AICRP- WHEAT & BARLEY

Salient Achievements:

1. Wheat research brought the recognition to Pantnagar as the birth place of Green Revolution Technologies in India.
2. Pantnagar has evolved 29 wheat varieties for various crop- growing conditions of different agro-climatic zones.
3. Three varieties namely, Kalyan Sona, Sonalika (RR 21) and UP 262 have been recognized as Landmark wheat varieties.
4. Released first triple dwarf wheat variety UP 301 in 1970 for its cultivation in Karnataka, Tamil Nadu and Uttar Pradesh.
5. Developed dual purpose wheat variety UP 2338 suitable for timely sown as well as late sown conditions of North Western Plain Zone of the country.
6. UP 262, a high quality variety released long back is still popular with the farmers in the country and adjoining countries like Nepal and Bangladesh.
7. Golan 81 developed from Pantnagar cross S 331/Nortino, which was released in Syria for dry land conditions. Another Pantnagar cultivar UP 2162 developed from a cross UP 234/HD 2009 was released in Thailand in the year 1987.
8. Wheat variety, UP 2572 released for its cultivation in rainfed and irrigated conditions of hills of Uttarakhand is a success story because of its popularity and wide adaptability.
9. Two popular wheat varieties, UP 2338 and UP 2382 were improved for stripe and leaf rusts with multiple gene introgression with marker assisted breeding (MAB).
10. More than 200 genetic stocks/donors developed possessing yield component traits, agronomic traits, rich in several quality attributes, resistant to rusts and other diseases and insects.
11. Discovered critical growth stage including CRI which revolutionized the water management concept.
12. Response of wheat to N up to 150 kg/ha was obtained.
13. Integrated weed and soil water management was standardized.
14. Management for zero till cultivation was developed.
15. Wheat based cropping system including rice-wheat was developed.
16. Crop residue management technology was developed as an alternate to burning.
17. Balanced site specific nutrient management practices have been developed to save the cost on fertilizers and improve wheat yields.
18. Indices of soil tilth and soil quality have been developed to optimize tillage requirements for sustainable wheat production.
19. A very effective and economical method of controlling loose smut of wheat by seed treatment with carboxin or carbendazim resulted in significant reduction in loose smut at national level.
20. Embryo Count Test (ECT) and Crown Seedling Test (CST), techniques were developed to detect loose smut infection in seeds or seedlings which helped saving millions of rupees annually on chemicals.
21. Multiple disease control in wheat including loose smut, brown and yellow rusts, powdery mildew and leaf blight were achieved by seed treatment with Raxil 2DS @ 1.5g/kg seed + one foliar spray of fungicide tebuconazole (Folicur 250 EW) @ 500 ml/ha just before heading.

22. To control Karnal bunt, sprays of propiconazole @ 500 ml/ha at heading time was recommended.

23. Two new pathotypes, 12-8(49R45) for brown rust of wheat and 6SO for yellow rust of wheat and barley were identified in 2008 and 2014, respectively.

24. The IPM modules for rice and wheat were synthesized and validated at farmers' fields.

25. A new method of inducing genetic variability by altering embryo nutrition was developed.

26. Sources for high photosynthetic efficiency, high Rubisco activity and low photorespiration have been identified.

27. Immunodiagnostic technology for detection of Karnal bunt was developed.

28. Elucidation of mystery of organ specificity and fungal colonization of Karnal bunt by identification of fungal growth promotory substance(s) in S-2 stage of wheat.

29. Jasmonic acid as potential activator of induced resistance against biotrophic pathogen- Karnal bunt and understanding of KB resistance by studying cystatin and cysteine protease genes.

30. Designed and developed the well known Pant Zero-till Ferti-Seed Drill. The Pant ZT-drill is now being manufactured and marketed by over sixty manufacturers and used for direct drilling of wheat, pulses and oil seeds by the farmers of IGPs.

A. Wheat and Barley Breeding

Objectives:

1. Development of widely adapted, high yielding, disease resistant, good grain quality wheat varieties for different agro-climatic zones of India and hill region of Uttarakhand.

2. To develop climate resilient wheat varieties particularly challenges being posed by new pathotypes of rusts and terminal heat stress due to climate change.

3. To develop varieties suitable for bread, biscuits and chapatti making quality and genetic stocks possessing high Zn and Fe content for nutritional security.

4. To develop package of practices for new and resource efficient technologies for wheat and wheat- based production systems.

1. Significant Achievements:

In the last 54 years, Pantnagar has developed 29 high yielding varieties of wheat and one of barley, which are being cultivated in different parts of the country. In the beginning, the wheat breeding work was initiated aiming at developing rust resistance breeding material, uniform plant type and amber colour grains in the segregating material received from the CIMMYT, Mexico, which was done in collaboration with the Indian Agricultural Research Institute, New Delhi. The selection, thus obtained, was named as Sona 227 and got later released as **Kalyan Sona** in 1967 for cultivation in all wheat growing areas of the country. A little later, in 1968, rust and shattering resistant selection of S-308 was released as **Sonalika (RR-21)**, which occupied the largest acreage in the country. It would not be an exaggeration to our claim that these improved varieties unflagged the green revolution in India during late 60s. Due to the significant contributions made by the University in increasing wheat yields as well as over all food grain production in the country, Nobel Laureate Dr. Norman E. Borlaug honour the University as '**Harbinger of Green Revolution**'. Subsequently 27 other varieties, viz., UP 301, UP 310, UP 319, UP 215, UP 262, UP 115, UP 368, UP 2003, UP 2121, UP 2113, UP 1109, UP 2338, UP 2382, UP 2425, UP 2565, UP 2554, UP 2526, UP 2572, UP 2628, UP 2584, UP 2684, UP 2784, UP 2785, UP 2748, UP 2844, UP 2855 and UP 2865 have been released for their cultivation in different agro-climatic and crop growing conditions of the country and states of Uttar Pradesh and Uttarakhand.

1. Kalyan Sona, Sonalika and UP 262 have been recognized as Landmark wheat

varieties by Indian Society of Genetics & Plant Breeding due to their wider adaptability and popularity in major wheat growing regions of the country.

2. Pantnagar centre has registered four novel genetic stocks with ICAR-NBPGR namely, UP 2645 resistance to leaf, stripe & stem rusts and high wet & dry gluten content, UP 2696 for good bread making quality (Glu 1 score:10), UP 2696 and UP 2672 possessing high protein content (>13%).

3. The centre has registered seven extant varieties of wheat namely, UP 2338, UP 2382, UP 2425, UP 2565, UP 2554, UP 2526 and UP 2572 were with PPV&FR authority.

4. The centre has also established Pantnagar Wheat & Barley Germplasm Bank which is owner of approximately 2100 indigenous and exotic collections.

5. UP 2338, UP 2680 and UP 2684 have been found resistance to Ug99 race of stem rust in screening done in Kenya.

6. In addition to the above, more than 250 genetic stocks/donors have been developed for different traits viz., rust resistance, Ug99 resistance, quality attributes like high protein content, high gluten strength, low to very low phenol colour reaction, high zinc and iron content, and terminal heat tolerance.

7. Pantnagar centre is nominating about 30 entries every year for different trials like State Variety Trials, All India Co-ordinated Wheat & Barley Improvement Trials and national nurseries constituted by ICAR-Indian Institute of Wheat & Barley Research for different traits and testing in different growing situations in plains and hills.

8. Pantnagar centre is also preserving the purity of all the released varieties and registered germplasm through maintenance breeding.

9. **Trials indented & conducted:** Pantnagar centre is conducting trials under irrigated, rainfed and restricted irrigation ecosystems that comprise the trials on early, timely, late and very late maturing wheat varieties. Every year, around 14-16 trials are being conducted to represent the Northern Western Plains Zone (NWPZ) of the country. However, centre is also contributing wheat and barley entries for their evaluation in trials conducted in Northern Hills Zone (NHZ) by ICAR-IIWBR and in SVTs conducted by Directorate of Agriculture, Uttarakhand.

10. **Germplasm evaluated in national and international nurseries/trials:**

    About 1000 germplasm lines are evaluated every crop season for the identification of suitable potential donors for different traits in national nurseries viz., EIGN, YCSN, NGSN, QCSN, SDSN received from ICAR-IIWBR, Karnal. Besides more than 7000 germplasm lines which includes indigenous and exotic germplasm were evaluated for various agronomic and biotic stress traits funded by ICAR-NBPGR under multilocation testing and CRP project, which helped in strengthening of thegermplasm base of the centre as well as development of germplasm catalogue.

11. On the other hand, Pantnagar centre has always very successfully evaluated 5 to 6 international trials namely, Elite Bread Wheat Yield Trial (EBWYT), Elite Spring Wheat Yield Trial (ESWYT), Semi Arid Wheat Yield Trial (SAWYT), Heat tolerance Wheat Yield Trial (HTWYT), Harvest Plus Yield Trial (HPYT), WYCYT and nurseries viz., and international nurseries and trials viz., IBWSN, SAWSN, KBSN, SATYN, STEMRRSN, IDSN, IDYN, WBN etc. every year supplied by International Centre for Maize and Wheat Improvement (CIMMYT), Mexico and and barley nurseries and trials viz., NBGSN, EIBGN, IBON-HI, IBYT-HI received from ICAR-IIWBR, Karnal and ICARDA, Morocco. The genotypes were evaluated for biotic and abiotic stress tolerance and yield components in the respective sowing conditions.

12. **Breeding material generated:** Pantnagar centre is known as one of the leading centres in North Western Plains Zone of the country. Centre has been recognized a hot spot for yellow and brown rusts, two very important diseases of wheat. Hence every year ~ 500 new crosses are made for disease resistance, drought and heat tolerance and quality traits involving high grain protein content, gluten strength, 1000 grain weight and zinc and iron content. Materials generated are evaluated in segregating generations from F_2 to F_6 and about 60 to 70 advance breeding line are subjected to testing in Initial Plant Protection Screening Nursery (IPPSN) at national level, and ~ 30 advance breeding lines are nominated every year for testing in AICRP trials and State trials.

13. **Elite breeding lines evaluated for yield potential in station trials**

Out of the progenies grown in various generations, the uniform looking desirable progenies in F_5 and onward generations having desired level of height, maturity, diseases resistance, and good grain quality are bulk harvested for multi location testing and yield evaluation under different crop growing conditions. Approximately 150-250 progenies meeting out desirable traits are bulked separately every crop season. These progenies are evaluated in replicated yield trials at Pantnagar under three crop conditions, early sown rainfed, timely sown and late sown irrigated programmes as this evaluation is pre-requisite to enter the advanced breeding lines in national trials. Each year nearly 200 promising lines of wheat and barley are evaluated in the station trials for their further testing in All India Coordinated trials.

14. ***S*amples analyzed for different quality *t*raits**

For improving the quality of future wheat genotypes a wheat grain quality laboratory was established at Pantnagar in 1970 with the help of Rockefeller Foundation and the ICAR. Pantnagar became a mandated centre for quality testing of advance breeding lines. Since then this centre has been sharing national responsibility for the quality analysis of National Trials (TSI and LSI), second year AVT entries of agronomic experiments, Quality Component Screening Nursery, National Yield Observation Trials and at present has the national responsibility for grain quality analysis of NIVT 3 (Late sown irrigated conditions) entries from various agro climatic zones of the country. Every year grain samples from 15 locations are analyzed for various quality parameters viz. grain appearance score, test weight (Hectoliter weight) protein content, sedimentation value and phenol colur reaction. In addition to this all advance generation materials are examined for various quality parameters.

So far more than 70000 samples received from different centres located in different zones of the country have been analyzed for different quality traits and data were submitted to ICAR-Indian Institute of Wheat & Quality Research (earlier Directorate of Wheat Research), Karnal. In addition to the above >10000 samples involving germplasm, advance breeding materials have also been analysed.

15. **Nucleus and Breeder Seed Produced**

Pantnagar center has the distinction of being in lead role in the production of nucleus and breeder seed of improved wheat varieties. Breeding programme is closely linked with the seed production programme of the University Seed Production Centers, University Farm and UP State Seed and Tarai Development Corporation (now Uttarakhand State Seed and Tarai Development Corporation). As a result, quality seeds of newly developed improved varieties are reaching to the farmers far and wide in the country with a faster pace. The adoption of single plant progeny and single ear progeny row methods of producing nucleus seed has gained impetus through the work and experience of the scientist of this University.

Nucleus and Breeder seed of national and state varieties of wheat have been produced against the DAC indent of Government of India with 100 per cent success. So far ~ 2200 qtls of nucleus seed and >50000 qtls of Breeder seed of different varieties have been produced to meet the demand of different seed producing agencies.

16. **Wheat front line demonstrations (FLDs) conducted**

The basic concept of FLD is to exploit maximum production potential to new varieties through transfer of latest technology to farmer's field. This programme is a brainchild of Ministry of Agriculture in collaboration with Directorate of Wheat Research. This center has been actively engaged in this programme in the area of responsibility. Pantnagar center successfully conducted a total of 323 Wheat FLDs on various technologies viz., new varieties under timely and late sown, Zero tillage, weed control, plant protection, combined use of organic and inorganic fertilizers, application of biofertilizers (PSB + Azotobactor), use of rotavator etc. were demonstrated to farmers and most of them have been adopted by the farmers.

Varieties released

Since 1965, 29 high yielding varieties of wheat and one variety of barley were released.

Wheat & Barley varieties developed and released during 1965-2018

Sl. No.	Variety	Year of release	Average maturity duration (Days)	Yield potential (q/ha)	Area of adaptation
Wheat					
1.	Kalyan Sona	1967	142	50 - 55	Throughout the country
2.	Sonalika (RR 21)	1968	128	45 - 50	Throughout the country
3.	UP 301	1970	140	50 - 55	Karnataka, Tamil Nadu and Uttar Pradesh
4.	UP 310	1973	130	50 - 55	Western & Central Uttar Pradesh
5.	UP 319	1973	128	50 - 55	Western & Central Uttar Pradesh
6.	UP 215	1974	132	45 - 50	Peninsular Zone
7.	UP 262*	1977	134	45 - 50	North Eastern Plains Zone (NEPZ)
8.	UP 368	1977	135	50 - 55	Western & Central Uttar Pradesh
9.	UP 115	1978	128	45 - 50	North Eastern Plains Zone (NEPZ)
10.	UP 2003	1980	145	55 - 60	Central & Western Uttar Pradesh
11.	UP 2121	1984	128	45 - 50	Central & Western Uttar Pradesh
12.	UP 2113	1985	150	35 - 40	Central & Western Uttar Pradesh
13.	UP 1109	1986 &	140	35 - 40	Northern Hills Zone (NHZ)
14.	UP 2338	1994	135	TSI: 55-70 LSI: 40-45	North Western Plains Zone (NWPZ)
15.	UP 2382	1998	135	60 - 70	Plains of Uttar Pradesh& Uttarakhand
16.	UP 2425	1999	120	40 - 50	North Western Plains Zone (NWPZ)
17.	UP 2565	2004	125	40 - 46	Plains of Uttarakhand and Uttar Pradesh

18.	UP 2572	2005	155	IR Hills: 35-40 RF Hills: 25-30	Hills of Uttarakhand
19.	UP 2554	2005	135	51 - 68	Plains of Uttarakhand and Uttar Pradesh
20.	UP 2526	2005	125	45 - 67	Plains of Uttarakhand and Uttar Pradesh
21.	UP 2584	2006/ 2010	155	30 - 35	Hills of Uttarakhand
22.	UP 2628	2008	140	55 - 65	Plains of Uttarakhand and Uttar Pradesh
23..	UP 2684	2011	140	50 - 55	Plains of Uttarakhand and Uttar Pradesh
24.	UP 2784	2015	138	55 - 60	Plains of Uttarakhand and Uttar Pradesh
25.	UP 2785	2015	140	55 - 60	Plains of Uttarakhand and Uttar Pradesh
26.	UP 2748	2015	125	45 - 50	Plains of Uttarakhand and Uttar Pradesh
27.	UP 2844	2018	125	52 - 64	Plains of Uttarakhand and Uttar Pradesh
28.	UP 2855	2018	140	55 - 67	Plains of Uttarakhand and Uttar Pradesh
29.	UP 2865	2018	125	45 - 50	Plains of Uttarakhand and Uttar Pradesh
Barley					
1.	UPB 1008	2011	160	30-35	Northern Hills Zone(Hills of Uttarakhand Himanchal Pradesh and Jammu & Kashmir)

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4. Awards/Honours:

1. Dr. J.P. Jaiswal honoured with *Faculty Excellence Award 2013* by the Board of Faculty of College of Agriculture, GBPUAT, Pantnagar.

2. Dr. J.P. Jaiswal has been nominated as *Member, Board of Trustee* for Wheat Research & Technology Fund (WRTF) of ICAR-Indian Institution of Wheat & Barley Research (IIWBR), Karnal (Haryana) for a period of 5 years (2017-2022).

3. Dr. J.P. Jaiswal honoured with *ISGPB Fellow award 2017* by Indian Society of Genetics & Plant Breeding, IARI, New Delhi.

4. Dr. J.P. Jaiswal honoured with *Distinguished Scientist Award 2018* by Agriculture Technology Development Society (ATDS), Ghaziabad in International Conference on Advances in Agricultural, Biological and Applied Science for Sustainable Future (ABAS – 2018), Oct 20-22, 2018, Swami Vivekanand Subharati University, Meerut.

5. Dr. J.P. Jaiswal received the *Best Oral Presentation Award* for the paper entitled “Molecular maker assisted transfer and pyramiding of rust resistance genes in bread wheat to meet the challenges being posed due to the emergence of new races” authored by Jai Prakash Jaiswal, Anupama Singh, N.C. Gahtyari, Shoukat A. Rather and Devender Sharma in SIDVES, SKUAST, Jammu, Feb 8-10, 2018.

6. Dr. Swati honoured with *Young Scientist Award* by the Society for Scientific Development in Agriculture & Technology, Meerut for outstanding contribution in the field of Genetics and Plant Breeding (2018).

7. Dr. Swati received *3rd Best Poster Presentation Award* during International conference on Global Research Initiative for Sustainable Agriculture & Allied Sciences (GRISAAS 2018) organized by Astha Foundation, Meerut from 28-30 October, 2018.

5. Future Thrusts:

1. Development of wheat varieties possessing durable rust resistance using marker assisted breeding approaches.
2. Development of drought tolerant wheat varieties suited to rainfed conditions of hills.
3. Development of wheat varieties suited to restricted irrigation conditions in plains.
4. Development of wheat varieties tolerant to terminal heat stress through marker assisted breeding approach.
5. Development of wheat varieties rich in micronutrients (Fe and Zn) through biofortification approach.
6. Creating genetic variability through pre-breeding approach.
7. Development of varieties suitable for bread and biscuits making quality.
8. Development of barley varieties for malt quality, feed and dual purpose.

B. Wheat Agronomy:

1. Significant Achievements:

1. Discovered critical growth stage including CRI which revolutionized the water management concept.
2. Suitable methods of wheat sowing for varying conditions were developed.
3. Yield potential of 6 t/ha was realized by evolving suitable agronomic practices.
4. Response of wheat to N up to 150 kg/ha was obtained.
5. Integrated weed and soil water management was standardized.
6. Management for zero till cultivation was developed.
7. Wheat based cropping system including rice wheat was developed.
8. Crop residue management technology was developed as an alternate to burning.
9. Integrated nutrient management using recommended NPK with FYM sustained wheat production together with maintaining soil fertility over three decades.
10. Balanced site specific nutrient management practices have been developed to save the cost on fertilizers and improve wheat yields.
11. Using soil-crop-climate data, a method for scheduling irrigation in wheat has been developed.
12. Indices of soil tilth and soil quality have been developed to optimize tillage requirements for sustainable wheat production.
13. The wheat productivity in both conventional and zero tillage are same, therefore the recommendation is sent to the government to adopt zero tillage technology.
14. Nitrogen use efficiency of urea can be enhanced by urea top dressing just before irrigation is recommended for the farmers. The technology is further refined by green seeker technology.
15. More than five hundred agronomical experiments have been conducted during 1965-2018.

1. Identification of wheat genotypes under changing climatic scenario

The yield potential of wheat genotypes since 1960’s in Pantnagar centre has been improved from 23 q/ha to 57 q/ha in year 2016-17. Further yield, improvement of more than 6 t/ha can be achieved with advanced production technology. In that manner, to establish the adaptability of new varieties with respect to climatic variation, several cultivars, breeding lines and coded varieties were tested within the time frame. Under the several experiments following varieties were found suitable in NWPZ in different time of sowing. Long duration varieties UP 2338, PBW 343, WH 542, HD 2687, WH-1105, WH-1138, DBW-88, PBW-550, PBW-502,DBW-17,HD-2967, HD-3086 & PBW-621-50 should be sown in first fortnight of November, whereas UP 2338, UP 2382 should be sown in second fortnight of November under irrigated condition. Varieties UP 2338, UP 2425, Raj 3765, Raj 3077 HUW-66, PBW-373, PBW-681, PBW-658, HD-3065, HD-2967, WH-1100, DBW-17, WH-1129, PBW-550, UP2425, HD-3065, DBW-71 & HD 3091 and PBW 373 are suitable in late and very late sown conditions.

2. Screening of crops and cropping sequence suited to wheat crops

Rice- wheat is one of the major occupying cropping systems in this zone. The high success rate of good returns, less risk involved due to adaptation of crop management technology by the farmers and convenient marketing facilities made it a popular cropping sequence. Considerable time and energy is being spent in preparation of field for wheat cultivation that sometimes causes late sown condition. This situation was tackled by developing the technology to put the seed in moist zone with minimum or reduced tillage. Several other wheat based cropping systems were also put under trial based on rice-wheat, maize-wheat, maize-lahi-wheat, rice - vegetable pea – wheat, sorghum-wheat and soybean-wheat etc. The main objective was to improve the wheat production but rice-wheat system has considerable advantage which was also commonly used by the local farmers of Tarai region. The centre has also standardized the effect of legume incorporation in maize wheat –legume rotation and recommended that legume incorporion in the system did not significantly influenced the maize and wheat yield. It was also inferred by the centre that nitrogen requirement of wheat crop almost same irrespective of preceding crop either legume or cereals.

3. Development of optimum tillage technologies for better wheat production

Tillage considered the most time consuming practice and labour intensive job in land preparation. Several experiments were laid to understand the suitability of wheat crop and to achieve higher production. It has been estimated that in order to reduce time and saving energy, the minimum tillage (especially for advance sowing) fit in the intensive agriculture technology under rice-wheat cropping system. Experiments were specific around chiselling, planking, no. of harrowing, zero tillage, wheat sowing following direct seeded and puddle transplanted rice etc. Rice straw and residue burning has been tremendously increased in recent years where suitable technique for their end uses were under trial in fields. However, incorporation of rice residue by mould board plough alongwith application of starter dose of nitrogen to maintain the C:N ratio was recommended as an option. It was estimated that rather burning of these residue, soil incorporation and surface retention of the straw improved the wheat production. Alternative solutions were also experimented about different residues including uses of by-products as mulch. It helps to rejuvenate physical strength of soil and improves the crop production. Hence, mulching and inclusion of foliar nutrition sprays were also tested keeping the point of many cases of delayed sowing in wheat and high radiation effect at later stage. The mulching is one key factor that can solve residue problem as well as found effective in case of terminal heat stress problem in late sown wheat varieties.

4. Development of various advanced and modified sowing technologies for wheat

Many agronomic approaches are categorised under non-monetary inputs which help to achieve better yield. In several experiments related with sowing conditions *eg.* sowing time, depth, direction, seed rate and sowing methods were tested with slight modifications as per demand in modern cropping system. It has been estimated that in NWPZ, the best sowing time of wheat is 25th October to mid November. After end of November there is huge reduction in yield. Sowing of wheat is often delayed due to late harvesting of paddy, toria, sugarcane and potato. Delayed sowing of wheat under low temperature conditions enhance time for germination and enforces the crop to mature early due to high temperature in late stages of crop. Late sown and very late sown crop reduced the wheat yield than normal sown crop. In *Triticum aestivum*, the yield reduction was 2.8 % in late sown and 25.7% in very late sown as compared to normal sown crop. Late sown crop of *Triticum durum* reduced the wheat yield upto 10.2 % as compared to normal sown crop. Increasing the seed rate 25% than normal sowing along with selection of suitable variety for late sown condition is advocated. Similarly, the optimum depth for dwarf or semi-dwarf wheat varieties found at 5 cm depth that could be suitable for higher germination and improved growth. Broadcasting is immensely popular among small land holders for wheat cultivation but scientific studies don't supported the practices which are non-scientific. Hence, Centre has many sowing method trials related with sowing behind the plough, pora method, Pantnagar zero till ferti-seed drill, surface seeding, strip till drill, FIRBS and ferti seed drill (conventional) which found better than broadcasting method. In earlier days of tall wheat genotypes, the plant spacing was quite wider upto 30 cm in 60's and 70's. But with the development of semi dwarf genotypes, the spacing was reduced earlier from 25 to 23 cm and now good response at 20 cm. too. But, dense planting *i.e.,* 15 and 17.5 cm reaches new heights of production and performed better than wider spacing (i.e., 20 and 22.5 cm).

5. Nutrient management strategies for wheat:

The feeding habit and nutritional requirement of new wheat genotypes differs from the previous developed varieties. Therefore, to explore the optimum yield potential of new wheat genotypes with their nutritional requirements, several filed experiments were conducted by the centre to establish the fertilizer requirement and their efficient use by wheat crop. Quantity on nutrient required, right source for the nutrients and methods of fertilizer application were standardized for optimum wheat production under different conditions like tall and dwarf wheat, irrigated and rain fed condition, timely and late sown conditions, heavy and light soil conditions etc. Refinement of nutrient doses for better wheat production was done from time to time. For example Nitrogen doses was 60 kg / ha (tall wheat) during 60s and refined as 150 kg /ha in present days. During initials days no response of micronutrient was noticed but now wheat is showing the response of some micronutrients like manganese and zinc. Centre also conducted numerous experiments on integrated nutrient management, precision nutrition to enhance fertilizer use efficiency which helps to mitigate economic burden on the farmers and also helps to protect our environment. Urea (as top dressing) applied just before irrigation help to improve nitrogen use efficiency in wheat. Optimum combination of organic (FYM @ 10 t/ha) and inorganic source of nutrients (150:60:40 kg NPK/ha) was also delineated for better nutrient use, wheat production and soil health. Nutrient requirement of wheat crop grown under different crop sequence were also optimized. Feasibility of green manure before or after rice cultivation was undertaken as forage legume or short duration grain legume in summer, legume as green manure or break crop or para crop and encouraging results explanation is recommended as per situation. The data generated on different nutritional aspect of wheat production is being used for development of package and practices for the cultivation of new genotypes of the wheat and this further utilized by different agencies and farmers.

6. **Water management strategies in wheat**

Maintenance of optimum moisture is indispensible for exploiting for the full yield potential of new wheat genotypes. Experiments were conducted to establish the irrigation scheduling for better wheat production. It was found that Crown root initiation (CRI) is the most critical stage for moisture stress; therefore first irrigation in wheat should be applied at this stage. Experiment to study critical stages for irrigations were conducted and it was found that two stage of plant growth is most critical in respect to moisture stress *i.e.,* the early stage of crop growth (when crown roots are developing and tillers are initiating); and reproductive stage (flowering and grain filling stage). On the basis of extensive research work conducted for the scheduling of irrigation for various physiological stages, it is recommended that if the amount of water is adequate, six irrigations are required to exploit full yield potential of wheat. Irrigation in wheat should be done when soil attained 0.8 atm tension or 0.5 barometric potential or -6 bar leaf water potential or 50 % available soil moisture in root zone of crop and IW/CPE=1.0 is as effective as irrigation at physiological growth stages. Screening of new wheat genotypes under restricted irrigation was also done. Application of Hydrogel @ 2-5 kg/ha help to enhance water use efficiency in wheat. Different criteria of irrigation were evaluated by the centre and it was found that irrigation in wheat can successfully be scheduled on the basis of physiological stages, soil moisture level etc. Maintaining the irrigation regime had non significant effect on yield but if the crop received irrigation at long day interval the depth of irrigation ranges between 6 to 8 cm depending on the irrigation interval. If the ground water table is closed to soil surface irrigation depth may be small.

7. **Development of weed management strategies for wheat crop**

Weeds do enormous damage in the wheat crop. It has been estimated that losses caused by weeds in wheat crop range from 10 to 80 % depending on the intensity of weeds. Centre has identified major weeds prevalent in wheat fields and these are wild oats (*Avena fatua*), Gulli danda (*Phalaris minor*), Bathua (*Chenopodium album*) etc. Due to introduction of dwarf wheat, two most serious weeds namely *Phalaris minor* and *Avena fatua* have been identified for major wheat growing region*s*. Weeds can be managed either manually or chemically; however manual management is difficult in wheat because of large acreage, therefore during initial days the centres developed chemical weed management techniques and standardized the technique for controlling non grassy weed by 2-4 D. Subsequently, introduction of *Phalaris minor* and *Avena fatua*, the centre has developed the strategies to control it by the application of pre emergence herbicides i.e. TOK-E-25@1.5 kg a.i/ha or Tribunil and Dosanex @ 1.5 kg a.i/ha. Some non chemical weed management strategies have also developed by the centre. Closure planting (15 cm) and cross sowing (22 cm) was also found effective to reduce the weeds. The recommendation of broad spectrum herbicides like Sulfosulfuron, Phenoxaprop, Carfentrazone, Metsulfuron Methyl etc. has also been developed by the centre.

8. **Other Alternate Management Achievements**

Other than AICRP, several *adhoc* and bio-efficacy projects were handled by the group. Results revealed that application of Gypsum @ 250 kg/ha help to boost yield of several field crops. Rock phosphate mixed with some acidulates like FYM, Pressmud, PSB etc can be used as an alternative for phosphorus nutrition. Soil samples from different part of Uttarakhand were collected and analysed by the group. Group also performed the training and create awareness about gypsum benefits in different village of Uttarakhand. In last so many years , different bistimulant like biovita, plantozyme , Mycorrhizea based product like Jumpstart, REVV etc and herbicidal molecules like Glufosinate Ammonium , of 2,4-D Sodium Salt 50% + Metribuzin 15% WP, PIH 485 85% WG have been evaluated. On the basis of such evaluations we are recommending the good molecules for better wheat production.

2. Research Publications:

1. Khati, P; Sharma, A; Gangola, S; Kumar Rajeew, Bhatt, P, and Kumar G. 2017. Impact of agri-usable nanocompounds on soil microbial activity: an indicator of soil health. *Clean Soil Air and Water. 45 (5) (Published online)*

2. Khati, P; Parul; Bhatt, P; Nisha; Kumar Rajeew ; Sharma, A. 2018. Effect of nanozeolite and plant growth promoting rhizobacteria on maize. *3 Biotech* (2018) 8:141

3. Kalhapure, A; Kumar Rajeew, Singh V. P. and Pandey, D. S. 2016. Hydrogels: a boon for increasing agricultural productivity in water-stressed environment. *Current Science*. 111(10) 1173- 1179.

4. Satpal, Kumar Rajeew, Chaudhary,S; Shukla, A. 2018. Effect of NPK level and nano TiO_2 concentration on growth and yield of wheat. *Indian Journal of Agricultural Sciences*. 88 (1).

5. Kumar Rajeew, Pandey, D.S, Singh, V.P, Singh, I.P. Pandey.2014.Wheat productivity under different legume options and tillage practices in rice and wheat cropping sequence.*Indian J. of Agricultural Sciences*.81(1):101-106

6. Kumar Rajeew, Krishna Maya, Bhatnagar Amit, Pandey DS, Singh Vijay Pal, and Pradeep Ram .2018. Effect of rock phosphate with different acidulates on growth and yield of different field crops. *Indian Journal of Agronomy*. 63 (3): 293-299

7. Kumar Rajeew, Pandey, D.S., Singh, V.P, Singh, I.P. Pandey, Dheeraj. 2013. Growth, yield and quality of wheat (*Triticumaestivum*) as influenced by organic sources of nitrogen nutrition. *Indian Journal of Agronomy.* 58 (3):334-339.

8. Pandey Madhulika, Singh, V.P , Kumar Rajeew, Pandey, D.S, Singh, I.P . 2014. Comparative performance of gypsum and micro-ionized sulphur on wheat crop. Indian Journal of Agronomy. 59 (4): 661-664

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a. Ram. P, 2018. Formulation of nano-apatite from eggshell for efficacy assessment in wheat (*Triticumaestivum* L.), Ph.D. thesis submitted to G.B. Pant University of Agriculture and Technology, Pantnagar(Major guide : Dr.Rajeew Kumar)

b. Krishna, M.2017. Tillage and precision nutrient management studies in wheat. Ph.D thesis submitted to GB Pant University of Agriculture & Technology, Pantnagar. (Major guide : Dr.D.S Pandey)

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d. Joshi.H, 2018. Cold atmospheric pressure plasma and nano-chitosan effect on nutrient use by wheat (*Triticumaestivum* L.), M.Sc. thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, 1-88.(Major guide : Dr.D.S Pandey)

e. Rawat,Anupama. 2017, Effect of nano-sized gypsum on growth and productivity of wheat (*TriticumaestivumL.*). M.Sc. thesis, G.B. Pant

University of Agriculture and Technology, Pantnagar.(Major guide : Dr.Vijay P Singh)

f. Hussain,Showkat, 2016, Studies on agro-chemicals for lodging management in wheat (*TriticumaestivumL.*). M.Sc thesis submitted to GB Pant University of Agriculture & Technology, Pantnagar.(Major guide : Dr.D.S Pandey)

g. Verma.N, 2015. Formulation and efficacy assessment of bio-nano minerals in wheat (*Triticumaestivum* L.). M.Sc. thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, 1-121.(Major guide : Dr.D.S Pandey)

h. Amit.2015.Efficacy assessment of bio-based nanomaterials of gypsum and rock phosphate in wheat (*Triticumaestivum*L)- M.Sc. thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, 1-121(Major guide : Dr.Rajeew Kumar)

i. Bhatt, P.2015.Precision nutrient management under different tillage practices in wheat.M.Sc thesis submitted to GB Pant University of Agriculture & Technology, Pantnagar.(Major guide : Dr.Vijay P Singh)

j. Rawat, P.S, 2013. Nanoparticle mediated seed treatment studies to enhance nutrient use efficiency in wheat (*Triticum aestivum* L.), M.Sc. thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, 1-89(Major guide : Dr. Rajeew Kumar)

4. Awards/Honours:

1. Young Scientist.2015.International.The Society of Tropical Agriculture, Delhi (Dr. Rajeew Kumar)

2. Outstanding Scientist in Agronomy 2018. International Venus Foundation Chennai (Dr. Rajeew Kumar)

5. Future Thrusts:

1. Screening of the varieties with their suitable agronomic practices for better wheat yield under changing climatic situation.

2. Development of a strategy to save input cost and increase input use efficiency.

3. Standardization of resource conservation technologies for better wheat production under different cropping system.

4. Designing modern technologies like Precision Agriculture, Nanotechnology, Plasma-technology for better wheat production.

5. Development of crop and cropping system suited to the need of the society considering soil and environmental health.

6. Management option study to improve the soil biology and empowering input use efficiency.

C. Wheat Physiology

1. Significant Achievements:

Wheat physiology initiated the studies with evaluation of genotypes/varieties were evaluated for terminal heat stress tolerance. Apart from this, deciphering physiological processes of plant responses due to terminal heat and agronomic interventions to combat heat stress has also been major objective of the research. Given below is the brief account of research achievements under the subject.

1. Identification of terminal heat tolerant varieties:

Following genotypes were found superior under terminal heat stress tolerance: HUW 234,HI 8691, WHD 943, PBW 590, HD 2864 and MP 4106 PDW 317 PBW 621 and PDW 315, Raj-3765 UP-2526, Raj 4101, Lok-54, HW-2045 and WH-1021 PBW 688 and RAJ 4295 RAJ 4250 , RAJ 3765, and GW 433

2. Identification of traits responsible for terminal heat stress tolerance

Following points were identified through several years of experimentation

a) Leaf Chlorophyll content in terms of SPAD value was highest at 60 day stage and gradually declined thereafter with advancement of crop stage.

b) It was observed that rate of photosynthesis declined with delay in sowing and advancement of crop age after anthesis. But stomatal conductance was high in late sown wheat.

c) The rate of leaf area index increase was more in late sown wheat than in timely sown crop but ultimate LAI was higher in timely sown crop.

c) The relationship between chlorophyll florescence parameters and photosynthesis was not consistent.

d) Super oxide Dismutase (SOD), Melandialdehyude (MDA) and Proline content increased with delay in sowing. Relative water content (RWC) decreased due to delay in sowing. SOD MDA and proline contents were negatively associated with grain yield.

e) Chlorophyll florescence variable yield (Fv/Fm) which is associated with the functionality of PS-II got impaired under late sown condition. In timely sown condition the value of Fv/Fm was 0.691 while under late sown condition it was 0.618 at the time of anthesis.

f) This decline was more pronounced after 15 days of anthesis. Fv/Fm was positively correlated with yield.

g) Relative water content might be one reason of yield loss during late sown condition. Low membrane stability index was recorded in heat sensitive genotypes than tolerant one. MSI showed positive correlation with heat tolerance.

h) Increasing temperature showed marked effect in various physiological and biochemical parameters tested in all genotypes under study.

i) Greater reduction in plant height, tiller number, LAI, relative chlorophyll content or Soil Plant Analysis Determination value (SPAD) and maximal efficiency of PSII or ratio of variable florescence to maximum florescence (Fv/Fm) was observed in sensitive genotypes

j) Tolerant genotypes exhibited increase in activity of antioxidant enzyme (viz., CAT, APX, POD, PPO, and PAL). These genotypes also exhibited lower heat induced damage in terms of lipid peroxidation, membrane leakage and H_2O_2 content. Higher Phenol and flavonoid content in these genotypes may serve as an adaptation toward scavenging of reactive oxygen species.

k) Terminal heat stress induces ROS which triggers the production of antioxidant enzymes, whose increased production provide tolerance to wheat genotypes. Continuous high temperature cause heat induces damage in terms of lipid peroxidation, membrane leakage and H_2O_2 content.

l) Phenol and flavonoid content increases under stress to scavenge ROS, by chelating transition metal ions which have role in free radical production.

3. Agronomic solutions to abiotic stress tolerance

i. Alleviation of cold stress under late sown through seed treatment and subsequent effect on yield and yield attributes of late sown wheat

Salient Findings

a) In low temperature hardened seeds {seeds were soaked in water for 18 hrs at 20 ^{o} C then keeping at chilling temperature (5±2^{o}C)}, 80 % emergence and first tiller formation occurred two days earlier than controlled seeds.

b) Low temperature hardening treatment not only shortened the time for 80 per cent emergence and first tiller formation but also improved plant stand as indicated by its higher plant population per unit area.

c) Low temperature hardened seeds also exhibited highest numbers of tillers/plant up to 35 days after sowing thereafter the priming effect became non-significant.

d) The priming treatments did not show significant variation on yield and spike characteristics. The highest grain and straw yields were recorded with low temperature hardened seeds.

ii. Mitigation of terminal heat through agronomic management in late sown wheat.

a. Wheat performed better under the FYM in terms of grain yield. FYM had higher value of Fv/Fm, SPAD at the post anthesis stage. All the foliar treatment performed well compared to control i.e. no spray in terms of producing grain yield of wheat. Differences among foliar treatment except control were found to be non-significant. Highest grain yield was obtained when $ZnSO_4$ (0.5%) was applied at post anthesis stage followed by KCl (2.0 %) at post anthesis stage.

b. Under late sown (II Fortnight of December) FYM (6t/ ha) and biochar (10t/ ha) were able to conserve moisture as indicated by increase soil moisture content and reduced soil temperature but could not compensate need of fourth irrigation at grain filling stage in terms of grain yield. However, at reduced irrigation levels (two and three irrigations) application of FYM and biochar had more pronounced effect on grain yield than at optimal irrigation level (four irrigations).

D. Wheat and barley pathology

1. Significant Achievements:

1. A very effective and economical method of controlling loose smut of wheat by seed treatment with carboxin or carbendazim resulted in significant reduction in loose smut at national level.

2. Embryo Count Test (ECT) and Crown Seedling Test (CST), techniques were developed to detect loose smut infection in seeds or seedlings which helped saving millions of rupees annually on chemicals.

3. Multiple disease control in wheat including loose smut, brown and yellow rusts, powdery mildew and leaf blight were achieved by seed treatment with Raxil 2DS @ 1.5g/kg seed + one foliar spray of fungicide tebuconazole (Folicur 250 EW) @ 500 ml/ha just before heading.

4. To control Karnal bunt sprays of propiconazole @ 500 ml/ha at heading time was recommended.

5. Two new pathotypes, 12-8(49R45) for brown rust of wheat and 6SO for yellow rust of wheat and barley were identified from Pantnagar in the year 2008 and 2014, respectively.

6. The IPM modules for rice and wheat were synthesized and validated at farmers' fields.

1. Management of wheat diseases through chemicals:

Rusts: Yellow and brown rust both are the major diseases of wheat of our Tarai and plains of Uttarakhand. During crop season 2010-2011 an epidemic arose due to Yellow rust in NWPZ and N Hills which causes a huge loss. This epidemic occurs due to the breakdown of rust resistant variety i.e. PBW343. The control of wheat rust through the use of fungicides has been attempted with considerable success. A trial conducted for several years and showed that the fungicides like Propiconazole 25EC, Tebuconazole 250 EC (Folicur 250 EC) and Triademefon (Bayleton 25 WP) @ 0.1percent could be used for the control rusts.

Powdery mildew: A number of field trials were conducted to determine efficacy of different fungicides for controlling powdery mildew of wheat and it was concluded that one spray of Propiconazole 25EC @ 0.1% or Triademefon (Bayleton 25 WP) @ 0.1% at ear head emergence or disease appearance (which usually occurs during early March in northern plains) is highly effective with corresponding yield increases.

Foliar Blight: The estimation of the losses due to foliar blight of wheat was also evaluated and it was observed that Propiconazole 25EC @0.1%, Mancozeb @ 0.25% and Tebuconazole 250EC (Folicur 250 EC) @

0.1% as single spray were found to be highly effective in controlling foliar blight. It was also noticed that losses due to the leaf blight were higher in the late sown wheat crop than timely sown. Based on numerous isolations and pathogenecity tests during last 12-13 years *Bipolaris sorokiniana* (=*D.sorokiniana*=*H. sativum*) was found to be involved in foliar blight and symptoms on ear head. *Bipolaris sorokiniana* showed wide variability in their cultural morphological and pathogenic characteristics between very slow grower and sporulator to those with double the growth and sporulation. Similarly, pathogenecity of the isolates varied between least pathogenic to highly pathogenic in nature.

Loose smut: The first systemic fungicide, Carboxin, was tested against loose smut at Pantnagar during the year just after its discovery (1967 onwards) and was found highly effective when applied as seed treatment @ 250g/q seed. Since than number of fungicides have been tested for controlling the disease. Of the several new systemic fungicides tested, Triademinol, carbendazim, benomyl, carboxin are the most effective one. The percentage of disease control increased with the increase in the seed treatment doses (62.5g-250g/q seed) of the fungicides. Slurry seed treatment proved superior to the dry seed treatment.

Among the number of the new fungicides, along with the recommended ones tested against loose smut, Tebuconazole (Raxil 2DS) @ 1.0, 1.5, 2.0 and 2.5g was found highly effective in controlling the disease. Tebuconazole (Raxil 2DS) @ 1.5g/Kg seed as slury seed treatment gave complete control of loose smut of wheat. Other fungicides also showed excellent results those are Carboxin@ 2 gm/kg seed or Carbendazim @ 1.0 gm /kg seed.

Field evaluation of *T.viride* and *T. harzianum* for biological control loose smut of wheat revealed complete control of the disease by seed treatment with cell free culture filtrate of T. viride (1:10 dilutions) alone or in combination of fungicides Carboxin (Vitavax) or Carbendazim (Bavistin) at half the recommended dose i.e. at 1.25g/kg seed or Tebuconazole (Raxil 2DS) @1.0g/Kg seed.

Karnal bunt: Due to recurring problem of Karnal bunt in *Tarai* area of Uttarakhand during 5-10 years back and no popular resistant variety available, seed growers that time suffered substantial economic loss every year, as thousand of quintals of their produce gets rejected for seed because of presence of Karnal bunt infected grains in quantity more than permitted by certification standards.

During crop season 2002-2003, most of the popular wheat varieties showed moderate to high incidence of karnal bunt. The seed growers in Uttrakhand have been recommended to spray Propiconazole @0.05-0.1% at heading time which resulted in wide spread reduction of the disease incidence.

3. Development of pathogen detection techniques

Embryo count and seedling crown tests for loose smut: Successful attempts were made during 1976-82 to develop/ standardize the procedures for the detection of loose smut infection in the seed and seedlings. The steps involved in the two procedures, named Embryo count test (ECT) and Seedling Crown test (SCT).

NaOH seed soak method for Karnal bunt detection: A simple technique was developed during 1982-83 for quicker and easier detection of karnal bunt infection in wheat seed. The seed are soaked overnight in 0.2% solution of NaOH. After removal of the soaking solution and washing of seed in tap water, the seed are spread on blotter sheet to remove the excess moisture. The seed are examined under light. The karnal bunt infected seed or the infected portion gives a shiny jet black color. The infection may be confirmed by giving slight pressure on the seed due to which a stream of spore mass comes out from the infected seed. The spore is studied under microscope. The technique is specially useful for detection of the minor infection and the infection in chemically treated seeds.

Development of smut sori of *Ustilago segetum tritici* on leaves: A rare type of symptom of loose smut i.e. the development of smut sori on leaves was observed only on two plants of variety Sonalika, one during 1979-80 and another in 1981-82.

4. Evaluation of national nurseries against major wheat and barley diseases

The center has evaluated thousands of elite breeding lines and varieties for resistance against major diseases such as rusts, powdery mildew, foliar blight and Karnal bunt. These diseases were tested under Plant pathological screening nurseries, Elite Plant pathological screening nurseries, Leaf blight screening nurseries, Karnal bunt screening nurseries, Multiple disease screening nurseries, Powdery mildew screening nurseries in artificial epiphytotic conditions. Pantnagar is the hot spot for major diseases i.e. Rust (yellow and brown) and powdery mildew. Due to climate change (increase in temperature) and crop intensification spot blotch disease which was previously prevalent at NEPZ has made its appearance in NWPZ, Penninsular and Central zone of India. Therefore, spot blotch is also one of the major disease at Pantnagar. In Barley, center evaluates almost 400 entries every year against leaf blight disease under artificial conditions in three nurseries i.e. NBDSN, EBDSN and IBDSN. The data generated in different nurasries of wheat and barley is being used for the breeding of resistant varieties for wheat and barley.

5. Evaluation of International varieties: Two international nurseries i.e. SAARC and WDMN (Wheat disease monitoring nursary) were also evaluated for leaf and stripe rust disease at Pantnagar under natural conditions (away from experimental field). These nurseries were conducted to track the appearance of new pathotype, simultanously yellow and brown rust infected samples from nursery were send to Flowerdales, Shimla for pathotype analysis.

5. Identification of new pathotypes:

12-8 (49R45): Identified in 2008 from a sample collected from Pantnagar, Uttarakhand**.**It has additional virulence on Thew (Lr20) in comparison to 12-3 (49R37). It is virulent on common genes present on Indian wheat materials *Lr23*&*Lr26* whereas avirulent on *Lr.*

6S0: Identified in 2014 and collected From Pantnagar, Uttarakhand. It is virulent on both wheat and barley lines. It is virulent on Lee (Yr7) and HeinesKolben (Yr6)

6. Survey and Surveillance:

Survey and Surveillance of wheat biotic stresses: Survey is being conducted regularly for the occurrence and spread of the disease, to predict or forewarn the inoculum in the environment and keep vigil on the entry of new pests or their races/ pathotypes etc. The concerned farmers have been advised immediately to take up the control measures. Adjoining districts of Uttar Pradesh are also dependent on G.B. Pant University of Agriculture Technology for technical advice which is provided regularly.

Post harvest survey: For monitoring and prevalence of Karnal bunt, black point and grain discoloration in harvested grains, wheat grain samples were collected from grain mandies/farmers field in districts U.S.Nagar and Nainital of the state these samples were studies for above said diseases and than were sent to P.I. (Crop protection) IIWBR, Karnal for further analysis.

9. Germplasm Registered: The germplasm line IC252459 carries stripe rust resistance genes viz., Yr5, Yr15 & Yr48 which were found resistant to stripe rust pathotypes K (47S102), P (46S103), L (70S69), 13 (67S8), I (38S102), 46S119 & 78S84 additionally also carries leaf rust resistance genes Lr46+, Lr50 & Lr24/Sr24. The accession may be considered carrying multiple disease resistant germplasm.

2. Research papers

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4. Future Thrusts:

1. To study epidemiology and control of wheat diseases.

2. To conduct timely survey and surveillance for the occurrence of rust
3. To develop and recommend suitable alternative measures for control of major diseases of wheat.
4. To study mechanics of tolerance, slow rusting and multilines with reference to brown rust.
5. To study the interaction of agrochemicals used on wheat crop with diseases.

E. Wheat Entomology:

1. Significant Achievements:

Survey of insect pests:

Some insect pests of wheat have been reported to be of such paramount importance that they bear special mention or have the potential to spread to other similar agro-climatic zones where wheat is grown.

1. Field survey conducted shown that the occurrence of insect pest attacking on wheat crop in Uttranchal. Most of these pests are sporadic and appear from time to time in varying intensities at different localities causing varying losses. Aphids, which were regarded as irregular and minor pests before now become regular pest. They feed on foliage, tender stems and on the ear heads, both in the Tarai and hilly areas wherever wheat crop is grown. In *Tarai* their intensity of incidence is recorded up to 200 aphids per tiller. The incidence of aphids in severe cases caused losses ranging from 22-32 percent.
2. The incidence of shoot fly, army worm and hairy caterpillar was also reported to cause severe losses.
3. The attack of termites at the seedling stage caused losses upto 30 percent, while it ranged from 20-40 percent if the attack was at maturity.
4. Some insect pests of minor economic impor-tance in the past, are assuming the role of potential enemies of wheat crop, for example army worm *(Pseudolatia seperata* Walker), gram cut worm *(Agrotis ipsilon Rott).* Bihar hairy caterpillar *(Diacrisia obliqua* Walker). the incidence of these pests varied with respect to different phyto-geographical strata, being somewhat higher in the Bhabar and *Tarai* as compared to hilly areas. Insects like shootfly (*Atherigona nagvii* steyskal), army-worm (*P. seperata* Wlk.) hairy caterpillar (*D. obliqua* WLK) attacked the crop and destroyed almost 50-60% of the crop in year 1968, 1970 and 1971.
5. Armyworm incidence was again noticed in 1978-79. Cutworms, stem borers, jassids were also observed damaging this crop in 1979-80. The termites are most important insect pests of wheat particularly under un-irrigated conditions. Also, in the survey conducted in the village Jiragaur of Distt. Farrukhabad, it was observed that *Microtermes obesi* Halm, caused upto 30% losses of germinating seedlings and particularly in sandy loam soils, they devastated the plants at maturity stage from 20 to 40 %.
6. The survey and survellience have revealed that the following insect pests of wheat have been found attacking wheat crop in tarai and adjoining areas during last twenty years.
    1. Shootfly (*Atherigona naqvii* steystkal.)
    2. Grass hopper (*Chrotogonus brachypterus* Bl.)
    3. Jassid (*Empoasca devestans* Ishida.)
    4. Gujia weevil (*Tanymecus indicus* Faust.)
    5. Spider (*Tetranychus sp*.)
    6. Cutworm (*Agrotis ipsilon* Hufn.)
    7. Stemborer (*Sesamia inferens*-WLK)
    8. Thrips (*Scirtothrips dorsalis* L.)
    9. Hairy caterpillar (*Diacrisia obliqua* WLK).
    10. Aphid (*Rhopalosiphum maidis* Fitch.)

11. Armyworm (*Mythimna seperata* WLK.)
12. Gram pod borer (*Heliothis armigera* Hubner)
13. Stemfly (*Melanagromyza phaseoli* Conquillett)
14. Wireworms (*Agriotes mancus*)

Stored grain pest:

1. The major pests reported to wheat grain in Uttarakhand were: the weevils, *Sitophilus oryzae*, lesser grain borer, *Rhyzopertha dominica* and red rust flour beetle, *Tribolium castaneum*.
2. The feeding of these insects caused losses both qualitatively and quantitatively. The wheat stored unhygienically without proper drying appeared to be more liable to damage. A sizable amount of protein is lost due to insect damage. The presence of excrement contamination in infested grains results in bad odour and taste. This also affects the palatability of the flour and may cause stomach disorders.
3. Investigations made on the management of this pest revealed that following measure limit the population build up of insects:

1. Changes in the crop rotation field with less moisture encourage insect infestation.
2. Sowing of wheat during 11-26 November has been observed best to avoid damage.
3. Metasystox 25 ECev200 ml *a.i.* per hectare was found to be the best for controlling the shootfly.

Screening of germplasm for resistance to insect pests:

1. Promising breeding materials, lines and varieties were evaluated for the resistance to many insects in the field as well as in the storage. UP-101 was most resistant to *S. oryzae* and UP 301 to *S. cerealella* UP 310, K-818, UP-308, UP-211 and UP 217 were most susceptible to *S. cerealella*, and UP211, Noroesta-66 NP-890 and HD-1962, Inia-66 and Tabari-66 were resistant to both the insects under field and laboratory testing.

Effect of storage structures on losses

Insect feed on grain kernel and lower the quality contaminating it with their body parts and excrement, reduce viability and quality of nutrients present insect feeding results in the destruction of germination and a high percentage of the nutritive portion of grain.

1. The deterioration of grain and loss in germinability was faster in case of germ eaten kernel.
2. Insect activity in storage encourages the development of fat acidity in grain and the development of rancidity results in off flavour.
3. The observations revealed that disappearance of non-reducing sugars is due to increase in moisture which is dependent on the climate and storage method. The safe storage limits of moisture in wheat in Ku Kuthala ranges between 10.5 to 12.4 per cent, in earthenpot 10 to 11 per cent and in case of bag storage there was continuous disappearance of non-reducing sugars with the increase of moisture levels.
4. It was observed that where kernel infestation and insect fragment including excrements were high the viability of the seed was reduced. Where the kernel infestation was more and insect fragment excrement contamination was less, the viability was not affected.