.16	15.21	17.00	19.02	19.19
Russia	43.50	32.10	30.10	46.90	34.10
Tunisia	1.40	0.50	0.53	1.12	1.60
E.U.	82.38	98.51	94.18	90.90	90.50
U.S.A.	65.22	63.17	59.48	53.00	63.81

The area under wheat throughout the world as well as in India has become constant *i.e.*, 215 m ha and 26 m ha, respectively. India can harvest over 95 m t of wheat merely by bridging the present level of yield gap between what is realized and what is possible as demonstrated through frontline trials. There lies tremendous scope of improving wheat production in UP, MP and Bihar.

World wheat area, production and productivity

Year	Area (m.ha)	Yield (t/ha)	Production (mt)
1990-91	231.4	2.54	588.0
1994-95	215.1	2.44	524.7
2000-01	214.6	2.71	580.9
2003-04	217.2	2.84	616.9

6.1.2 Wheat production in India

A production figure of 72 m t of wheat does look impressive but not so much if one realizes that it comes from 26 m ha area with an average yield of 2.7 t/ha. Under very good management, yield of 6-8 t/ha have been obtained in some parts of NWPZ. In Punjab and Haryana, the average productivity levels are 4.35 and 4.02 t/ha.

Average yield (kg/ha) of major wheat growing states of India

State	Period				
	1961-70	1971-80	1981-90	1991-2000	2000-05
Punjab	1527	2487	3325	4138	4345
Haryana	1318	1919	2732	3655	4020
Uttar Pradesh	1022	1307	1959	2489	2674
Madhya Pradesh	599	811	1150	1551	1616
Bihar	679	969	1565	1880	1898
Maharashtra	431	708	895	1237	1291
Gujarat	1104	1718	2069	2502	2366

A comparison of the various sectors of usage of the total wheat production now and by 2025 AD shows that there will be steep growth in demand for wheat grains as the processed usage is likely to be higher in future.

Various sectorial uses of wheat (mt)

Categories	1995 AD	2025 AD
Retained by growers (As food grain)	45.5	81.0
Buffer stock (procured amount)	15.0	20.0
Export / trade	2.0	3.0
Seed	2.5	3.0
Transport loss/ damage, etc.	1.5	2.0
Total	**66.5**	**109.0**

6.1.3 Projections for 2025 A.D.

As per present population growth rate, population of India by 2025 will be around 1.3 billion. Assuming 20% more per capita requirement of food grains, due to better standard of living and increase in the demand of processing industries, required wheat production will be around 109 mt by the year 2025 AD.

Net availability of food grains (gm/capita/ day) in India

Year	Rice	Wheat	Other Cereals	Pulses	Food grains
1951	158.9	65.7	109.6	60.7	394.9
1960	187.8	78.3	118.0	65.5	449.6
1970	190.2	102.3	110.6	51.9	455.0
1980	166.1	126.8	86.6	30.9	410.4
1990	212.1	132.6	86.8	41.1	472.6
1995	220.0	172.7	64.9	37.8	495.4
2000	203.7	160.0	59.0	31.8	454.5
2004	183.4	178.9	44.5	29.1	436.3

6.1.4 SWOT analysis -wheat

An effort has been made to analyse the strengths, weaknesses, opportunities and threats of the wheat and barley programme. Keeping all these points in view, a perspective has been designed for wheat programme until 2025 AD.

Strengths

- Strong coordinated set-up
- Strong research and development support
- Genetic diversity
- Suitable varieties for diverse agro-climatic conditions
- Suitable climatic conditions for growing three species of wheat
- Trained human resources and well developed infrastructure
- Repository of all wheat rusts pathotypes at Flowerdale, Shimla
- Facility of off-season nursery at Dalang Maidan for advancement of generation and evaluation against wheat rusts under natural conditions
- International linkages

Weaknesses

- Narrow genetic base
- Absence of procurement based on quality
- Need to match international standards
- More dependency on international materials
- Poor extension activities – State Governments
- Poor commercialization initiatives
- Inadequate linkages between research and industries

Opportunities

- Bridging yield gaps
- Focus on harnessing higher wheat production from states having low wheat production, i. e. UP, MP, Bihar, Gujarat, Rajasthan and eastern parts
- Strong domestic demands form processing and baking industries
- Use of new biotechnological and bio-informatics tools
- India situated geographically at advantageous location for wheat export
- Value addition

Threats

- Global climate change
- Deteriorating soil health
- New diseases and insect pests
- Water scarcity
- Patent regulated genetic flow
- Global pricing and subsidy policies
- Population pressure – reducing arable area due to urbanization

6.2 Barley

Barley (*Hordeum vulgare*) an ancient cereal crop in India is being utilized in feed, food, and industrial raw material for malting and brewing. It is presently cultivated nearly on 0.62 m ha area, producing 1.21 m t grain with an average productivity of 1.96 t/ha. The productivity has improved from 0.88 to nearly 2.0 t/ha, because of availability of better varieties and other management technologies.

State-wise area and production of barley (Rabi 2004-05)

State	Area ('000 ha)	Production ('000 t)	Yield (q/ha)
Haryana	25.0	67.0	26.8
Himachal Pradesh	24.0	42.0	17.5
Madhya Pradesh	83.2	104.1	12.5
Punjab	22.0	74.0	33.6
Rajasthan	175.5	417.7	23.8
Uttar Pradesh	205.4	411.7	20.0
Uttranchal	24.0	33.0	13.8
All India	616.5	1207.1	19.6

Amongst the states, maximum barley acreage falls in U.P. followed by Rajasthan. Punjab ranks first with a productivity of 33.6 q/ha, followed by Haryana (26.8), but the area in these two states has reduced. The economic liberalization policies of the government coupled with hike in industrial demand of barley has increased the market price dramatically and therefore rejuvenated the crop in various states.

6.2.1 International scenario

Barley ranks fourth among the cereals after rice, maize and wheat in world wide production. Globally, about 57 m ha area falls under barley with an average productivity of 25.5 q/ha. Russian Federation (9.3 m ha), Ukraine (4.4 m ha), Canada (4.2 m ha), Australia (3.8 m ha), Turkey (3.5 m ha) and Spain (3.12 m ha) are the leading barley growers in the world. In barley production, Russian Federation, Germany, Canada, Ukraine, France, Spain, Turkey and Australia are major producers.

Average area, production and productivity in major barley growing countries

Country	Area ('000 ha)	Production ('000mt)	Yield (q/ha)
Russian Federation	9329	18236	19.6
Ukraine	4452	9413	21.4
Canada	3985	10952	27.1
Australia	3777	6677	17.6
Turkey	3517	8467	24.1
Spain	3122	9205	29.5
Germany	2098	11520	54.9
USA	1733	5681	32.9
France	1673	10602	63.5
Iran	1573	2962	18.9
U K	1062	6119	57.7
China	813	3213	39.9
India	707	1400	19.9
World	56469	143873	25.5

6.2.2 SWOT Analysis - Barley

Strengths

- Strong coordinated set-up
- The entire germplasm collection has been evaluated for various morphological, agronomic traits, resistance to biotic/ abiotic stresses and malting quality
- Almost all kinds of agro-climatic conditions are available including the off season nursery facilities for diverse evaluation and speedy advancement of generations.
- The disease/pest screening programme under the network is well organized and is well supported by hot spot locations and artificial inoculation facilities.

Weaknesses

- The major weakness of the programme is the lack of advanced stage programme on molecular breeding for quality and resistance.

Opportunities

- Export potential of malt type barley grain, malt or the malt extract to the neighbouring countries
- The increasing pressure on various inputs like water and fertilizers makes barley as profitable proposition for farmers especially in areas where water is becoming problem.
- It can be used for diversification purposes in states like Punjab and Haryana with contract farming by industry, which can be equally remunerative.

Threats

- Erosion of genetic diversity
- Shift in area for more remunerative crops
- Lack of organized industrial demand and support

7. PERSPECTIVE

Varietal improvement has so far been successful in improving productivity and disease resistance. Now we need to emphasize more on precise breeding in pyramiding of genes for biotic, abiotic and yield contributing traits, integrated pest, nutrient and water management. To exploit befitting benefits of RCT's, tailor made varieties are required to sustain soil health and improve per hectare productivity. For achieving the wheat production targets, the following short term and long term strategies are to be implemented.

7. 1 Varietal Replacement

Breeder seed production of high yielding and disease resistant wheat varieties should be promoted and obsolete varieties should be denotified. The breeder seed production of varieties that need be enhanced are:

- *Punjab, Haryana, western UP and northern Rajasthan*

  Since the predominant variety PBW 343 has become susceptible to new yellow rust race (78S84), alternate varieties with adult plant resistance against new race, as noted in DBW 17, are required.
- *Eastern UP, Bihar*

  Under timely sown conditions, varieties like HD 2733, HD 2824, PBW 443, and HUW 468 need to be promoted by curtailing UP 262 and HUW 234. Similarly under late sown conditions, varieties like DBW 14, NW 2036, HW 2045, NW 1014, K 8962 and HD 2643 should be promoted.
- *Intensify Varietal Spread in NEPZ*

  In contrast to NWPZ, a large number of genotypes have been notified for the NEPZ but the variety released in 1984 i.e. HUW 234 is still in great demand. The average life of a wheat variety in NEPZ is about 12 years and it is mainly due to poor seed replacement. The north-eastern region is catching attention in release of new wheat varieties but the seed demand of new varieties is quite low. The developmental agencies will have to play a significant role in popularising the improved wheat varieties.
- *Madhya Pradesh, Chhatisgarh, Gujarat and Kota region of Rajasthan*

  Lok 1 a reigning variety in central India needs replacement as it is highly susceptible to rusts. GW 322 and GW 273 under timely sown conditions while HD 2864 and MP 4010 under late sown conditions can be the good substitutes. HI 8498 and HI 8381 are the best varieties for durum cultivation in this region. These states have a sizeable rainfed or limited irrigation areas for which HI 1531, HI 1500 of bread wheat and HD 4672 and HI 8627 for durum should be promoted while WH 147 should be phased out.
- *Maharashtra* and *Karnataka*

  For timely sown conditions DWR 162, GW 322, NIAW 917, MACS 2496 and RAJ 4037 in bread wheat and MACS 2846 for durum should be promoted. Under late sown conditions PBW 533, HD 2833 and NIAW 34 are recommended. Under rainfed conditions HD 2781, K 9644 for bread wheat and durum wheat variety AKDW 2997-16 should be promoted. New dicoccum varieties namely DDK 1009, DDK 1025 are also good options for the areas under dicoccum cultivation.
- *Non-traditional wheat growing areas*

  Some areas in Jharkhand, Orissa, West Bengal, Tamil Nadu and Andhra Pradesh should be looked into for increase in the wheat acreage. Suitable varieties falling in that zone need to be tested at farmer's field.

7.1.1 Demand driven efforts

The AICW&BIP has been successful to develop wheat varieties for all cultivated *Triticum* species (*aestivum, durum* and *dicoccum*) and production conditions in the plains. It appears that the success rate was higher in late sown bread wheat as more varieties were notified even though area under late sown condition is much less than normal sown situation. The diversity index calculated as the number of releases per million hectares per year, underlines the point that varietal diversity for this important environment could not be properly supplemented. To make the coordinated wheat research programme more vibrant, it will therefore, be necessary to make it demand driven.

7.1.2 Breeding for very high productivity

A number of districts in Punjab, Haryana and Uttar Pradesh have touched an average productivity level of 4t/ha. It is, therefore, necessary to develop very high yielding varieties to meet the requirement of these frontline districts. Such genotypes should be responsive to high levels of nitrogen application, possess more number of effective tillers, more spikelets and better thousand grain weight. It can be noted that in comparison to Kalyan Sona, identified in 1965, WL 711 had a clear yield advantage and HD 2329 released in 1985 was better than WL 711, identified in 1974.

7.1.3 Varieties to harness RCTs advantages

High priority is in place for new tillage practices for minimization of cost of cultivation and also to save precious natural resources. However, initial studies have shown that there exists genotype x tillage interaction and hence, better performing genotypes, specifically suited to a particular tillage option such as zero tillage, Furrow Irrigate Raised Bed (FIRB) planting and rotavator tillage technology will be needed. An early generation screening of potential crosses shall be made to identify suitable genotypes for specific tillage options.

7.2 Biodiversity, Conservation and Utilization

There are number of centres under the AICW&BIP holding various types of wheat and barley collections coming out of the early explorations and subsequent exchange programmes. These centres also maintain native germplasm collections, useful genetic stocks, working collections, etc. It has been quantified by this Directorate that there are approximately 26,000 collections of wheat in the country retained by various centres and DWR holds the maximum number nearly 9200. Around 6000 germplasm lines have been stored under natural conditions at DWR Regional Station, Dalang Maidan with reduced cost of maintenance. In the coming years, a long term repository will also be developed. In addition, approximately 8000 accessions of barley are also conserved for medium term.

7.2.1 Utilization of land races

Land races are the most important source of new genes coupled with local adaptability. The Indian land races like *Hard Red Calcutta, Etawah* and *Indian G* have contributed in the development of Veery and Kauz lines of CIMMYT. Use of land races in crossing programme is expected to improve adaptation, quality and tolerance against abiotic stresses.

7.2.2 National wheat germplasm system

A national wheat germplasm system should be developed involving major wheat breeding centres of the country. The efforts will focus on involvement of different germplasm lines in synthesizing new and diverse materials to compensate the anticipated decline in germplasm flow from CIMMYT and other international organizations. This will also commensurate the restrictions imposed by WTO/ new IPR regime.

7.3 Harnessing Winter Wheat Variability

The potential of winter x spring wheat crosses has been widely demonstrated by the release of ‘Veery’ lines. The winter wheats carry novel genes hitherto not available in spring wheat grown in India. The winter x spring hybridization programme has been initiated at DWR with the aim to transfer the high yielding traits into spring wheat background suitable particularly for NWPZ targeting an yield level of 8 t/ha. DWR regional station located at Dalang Maidan in Lahaul valley of Himachal Pradesh is very suitable for attempting winter x spring crosses. The thrust in the coming years will be:

- Genetic stocks for abiotic stresses like heat and drought
- Resistance to biotic stresses particularly foliar blights and powdery mildew
- Variation for yield components like tillering, grain weight and protein content

7.4 Wide Crosses Approach

For adding new variability, wide cross approach can serve a great opportunity for wheat geneticists. An access to accessions carrying novel traits is the pre requisite. The wild progenies and related genera of wheat offer large number of genes for resistance/tolerance to various biotic and abiotic stresses. A well defined programme alongwith well-equipped and trained manpower is essential for success in making crosses and handling the segregating generations for transferring the target traits in the desired background. Sterile or partially sterile F_1s restrict the use of wild species. A wild species of exotic material will be prepared and co-adapted in a “buffer” population before finally being used in the recurrent variety. Several selections of recombination and mild selection may be required to develop a gene pool that is adequately adapted.

Species for utilization for improving specific traits

S No.	Desirable traits	Sources
1.	Heat tolerance	*Aegilops peregrina , Ae. Kotschyii, T. longissimum*
2.	Drought tolerance	*Ae. Kotschyii, T. polonicum, T. longissimum, T. sphaerococcum*
3.	Salt tolerance	*T. sharonense, Ae. ovata, Ae. Kotschyii*
4.	Powdery mildew resistance	*Ae. speltoides, T. longissimum*
5.	High tillering	*T. carthalicum*
6.	Grain weight	*T. carthalicum, T. polonicum*
7.	High protein	*T. dicoccoides, Ae. ovata, T. longissimum,*
8.	Baking and pasta quality	*Ae. tauschii*

Traits that can be exploited through conventional (hybridization, seed irradiation, cytological studies) and biotechnological procedures (making amphidiploids through colchicine treatment/embryo-rescue) are presented below:

Important traits to be introgressed from wild sources

Target/traits	Donors/sources	Recurrent parents
Heat tolerance	*Ae. peregrina* (UUSS), *Ae. kotschyiiv*(UUSS), *T. Longissimum* (S^lS^l)	PBW 343, DBW 14 and PDW 233
Powdery mildew and leaf blight	*Ae. speltoides*-SS (*Pm 12*), *T. longissimum* (Pm 13), *T. spelta*-AABBDD (Pm1d)	PBW 343, DBW 14 and PDW 233
Grain weight	*T. carthalicum(AABB), T. polonicum*(AABB), Synthetic hexaploid wheats (AABB+DD/AA)	PBW 343, WH 542, DBW 14, PDW 233 and HI 8498

7.5 Creating New Variability Through Pre-breeding

One of the main requirements of a dynamic programme is an easy access to the genetic diversity for yield contributing genes and resistance to biotic and abiotic stresses. With a high selection pressure for few agronomic traits, the diversity in the germplasm available particularly genetic stocks is shrinking slowly. To strengthen the Indian wheat breeding programme, DWR initiated the pre-breeding work at Karnal. Initially, the emphasis was laid on unexploited germplasm like long spike buitre plant types, synthetic hexaploids, Chinese sub *compactoid* ear germplasm and wild relatives. A large number of synthetic hexaploids endowed with genetic richness for high grain weight, delayed senescence (stay green), HMW glutenins, resistance to KB and yellow rust are also in use.

7.6 Developing Hybrid Wheat

The exploitation of heterosis over the best commercial variety through hybrid wheat will help in breaking yield barrier. The major bottleneck in commercialization of hybrid wheat is lack of sufficient yield advantage. The CMS system has to be examined and further improved for commercial exploitation. The key issues therefore shall be :

- Identification of heterotic gene pools
- Evaluation and diversification of CMS system
- Improving the fertility restoration
- Search for heterosis in diverse gene pools

7.7 Revitalizing the Seed Production System

A massive programme should be designed to produce seed in large quantity in the very first year of its release for quick distribution to the farmers. Few villages can be adopted for the production of seed of new varieties in different districts. The progressive farmers in ‘Seed Villages’ can be trained to grow quality seed and mobilize farmers to meet the seed demand of improved varieties. Training on seed production will be provided to private seed producers and govt official involved in seed production.

7.8 Using Biotechnological Tools

One of the important goals of molecular biology is to expedite the breeding programme with precision for developing cultivars with specific traits within a short period of time. The different aspects of molecular interventions in wheat improvement are:

7.8.1 Development of marker

The programme at DWR envisages to utilize the mapping population either developed or in the process of making, for identification of linked markers or QTL mapping of the associated genes for the traits of disease resistance (particularly rusts and Karnal Bunt), abiotic stress tolerance (terminal heat and salinity tolerance) and end product making grain quality (chapati and bread making quality).

7.8.2 Marker aided selection

One of the immediate uses of molecular biology in the wheat programme has been marker-assisted selection. Further refinement of procedures for high throughput screening and MAS, particularly in the early segregating generations will be another thrust area. Multiplexing of markers and efficient data reading and analysis systems will be areas where improvements are possible through intensive efforts.

7.8.3 Genetic transformations

It is expected that transfer of single gene governing important traits and of regulator genes that turn existing genes on or off will be accomplished in wheat within the next ten years. However, most traits of interest are controlled by multiple genes and such complex gene transfers shall be possible in the future. The limiting factor in multigene transfers may not be the technical ability but the level of understanding of genetics. Also, problems with the regeneration of whole fertile plants from protoplast, cell, or callus culture may hinder the practical utility of gene transfers.

7.8.4 Utilization of rice/*Arabidopsis* sequence generated information

Recently, syntenic genomic areas for a few of the wheat rust resistance genes have been identified in rice. This offers an excellent opportunity for cloning of the rust resistance gene homologues from rice and their deployment in wheat. Based on synteny mapping the chromosomal location of major wheat rust resistance genes will be identified and the genes will be cloned and deployed in wheat through transgenics.

- Syntenic mapping of the chromosomal location of wheat chitinase gene, its cloning and deployment in rice through transgenesis.
- Generating haplotype information among wheat genotypes using SNP markers for selecting specific allele combinations and improving the desirable trait.
- Fine mapping and characterization of disease resistance and grain quality gene(s)/QTLs
- Pyramiding of specific genes conferring resistance against fungal diseases

7.8.5 Tissue culture and double haploid production

The selection of parents and evaluation of recombinant lines using molecular markers further reduces the number of generations required in developing a variety and the expression also remained unaffected by the environment. Keeping all the above points in view, the double haploid system in wheat will be developed and then the RILs will be generated for genetic studies on complex characteristics.

- Completely homozygous lines are obtained in a single step
- Easy *in-vitro* screening for complex traits like drought during culture process
- RILs to be used in QTL mapping
- Energy & time is reduced in screening the segregating generations.

7.9 Genetic Potential for Water Use Efficiency

Even though new released varieties of irrigated conditions have yielded over 6t/ha at several places, the progress has been slow for moisture stress conditions. The yield of new cultivars is generally the same as that of C 306, Sujata or NI 5439 though there has been improvement for rust resistance and grain appearance, etc. Even when 86% area under wheat is irrigated at the national level, for attaining high yield potential, water scarce areas like Maharashtra, Madhya Pradesh, Karnatala, Gujarat and Rajasthan should also catch attention, especially for the marginal farmers.

For water starved wheat, productivity can be increased either by applying better production technology centered around water conservation/management practices or promoting genotypes that have inbuilt capacity to respond well under moisture stress conditions. Both these factors if applied in tandem can help to increase productivity in the area where optimum number of irrigations are generally not met even under irrigated areas. Developing genotypes for restricted irrigation conditions is a feasible option to exploit moisture usage efficiency in central and peninsular India.

7.10 Coping with Abiotic Stresses–Heat, Drought and Salinity

Nearly 2.5 m ha wheat area in central India comes under residual moisture regimes. An effort will be made to identify genotypes superior with respect to stress tolerant traits as well as yield potential. Simultaneously, a large pool of germplasm represented by local land races, synthetics and exotic lines from known sources will be subjected to screening for stress tolerance with main emphasis on drought, heat and salinity. Stem reserve mobilization, cell membrane thermo-stability and canopy temperature depression will be used for screening the germplasm.

7.10.1 Chlorophyll fluorescence

It is one of the recent techniques widely used to study high temperature tolerance in wheat. This technique has been found to be more efficient in differentiating stress tolerant and stress susceptible genotypes. Efforts have to be made to standardize and adapt this technique for characterizing wheat genotypes for high temperature and moisture stress tolerance.

7.10.2 Heat shock proteins

Heat shock proteins involvement in acquired thermo tolerance have been investigated in detail in many labs. However under field condition, its direct association with grain yield performance is yet to be elucidated. This can be attributed to various factors other than high temperature tolerance. Since there is lack of information on status of heat shock proteins in promising advanced wheat accessions, it is necessary to establish facilities for characterizing these genotypes for heat shock proteins.

7.10.3 Variability in isozyme pattern of starch synthase

It is likely to be one of the factors in determining differential response of wheat genotypes to high temperature and moisture stress tolerance. This aspect will be studied in future and wheat genotypes will be characterized for this trait.

7.11 Tackling Biotic Stresses

Among biotic stresses, the rust diseases pose major threat in India. The criterion to choose cultivars for a particular zone was mainly based upon the potential of these genotypes to restrict epidemics occurring due to respective races/pathotypes of rust pathogens prevalent in that zone. The last few decades representing post green revolution era supported “boom and bust cycle” leading to emergence/build up of several new races of rust pathogens as a result of wide-spread use of narrow genetic bases in our wheat cultivars. Only a limited number of known resistance genes (*Lr10*, *Lr13*, *Lr23*, *Lr26*, *Lr24* in brown rust, *Sr2*, *Sr9*, *Sr11*, *Sr31* in stem rust and *Yr2*, *Yr2 (KS)* and *Yr9* for yellow rust) could be used in our breeding programme, so far. Also isolated efforts have been made in characterizing the phenomenon of slow rusting (a trait of durability) in Indian wheat germplasm. At this juncture, none of the genes or their compatible combinations in use is capable of providing complete protection from stripe and leaf rusts. Therefore, it becomes imperative to make use of other unexploited genes especially those derived from alien sources as well as slow ruster lines (APR-adult plant resistance) to keep the rust epidemics under check in Indian sub continent. Some of the genes that are targeted to be pyramided are *Lr24, Lr28*, *Lr35* and *Lr37* for leaf rust and *Yr10* and *Yr15* for stripe rust resistance. Available PCR based markers linked to these resistance genes will be used for marker assisted pyramiding.

7.11.1 Creation of genetic barriers

Cereal rusts can be controlled or managed effectively through proper gene deployment in different epidemiological zones in the country. It will help in cutting down the inoculum build up, thus influencing the rust development and spread in the target areas. Hence, there is a need to deploy zone-specific cultivars that are capable of checking the arousal of new variants. Cultivars representing a mosaic of gene combinations have to be cultivated in the target areas to avert losses occurring due to susceptibility of monoculture in the main wheat belt of the country. Thus, cultivars with at least 3-5 different gene combinations are required to create genetic barrier for different pathotypes in space and time.

7.11.2 Pre-empting the rust pathogen

In order to pre-empt the wheat rust pathogens, there is an urgent need/requirement to introgress different rust resistance genes in agronomically suitable variety. Hence the regional station would provide efforts oriented for anticipatory pre breeding by producing genetic stocks, so that these may be distributed to the wheat breeders through out the country for further usage.

7.11.3 Adult plant resistance/slow rusting genes

DWR Regional Station, Flowerdale, Shimla would play an analytical role by evaluating rust resistance both at seedling as well as adult plant stage in pre breeding material. Screening adult plants in controlled condition would elucidate the role of adult plants in containing yellow rust in NWPZ. Other APR gene like *Sr2*, *Lr34* can also be evaluated.

7.11.4 Understanding variation of rust at DNA level

The preliminary studies on variation in rusts pathotypes at the DNA level with random as well as few specific primers have not proved to be very informative. Therefore, there is a need to use other markers like AFLP, micro-satellites etc. in order to resolve the differences at the DNA level. Form the host point, few known markers have been used to confirm the incorporated rust resistance genes in superior background. Few rust resistance genes known to be associated with micro satellite, may also be used in this perspective.

7.11.5 Scouting for *Puccinia striiformis* virulences

Stripe rust (*Puccinia striiformis tritici*) is the most important disease of wheat in the countries of Middle East and South Asia (MEASA). Any introduction of a genotype with novel resistance genes in Middle East might pave way for arousal of new virulence which through western disturbances will be transported eastward rendering new gene cultivars susceptible in all the South East Asian countries. This is a serious concern of the whole subcontinent in general and Iran, Iraq, Pakistan and India in particular whose national food resource largely depends upon wheat. More so, the Trans-Caucasian region in the Middle East is also presumed to be centre of origin of stripe rust, therefore virulent pathotypes may arise and proliferate there even if pathogen does not encounter selection pressure by not introducing new wheat cultivars. Therefore, there is a need to establish a regional network of West and South East Asian countries for addressing the following objectives:

- Mapping virulence/avirulence patterns of yellow rust pathotypes prevailing in the continuum of MEASA countries.
- Preparation of database on past and present varieties of wheat grown in MEASA countries with particular reference to the yellow rust resistance.
- Survey of grasses (collateral hosts) in the countries of concern and explore their potential to support over-summering of *P. striiformis*.
- Development of a common strategy to manage yellow rust in MEASA region.

7.11.6 Leaf blight

Leaf blight or spot blotch of wheat mainly caused by *Bipolaris sorokiniana* is expected to increase further in Indo-Gangetic plains and Peninsular India due to global warming and changing cropping system. Following aspects will be addressed:

- Mapping of pathogenic races present in *B. sorokiniana* in different agroclimatic zones in India and their relative importance.
- Standardization of method for rapid screening of genotypes and segregating population *in situ* against fungus and its toxins at seedling stage.
- Identification of model genotypes possessing high level of resistance to different races of *B. sorokiniana* and their toxins both at seedling and adult plant stages.
- To establish the possible role of weather factors in breaking the resistance against spot blotch in resistant genotypes, testing of elite genotypes and identification of stable genotypes maintaining resistance under a range of weather conditions.

7.11.7 Karnal bunt

There is a need to strengthen resistance to Karnal bunt (KB) in some of commercial cultivars which are under large scale cultivation. Exploitation of resistance sources must be facilitated by characterizing the resistance genes and developing suitable molecular markers for those genes. Owing to the lack of uniform population of pathogen applied to screen the filial generations, it could not be revealed so far, whether resistance to KB is governed by single major genes or expresses as a polygenic character. Pathogen *Tilletia indica* is a heterothallic fungus and the stability of variants/races recognized individually by several laboratories in India needs re - examination and analysis on integrated basis.

7.11.8 Head scab

Epidemics of FHB occur sporadically in some parts of the world but under warm and wet weather conditions during flowering, the disease has the potential to cause considerable loss in grain yield and quality. Such favourable weather may also occur more frequently as a consequence of global weather change. Therefore, there is a need to be prepared for this potential wheat pathogen. Such a wet period over North India towards March/April may not only favour Karnal bunt and pre-harvest sprouting but will also increase the incidence of FHB. Research will be carried out on following aspects of this disease:

- *Fusarium* spp. identification and variation at genetic level using molecular markers
- Role of toxins produced by *Fusarium* spp. in pathogenicity and epidemiology studies
- Genetics of head scab of wheat and management

7.11.9 Molecular studies

Marker assisted selection will be supported through investigations on pest variability, especially in case of rusts, Karnal bunt, head scab and insect pests like aphids. Molecular approaches will hasten the process of screening against the diseases and pests.

7.11.10 Integrated pest management

Multiple disease resistance approach is paramount in tackling biotic stresses. As compared to several other crops, the wheat ecosystem is relatively free from pesticides till now. Breeding strategies with emphasis on durable resistance/slow disease development involving more then one disease and utilization of alien genes like those for leaf blight resistance, are required for further improvement. Some such genes (*Lr* 9, 19 and 24) are already in use for leaf rust resistance. Multiple disease resistance will provide a very strong component of IPM and will help in keeping the pesticide use in wheat to the minimum possible. It is visualized that from now on, the main plank for Plant Protection Sciences to curtail crop loss shall be through the adoption of the Integrated Pest Management (IPM) system. In combination with rust surveillance, virulence typing, gene deployment and use of PGPR/PGPF like organisms, this eco friendly IPM can be used to curtail losses. Effect of bioagents alone and in combination with reduced dosages of chemicals will be studied on management of wheat diseases and insect pests.

7.11.11 Transfer of crop protection technology

Transfer of Crop Protection Technology will be assured through farmer's participatory mode. For achieving this goal, the location specific IPM modules will be validated through farmer's active participation to promote large scale adoption in a system perspective. The research results and technology transfer will also be backed up with the traditional/ conventional as well as through the latest information technology means.

7.11.12 Soil health

As a consequence of intensive farming, new pest problems are being encountered. The insects survive on the harvested rice stubbles or migrate from the adjoining crop of rice. It is therefore, necessary to develop a technique for removing the rice stubbles and other crop residue to avoid pest build up. There is a need for a continuous monitoring of this pest over NWPZ and NEPZ and understand the insect ecology better. In view of the environment friendly control measures, neem products and *Pasteuria* etc. can also be synthesized for the control of nematodes.

7.11.13 Pest risk analysis (PRA) for global trade

Anticipated global weather changes also warrant against newer disease epidemiological changes. This requires preparedness in terms of ready PRA systems for various important wheat diseases such as *Fusarium* head blight, Karnal bunt, rusts etc. DWR has been able to provide a PRA system for KB and would be inclined to carry it further for other diseases.

7.11.14 Global climate change

Strategic planning for management of newly emerging or potentially important diseases/ pests will be an important aspect. This will be done by reviewing the situation periodically and on need basis to meet the challenges. For example, diseases and pests like head scab, Russian aphid (which is not known from India, but is present in the neighbouring countries in the western side), changing pest scenario in traditional and changing cropping systems, new RCT's, and emergence or development of new virulence(s) of rusts in India, will be tackled through proper strategy planning and strengthening of the present programmes.

7.12 Quality Improvement

Improvement of *chapati,* bread and biscuit making quality of bread wheat and pasta making quality of durum wheat, and the nutritional quality are major concerns of breeding wheat varieties. Defining parameters related to quality of each end-use product and understanding the biochemical/molecular basis of quality of these products will help in developing varieties suitable for these products. Identification of molecular markers linked to pasta quality and higher beta-carotene content can help in improving the nutritional quality of durum wheat and thus enhancing the availability of better nutrition for undernourished population. Micro level tests requiring little (<1.0gram) amount of flour will be identified which will be useful for breeders in screening early segregating generations and thus selecting desirable recombinants. Understanding the molecular basis of grain quality will facilitate the use of wheat for all these products and will almost certainly reduce the reliance on chemical improvers. This will enhance our efficiency for monitoring quality traits in wheat in early segregating generations with greater precision and accuracy under the background of high yield and disease resistance. Further, this will enhance our understanding of genes and proteins involved in product making quality which eventually lead to their manipulation for improved quality.

7.12.1 Product specific varieties

Varieties specifically bred for product like bread, biscuit, pasta, noodles and chapati etc. will be a key issue in wheat research. Besides developing breeding programme for product specific varieties, it shall be crucial to define areas and situations where such varieties can be better exploited. Given a large geographic area in different agro-climatic regions, concerted efforts in this direction can help in fine tuning the quality improvement programme of the country.

7.12.2 Nutritional security

Wheat has tremendous potential for improvement in the protein content and its quality, beta-carotene and micronutrient contents like iron, zinc, copper, manganese, etc. Such an improvement in nutritional properties of wheat can usher nutritional security to a large population that uses wheat as a staple food crop. Bio-fortification and enhanced bio-availability of micronutrients shall become an important part of the quality improvement activities. It shall also be pertinent to demarcate areas, regions or situations that facilitate rich harvest of grain nutrition.

7.12.3 Interface with industry

Even though big opportunity lies to convert a sizable quantity of wheat for value addition, the Indian entrepreneurs are found reluctant whereas multinationals have started spinning money immediately after liberalization. It is possible that the established food manufacturers as well as the new aspirants for the trade are not familiar with the need based product development processes. An interface with the industry therefore is so crucial to promote healthy interaction between researchers, industry and planners.

7.12.4 Wheat nutrition and human health

There lies good scope of targeting wheat as a commodity for good health. *Triticum dicoccum* has already established itself as a good cereal crop for diabetic patients. Change in bran proportion in flour makes it more suitable for patients with chronic constipation. Wheat being the basic ingredient of daily diets has enough scope to be manipulated for making different instant foods by supplementing with nutrients/vitamins/phospholipids etc. to contain various syndromes likes hypertension, diabetes, bone and skin abnormalities. It may prove quite rewarding to explore possibilities of threats/benefits that wheat can bring in human health.

7.12.5 Durum quality

Durum is mainly used for production of pasta products and its quality characteristics like yellow colour and resistant to over cooking i.e.; cooked pasta should maintain good texture, resists surface disintegration, and has firm structure consistency. Most of these characteristics are determined by the quantity and quality of gluten proteins. Strong gluten with high elastic recovery gives greater cooking stability and higher cooked firmness score, whereas pasta made from weak gluten with low elastic recovery is prone to deteriorate rapidly and become soft with overcooking. The gluten strength in turn is governed by the composition of protein subunits. Therefore, assessing the relative importance of glutenin and gliadin alleles and their interactive effects on pasta making quality, followed by the characterization of their corresponding genes are important for durum improvement.

7.12.6 Uniqueness of the Indian *dicoccum*

India is the only country in the world growing *T. dicoccum* in approximately 50,000 ha area. It is a highly priced commodity as it has nutritional value. This nutritive species of wheat is tall and low yielding, therefore, there is a need to increase its yield potential. It is also needed to protect the collections available in the peninsular India including the new dwarf dicoccum for reasons of commercial interest. Two additional centres for evaluating the yield trials at Coimbatore and Rudrur are to be established. The resistance to leaf rust is another important aspect to be worked upon. The improvement of existing varieties with respect to various quality aspects/traits of importance is of paramount consideration.

7.12.7 Shift in food needs of urbanites

The process of social and economic development has developed a sense of competitiveness among the people at large and urbanites in particular. These days earning by each and every one in a family has become a way of thinking. This arduous exercise leaves very little time for the working class to get their meals with traditional approach. More and more people are therefore, now going for instant foods. Preference for low calorie foods is slowly developing among the urbanites that are health conscious. Demand for baby foods and pasta products as well as baked foods are on the rise in the cities. Affluent people are finding convenient food as easy source of their daily meals. Therefore, there is a big scope for converting the wheat grain into value addition.

7.12.8 Grain trade

Wheat traditionally looked upon as a crop grown for *chapati*, semolina or *dalia* has been recognized as tasteful commodity for variety of products today. Therefore, commerce driven support for this crop, may be for domestic industry through value addition or grain export to earn foreign currency has to be duly recognized. Even though export driven programme as in Australia, USA or Canada is totally missing in the country, a step forward has been taken by the Directorate to produce an atlas of Indian Wheats that will prove handy to offer choice to the importing nations. The grading pattern and the suggested means to improve the grade of wheat produced in various parts of the country will also improve quality of the grains selected for trading. PRA (Pest Risk Analysis) to Karnal bunt, a model design to foresee the risks associated in shipping of wheat from destination, will also be useful in grain trade.

7.12.9 Need of a 'Wheat Board'

In satisfaction to needs of the wheat importing nations, it will be worth to study their food product demands so as to offer right choice of the variety. This task can be done by a separate statuary body on the pattern of *Coffee Board* which can device, regulate and implement the export promotion policy and other R&D issues of marketing intelligence.

7.12.10 Development of 'Wheat Technology Research Centre'

Attempts are needed to make cheap but nutritious instant foods to cater the need of all the sections of urban society. Baby foods available in the market are quite expensive and are a commodity that affluent and upper middle class people can afford. Hardly, there is any other institute except CFTRI, Mysore that has developed paraphernalia for milling, baking and the basic source for all the products. Directorate would therefore take the lead in developing wheat based products which would not only take care of dietary and socio-economic status of the urbanites but would also bring them in reach of each person. Establishing the centre would not only help in classifying the newly developed/advanced genotypes but would also be an asset to impart training to the entrepreneurs. Such an establishment can also facilitate characterizing chapati and other traditional products.

7.13 Resource Management

The increased energy usage and other inputs contributed to the gain in grain production during the green revolution. However, their mismanagement started exerting strain on the natural resources like soil, water as well as environment. The second generation problems of the green revolution are, therefore, related with the systems efficiency. In terms of agricultural productivity, the sustainability of the farming system is an important issue. For example, greater access to the tractor and tube wells led to the replacement of draft animals by machines. This created scarcity of FYM for field use. Intensive cropping system with omission of legume and green manuring crops *etc.* also led to the instability of the agricultural system as a whole. More than ten million hectare under rice-wheat cropping system in North India is one of the most intensively cultivated areas in the world, which is possible only through the use of more intensive inputs. Excessive use of external inputs is causing harmful effect on the soil, physical environment and the productivity of the system. Moreover, intensive tillage and burning of crop residues especially rice and to some extent wheat in the north western plains has led to the depletion of soil organic carbon, a direct indicator of sustainability of soil resource. Continuous mining of soil has started showing systems fatigue in the form of multiple nutritional deficiencies. The declining response to inputs has been perceived to be the major challenge for the sustainability of wheat based cropping systems across the Indo-Gangetic plain. In addition, the effect of climate change needs to be addressed to enhance or at least maintain the productivity at lower production costs. The issues and the strategies to address those are discussed as follows:

7.13.1 Soil degradation

The intensive tillage coupled with crop residue burning and continuous mining of soil has lead to the depletion of soil organic matter as well as essential plant nutrients. The situation is further complicated by imbalanced fertilisation leading to expression of multiple nutrient deficiencies. The Zn is already recommended and there are more frequent occurrence of deficiencies of Mn, Fe, Cu, Mo and B in the rice wheat system. More than 35% soils are also deficient in sulphur and the K status has also reached a threshold in many soils since farmers are mainly applying nitrogen and phosphorus to the crops. Following strategies may help in reversing the adverse effects on soil:

(i) Adoption of RCTs like zero tillage and conservation agriculture
(ii) Residue management
(iii) Improved farm machinery
(iv) Green manuring
(v) Balanced use of fertilisers

7.13.2 Good quality water

The indiscriminate use of water, especially ground water, has led to its depletion and pollution. Since, the water recharge due to monsoon rains is less compared to its mining; water table is going down in major part of the north western India, the food basket of the country. Though wheat requires only 4-6 irrigations, the consequences of water shortage on production can be substantially high. Taking advantage of the flat electricity charges, farmers continue to irrigate rice fields, even during rainy days leading to decline in ground water levels in the northern, whereas, in southern Punjab and Haryana, water level and salinity is increasing. Moreover, due to excessive irrigations, there are indications that the ground water is getting polluted by nitrate. The need of the hour is to adopt integrated water management practices, which require judicious use of good quality water and conjunctive use of brackish water. The strategies to address ground water quality will focus on:

- Laser land leveller for efficient water usage
- Surface residue retention to conserve soil moisture
- Water conservation, watershed management, and sprinkler irrigation need greater research efforts.
- Need based nitrogen application using NDVI sensors etc. for checking the ground water pollution.
- Diversification/Intensification through alternative crops like maize, soybean, *etc*. through FIRB technology for increasing water use efficiency.

7.13.3 Mitigating the climate change

Based on the climate scenario predicted by the Geophysical Fluid Dynamics Laboratory (GFDL) model, impact of changed climate on wheat production is predicted for various latitude limits for the summer and winter seasons. In the mid to higher latitudes of developed countries, significant increase in area accompanied by crop yield reductions are expected. At lower latitudes with increasing temperature, significant area will become unsuitable for wheat and yield may decline. Increased water requirements may be anticipated in all regions in these latitudes, which will highlight the importance of irrigation management. A net reduction in wheat production is anticipated due to reduction in growth period as a result of increased temperature. It is predicted that with the doubling of CO_2, ambient temperature in India would increase by 3°C and will affect both the area and productivity of wheat. So, there will be a need to evaluate the genotype and environment interaction. It is also predicted that due to increase in ambient temperature agroclimatic zones may shift towards the pole about 100 km per degree centigrade rise in average temperature. This may lead to replacement of wheat area by maize or sorghum and spread of durum wheat in NWPZ as they are more tolerant to heat than bread wheat. The following strategies can help in overcoming the effect of climatic changes:

- Identify/develop short duration varieties having tolerance to early and late heat
- Revisit the sowing time and seeding procedures
- Surface residue retention for temperature moderation and water conservation
- Intercropping of tall and short crops to moderate the micro-climate by shading *etc*
- Diversification of the rice-wheat system

7.13.4 Companion/intercropping for increasing production

Since, the area under wheat is not going to expand, there is a need to evolve suitable genotypes and production technology for various synergistic and parallel intercropping/ companion cropping systems. Under irrigated conditions, opportunities for intercropping of wheat exist with autumn planted sugarcane and potato. It could be achieved by establishing inter-institutional linkages and effective extension net work. By bringing about 25% of sugarcane area under autumn planted cane an estimated increase in wheat production may be in the order of 1.5 m tonne in U.P. alone. To exploit this opportunity, the strategies should involve i) intercropping wheat with autumn planted sugarcane and potato and ii) seeding wheat in ratoon sugarcane using rotary disc drill.

7.13.5 Weed management

Among biotic stresses, weeds play an important role in deciding productivity of any crop. Unfortunately, they are more resistant to abiotic stresses and their nutrient absorption capacity is also better than the wheat crop. In the past, weed control measures were developed in individual crops and very little work has been done to control weeds in a cropping sequence. Therefore, there is a need to focus on integrated weed management and succession of weeds in a cropping sequence. Besides, physical, cultural and chemical means, biological weed control in wheat crop using plant pathogens, especially in the form of mycoherbicides needs to be focused in future. If the rate of current use of herbicide continues, then in future we have to be cautious about ground water contamination, food safety, health hazards, protection of endangered species and herbicide resistant weeds. Therefore, an understanding of weed succession and weed dynamics in relation to various cropping systems, agro-techniques, soil and climate of the agro-ecological system is essential and need following strategies.

- Evaluation of alternate herbicides and herbicide mixtures for resistance inactivation
- Molecular basis of herbicide resistance and identification of markers
- Improving the efficiency of herbicides by using adjuvants/surfactants/proper spray techniques/synergistic herbicide mixtures
- Integration of effective non-chemical measures like competitive varieties, crop rotations, tillage practices, residue retention, etc. with chemical measures
- Exploiting the feasibility of biological control, *i.e.* mycoherbicides
- Studies on weed succession and weed dynamics in relation to various cropping systems and tillage techniques.
- Studies on chemical weed control for companion and intercropping systems
- Identifying the possibility of allelopathic wheat cultivars for weed management
- Studies on weed biology for the efficient weed management

7.13.6 Nutrient management

With intensive agriculture, deficiency of essential nutrients has also become wide spread. The work conducted under the All India Coordinated Research Project on Micronutrient in Crops and Soils, has shown wide spread deficiency of zinc in soils in India. At the national level, the deficiency level in micro nutrients is Zn: 46 %, B: 17 %, Mo: 12 %, Fe: 11 % and Cu: 5%. The deficiency of sulphur has also been reported across a wide range of soils (38%). The yield response to sulphur has been obtained in more than 40 crops including cereal, millets, oilseeds and pulses *etc*. To realize the potential yield, strategies may iclude:

- Site specific nutrient management for targeted yields
- Integration of crop residues, bio fertilisers etc with inorganic fertilisation
- Tillage techniques like FIRBS for increasing nutrient use efficiencies
- Remote sensing for efficient N management
- Nutrient management, straw quality vis-à-vis human and animal health

7.13.7 Targeting the low productivity areas

A sizeable area under wheat cultivation comes from eastern part of India. This area has the potential to increase productivity levels, but as on date, the productivity is quite low. DWR conducted a survey and tried to identify the reasons of low productivity and slow replacement rate with seeds of new varieties in the farmer's field. The moisture availability period and the moisture range in different states of eastern India vary considerably. As we move from eastern part of UP to West Bengal, there is an increase in relative humidity and number of humid days. The period from mid June to September end is humid and the total water availability through rain exceeds the evapo-transpiration potential. During rest of the months, there is an acute water deficit. Therefore, there is a need to utilize/harvest this additional water for extending the cropping period to *Rabi* season as well. Temperature is another are of concern as a large area in the eastern India gets hot winds at the grain filling stage reducing the yield substantially. Moreover, considerable area in north eastern India is mono-cropped as the soil remains wet after rice harvesting. Following strategies may be helpful for these areas.

- Develop and standardize water harvesting techniques
- Surface seeding and zero tillage for doubling the cropping intensity
- Adoption of furrow and sprinkler irrigation

7.13.8 Production technology for dry lands

The dry land agriculture which concerns more than 70% of the agricultural area of the country, is characterized by low or no input system, soil erosion, land degradation, desertification. While developing technologies for dry land areas, these constraints must be kept in mind for efficient and effective utilization of scarce resources available under these stress conditions. Wheat yields can be improved if moisture is conserved. Rain water harvesting and moisture conservation technologies will be developed.

7.13.9 Organic farming

There is a growing concern about increasing health problems due to consumption of farm produce involving inorganic means of production. It is anticipated that a sizeable proportion of rich consumers will be attracted towards organically produced wheat crop. Therefore, a research programme is needed to address the involved economics and effect on soil health due to organic wheat production.

7.13.10 Remote sensing and GIS

Application of Remote Sensing and Geographic Information System in conjunction with weather parameters will be used for simulation modelling to determine the potential irrigated wheat yields and the N and water requirements to achieve targeted yield in various land units. Moreover, it can be used to simulate productivity and sustainability options of rice-wheat cropping system. The principal objective of developing these models will be to determine climatically potential yields as well as to analyse the effect of climatic variables and management of water and nitrogen availability on productivity of wheat. In general, it will be able to simulate the trends in water and nitrogen uptake, dry matter growth and productivity. In particular, the productivity as affected by various climatic constraints and management treatment will be simulated.

7.14 Off-season Summer Nursery at Lahaul & Spiti (H.P.)

Wheat Summer Nursery situated in the Lahaul Valley of Himachal Pradesh facilitates screening against yellow rust and there is proper grain filling due to longer day length and optimum temperature. The centre can effectively be utilized for creating a national facility for natural repository for wheat & barley germplasm. Since the temperatures during winter month range from -30 to -20^0 C, it can be utilized for long-term storage of germplasm. The facility will be upgraded to make the varietal improvement efforts vibrant and proactive:

- To advance the generation of promising breeding materials for reducing the time lag in the development of a variety
- To screen the advance generation wheat material against yellow rust and low temperature stress
- Rapid multiplication of important new bulks
- Raising winter wheat varieties for attempting crosses with spring wheat
- Attempting most important/corrective crosses for development of superior lines

7.15 National Repository of Wheat Rusts and Seeds of Differentials

Presently, about 100 cultures of different rust pathogen are being maintained every year at DWR Regional Station, Flowerdale, Shimla. In the near future, these variants would increase in number, therefore a long term preservation facility is needed to keep the wheat rust inocula. Also the seed of differentials which is being used to analyze the wheat rust samples also needs to be stored at low temperature so two cold rooms storing the seed of differentials and genetic stocks would be constructed.

7.16 Technology Promotional Activities

The Directorate coordinates the wheat and barley FLDs as per the approval by the Ministry of Agriculture. Besides serving as a big tool of technology demonstration, they have helped in examining the yield gaps in different regions and various other constraints in realizing the potential yield. The directorate will strengthen these activities and blend them. Various technology promotional activities such as Farmers' Days, Seed Days, and Travelling Seminars and use of print and electronic media to disseminate knowledge are useful to educate the farmers and scale up the level of adoption of the latest wheat and barley technologies. Demonstration of technology through video films can make a long lasting effect on the farmers' psyche.

7.17 Agricultural Market Intelligence System (AMIS)

Agricultural marketing essentially deals with post harvest management of produce and finding competitive markets for getting best available returns. In order to reduce the risk of marginalisation and vulnerability of small farmers, who constitute about 76% of total farmers of the country, it is necessary to develop an 'Agricultural Market Information System' (AMIS) that is accessible to the resource poor farming community. Internet technology based applications on agricultural resources are expected to facilitate agriculture-based development of rural and economically backward areas in the country. AMIS model will be an informatics model aimed towards developing a reliable and integrated system, wherein all the information associated with marketing is readily available. Informatics for AMIS requires coordinated inter sectoral approach and application of appropriate information technology tools in the area of agricultural marketing (involving storage, packaging, infrastructure), agricultural extension and transfer of technology, agro-meteorology, agribusiness, quality assurance and agricultural inputs (seeds, fertilizers, manures).

7.18 Pricing Policy Needs a Re-look

With the opening of international market, the present system of flat pricing which has little or no consideration for grain quality may have to be dispensed with. A quality driven price will motivate interest in the farmers to produce grains useful for quality end-products. Apart from the government, the private business houses that have now been permitted to produce, store, transport and trade this commodity grain may play an important role as they can afford to provide incentive for clean and quality grain.

7.19 Barley

Strength of the barley programme lies in responding to recent industrial needs like malt and other brewed products, as easy human food, value addition, feed barley, potential use as green fodder in certain areas and a number of health benefits. This crop traditionally suited for low inputs, has registered tremendous potential for high productivity. It has also shown way of establishing partnerships with industry. The future will be served well by strengthening these activities further to make it a high value crop. Application of RCTs and biotechnology to build aphid resistance and value addition are some of the important issues need to be handled in coming days.

7.20 Human Resource Development

There is a need for international exposure to the scientists which could be undertaken through the international linkages with CIMMYT and/or other international institutes/ organizations under the guidance of the Council. Human resource development is needed particularly in areas like biotechnology, quality, bioinformatics, new resource conservation techniques, wheat breeding approaches and biotic and abiotic stresses.

7.21 Elevating DWR to the Level of Indian Wheat Research Institute

Even though wheat research in the country has been a success story and its contribution in national food security has always been applauded, somehow, the institutional structure as provided to other important cereal of the country, i.e. rice has been eluding wheat. DWR has been entrusted with two major mandates i) handling wheat improvement projects of the ICAR and ii) addressing important research components in wheat research. Separate institutional structure for wheat research and coordination (as in case of rice, pulses and vegetables) will give more opportunities to focus on the strategic research, crop diversification and widen the field of wheat research by incorporating unattended research components like food technology, seed technology, GIS, microbial aspects, machinery etc.

8. ISSUES AND STRATEGIES

The wheat programme is one of the most important programme in the country and has been very vibrant during the last four decades, as indicated by the production, productivity and other achievements. But there is no room for complacency and the programme needs to be more responsive to the new emerging issues under the present scenario. Some of the important issues, which are to be addressed in the coming years, are discussed henceforth.

8.1 Wheat Improvement

8.1.1 Improved ideotypes for high productivity

8.1.1.1 Enhancing heat and drought tolerance

- Developing short duration varieties
- Utilizing physiological tools like canopy temperature depression, stem reserve mobilization, cell membrane thermo-stability etc.
- Utilizing genetic resources of heat tolerance
- Developing genotypes for limited irrigation conditions

8.1.1.2 Resistance to rusts

- Pyramiding of durable resistance through marker aided breeding
- Transfer of unutilized sources of genes – *Yr*10, *Yr*15, *Lr*35, *Lr*37 in good agronomical background
- Tackling Ug99 a new race for black rust

8.1.1.3 Resistance to leaf blight

- Special emphasis in eastern, central and peninsular India
- Utilization of confirmed sources for developing better resistant varieties

8.1.1.4 Targeting the low productivity areas

8.1.2 Biotechnological interventions

- Durable leaf & stripe rust resistance, leaf blight, Karnal bunt
- Rice wheat gene synteny and comparative genomics
- Beta-carotene, protein & grain weight in durums
- Salinity/alkalinity tolerance and heat tolerance
- Grain hardness, bread and chapati quality
- Aphid resistance in barley

8.1.2.1 Structural and functional genomics

8.1.2.2 Gene pyramiding

- Leaf and stripe rusts in better agronomic backgrounds, e. g., PBW 343, HD 2687, Lok 1, HUW 234, C 306, HD 2733
- Karnal bunt resistance- PBW 343

8.1.2.3 Transgenics through use of *Agrobacterium*

- Male sterility, salinity/alkalinity tolerance, transgene deployment (DREB gene, Trehlose gene etc)

8.1.2.4 Doubled haploids using wheat x maize system

- Developing mapping populations and generation advancement

8.1.3 Breeding specific genotypes for different tillage options in systems perspective

- Genotype x tillage interaction studies
- To develop specific genotypes for zero tillage and FIRBS

8.1.4 Hybrid wheat

- Create male sterile lines in the background of important cultivars using *timopheevi* cytoplasm
- Search for maintainers and restorers
- Identify superior cross combinations that give higher and stable heterosis
- Identify heterotic gene pool
- Floral biology studies for enhanced cross pollination

8.1.5 Creating new variability

- Utilization of winter x spring crosses
- Pre-breeding activities involving buitre, synthetics and Chinese lines
- Utilization of wild species for heat and drought tolerance, powdery mildew, grain weight

8.1.6 Improving quality traits in durums

- Beta carotene (available 5-6 ppm; target - 10.0 ppm)
- Hectolitre weight (>78)
- Protein content (available- 12%; target – 14%)
- Pasta quality (gamma gliadin 45 band LMW 2 – available in few)
- Minimizing yellow berry incidence (high in NWPZ)

8.1.7 Perseverance of genetic variability

- Collection, evaluation and conservation
- Characterization & documentation
- DUS data base on released varieties

8.1.8 Breeding varieties for suppressive soils

- Salinity/alkalinity tolerance
- Water logging tolerance
- Micro-nutrient efficient varieties (Zn, B, Mo, Fe, S)

8.2 Barley Improvement

- Identification of new sources for malt purpose barley

- Improving yield and malting quality and incorporation of biotic resistance
- Identification of dual purpose barley for fodder and grain production

8.3 Resource Management

8.3.1 Resource conservation technologies and conservation agriculture

- Zero tillage technology and Rotary tillage for reduced energy usage
- FIRBS for water use optimization and laser leveller
- Residue management through surface retention and/or incorporation

8.3.2 Diversification/intensification of rice-wheat system

- Through alternative crops like maize, soybean etc through FIRB technology for increasing water use efficiency
- Introduction of leguminous crops to regain and build up the soil health.
- Green manuring

8.3.3 Intercropping/companion cropping

- Wheat with autumn planted sugarcane and potato
- Seeding wheat in ratoon sugarcane

8.3.4 Weed dynamics and integrated weed management

- Cultural and chemical means
- Biological control – mycoherbicides
- Studies on weed succession and weed dynamics in relation to various cropping systems, agro-techniques, soil and climate of the agro-ecological system

8.3.5 Organic farming and micronutrients

- Long term experiments on use of organics in wheat production
- Studies on effect of mocronutrients deficiencies on grain and straw quality vis-à-vis human and animal health

8.3.6 Farming system approach for sustainability

- Issues of increased input, energy usage and soil health
- Sustainability of rice-wheat system
- Water scarcity & water use efficiency
- Optimization of inputs and maximization of input use efficiency

8.4 Cop Protection

8.4.1 Combating cereal rusts

- Proper deployment of resistance genes in different epidemiological zones
- Tackling new virulence of yellow rust, 78S84 in PBW 343
- Combating Sr31 virulence (Ug99) for stem rust
- Postulation of rust resistant genes and identification of new races

8.4.2 Tackling leaf blight, Karnal bunt, powdery mildew and head scab

- Pathogenic and genetic variability studies
- Incorporation of resistance in popular wheat varieties

8.4.3 Other priority areas

- Bioagents for disease management (*Trichoderma* spp. and *Pseudomonas fluorescens*)
- Taking care of nematodes, aphids and termites
- Identification of sources of resistance against diseases and insect pests
- Survey and surveillance for disease and insect pests
- IPM : Use of bioagents and Plant Growth Promoting Rhizobacteria (PGPR)
- Pest risk analysis for important diseases
- Impact of climatic changes on disease spectrum and Pest dynamics in new RCTs

8.4.4 Strategy for stripe rust

There is a need to establish a mechanism by which all the west and south east Asian countries are brought under one network for wheat rusts scouting, sharing of knowledge and expertise involving the following points:

- Mapping virulence/avirulence patterns of yellow rust pathotypes prevailing in the continuum of MEASA countries.
- Preparation of database on past and present varieties of wheat grown in MEASA countries with particular reference to the yellow rust resistance.
- Survey of grasses (collateral hosts) in the countries of concern and explore their potential to support over summering of *P. striiformis*.
- Development of a common strategy to manage yellow rust in MEASA region.

8.5 Wheat Quality

Improvement of nutritional and processing quality of wheat is paramount. The improvement depends on understanding major gene systems related to different quality traits. Structural and functional genomics can help in identifying major genes associated with quality traits.

- Understanding genetics of quality traits and their molecular basis to use them in precision breeding for product specific varieties
- Development of micro level tests requiring lesser amount of materials, lower technical expertise, high throughput, low cost and explaining larger variability in the quality of end-products are needed to expedite the breeding efforts
- Characterizing genes on starch biosynthetic pathway to manipulate yield potential and enhancing starch quality through both transgenic and non-transgenic routes.
- Enhancing nutritional quality of wheat by improving micronutrient density and their bioavailability and enhancing lysine content
- Identifying and utilizing germplasm resources for improvement of wheat for different quality traits

8.6 Second generation problems

RCTs have a defining role to bring down the production cost. Zero tillage technology has already been adopted by the farmers in the Indo-Gangetic plains and other options like FIRBs, Rotary-Till Drill, and Strip Till Drill *etc*. are under investigations. Under the changed tillage practices, the weed flora and the dynamics of insect-pests are also showing apparent changes. Hence, there will be need of monitoring not only incidences of weeds and diseases but also the soil health aspects. The introduction of mechanical harvesting of wheat and rice under rice-wheat cropping system has necessitated proper *in-situ* residue management. The seeding/transplanting under zero tillage situations with lots of loose residue is warranting to modify existing tillage machines. There is a need to develop new wheat and rice varieties better suited for growing under specific-tillage practices.

8.7 Plant Variety Rights

Several international laws are being framed and/or are likely to be framed in future. Such laws as IPR (Intellectual Property Rights), GATT (General Agreement on Tariffs and Trade) and PVR (Plant Variety Rights) may restrict the free or easy availability of new germplasm to the Indian wheat programme. These laws and regulations are the major issues that the Indian Wheat Programme is likely to face.

8.8 Information Technology

The recent advances in computer technology and data management system have vastly augmented the ability to store, access, distribute and process large quantities of information at low cost. Large amount of data/results generated through field experiments, laboratories analysis and collection, will be properly documented in the form of database. A strong database will be developed on sound and scientific lines on various aspects like pedigree management, genetic resources, crop protection system, geographical information system, statistics on fertilizer usage, results of the coordinated trials etc. This will provide timely and accurate information for future research and planning. Computer networking through ERNET, LAN etc. using satellite, digital communication will be utilized for the rapid exchange of information contained in the database within and outside the organizations engaged in wheat research in India and abroad.

8.9 Human Resource Development

Creating trained and confident human resource will always remain one of the thrust areas. This not only includes training of DWR and other wheat scientists to take up the new challenges and frontline research areas, but also to organize training/orientation course programmes for researchers, private industry personnel, farmers, etc. to take wheat production in the country to new heights.

8.10 Resource Generation

Due to increasing pressure on government funding, there will be dire need to meet some proportion of institute's requirement by arranging finance through consultancies, contract research, revolving fund schemes, by organizing training programmes and seed production of new varieties.

9. PROGRAMMES AND PROJECTS ON A TI ME SCALE AND FUND REQUIREMENT

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
A.	**Multilocational and multidisciplinary research programme on wheat & barley improvement (AICW&BIP)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
B. Research Programmes																			
1.0	**Crop Improvement**																		
1.1	Genetic enhancement and varietal development in wheat	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1.2	Genetic enhancement for yield, resistance and quality to augment wheat production under different prod uction conditions and mega zones of India	√	√	√	√	√	√	√	√	√	√								
1.3	Improving yield potential and quality of durum and dicoccum wheats in central and peninsular India	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1.4	Increasing wheat yield potential through winter x spring hybridization by utilizing diversity from winter wheats	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1.5	Exploiting related wild species, synthetics and other elite material of wheat for introgression of yield contributing traits and creating new diversity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1.6	Development of hybrids in wheat through CMS system	√	√	√	√	√	√	√	√	√	√								
1.7	Tailoring wheat genotypes for different cropping systems and resource conservation technologies under northern plains of India	√	√	√	√	√	√	√	√	√	√								
1.8	Physiological interventions for improving heat, salinity and drought tolerance in wheat	√	√	√	√	√	√	√	√	√	√								
1.9	Development of wheat genotypes with improved micronutrient use efficiency	√	√	√	√	√	√	√	√	√	√								
1.10	Molecular approaches for yield stability through improved biotic and abiotic stress tolerance and quality improvement	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
1.11	Use of molecular divergence in Indian wheat cultivars	√	√	√	√	√	√	√	√	√	√								
1.12	Maintenance breeding and seed production of recently released varieties for varietal replacement at national level for increasing production and productivity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
1.13	Anticipatory breeding approaches for development of high yielding genotypes of wheat possessing resistance against Ug99	√	√	√	√	√	√	√	√	√	√								
1.14	Development of wheat genotypes with improved input use efficiency with emphasis on water and fertilizer responsiveness	√	√	√	√	√	√	√	√	√	√								
1.15	Germplasm acquisition, evaluation, cataloguing, maintenance and exchange of wheat	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.0	**Resource Management**																		
2.1	Resource conservation, crop diversification and integrated nutrient and weed management in wheat based cropping systems	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.2	Long term effects of tillage and residue management on soil properties						√	√	√	√	√	√	√	√	√	√	√	√	√
2.3	Effect of crop diversification and intensification on soil health	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.4	Herbicide resistance profiles and management studies in *Phalaris minor*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.5	Studies on the biology of major weeds of wheat	√	√	√	√	√													
2.6	Integrated weed management studies in wheat based cropping system	√	√	√	√	√	√	√	√	√	√								
2.7	Effect of tillage, residue management and crop diversification on the productivity of wheat based cropping systems						√	√	√	√	√	√							
2.8	Effect of tillage, residue management and crop diversification on the pest dynamics	√	√	√	√	√	√	√	√	√	√								
2.9	Integrated nutrient management in wheat based systems for increased productivity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.10	Resource conservation technologies for reducing the cost of production and sustainability of resources.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3.0	**Crop Protection**																		
3.1	Survey and surveillance for diseases and insect pests of wheat, barley and wheat based cropping system	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3.2	Role of induced systemic resistance in wheat against major diseases and pests through PGPR/PGPR-like organisms and validation /promotion of IPM in rice-wheat system	√	√	√	√	√													

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
3.3	Studies on foliar blight of wheat-pathogenic, genetic variability, epidemiology, host resistance, use of toxins and role of PGPR	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3.4	Studies on Karnal bunt of wheat, host resistance, pathogenic, genetic variability and management through eco-friendly means	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3.5	Basic research on field and storage insect pests of wheat	√	√	√	√	√	√	√	√	√	√								
3.6	Studies on host resistance, epidemiology, pathogenic/ molecular variations and management of head scab of wheat.	√	√	√	√	√	√	√	√	√	√								
3.7	Managing biological entity in soil to regulate nematode population in wheat based cropping systems and integrated management of CCN and ECN	√	√	√	√	√	√	√	√	√	√								
3.8	Genetic diversity of important pathogens of wheat through molecular approaches and gene profiling of pests of wheat during pathogenesis						√	√	√	√	√	√	√	√	√	√	√	√	√
3.9	Pest dynamics under new RCTs in wheat based cropping system	√	√	√	√	√	√	√	√	√	√								
3.10	Effect of climate change on diseases and insect pests of wheat						√	√	√	√	√	√	√	√	√	√	√	√	√
3.11	Pest risk analysis of important pathogens of wheat						√	√	√	√	√	√	√	√	√	√	√	√	√
3.12	IPM in wheat based cropping systems	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.0	**Quality and Basic Sciences**																		
4.1	Development of product specific varieties for different end-use products as chapati, bread, biscuit, noodles and pasta products	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.2	Understanding genetics of quality traits and their molecular basis to accelerate breeding for producing wheat varieties for each end-use product separately using molecular marker assisted approach	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.3	Development of micro level tests requiring lesser amount of materials, lower technical expertise, high throughput, low cost and explaining larger variability in the quality of end-products are needed to expedite the breeding programme for developing varieties	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
4.4	Characterizing genes on starch biosynthetic pathway to manipulate yield potential and enhancing starch quality through both transgenic and non-transgenic routes	√	√	√	√	√	√												
4.5	Enhancing nutritional quality of wheat by improving micronutrient density (biofortification) and their enhanced bioavailability and enhancing lysine content.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.6	Identifying and utilizing germplasm resources for improvement of wheat for different quality traits	√	√	√	√	√	√												
4.7	Establishment of wheat technology centre with a view to develop pilot scale testing of quality of different products, fortification by micronutrients and to establish linkages with the industry						√	√	√	√	√								
5.0	**Transfer of Technology and Impact Assessment**																		
5.1	Technology transfer, validation and impact assessment	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5.2	Enhancing profitability of wheat-based farming in NW India by improving grain quality	√	√	√	√	√													
5.3	Economic analysis of wheat based systems, properties like stability, sustainability, equability, etc. and producers' core system e.g. factor demand, output supply, etc.	√	√	√	√	√													
5.4	Constraint analysis, zone wise and region wise, to exploit untapped yield potential of wheat and barley	√	√	√	√	√	√	√	√	√	√								
5.5	To study production requirements vis–a-vis food pattern dynamics and impact on food security	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5.6	To devise suitable extension methodologies for effective dissemination of improved wheat and barley technologies	√	√	√	√	√						√	√	√	√	√	√	√	√
5.7	To study the socio economic dynamics and technological needs of the farmers to develop location specific strategies to enhance profitability of farmers	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
6.0	**Barley improvement**																		
6.1	Evaluation, characterization, conservation and documentation of barley germplasm	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6.2	Improvement of malt barleys for northern plains	√	√	√	√	√													
6.3	Genetic and molecular studies for marker aided selection in barley improvement	√	√	√	√	√													
6.4	Resource conservation and input management for sustainable barley production for feed fodder and malting purposes	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6.5	Identification of genetic diversity of the resistance to biotic and abiotic stresses (rusts, blights, drought and salinity) in Indian barley programme	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.0	**DWR Regional Station, Flowerdale, Shimla**																		
7.1	Monitoring Wheat and Barley Rusts through extensive surveys in the wheat growing areas for (farmers fields, tarp plot nurseries) for detection of new variation early before their build-up	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.2	Analysis of rust infected samples of wheat and barley to map the prevalence of pathotypes/ detect new variations	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.3	Maintenance of pathotypes both old and new ones in pure form and supply of this inocula to wheat workers for creation of epiphytotics	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.4	Multipathotype evaluation of advanced lines of Advanced Varietal Trials (AVT) of all the wheat growing areas and advanced lines of National Barley Disease Screening Nursery (NBDSN), characterizing/ postulating rust resistance genes (*Lr*, *Sr* and *Yr*) in wheat entries	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.5	Recasting/ Updating of rust differentials system regularly with a view to make it more refined to detect more variations and provide more information to wheat workers	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.6	Design/develop rust management strategies based on pathotype distribution and available rust resistance	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

S.No.	Programme and Projects	2007-2012					2012-2017					2017-2022					2022-2025		
7.7	Adult plant evaluation of promising entries of AVT material against either mixture of different pathotypes or against individual pathotypes	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.8	Inheritance studies of rust resistance and development of genetic stocks	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.9	Procure newly developed rust resistance seed to update repository of wheat and barley rust differentials	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.10	Pyramid rust resistance genes in high yielding cultivars through marker assisted selection and distributing these seeds to wheat workers for their further usage	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8.0	**DWR Regional Station, Lahaul Spiti**																		
8.1	Establishing permanent crossing block for resourcing winter wheat traits to enhance yield potential	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Proposed XI plan funds for research programmes

Research Programme	Rs. in lakhs
AICW&BIP	1250
Crop Improvement	750
Resource Management	400
Crop Protection	400
Quality and Basic Sciences	250
Transfer of Technology and Impact Assessment	250
Barley improvement	500
DWR Regional Station, Flowerdale, Shimla	800
DWR Regional Station, Lahaul Spiti	150

10. LINKAGE, COORDINATION AND EXECUTION ARRANGEMENTS

The All India Coordinated Wheat and Barley Improvement Project is a well knitted research project across the country and involves centers in every agro-climatic conditions of India. The project has 29 funded centers for wheat and 7 for Barley. Nearly 120 scientists located in the State Agricultural Universities (SAUs) execute the project on a cost-sharing basis of 75:25 between ICAR and SAUs.

Funded centres under AICW & BIP

Sr. No.	State	Centres	Name of centre
1	Assam	1	AAU-Shillongani
2	Bihar	1	RAU-Sabour
3	Chhattisgarh	1	IGKVV-Bilaspur
4	Gujarat	2	SDAU-Vijapur & GAU, Junagarh
5	Haryana	1	CCSHAU-Hisar
6	Himachal Pradesh	3	CSKHPKV-Palampur, Dhaulakuan & Bajaura
7	J & K	1	SKUAS&T-Shalimar (Srinagar)
8	Jharkhand	1	BAU-Ranchi
9	Karnataka	1	UAS-Dharwad
10	Madhya Pradesh	4	JNKVV-Powarkheda, Gwalior, Sagar & Rewa
11	Maharashtra	3	MPKV-Niphad & Mahabaleshwar; ARI-Pune
12	Manipur	1	Dir. of Agril., Mantripukhri
13	Punjab	1	PAU-Ludhiana
14	Rajasthan	3	RAU-Durgapura, MPUAT-Udaipur & Kota
15	Uttaranchal	1	GBPUA&T-Pantnagar
16	Uttar Pradesh	3	CSAUA&T-Kanpur, NDUA&T-Faizabad, BHU, Varanasi
17	West Bengal	2	BCKV-Kalyani, UBKV-Pundibari

For better and effective execution of the research activities, the whole country has been divided into six wheat growing zones. Area under NHZ, SHZ and PZ is small in comparison to plains but need based programmes are being co-ordinated with collaboration of centres. Similarly in case of Barley, the country has been divided into five mega barley growing zones.

Wheat growing zones in India

Zone	Constitution	App. Area (m. ha)*
Northern Hills Zone (NHZ)	Western Himalayan regions of J&K (except Jammu and Kathua distt.), H.P. (except Una and Paonta Valley), Uttaranchal (except Tarai area), Sikkim and hills of West Bengal and N.E. States	0.8
North Western Plains Zone (NWPZ)	Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions) and Western UP (except Jhansi division), parts of J&K (Jammu and Kathua distt.) and parts of HP (Una dist. and Paonta valley) and Uttaranchal (Tarai region)	11.1
North Eastern Plains Zone (NEPZ)	Eastern UP, Bihar, Jharkhand, Orissa, West Bengal, Assam and plains of NE States	9.2
Central Zone (CZ)	Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh	5.0
Peninsular Zone (PZ)	Maharashtra, Karnataka, Andhra Pradesh, Goa, plains of Tamil Nadu	1.5
Southern Hills Zone (SHZ)	Hilly areas of Tamil Nadu and Kerala comprising the Nilgiri and Palni hills of southern plateau.	0.1

* Based on 1999-2000 estimates

Barley growing zones in India

Zone	Constitution
Northern Hills Zone (NHZ)	Western Himalayan regions of J&K (except Jammu and Kathua distt.), H.P. (except Una and Paonta Valley), Uttaranchal (except Tarai area), Sikkim and hills of West Bengal and N.E. States
North Western Plains Zone (NWPZ)	Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions) and Western UP (except Jhansi division), parts of J&K (Jammu and Kathua distt.) and parts of HP (Una dist. and Paonta valley) and Uttaranchal (Tarai region)
North Eastern Plains Zone (NEPZ)	Eastern UP, Bihar, Jharkhand, Eastern MP (Rewa Division), and West Bengal.
Central Zone(CZ)	Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh
Peninsular Zone (PZ)	Maharashtra and Karnataka

10.1 National and International Linkages

To create awareness among the farmers about various technologies, linkages are being established with the SAUs, State Departments of Agriculture, Fertilizer Companies, Input Suppliers, Hariyali Kisan Bazar etc. to carry out research. The Directorate of Wheat Research and the AICW&BIP are having active collaborations with following international and national organizations :

International linkages

- International Center for Maize and Wheat Improvement (CIMMYT), Mexico
- International Center for Agricultural Research in Dry Areas (ICARDA), Syria
- International Rice Research Institute (IRRI), Philippines
- United States Department of Agriculture (USDA), USA
- Australian Council of International Agricultural Research (ACIAR), Australia
- Indo-Swiss Collaboration in Biotechnology (ISCB)

National linkages

- Department of Biotechnology (DBT), Government of India, New Delhi
- Department of Science and Technology (DST), Government of India, New Delhi
- Council of Scientific and Industrial Research (CSIR)
- State Agricultural Universities (SAUs)
- Banaras Hindu University (BHU)
- Other ICAR Institutes

11. CRITICAL INPUTS

11.1 Manpower

In view of the proposed elevation of the Directorate to National Wheat Research Institute, extra manpower will be required in the future.

S.No.	Category	XI plan 2007-2012	XII Plan 2012-2017	XIII Plan 2017-2022	XIV Plan 2022-2025
1	Scientific Staff	70	76	77	80
2	Administrative	40	40	40	40
3	Technical	70	75	75	80
4	Supporting	50	50	50	50
5	Legal / IPR Experts	2	2	2	2
6	Scientific Consultants	2	2	2	2

11.2 Equipments/Building/Other Facilities

In the event of DWR expansion, the budgetary provisions will be expanded to accommodate more areas of research including biotechnology and transgenics, double haploids, food science and technology, etc.

S. No.	Category	Anticipated Budget (Rs. Crores)			
		XI plan 2007-2012	XII Plan 2012-2017	XIII Plan 2017-2022	XIV Plan 2022-2025
1	Scientific equipments	50	70	90	100
2	DH facility	25	5	5	5
3	Hi-Tech Glass house	10	2	2	2
4	GIS facility	10	5	5	5
5	Support for Information Technology	2	2	2	2
6	Additional Building	50	25	10	10
7.	Centre for excellence for biotechnology	20	10	10	10

11.3 Human Resource Development and Training

There is a need for international exposure for the scientists which could be undertaken through the international linkages with CIMMYT, ICARDA, IRRI, Indo-US Knowledge Initiative, ISCB, USDA and/or other international institutes/organizations in frontier areas like biotechnology, molecular breeding, pre-breeding approaches, germplasm conservation technologies, molecular plant pathology, quality, resource conservation technologies, biotic and abiotic stresses, bioinformatics, integrated pest, nutrient and weed Management.

12. RISK ANALYSIS

The Indian agriculture involves lot of risks and is highly vulnerable to the climate. Various programmes have been developed to analyse the risk of crop loss. Realizing its importance, the Directorate has initiated some steps to gather following information:

12.1 Wheat Atlas

An atlas of Indian Wheats has been prepared which will prove handy to offer choice to the importing nations. The grading pattern and the suggested means to improve the grade of wheat produced in various parts of the country will also improve quality of the grains selected for trading. PRA (Pest Risk Analysis) to Karnal bunt, a model design to foresee the risks associated with shipping of wheat from destination, can also contribute a great deal in grain trade.

12.2 Use of Computer Softwares for Tracking Karnal Bunt of Wheat

Utilizing 70 years information on Karnal Bunt pathogen and the epidemiology, a PRA has been developed to calculate the risk of shipping wheat from India. Issues related to post harvest handling, survival during the wheat free summer, effect of extreme cold weather and extreme summer heat of desert were covered. The probability of risk was calculated using the computer software called GEOKB and KBRISK. Based on geographical details and general agronomic practices of wheat growing of the area, GEOKB works out the probability of KB getting established. This probability value of calculations was based on the database of the Indian wheat disease survey information on the occurrence of KB in different parts of the country and farming conditions. The reliability of the GEOKB was tested through some case studies. Similar software programmes will also be needed in future to analyze the risk from other biotic factors.

12.3 Scouting for *Puccinia striiformis* Virulences in West and South Asia

Stripe rust (*Puccinia striiformis tritici*) is the most important disease of wheat in the countries of Middle East and South Asia (MEASA). Stripe rust has also been the most important wheat disease of the Indo-Pak subcontinent. Through *Yr9* gene derived from rye, the disease was successfully kept under check for a decade or more. But *Yr9* virulence migrated from west Asia to this subcontinent has again put a serious threat to wheat cultivation in cooler north west India and adjoining parts of Pakistan.

The widespread cultivation of semi-dwarf cultivars and the exposure of the *Yr2* gene made it possible to track the “new” virulence associated with these cultivars. The first report of the *Yr2* virulence, also known as 8156 virulence was noted from Turkey in 1967. Subsequently it was reported from Lebanon, Iran, Afghanistan, Pakistan and India and eventually from Nepal. The tracking of the sequential appearance of the *Yr2* virulence was possible because of the newness of the *Yr2* gene in the host population, and the international network of nurseries and cooperators. The sequential spread of the *Yr2* virulence could also be associated with the weather system referred to as the “western disturbance”.

12.3.1 Foreseeing threat from stripe rust

The previous experiences strongly support the migration of yellow rust from west Asia towards South East Asia. With the expected introduction of novel resistance genes in future cultivars, one can intuitively perceive much more build up of new virulences in west Asia and their migration towards south east. This is a serious concern of the whole subcontinent in general and Iran, Iraq, Pakistan and India in particular whose national food resource largely depends upon wheat.

A new stripe rust race designated as 78S84 has been reported in ruling wheat variety of India, PBW 343 in 2001. In 2005-06 and 2006-07, new rust race has made PBW 343 and PBW 502 susceptible at many locations in India. So there is an urgent need to incorporate resistance to this new virulence in popular wheat varieties grown in NWPZ and NHZ on priority.

12.4 Threat From New Stem Rust Race Ug99

With the emergence of *Sr31* pathotype in Africa, the black rust pathogen brought back the memories of catastrophic losses this rust can cause. This pathotype has now spread to Kenya and Ethiopia. Ug99 pathotype of stem rust combines virulence for *Sr31* along with other genes. With the wide usage of *Sr31* in Indian cultivars, it is a cause of concern for Indian wheat programme since several varieties including PBW 343 possess this gene. For pre-empting the threat posed by this pathotype, strategic follow up action has been initiated under Global Rust Initiative. Several Indian wheat genotypes have shown resistance against Ug99 when tested at Kenya but it may we need to keep a continuous vigil on Ug99 and its variants.

12.5 Global Climate Change

The incidence of *Fusarium* head blight, powdery mildew and leaf blight of wheat that were thought earlier as minor diseases, are increasing tremendously now a days due to global climate change. The changing raining pattern during the wheat cropping season may make wheat vulnerable to these diseases. There are reports that countries that have followed new tillage practices like zero tillage, are facing more problem due to these disease. Under FIRBS, incidence of powdery mildew has been reported more due to change in microclimate. Thus, there will be an urgent need to keep vigil on head blight, leaf blight and powdery mildew of wheat under changed tillage practices and climate change.

In addition to the above the following will be taken care of :

- Narrowing genetic variability
- Fluctuations in wheat prices in international market
- Depleting the ground water table
- Deteriorating soil health and Micronutrient deficiencies
- Change in pest dynamics scenario due to adoption of new RCTs
- Global climatic changes including warming during next decades
- Patent regulated genetic flow
- Population pressure reducing arable area
- Patent regulated genetic flow

13. PROJECT REVIEW, REPORTING AND EVALUATION ARRANGEMENTS

A number of projects for wheat & barley improvement are operating at the Directorate. A well established system for reviewing, evaluation and reporting of the projects at the Directorate are :

- Annual review by Research Advisory Committee
- Annual review assessment by Institute Research Council
- Half yearly assessment by Project Monitoring and Evaluation Committee
- Zonal Monitoring of coordinated trials
- Review of results of AICW&BIP in Wheat and Barley Researchers Meet annually
- Expert committee for externally funded projects
- Assessment of half yearly progress of scientists by DG, ICAR
- Assessment by Quinquennial Review Team

14. RESOURCE GENERATION

As per the directions of the Council, revenue generation is given due priority at the Directorate. In this context, certain potential areas have been demarcated:

- Sale of seed of improved varieties of wheat and barley
- Testing of molecules/hybrids/varieties
- Revolving fund
- Training to students
- Off season crop sale
- Consultancy to private industries
- Sale of wheat based end-products

The revenue generated since 1991 is reflected and being given in the following tables:

Revenue receipt for the year 1991-92 to 1996-97 DWR, Karnal (in Rupees)

S. No.	Sub head	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	Total
1	Farm Produce	30483	77739	230015	187303	189173	256788	971501
2	Institutional Service	-	-	-	24826	-	-	24826
3	Rent/License Fee	-	11964	14071	24707	88049	126957	265748
4	Condemned Material	-	-	211100	20900	17600		249600
5	Interest on Loans . & Adv	-	88	39	528	5287	12608	18550
6	L & P C	-	8931	-	-	-	-	8931
7	Tender form /Publication	-	-	-	2220	-	-	2220
8	Testing Fee	-	-	-	-	73750	-	73750
9	Registration Fee	-	-	-	-	-	-	
10	Interest on FDR	-	72688	1499503	1408883	2981074		
11	Unspent bal. of Schemes		-	-	-	-	-	-
12	Miscellaneous Receipt	16835	9680	43952	282021	177500	217085	747073
Total Receipt		**47318**	**108402**	**499177**	**615193**	**2050862**	**2022321**	**5343273**

Revenue receipt for the year 1997-98 to 2001-02, DWR, Karnal (in Rupees)

S. No.	Sub head	1997-98	1998-99	1999-00	2000-01	2001-02	G.Total
1	Farm Produce	457246	162916	183244	495512	329000	1627918
2	Institutional Service	1051	-	1038	-	-	2089
3	Rent/Licence Fee	127152	149497	149047	162468	210389	798553
4	Condemned Material	29870	34000	60825	42800	167495	
5	Interest on Loans & Adv.	25946	24046	21969	108564	85492	266017
6	L & P C	-	-	-	-	-	-
7	Tender form /Publication	19000	28250	17475	44675	20825	130225
8	Testing Fee	500	-	35000	-	-	35500
9	Registration Fee	900	33400	9762	10000	11000	65062
10	Interest on FDR	330036	260174	275826	488153	610577	1964766
11	Unspent bal. of Schemes	-	-	86	-	-	86
12	Miscellaneous Receipt	142084	66024	220688	111037	298290	838123
Total Receipts		**1133785**	**758307**	**974960**	**1420409**	**1608373**	**5895834**

Revenue receipt for the year 2002-03 to 2005-06, DWR, Karnal (in Rupees)

S.No.	Sub head	2002-03	2003-04	2004-05	2005-06	Total
I	**OTHER RECEIPT**					
1	Farm Produce	386239	391087	591450	868591	2237367
2	Institutional Service	141	141			
3	Rent/Lincence Fee	230727	254067	104828	232945	822567
4	Condemned Material	11100	207900	219000		
5	Interest on Loans & Adv.	129213	235881	448754	134763	948611
6	L & P C	0				
7	Tender form/Publication	12625	297437	3900	313962	
8	Testing Fee	6203	500	41500	48203	
9	Registration Fee	30600	6000	50000	86600	
10	Unspent bal. of Schemes	6500	6500			
11	Miscellaneous Receipt	174590	177039	586538	181421	1119588
12	Contract Research /Consultancy	1572509	1065654	2638163		
	Total Receipts	981297	1361511	3566520	2531374	8440702
13	Interest on FDR	846150	804988	985042	894710	3530890
	GRAND TOTAL	1827447	2166499	4551562	3426084	11971592

The proposed target for revenue generation during the XI plan is 200 lakhs.

15. OUTPUT

Wheat is one of the major food crop that contributes significantly to the central pool. The area under wheat has been around 27 million ha with total production of 70 million tones. The proposed research programmes under different disciplines, mega-environments and production conditions will help in enhancing the production, productivity and thus the income of Indian farmers along with the secured food supply during next few decades. The salient anticipated output from the programmes and projects are enumerated as below.

- About 100 new improved varieties of wheat and barley crops will be developed, identified and released for different production and agro-climatic conditions.
- The yield levels of different zones will be further increased to the tune of 10 percent over next three decades thereby increasing total productivity at the pace of three percent per year.
- New varieties of wheat will be more efficient for inputs, nutritive and cost effective.
- The maintenance and conservation of biodiversity will make India self reliant for future needs.
- New and anticipated threats will be managed by tailoring need and area specific genotypes.
- Resource conservation technologies will help in reducing the cost, conserving the natural resources and creating better and healthy environment.
- The weed, water and nutrient management through integrated approach will help in further reducing the cost and use of unhealthy chemicals.
- The approaches on cropping system, residue management and diversification will help in sustaining the soil health for better crop production.
- Monitoring of pest and pathogens in changed agro-climatic scenario will help in reducing the crop losses.
- Integrated pest management module will help in ecofriendly management of the diseases and pests on sustainable basis.
- New sources of resistance identified will help in introgressing the desired genes into the commercial cultivars.
- New genotypes will be developed with better end product quality.
- Molecular markers identified will help in developing the improved genotypes with better nutritional and industrial quality attributes.
- Transfer of technology modules developed will narrow down the yield gaps to around 15 percent thereby increasing the total production and productivity across the zones.
- The feedback from the ultimate beneficiary will help in removing the bottlenecks and also fine tuning the wheat production technologies.
- The new varieties of malt barley will boost the contractual farming, support to industry and income of the farmers.
- The technologies developed and patented through this programme will help in protecting Indian rights under changing IPR regimes.

16. OUTCOME

The targeted wheat production levels of 109 millions tones by 2025 can only be achieved by increasing average productivity levels to 3.5 t/ha. The availability of per capita wheat for increased population will be secured through improved and eco-friendly technologies. The enhanced nutritional value of the future genotypes will help in eradicating the malnutrition of under-nourished rural/urban population of the country. Some of the expected major outcomes from the proposed programmes include the followings.

- Improved, high yielding, disease resistant and nutritionally superior wheat and barley varieties for changed scenario to ensure sustainable production and productivity.
- Resource conservation technologies to reduce cost of cultivation and increase profitability to the farmers. This will also include conservation of expensive and scarce inputs like fertilizers and water by improving input use efficiencies.
- Increasing profit margins to farmers and increasing export potential through nutritionally superior wheat and barley varieties.
- The changed food habits of Indian population will be fulfilled.
- The new technologies will also help in producing the wheat free from myco-toxins and thus will meet the CODEX requirement for international trade.
- Eco-friendly means of wheat and barley cultivation through integrated management practices.