Vision 2030

Directorate of Wheat Research

Karnal-132 001 (Haryana) India

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FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

The demand for wheat is increasing due to changes in food consumption habits and preferences for packaged products by the urban and rural population. The growth in wheat production witnessed over the years has to be enhanced further while overcoming the challenges like climate change, over-exploitation of natural resources, vulnerability to disease incidences and decreasing factor productivity to make wheat cultivation profitable to farmers. Quality traits have to be given due emphasis for value addition and to make Indian wheat competitive in global trade. The Directorate of Wheat Research (DWR), Karnal through its network of research centres under the All India Coordinated Wheat and Barley Improvement Project has developed large number of improved wheat and barley varieties, coordinated breeder seed production, standardized production and protection technologies and undertaken extension of new technologies to the farmers in different agro-climatic zones.

It is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 6th July, 2011
New Delhi

Preface

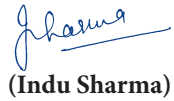
The Directorate of Wheat Research is the nodal institution for coordinating the multidisciplinary and multi-location testing of wheat and barley technologies under All India Coordinated Wheat and Barley Improvement Project with the active support from a large number of funded and voluntary centres spread across six mega zones of the country. In addition, DWR is also contributing to the basic, strategic and applied research in thrust areas dealing with crop improvement, crop protection, resource management and quality of wheat and barley crops.

Wheat is the second most important cereal crop and plays an important role in food and nutritional security of India. The record production of 84.27 million tonnes during 2010-11 clearly indicates the strength of systematic and planned wheat research and extension in the country. It may be recalled that the total wheat production of the country during 1947-48 was just 5.6 million tonnes with average productivity of less than one tonne per hectare. In historical perspective, India had made spectacular advances in productivity and sustainability of wheat cropping system.

Nevertheless, this progress should not make us contented as the country faces countless challenges in the form of population growth coupled with decreasing arable land, depleting water resources, soil health deterioration and climate change. To meet the demand of approximately 100 million tonnes wheat by 2030, there is a need to produce more wheat with fewer resources in a sustainable and cost effective way.

This particular flagship Vision document is being published against a backdrop of huge challenges the country faces after decades of steady growth; wheat productivity is stagnating in high productive environments. This document highlights the achievements and proposes new research concepts to develop and promote innovative and need based scientific technologies to meet the demand of continuously changing social and economic needs together with an explicit analysis of our weaknesses and strengths.

I would like to express my sincere gratitude to Dr. S Ayyapan, Director General (ICAR) and Secretary, DARE and Dr. Swapan K. Datta, DDG (Crop Sciences) for their constant support to the Indian wheat programme. The efforts of Dr. Vinod Tiwari and his team comprising Drs. CN Mishra, K Venkatesh, VK Goyal, Pradeep Sharma, SC Gill, BS Tyagi, Ratan Tiwari, Sewa Ram and Ravish Chatrath in bringing out this document are greatly appreciated. The contributions of all the Principal Investigators of various programmes and cooperating scientists of all coordinating centres are duly acknowledged.



(Indu Sharma)

Preamble

Wheat research in India began in a systematic way more than a hundred years ago. The coordinated system of multi-location research to address the needs of different agro-ecological zones in wheat has also completed fifty years now. During this period India witnessed the dramatic successes of the green revolution and has been able to rise from a deficit state to a self-sufficient one with surplus production at times. India harvested a record production of 84.27 million tonnes of wheat during the crop year 2010-11. This may seem a landmark but it's not the summit as more wheat has to be produced to feed the increasing human population and meet the industrial requirements as well.

World population is expected to reach more than 8 billion by 2030. It has been projected that 55 percent enhancement in the demand for food shall be caused by population increase and income gains by 2030. The projected food demand by 2030 in terms of per capita energy is 3000 Kcal. Thus, wheat production has to be geared up to meet the increasing demand for food and nutritional security. In India, approximately 100 million tonnes of wheat would be required to be produced to cover an estimated demand for 345 million tonnes of food grains in 2030.

Climatic changes have implications on food production, food security and food safety. Natural resources will be far more stretched 20 years after than they are now. With climatic changes leading to temperature extremes, weather changes, erratic precipitation and changes in pest dynamics, overall changes in the micro-environments are expected to be more severe in the coming years. It is estimated that India's water needs will be doubled by 2030 and water scarcity shall affect crop production the most. Wheat production has to bear many challenges due to decrease in arable land caused by increasing urbanization coupled with land degradation, limited water for irrigation and changes in incidence of diseases and pests. Similarly the demand for high value products of wheat shall also have to be met.

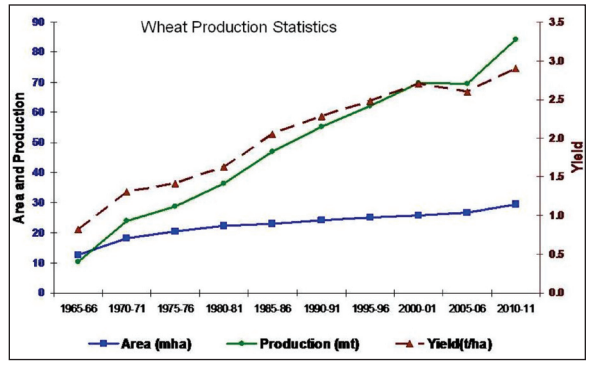
Wheat production in some states in India is faced with large gaps in potential and realized yield. Some of the gaps can be filled up through development of infrastructure facilities, while the production related barriers can be effectively overcome through adoption of appropriate interventions and technologies. The sustainability issues in the wheat cropping system will have to be addressed properly so that the long-term growth as well as national food security and household nutritional security are not adversely affected.

The vision document presented herein envisages the challenges, opportunities and a strategic plan to enhance wheat yield and production so that it becomes profitable to the farmers and is available in plenty to consumers.

Contents

The Scenario

The seven-fold increase in wheat production (12.57 million tonnes in 1965-66 to 84.27 million tonnes in 2010-11) during the last five decades has been a remarkable and unparalleled achievement. Wheat production recorded a growth of about 21 per cent during the last decade with regular upward growth during the last five years. The increasing trend recorded in wheat production has been the outcome of concerted efforts made in crop improvement, crop protection, resource management and extension activities.



In India, Uttar Pradesh has the largest area (9.67 mha) under wheat cultivation and it is the highest producer (27.52 mt) as well. The major area under wheat falls in the Indo-Gangetic Plains (IGP) which accounts for roughly 20 million hectares covering the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. The states of Punjab and Haryana provide maximum contribution to the wheat buffer stock, an essential component of food security in our country.

Wheat production is governed by temperature regimes during sowing and harvest time, duration of the cold period, availability of irrigation water and input supply. The growing situations vary from harsh conditions in peninsular and central regions to the favourable conditions of northern India. Even in the IGP, growing conditions vary from less favourable eastern parts to the more conducive western states. The rice-wheat cropping system, although one of the most productive wheat based cropping systems, has inherent problems which are not advantageous to wheat production at least in the eastern parts of the IGP. In addition to the climatic conditions, that may vary from year to year, the occurrence of diseases has a reducing effect on yield and total production. In case of the cultural practices under different wheat based cropping systems, particularly under the rice-wheat cropping system, injudicious use of fertilizers and water has led to numerous problems such as deteriorating soil health and receding water table. Wheat grown in rainfed/dryland areas is faced with water scarcity, temperature extremes and minimal use of nutrients that limit the yield potential and also result in irregular production.

The average growth rate in wheat production for the last 15 years from 1994-95 to 2009-10 was 2.12 percent. This substantial growth in production was due to the contribution of 0.85 percent growth in area and 1.25 percent in yield. The area under rainfed wheat cultivation is affected by the amount and distribution of precipitation primarily in the months of September and October. The rainfall thus leads to an increase or decrease in the area under rainfed cultivation. In good rainfall years, an increase of about five lakh hectares under wheat cultivation is recorded.

Wheat has enjoyed the highest benefit of technological breakthrough during the past three decades with its total factor productivity (TFP) growth close to 2% (Ramesh Chand et al., 2011). The development and adoption of new varieties have significantly contributed in increasing yield and production. From the earliest semi-dwarf varieties like Lerma Rojo, Sonora 64, Chhoti Lerma, Kalyansona and Sonalika, the All India Coordinated Wheat and Barley Improvement Project (AICW&BIP) has contributed in the release of 378 wheat varieties suited to different growing situations in six agro-climatic zones of the country. Some of the varieties became extremely popular and occupied large acreage. These include C 306, HD 2009, WL 711, UP 262, HUW 234, HD 2189, WH 147, Lok 1, HI 617 (Sujata), HD 2285, HD 2329, PBW 343, Raj 3765, PBW 502, HD 2733, DBW 17, PBW 550, GW 273, GW 322, GW 496 in bread wheat and Raj 1555, HI 8498, and PDW 233 in durum wheat. Many varieties such as NP 4, Kalyansona, Sonalika, Sharbati Sonora, WL 711, HD 1220, HD 1931 'SIB', HD 2009, HD 2172, UP 262 etc. developed by the project, are also under cultivation in many foreign countries.

The technologies developed for management of irrigation water, fertilizer dosage and scheduling, weed control, crop geometry and crop residue management in wheat based crop sequences in various wheat growing zones have significantly contributed in harnessing the yield potential of new varieties. Presently, there are wide gaps between the realized and potential wheat production particularly in eastern, central and peninsular parts of India. The gaps in yield as assessed from front line demonstrations (FLD) vary among states and there is scope for bridging the gaps with adoption of recommended package of practices.

The wheat rusts are the most damaging fungal pathogens that affect yield and overall production. It has been a rewarding situation that for the last more than four decades no major incidence of rust attack has been recorded. The measures adopted during development and release of varieties has paid dividends to keep the wheat diseases under control.

Wheat is traditionally consumed in India as home-made chapaties. The Indian wheat is rated superior for chapati making and the quality of chapaties prepared from wheat produced in central India is far more superior in comparison to north-western India. With changing times, liking and consumption of bread, biscuit, cookies, noodles,

macaroni, pasta etc. has gradually increased. The changed food preferences have also enhanced the scope for industrial production of wheat products.

Global wheat production during 2009-10 was 679 million tonnes and during 2011-12 it is estimated at 667 million tonnes (International Grains Council, Grain Market Report (GMR 411; May, 2011). Wheat consumption worldwide is estimated to surpass 817 million tonnes by 2030 and production would need to increase at 22.6-43.6% in different countries at the current production level to meet the estimated consumption demand (Zhang et al., 2007. *A forecast analysis on global production of staple crops.* www.stats.gov.cn). It is presumed that climate changes would affect wheat production leading to fluctuations in demand and supply. Availability and prices of wheat for international trade would therefore be variable from year to year.

Research achievements

The All India Coordinated Wheat Improvement Project (AICWIP) began its operations in 1960 while it was launched officially in 1965 at IARI, New Delhi and was elevated to the status of Directorate of Wheat Research in 1978. The Directorate was moved to the present location at Karnal in 1990, and with addition of Barley Network it was renamed as All India Coordinated Wheat and Barley Improvement Project (AICW&BIP). The 31 funded centres located in different SAU's support multidisciplinary research on wheat and barley. Besides the funded centres many voluntary centres in SAUs also cooperate in evaluation of genotypes. In addition, some other testing sites are also provided by State Agriculture Departments and a few NGOs. These locations have been identified in such a way that all the agro-climatic zones of the country are represented. The specific achievements in different scientific fields have been elaborated below.

Crop Improvement

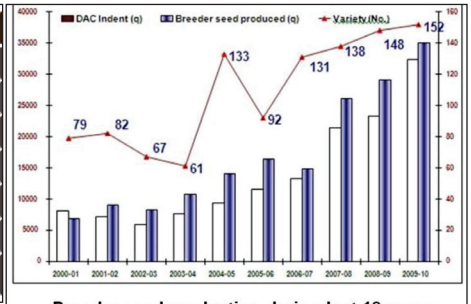
Development of improved wheat varieties and breeder seed production

New varieties are developed through a well planned testing procedure that involves multilocation varietal evaluation for yield, disease resistance, agronomic performance and quality characteristics. Every year around 500 entries contributed by the wheat

Released varieties since 1965

	CVRC	SVRC	TOTAL
Bread wheat	207	112	319
Durum wheat	25	24	49
Dicoccum wheat	05	-	5
Triticale	04	01	5
TOTAL	241	137	378

CVRC: Central Varietal Release Committee
SVRC: State Varietal Release Committee



Breeder seed production during last 10 years

breeding centres are tested in around 450 varietal trials under different cultural conditions at about 130 locations. Another 200 nurseries and trials are organized to test the new genotypes and develop improved crop production and protection technologies. So far 378 wheat varieties suited to different growing situations in six agro-climatic zones of the country have been developed and released for commercial cultivation. The production of breeder seeds of wheat and barley is coordinated by DWR. There has been a steady increase in breeder seed production with surplus every year.

Maintenance and utilization of genetic resources

The Germplasm Resource Unit at the Directorate maintains more than 11000 germplasm lines of wheat which includes indigenous collections, donors from trials/ nurseries, genetic and cytogenetic stocks, wild species and close relatives, and exotic collections. These germplasm are freely available to breeders across the country for utilization in breeding programmes. The different research centres also maintain working collections and utilize them in creating new variability. Germplasm from many countries e.g., USA, Canada, Australia, China, Syria and South Africa have also been acquired.

Germplasm enrichment and sharing

The diverse material coming out of different programmes, including genetic stocks, yield 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 the national nurseries, two more nurseries EIGN-I and EIGN-II are also constituted which involve selected exotic aestivum and durum material. CIMMYT and ICARDA have contributed to increase the genetic diversity by supplying international nurseries/trials in both wheat and barley.

Till the year 2010, a total of 138 genetic stocks of wheat have been registered with NBPGR for various useful traits such as yield components, resistance to diseases, tolerance to drought, heat, salinity and quality traits. These stocks are available in public domain for utilization.

Deployment of new genes for rust resistance

As rusts comprise the most damaging fungal pathogens affecting wheat productivity and production, there is constant effort to replace the rust susceptible varieties with new improved types. As an alternative to the ruling varieties in each zone, new varieties having inbuilt resistance to rusts and other wheat diseases with superior quality and agronomic traits have been released for commercial cultivation. New varieties like DBW17 and PBW550 for timely sown condition and UP2425, DBW16, WH1021 and PBW590 for late sown condition have been released for the NWPZ. Many new wheat varieties viz. HD2643, HW2045, HUW468, HD2733, HD2824, DBW14, K0307, CBW38, DBW39, Raj4120 and HI1563 have been recommended for the NEPZ region.

New varieties like GW322, GW496, HD2864, HI1531 and MP4010 etc. have been developed and recommended as an alternate to popular but susceptible variety Lok1 in central India.

Utilization of biotechnological tools in wheat improvement

PCR based markers have been developed for selection of *Yr10* (DWR, Karnal), *Sr31* (BARC, Trombay), *Lr24* and *Lr19* (IARI, New Delhi) and markers linked to *Lr15, Lr3a, Lr28, Sr22* (NCL, Pune). Besides these, quantitative trait loci (QTL) were identified for stripe rust resistance from *T. monococcum* and *T. boeoticum* (PAU); for spot blotch resistance (BHU), for grain quality traits viz., grain protein content, preharvest sprouting tolerance and grain weight (CCSU, Meerut in collaboration with PAU) and bread making quality (NCL in collaboration with DWR), yellow pigment content and gluten strength in durum wheat (ARI, Pune).

Marker assisted selection was utilized to transfer different effective resistance genes for leaf rust *(Lr24, Lr28, Lr34, Lr35, Lr37)* and stripe rust *(Yr10, Yr15)* in the background of popular cultivars PBW 343, HD2733, WH147, HUW 234, Lok1. Rust resistance genes *Lr57, Lr58, LrU1, LrU2, Yr40* and some QTL regions from wild wheats viz., QYrtm. pau-2A, QYrtb.pau-5A, Qcretm.pau-1A, Qcretm.pau-2A were transferred to WL 711.

Transgenics having herbicide tolerance and *pin2* gene were developed at the University of Delhi, South campus. For production of doubled haploid (DH) wheat x maize (at PAU) and wheat x *Imperata cylindrica* methodologies (at CSKHPKVV) have been used.

Resource Management

Input management

Seed rate, sowing depth and spacing determines crop performance and production of wheat. For dwarf varieties seed rate of 100 kg/ha is necessary for a proper crop stand and it may be suitably modified for different cultural situations. The water requirement of high yielding varieties is about 40 cm of water. Frequency of irrigations varies with soil and agro-climatic conditions and hence upto 6 irrigations are applied in medium-heavy and upto 18 irrigations in very light to sandy soils through sprinkler. However, irrigation at the crown root initiation (CRI) stage, which coincides approximately 21 days after sowing, is the most critical.

It was demonstrated that 120 kg nitrogen, 60 kg phosphorus and 30 kg potash per hectare were required for optimum productivity. New wheat varieties have responded upto 180 kg/ha N application with optimal at around 150 kg/ha in NWPZ and NEPZ. Application of 25 kg/ha zinc was found to increase yield substantially in rice-wheat system and use of sulphur has been found beneficial in some areas.

Depending on the type of weed flora, different herbicides have been recommended for effective control of weeds. Isoproturon was recommended in the early 1980s, but its overuse led to resistance in *Phalaris minor*. Other herbicides such as clodinafop, fenoxaprop and sulfosulfuron were recommended in the late 1990s, but of late resistance against these alternate herbicides has also been reported.

Conservation agriculture

New resource conservation technologies such as zero-tillage technology was developed and adopted by the farmers of NWPZ and NEPZ for producing wheat at lower cost. The laser land leveling is paying rich dividends in the NWPZ by enhancing input use efficiency and increasing productivity. The other RCTs which can be adopted by the farmers in near future are FIRB, Rotary-Till Drill, Strip Till Drill and Rotary Disc Drill. Adopting conservation agriculture, i.e., seeding into surface retained residue will help in improving the sustainability of soil and water resources by avoiding crop residue burning leading to healthier environment as well as enhanced productivity with lower external inputs.

Diversification/intensification of rice-wheat system

Due to the exhaustive nature of rice-wheat cropping sequence, soil fertility is depleting leading to decline in productivity. Diversification/intensification for replacing one or the other crop or such options like introducing a short duration legume crop was explored. The alternative cropping systems which were more remunerative with accompanying changes in tillage options (FIRBS) were, rice-vegetable pea-winter maize, rice-wheat-greengram, rice-vegetable pea-wheat for one year rotation and pigeonpea-wheat-rice-wheat and rice-mustard-greengram-rice-wheat for two year rotation.

Crop Protection

Different disease and pest screening nurseries are organized for multilocation testing of new genotypes in every crop season. The data on disease/pest reactions helps in releasing disease resistant varieties for commercial cultivation. 'Wheat Crop Health Newsletter' is issued every month on the basis of survey and surveillance of wheat diseases during the crop season and contains advisory for disease control measures.

A continuous monitoring to map the prevalence and distribution of the black *(Puccinia graminis tritici)*, brown *(P. triticina)* and yellow rust *(P. striiformis)* virulence across the zones is done by characterizing about 2000 samples of rusts every year. These data are useful in planning deployment of suitable resistance gene(s). The deployment strategy has helped in preventing occurrence of any major rust incidence over the past four decades.

The pathogenic and genetic variation in wheat pathogens, viz., *Tilletia indica* (three variants), *Fusarium* spp. (31 isolates) and *Bipolaris sorokiniana* (13 isolates) was analyzed using host differentials and molecular markers.

The IPM in wheat exhibited yield advantage in the range of 9 to 15 per cent. The IPM modules have been included in extension activities for adoption in NWPZ and with slight modifications in the NEPZ and PZ. Two softwares GEOKB and KBRISK were developed for pest risk analysis in Karnal bunt. Karnal bunt resistance has been incorporated in wheat varieties PBW 343 by PAU, Ludhiana.

Wheat Quality

The Indian wheat varieties are generally rated superior for chapati making. Varieties recommended for rainfed situation have a clear edge over irrigated ones. Chapati quality of the wheat produced in central India is superior in comparison to wheat of north-western India. Several varieties e.g., C 306, HW 2004, PBW 175, Lok 1, GW 322, HI 1500, HI 1531, HI 1544, etc. are known for excellent chapati quality. Bread making feature was not given much importance earlier, but with changing consumer preferences varieties with acceptable bread making quality are available now e.g., HI 977, UAS 304, MACS 6222, MACS 6273 and AKAW 4627. Similarly, HS 490 is released for biscuit making quality. Durum and dicoccum varieties suitable for pasta are also available.

Under the coordinated and other research programmes, evaluation of thousands of germplasm lines has facilitated identification of genetic resource useful for improvement of processing and nutritional quality. Allelic diversity of HMW and LMW glutenin subunits has been explored using both protein and DNA based markers. Molecular markers associated with gluten strength in durum wheat have been identified using recombinant inbred lines. Micro-level tests for solvent retention capacity and sedimentation test were developed and applied in evaluating early segregating generations to improve wheat quality. Molecular basis of grain hardness has been studied in detail and found useful in improvement of biscuit making quality of Indian wheats.

Extension activities and frontline demonstrations (FLD)

Exhibitions, farmers' days, seed days, travelling seminars, TV talks and training programmes form a regular part of extension activities. Visit by various national and international delegations to DWR were also coordinated.

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 revealed the yield gap existing

in different wheat growing zones in the country. Bridging the yield gap would raise the total production of wheat.

Barley Network

The barley network programme functions at seven funded centres with voluntary participation by some ICAR institutes and SAUs. So far, 78 varieties have been released for commercial cultivation and 14 genetic stocks registered with the NBPGR. The priority areas of research include development of barley for malt, feed and dual purpose.

New semi-dwarf, lodging resistant and management responsive plant type varieties

Traditionally, tall plant types were common in barley. The barley network programme successfully developed semi-dwarf, management responsive, lodging resistant cultivars with erect leaves, compact plant having thick stem and stiff straw. The varieties like BH902, DWRUB52, RD2668, RD2592, NDB1173, and DWRB73 are some examples for such plant type in malt and feed barley.

Resistance to diseases and pests

Stripe rust and leaf blight are the major diseases of barley, although yellow and brown rust in NWPZ and brown rust and leaf spot are of importance in NEPZ. New varieties developed have resistance to such diseases. Resistance to CCN has been incorporated in some new cultivars.

Value addition

Varieties having good malting/brewing qualities comparable to European malt barley cultivars have been developed. The recently released varieties DWRUB52 and DWRUB73 (developed through 2x6 row type hybridization) hold promise as industrial barley with better yield, resistance and maturity duration as compared to earlier releases.

Mandate

- Organize, coordinate and monitor multilocation and multidisciplinary research for developing and identifying superior wheat and barley varieties having better quality, tolerance to biotic and abiotic stresses under varied agro-climatic conditions.
- Collect, acquire, evaluate, catalogue, maintain and share germplasm collections of wheat and barley with focused attention on identifying suitable donors for yield components, biotic and abiotic stresses and quality traits.
- Mobilize genetic diversity from national and international sources for developing new genetic stocks for distribution to the cooperating centres in different zones.
- Undertake basic and strategic research for achieving a major advance in genetic yield potential, quality and durable disease resistance through utilization of genetic resources and genetic enhancement.
- Develop strategic research which will lead into precision farming, enhance input use efficiency 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 diseases and pests.
- Coordinate and organize nucleus and breeder seed production.
- 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 for all wheat and barley databases.
- Impart training/education related to wheat and barley improvement, production, protection, utilization and trade.

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.

Harnessing Science

As agriculture will continue to be the backbone of livelihood in the coming decades, its vigour would affect the food and economic security in India. New technologies were promoted and adopted during the green revolution to bring the much needed food security in the country, but their overall effect has led to adverse effects on ecology and environment. Science-led growth, through availability and use of modern technologies, would form the core for sustainable growth in agriculture for national progress. The technology-led growth has to be directed in such a manner that it should ensure enhanced productivity and profitability of wheat and barley cultivation.

Utilization of genetic resources

Evaluation and management of germplasm resources is essential for wheat and barley improvement. Not all the germplasm available in the vast genetic resources collection have been assessed for genetic diversity for a wide range of agronomic and developmental traits. Identifying novel genetic elements associated with disease resistance, quality and value-adding traits together with specific genes and alleles for utilization in crop improvement requires continuous efforts.

Providing an opportunity for the blossoming of variability in germplasm is the science of plant breeding. The utilization of many germplasm lines is restricted due to the load of redundant variability and deleterious genes carried during introgression to commercial varieties. Pre-breeding entails harnessing beneficial alleles and exploiting genetic diversity from wild species and exotic germplasm for introgression of specific traits and providing suitable 'housing' for genes for better expression and utilization. Re-visiting the wild relatives of wheat for mining of specific genes and traits is very essential. Facilities for rescuing embryos of wide hybridizations and mass production of doubled haploids are required at a number of research centres for faster and better results. The utilization of genetic resources can be further enhanced through application of cytogenetic and biotechnological tools to enable precise transfer in desirable genetic background.

Exploiting the power of biotechnology

Biotechnology has emerged globally as an indispensable tool in crop improvement. Whole genome mapping and sequencing would provide an insight into the structure and evolution of the genomes. Genomics facilitates functional analysis of plant genes for developing markers to identify genes involved in different developmental, physiological and biochemical pathways. This also helps in development of functional/ perfect markers. Molecular markers, in general, have several applications e.g.,

characterization and conservation of genetic resources, genotype verification and marker assisted selection (MAS). Development and utilization of molecular markers has provided support in the advancement of conventional breeding in wheat. The gene specific markers available for some traits (*Rht, Vrn,* rust resistance and grain quality) in wheat are being utilized for MAS. The pyramiding of genes for resistance to stripe rust *(Yr10* and *Yr15)* and leaf rust *(Lr24, Lr28, Lr35,* and *Lr37)* has been targeted in desirable backgrounds using linked markers. The development of second generation markers (SNPs, DArT, COS and ISBP) and robust markers for other important traits is underway which would add precision and speed up the varietal development process.

The development of suitable regeneration and transformation protocols has provided new avenues for development of transgenics having improved tolerance to biotic and abiotic stresses. Public and private partnership in biotechnology research and application would be strengthened to obtain faster results.

Crop improvement and seed production

The development of higher yielding varieties possessing resistance to biotic and abiotic stresses is required to achieve the higher production targets. In order to meet the perpetual requirement of new varieties by the producers, wheat improvement at DWR and its cooperating centres would focus on developing new varieties with enhanced yield, disease resistance and end-use quality. The specific problems of the wheat producing areas such as heat stress particularly in the central and peninsular zones, terminal heat stress in the Indo-Gangetic plains, pre-harvest sprouting in eastern and far-eastern parts of the country, and salt affected soils are addressed along with incorporation of biotic resistance. An integrated approach utilizing molecular technologies along with the classical approaches has to be adopted on a larger scale so as to make wheat cultivation farmer friendly.

The hybrid technology in wheat has not been successful so far. As hybrids can really bring about a quantum jump in productivity, the technology has to be carried forward and solution for the barriers in development of effective hybrids has to be devised. The development of wheat hybrids can be realized through collaboration between public institutes and private companies. Some private companies of late have made investment in initiating research on development of hybrid wheat.

The supply of quality seeds has to be ensured to reach the production targets in wheat. Supply of quality seeds is very crucial in order to maintain proper seed replacement rate. The private seed industries cooperate in large scale production and distribution of seeds. There is, however, a need for strict monitoring of the production and sale of quality seeds in wheat so that farmers are not involved in legal wrangles regarding quality assurance.

Basic genetic studies on biotic and abiotic stresses

Climate changes influence the virulence patterns in pathogens. Pursuing basic research to understand the genetics of host-pathogen interaction would lead to identifying sources for durable resistance. In wheat leaf and stem rust genomes have been sequenced. This information would be useful in understanding the evolution of new virulence, race identification, virulence pattern and population genetics of the pathogen.

The mechanism of tolerance to abiotic stresses is not fully understood. Heat and drought stress are important in the context of climate changes. Genetic studies are difficult in these stresses as field validation is inaccurate and not reproducible. Developing efficient and precise screening platforms like phenomics, a rapid and noninvasive technology, would facilitate identification of stress tolerant genotypes for use in crop improvement.

Managing the natural resources

Crop productivity is determined by the production capacity, production efficiency and crop protection. Increasing the efficiency of the production system through development of economically viable and environmentally sustainable technologies is needed. Crop management research is relatively location specific. Strategies for effective management of natural resources require an integrated approach. The integrated plant nutrient management (IPNM), integrated water management, integrated weed management and residue management are very important and deserve impetus.

Balanced use of fertilisers is fundamental to remunerative cropping systems and in maintaining soil health. Secondary and micro-nutrients have become deficient due to unbalanced use of fertilizers that has also aggravated the degradation of soil. Enhancing the awareness among stakeholders about the importance of balanced use of fertilizers would be undertaken. As the quantity and quality of irrigation water is expected to become scarcer and polluted in future, efficient management of water is necessary. Propagation of crop diversification and area specific water utilization practices such as water harvesting and sprinkler irrigation would be appropriate.

In view of the large scale misuse or overuse of natural resources which have led to degradation of the whole crop environment, conservation agriculture practices have a very important role to play in reversing the trend. Resource conservation technologies such as zero tillage, residue management, intercropping and crop rotation are beneficial for enhancing wheat productivity by increasing carbon sequestration and the health of rhizosphere and phyllosphere.

Promoting *in situ* moisture conservation techniques and water harvesting would enhance productivity of rainfed/dryland areas. The development of moisture stress tolerant genotypes would be further strengthened to enhance the productivity. Weather forecasting would sensitize the farmers for preparedness against vagaries of weather.

Plant protection

Survey and surveillance of wheat and barley diseases indicate the severity of infection on the crop and help to assess crop damage. Pathotype analysis gives an idea about emerging races of rusts on a zonal basis. Screening of germplasm and breeding lines and multilocation evaluation of genotypes of wheat and barley through artificial epiphytotics has proved beneficial in releasing commercial cultivars which led to prevention of major rust incidences in various wheat producing zones. Varieties with durable rust resistance have prolonged effective period and enhanced utility on farmers' fields.

IPM practices have a greater role to play in view of expected changes in the crop environment due to climatic changes. Strict vigil has to be maintained for tracking emergence of new virulence and planning effective control measures. Centres for bio-risk assessment in various zones have to be established for drafting amelioration strategies.

Application of molecular tools to understand the mechanisms of host-pathogen interaction need to be carried forward. Genetic studies of host resistance and molecular mapping of pathogen virulence would be pursued vigorously.

Quality and value addition

Although quantity of the produce is important, quality is equally significant for its utilization. The end-use determines the quality requirements in wheat. There are different parameters in wheat that govern chapati, bread, biscuit and pasta quality among which grain hardness, protein content and gluten strength are the key components. Changes in consumer preferences towards industrial products demand an increased supply of raw material possessing desired processing quality. Greater understanding of genetic/molecular components associated with various quality traits will lead to the improvement of wheat quality.

Higher production of wheat leads to surplus stocks which may be traded. International trade requires production of quality wheats to meet the specific requirements of the importers. In India there is no segregation of the wheat produced according to quality parameters. Thus, Indian wheat fetches low price in the international market. In spite of the fact that quality parameters of some of the Indian varieties match international standards, there has been no effort to procure wheat based on quality. Millers and bakers resort to various manipulations to produce packaged products which may often not be of international standards. A better pricing policy and contract farming for production of quality wheats may go a long way to meet the requirements of the wheat based industries.

The demand for malt is gradually increasing. Giving incentive for production of malt grade barley would make it profitable for the growers. Promoting entrepreneurs, even

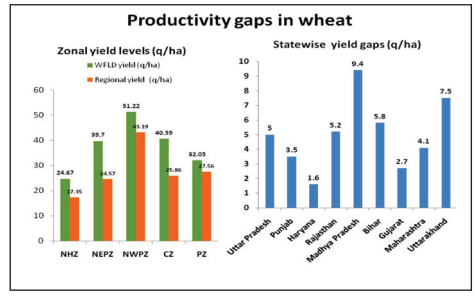
in villages, for small-scale production of wheat products such as dalia (semolina), suji, sevai, cookies etc. would encourage income generation among the villagers.

Harnessing frontier arenas of science

Geographic information system (GIS) application would be desirable for surveillance of crop situation, occurrence of diseases, drought and other weather vagaries to determine the extent of crop losses so that timely corrective measures could be taken. Nanotechnology has some application in wheat such as enriching the wheat flour with minerals, Central laboratory facility for undertaking biotechnology, biochemistry and physiological research by scientists who wish to pursue any scientific hypothesis would be set up.

Transfer of technology

The delivery of new technologies and their adoption by farmers has played a great role in enhancing productivity and production. The front line demonstrations (FLDs) have proved a strong instrument in propagating new technologies and in their assessment and refinement. The FLDs of wheat and barley are conducted across the country to demonstrate recent varieties and new crop management practices. There are large gaps in yield of wheat and barley in some of the zones which can be bridged by adoption of new technologies. Application of improved knowledge management systems and e-extension would further enhance the effectiveness of technology delivery mechanism.



Tackling issues related to climate change

Climatic upheavals have become crucial to crop production. Changes in the temperature regimes are of particular importance to cultivation of cold loving crops like wheat. It is postulated that rise in temperature at lower latitudes would make much areas unsuitable for wheat cultivation and lead to decline in yield. It has also been predicted that with the increase in levels of atmospheric CO_2, ambient temperature would increase by 3°C and affect both the area and productivity of wheat in India. A fall back of high temperature incidence would also be a net decrease in wheat production due to reduction in duration of the growth period. Hence, development of heat tolerant genotypes would deserve utmost priority to mitigate the production losses due to rise in temperature. Another consequence of the rise in temperature would be an increase in water requirement which would necessitate efficient management of irrigation

water. Cultivation of early maturing varieties of wheat and manipulation in the depth and sowing time may lead to escaping the weather vagaries.

As climate changes may aggravate changes in the prevailing weather during the crop season, the pathogens and pests may undergo a drastic change in prevalence. The whole dynamics of diseases and pests may be significantly altered leading to instability in food production causing food insecurity and affecting the livelihood of farmers. Tackling the abiotic and biotic stresses under changing climate would require utmost priority.

Capacity building and HRD

Upgradation of scientific knowledge through capacity building is beneficial in keeping pace with developing technologies. Training at both national and international centres of excellence would be promoted for enhancing competence. Faculty exchange programmes and providing guidance to research students would be encouraged. In this regard required infrastructure facilities would be established.

Linkages

Developing strong linkages with national and international institutes and universities have immense mutual benefits. Wheat and barley development programmes have excelled due to strong linkages with national institutes, universities and international institute like CIMMYT. There is now greater opportunity for establishing strong institutional linkages in some important fields like biotechnology with many national research organizations and foreign institutes. There is also scope for associating private companies involved in biological research in many areas of mutual interest.

Researchable Issues

Crop Improvement

- Enhancing yield and adaptability of wheat varieties under changing climatic conditions.
- Characterization of genetic resources for useful traits.
- Creation of new variability from un-utilized genetic resources.
- Utilizing molecular approaches for precision breeding.
- Enhancing seed production for increased seed replacement of older varieties.
- Adopting suitable screening assays for heat stress tolerance, water and nutrient use efficiency to facilitate large scale germplasm evaluation.
- Initiating breeding for heat stress tolerance and water use efficiency on the basis of physiological indices and molecular markers.
- Exploring the possibility of transgenic approach for abiotic stress tolerance.

Crop Protection

- Survey-surveillance, crop health monitoring and tackling new races of rusts.
- National repository of pathotypes of different rust pathogens.
- Epidemiological studies in relation to changing climatic scenario.
- Host resistance – identification of new and diverse sources of resistance with emphasis on multiple disease/pest resistance.
- Devise eco-friendly management strategies for disease and pest control and promote IPM.
- Integrating molecular tools for understanding variability in pathogens.

- Managing leaf blight in eastern, central and peninsular zones and Karnal bunt for western India.

Resource Management

- Develop and fine-tune the package of practices and varieties specific to RCTs - zero tillage, bed planting, need based application of nutrients (N) using leaf colour charts and remote sensing based crop canopy sensors etc.
- Evaluating the long term effect of tillage and residue management options on soil properties, pest dynamics and productivity of wheat.
- Focused attention on integrated nutrient and water management.
- Diversification/intensification of rice-wheat and other wheat based systems to improve profitability and sustainability.
- Integrated weed management strategies for wheat and addressing the issue of multiple and cross herbicide resistances in *Phalaris minor.*
- Special emphasis on conservation agriculture to address the issue of climate change and ill-effects of residue burning.

Quality Improvement

- Development of product specific varieties with enhanced nutritional quality
- Understanding genetic and molecular basis of quality traits
- Development of micro level tests to expedite the breeding efforts
- Enhancing bio-availability of micronutrients (Fe and Zn) by reducing anti-nutritional factors and increasing antioxidant activities.

Transfer of technology

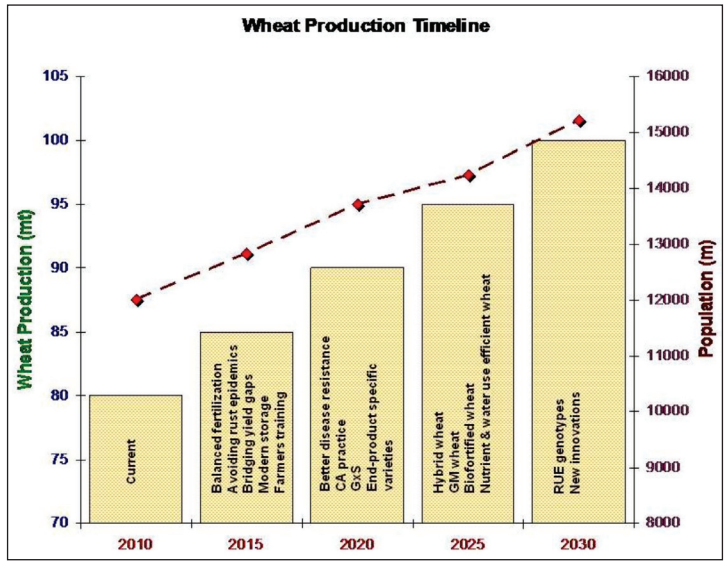
- Faster dissemination of improved technologies developed for increasing wheat productivity.
- Data base of farmers for bulk SMS message during crop period.
- Multidimensional impact assessment of various improved technologies.

- Analysis of returns to investment in wheat and barley research and development.

Barley Improvement

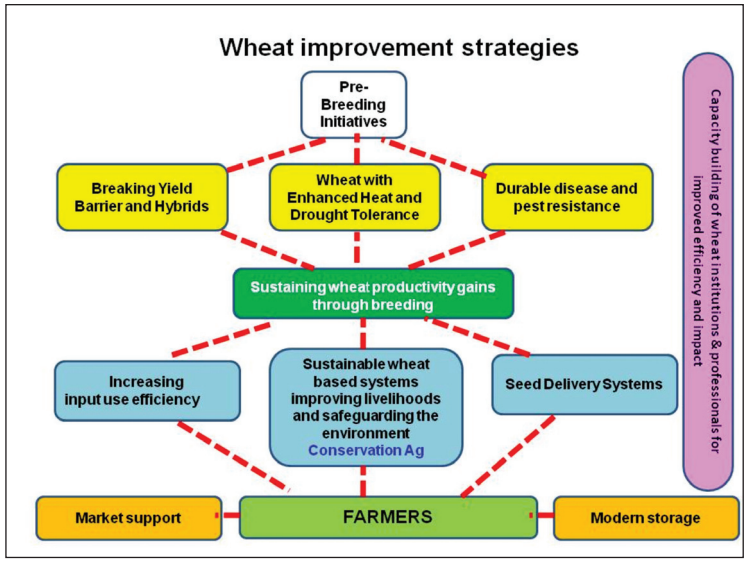
- Improvement for feed and dual purposes in rainfed and restricted irrigated conditions.
- Germplasm enhancement through pre-breeding involving wide crosses and winter x spring hybridization.
- Incorporation of diverse resistance for stripe and leaf rusts, leaf spot and aphid.
- Use of MAS in resistance breeding and malting quality improvement.
- Molecular diagnostics of pathogens (race identification) and host resistance
- Biochemical basis of malting and nutritional quality in Indian barley.
- Nutrient management of dual purpose barley and in saline-sodic soils.
- New agronomy for malt barley.

Based on the above challenges and issues, following time line is proposed to meet the target of wheat production by 2030 to meet the demand of rising population.



Strategy and Framework

To achieve the future projections of wheat production following strategies and framework would be adopted. In order to address the site specific issues, the coordinating centres will be strengthened. Various activities as shown in chart below will be taken in an integrated manner to enhance the wheat production.



I. Crop Improvement

Varietal Improvement for enhancing yield, disease resistance and end-use quality would be a continuing feature of wheat improvement at DWR and its cooperating centres. Besides this major activity, the following research programmes would be undertaken.

Regular flow of germplasm to increase genetic variability

Germplasm constitute the building blocks for plant breeding. Acquisition, evaluation and management of germplasm resources, assessing genetic diversity for agronomic and developmental traits, identifying novel genetic elements associated with disease resistance, quality and value-adding traits and specific genes and alleles for utilization in wheat and barley improvement would be continued. Conserving the biodiversity and genetic wealth of wheat and barley would be given priority.

Re-visiting the wild relatives of wheat – Prebreeding

Pre-breeding for capturing variability from wild/related species (*Aegilops* spp. and derived synthetics) and exotic germplasm (winter wheat, buitre and Chinese lines) needs to be pursued with renewed vigour for diversifying genetic variability to increase yield, resistance to biotic stresses and tolerance to abiotic stresses. The pre-breeding work would be carried in a network mode with selected centres. Required infrastructure would be provided for the purpose. Embryo rescue and modern molecular cytogenetic tools for introgression of specific genomic segments from wild/related species would be utilized.

The dicoccum wheat would be used for transferring some desired (quality and stem rust resistance) traits. Similarly different sources of rye genome (e.g., hexaploid triticale lines) would be used for producing translocations with different rye segments (R genome) to introgress abiotic features into hexaploid wheat.

Production of doubled haploids on large scale for shortening the breeding cycle

Doubled haploid (DH) production would be undertaken on a large scale at many centres for producing completely homozygous lines in a single generation to shorten the time for developing varieties. DH would also be useful for meta-QTL analysis.

Developing varieties suitable under changing environments

As climatic changes may cause widespread changes in the prevailing abiotic and biotic situations, incorporating resistance/tolerance features during varietal development would be a safe proposition. Varieties possessing enhanced resistance to biotic stresses, terminal heat and moisture stress, pre-harvest sprouting resistance, tolerance to saline, alkaline and waterlogged conditions and systems adaptability would be developed. Molecular breeding tools would be used wherever possible. Improving the yield of short duration varieties for intensive farming would be prioritized.

Heterosis breeding and development of hybrid seed production in PPP mode

The development of hybrids in wheat will be undertaken to raise the ceiling of yield in a public-private partnership (PPP) mode. The private sector seed companies would be involved in production and marketing of wheat hybrids. The role of apomixes for hybrid wheat development would be explored.

Raising yield potential – Trait based approach

- Increasing photosynthetic capacity and efficiency
  - Improving performance and regulation of Rubisco
  - Introduction of C_4 like trait – carbon concentrating mechanism
  - Improving light interception
  - Optimizing spike and canopy photosynthesis
- Optimizing partitioning to grain
  - Optimizing HI – increased partitioning to spike growth and maximizing the grain number
  - Improving spike fertility – Hormone concentration
  - Lodging resistance – stiff straw

Seed production

For quick dissemination of seeds of new varieties among farmers, higher quantity of quality seed production is required. Higher seed replacement rate would be thus achieved. The capacity of private seed industries would be harnessed for achieving high seed production and expediting distribution of new varieties.

Biotechnology in wheat improvement

Biotechnology is intended for strengthening basic research and utilizing molecular tools for augmenting crop improvement.

Integrating 'omics' with wheat improvement

The platforms such as genomics, proteomics, transcriptomics and metabolomics are useful in understanding the gene functions associated with various regulatory pathways determining phenotypic and biochemical expression. These methodologies would be utilized in designing desired genotypes of wheat and barley.

Utilizing high throughput genotyping for precision breeding

Utilization of markers would form one of the basic steps for precision breeding in future. In order to expand the use of next generation markers, facilities for high throughput genotyping would be set up at selected wheat research centres across the country.

Molecular strategy for developing resistance to biotic stresses

Pyramiding of genes providing resistance against the three rusts, powdery mildew, and leaf blight would be undertaken in a network mode with selected centres.

Development of transgenic wheat

Transgenics are the future sources for effective control of biotic and abiotic stresses which may be more serious in the coming years due to climate changes. A core competence on transformation techniques and containment facilities for development and evaluation of transgenics in wheat is proposed to be established. Cooperation between public and private sectors would be sought in this endevour.

Developing national wheat phenomics facility to screen for abiotic stresses

A national phenomics facility is proposed for establishment at DWR, Karnal which would also be extended to all wheat scientists across the country. This facility would offer rapid, precise and noninvasive characterization of plant traits responsible for tolerance to abiotic stresses. The screening would identify genotypes for use in molecular and conventional breeding.

Basic genetic studies

Genetic studies on abiotic stress tolerance

The expression of phenotypic traits under heat and drought stress is not stable, i.e., varies with locations and is not reproducible. The phenomics and genomics platforms would be utilized to study the genetic behaviour of traits in tolerant genotypes. As a long term objectives the priority areas for heat tolerance will include night temperature adaptation (respiration), rubisco activity, plant architecture, photo-protection, starch synthase and C_4 photosynthesis. In addition work will include characterization of genes, QTLs and transcription factors for abiotic stresses, development and use of transgenics for *DREB, ACC, 27one, otsB, p5CS* etc. Alternate dwarfing genes like *Rht5, Rht8, Rht13* and *Rht18* will be utilized for increasing *27ones* 27tiles length using molecular marker approach for improving drought tolerance.

Genetics of disease resistance – rusts, powdery mildew, Karnal bunt etc.

Inheritance of resistance to rusts, powdery mildew, Karnal bunt and other diseases of wheat would be undertaken. Postulation of host resistance gene(s) and APR gene(s) in rusts and powdery mildew would be done in cooperation with few institutes in a network mode.

Unraveling the molecular mechanism in host-pathogen interactions

The precise molecular mechanism of plant pathogen recognition and R gene-mediated signaling network remains elusive despite major advances in the field of plant disease resistance. Determination of genetic features underlying pathogenesis of rust pathotypes is needed urgently. Genomics and proteomics technologies will provide insight into the biochemical functions of R proteins involved in rust resistance. Comparative genomics will be exploited for identification of new virulence genes.

Epigenetics

Studying the epigenetic mechanisms controlling plant responses under different stresses targeted will lead to better understanding of stress mechanisms and guide in developing management strategies.

II. Crop Protection

Besides the regular activities like survey and surveillance, rust pathotype identification and scoring host response against pathogens, the following researchable issues would be undertaken.

Integrated pest management (IPM) – Ecofriendly approaches

Growing public concern over potential health hazards of pesticides has led to the exploration of eco-friendly integrated pest management (IPM) practices aiming at suppressing the pathogen/pest by combining more than one method of control in a harmonious way with minimum use of pesticides.

Development of diagnostic kits

Diagnostic kits will be developed for identification of different pathogens for quick and precise identification.

Disease prediction modules – Managing the bio-risks

With the intensification of agriculture, changing cropping pattern and climatic changes, new pathogens/pests come to the fore either from outside or minor pathogens/pests acquire key status. Pest risk analysis would help in the prediction of impending problem and for taking preventive measures. Dictated by climate change, pesticides usage may change as the pest scenario changes. It is, therefore, essential that bio-risk analysis is carried out and disease prediction modules are developed.

III. Resource Management

Conservation agriculture for resilience in wheat productivity

Research efforts on optimization of tillage, residue management, intercropping and crop rotation, weed management and balanced use of fertilizers for reversing soil degradation and increasing resource use efficiency leading to enhancement in wheat productivity in different agro-climatic zones would be focused.

Water and nutrient management for enhancing crop productivity

Research efforts on water conservation and devising suitable irrigation methods as per soil and agro-climatic conditions of the area would be given priority. Balanced use of nutrients, site specific nutrient management for targeted yields, need based nitrogen application using handheld sensors for efficient N management and integrated nutrient management options for different cropping systems would be standardized and popularized.

Enhancing productivity of rainfed areas

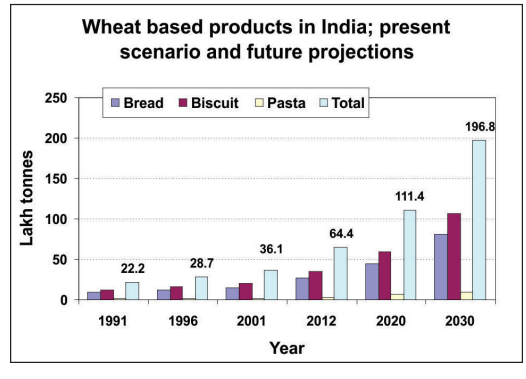
In rainfed/ dryland areas water conservation practices and efficient utilization of residual soil moisture are important for increasing productivity. Revisiting the sowing time and manipulating seeding procedures to obtain good crop stand and cultivation of drought tolerant varieties would enhance production in different zones.

IV. Quality

Besides providing support services in analyzing the quality traits of new genotypes in coordinated testing programme, development of end-product specific varieties with enhanced nutritional quality will be the priority to meet the rising demand for industrial products.

Enhancing wheat end-use quality

Selected centres would be strengthened for developing wheat varieties with better end-use quality. Molecular tools would be used for identification of donors and selection of desirable segregants in breeding programme.



Enhancing nutritional quality

Bio-fortification and enhanced bioavailability of micronutrients (Fe and Zn) would become an important part of the quality improvement activities. In addition, increasing grain protein and yellow pigment content would be the priority areas. Studies on anti-oxidant properties in durum and bread wheat will also be undertaken.

Establishing a Wheat Board

Taking into account the future trade scenario in wheat, there is need to establish a Wheat Board on the pattern of other boards in the country. The Board would regulate and implement the export promotion policies and other R&D issues arising from marketing intelligence.

Malt quality in barley

The requirement for malt barley is expected to rise with growth in population. The malt content and quality of barley varieties would be improved for higher extraction of malt.

V. Barley Improvement

Barley would be promoted as an industrial cereal in co-operation with malting and brewing industry. Work on salinity and alkalinity aspects would be taken up more comprehensively to address the problem existing in the states of Uttar Pradesh, Haryana, Rajasthan, and Gujarat. The major usage of barley for feed and forage requires development of genotypes with higher biomass production and better feed qualities with respect to protein and fibre content. Development of vigorous, single-cut, dual-type barley genotypes with better regenera¬tion capacity to fulfil the green fodder demand in Rajasthan, Madhya Pradesh, Punjab, Uttrakhand and Himachal Pradesh would be accelerated. Incorporation of resistance to leaf blight, rusts and aphid would be given due preference. Development of malt barley varieties would be prioritized. As scope for export of malt from India may increase, the development of malt varieties deserves impetus.

VI. Transfer of Technology

Promoting extension activities for effective transfer of new technologies, assessing market and trade requirements and increasing the profitability of farmers would form the core activities for extension and transfer of wheat and barley technologies. Reducing the uptake time for transfer and adoption of technologies by farmers would be carried out through participatory research. Adaptive research to address area-

specific needs would be undertaken. In order to propagate adoption of seeds of new varieties, the practice of 'own farm, own seed' through establishment of seed villages would be popularized.

Training of farmers to improve the skills and capacity building for rural entrepreneurship and women empowerment would be prioritized. The e-extension activities would be given a boost for providing agro-advisory services.

Centralized facilities

Central laboratory facility for undertaking biotechnology, biochemistry and physiological research by scientists who wish to pursue any scientific hypothesis would be set up. A bioinformatics data bank would also be established.

Linkages

Linkages with SAUs

The funded coordinated centres in SAUs and some NGOs would be facilitated with improved infrastructure facilities for target based coordinated research. The centres would also be provided with precision farm machinery for better conduction of trials, basic facilities for MAS at all centres for advancing the breeding programmes, and quality analysis labs at selected centres.

Linkages with national and international institutions

Linkages with national institutes under ICAR, DBT, DST, CSIR, government organizations, international institutions like CIMMYT, ICARDA, ACIAR, INRA, etc. would be strengthened for better cooperation in various activities. Partnership with private companies would be stepped up for cooperation and more investment in research.

Increasing opportunities for capacity building

Scientific and technical personnel employed would be offered increased opportunities for capacity building at both national and international centres of excellence. Opportunities for pursuing post-doctoral work in specific areas would be extended for international scientists in India and vice-versa. The scientists of DWR would also impart guidance of doctoral dissertations to students from various universities.

Epilogue

Producing 100 million tonnes of wheat by 2030 is the prime goal of the Directorate. This target has to be met despite the odds of climatic change, limited resources and decreasing acreage under wheat cultivation. The new biotic and abiotic problems arising due to climate change would adversely affect the crop. The targets of productivity and production of wheat can be suitably met by developing new varieties utilizing cutting edge technologies through implementing a science-led growth to enhance WUE, NUE and checking further soil degradation under high cropping intensity. Marker assisted breeding approach will be used for faster development of varieties and seed multiplication. It would also generate technology-led solutions for mitigating the effects of climatic changes. Infrastructure and manpower needs would have to be revamped to achieve targeted gains in research.

Concerted efforts would be made to address the needs of the smallholding farmers in the foreseeable future. Augmenting the needs of the small farmers and insulating him from the shocks of low production and market prices would have to be given extra care. There would be increased opportunity for growth in trade of wheat and value-added products in the coming years. More entrepreneurs may be attracted in domestic supply and trade of value-added products which may bring in the culture of contract farming of quality varieties.

Inter-institutional cooperation with SAUs would be further strengthened for making the coordinated system of research more effective and result oriented. An effective monitoring system would be developed to forecast second generation problems due to changed pest dynamics. GIS application would be materialized in collaboration with ISRO and Indian Meteorological Department. New linkages with national and international institutes would be made to harness the advancements in science. The private companies would be associated as important partners in research and seed production.

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Annexure : Strategic Framework

Goal	Approach	Performance measure
Increasing wheat and barley production for food security	Developing high yielding varieties of wheat and barley	Varieties developed
	Utilization of molecular tools for precision breeding	
	Developing hybrid wheat varieties	
	Producing quality seed	Quantity of seed produced
	Standardizing production techniques for efficient utilization of resources	Production technologies standardized
	Bridging the yield gaps through FLDs, on farm trials and adaptive research	Technologies assessed, transferred and adopted
Enhance opportunities for inclusive growth	Increase efficiency and profitability of wheat and barley production system	Increased profitability
	Diversification and intensification of wheat based cropping systems	Diversification and intensification options developed
	Capacity building of farmers and promotion of rural entrepreneurship	Improved livelihood opportunities
Maintain and improve the status and quality of natural resources	Conservation and acquisition of germplasm	Germplasm conserved and acquired
	Management options to improve soil and land quality e.g. RCTs, residue management, laser land leveling, slow release fertilizer use.	Technologies for improved resource use efficiency developed
	Technological options to enhance water use efficiency, water quality and increase water availability e.g., furrow and sprinkler irrigation	
	Improving air quality by reducing emissions	
Improve value addition of wheat and barley	Develop technologies for demand driven value added products of wheat and barley for industrial and other purposes	Techniques developed and products processed
	Linking production, value addition and marketing	Linkages with industry and farmers established
	Promote intellectual property management for commercialization of technologies and food processing	

Improve risk management	Survey and surveillance of wheat and barley diseases	Surveys conducted
	Developing disease resistant varieties and IPM modules	Resistant varieties and IPM modules developed
	Developing genotypes and technologies to mitigate climate change in wheat and barley	Drought and heat tolerant varieties and management practices developed
Improve access to genetic material, information, knowledge and resources	Improve access to genetic resources through repository of germplasm and access to genomic resources and tools	Germplasm shared
	Policy issues in conservation and utilization of germplasm	Contribution in framing policies
	More access to technologies through Improved technology delivery mechanism	Developed website for sharing knowledge and information
	Improve access to information through effective use of information and communication technology (ICT)	Multi-media and ICT based knowledge support system developed
Improve basic genetic knowledge on wheat and barley	Conducting basic and molecular genetic research	Knowledge gained
Create adequate and quality human resources	Capacity building through training at national and international level	Improved research efficiency
	Creating infrastructure facility	Qualified manpower
Enhance competitiveness of Indian agriculture	Improve market intelligence, identifying niche markets for products in domestic and global markets	Contribution of research in development of products and promotion of trade/ development of products and trade promotional activities