AICRP-RICE

Objectives

1. Development of high yielding varieties of early, medium early and medium duration with resistance to major diseases and pests and acceptable grain quality for irrigated ecology and hill region of Uttarakhand.
2. To study the grain yield potential, nutrient response and nutrient use efficiencies of promising rice cultures of Early, Medium, Basmati, Aerobic rice, Fortifies and Hybrids under high and low input management.
3. To develop package of practices for new and resource efficient technologies for rice and rice based production systems.

A. Rice Breeding

1. Significant Achievements:

In the last 49 years, Pantnagar University has developed 26 high yielding varieties and hybrids of rice which are being cultivated in different parts of the country. In 1972, the centre released first variety IR 24, an introduction from IRRI, Philippines which was followed by the development and release of 17 other high yielding varieties namely IR 24, Prasad, Govind, Pant Dhan 4, Manhar, Pant Dhan 6, Pant Dhan 10, Pant Dhan 11, Pant Dhan 12, Pant Dhan 16, Pant Dhan 18, Pant Dhan 19, Pant Dhan 22, Pant Dhan 23, Pant Dhan 24 Pant Dhan 26, Pant Dhan 28 and the two hybrids Pant Sankar Dhan 1 and Pant Sankar Dhan 3. The centre has developed five aromatic fine grain varieties Pant Sugandh Dhan15, Pant Sugandh Dhan17, Pant Sugandh Dhan 21, Pant Sugandh Dhan25 and Pant Sugandh Dhan 27.The centre has developed two basmati varieties Pant Basmati 1 and Pant Basmati 2.

1. Pantnagar centre has registered two lines namely, UPRI 95-140 TGMS and UPRI 95-167 TGMS with NBPGR as useful donors for TGMS and UPR 2870-98-125 for new plant type.
2. The centre has also established Pantnagar Rice Germplasm Bank which is owner of approximately 1000 indigenous and exotic collections.
3. Pantnagar centre is nominating 20-25 entries every year for different trials like State Variety Trial, All India Co-ordinated Rice Improvement Trial and INGER nurseries. During 1985 to 2018 the centre has nominated approximately 1350 entries for different trials.
4. Pantnagar centre is also preserving the purity of all the 26 released varieties through maintenance breeding.
5. ***Trials indented & conducted:*** Pantnagar centre is mainly conducting trials under irrigated ecosystem that comprises the trials on early, mid- early and medium maturing rice varieties, basmati varieties and hybrids. Every year, around 14-16 trials are being conducted to represent the Northern plain zone of the country including geographical area of basmati trials. Beside, multilocation evaluation of rice germplasm funded by ICAR was also being conducted which lead to strengthen the germplasm base of the centre. On the other hand, Pantnagar centre has always shown interest to evaluate IRRI-IIRON module 1 & 2 and IRFOAN nurseries to find out promising lines for breeding programme. Based on the yield, resistance/tolerance to biotic stresses,

maturity duration and over all phenotypic acceptability under respective situations, promising lines were identified.

6. ***Entries nominated in trials**:* Pantnagar centre is nominating 20-25 entries of rice every year in AICRP, SVT and INGER trials. Since 1969, more than 2000 entries were nominated for different trials under irrigated ecosystem of plains and hills.

7. ***Breeding material generated:*** Pantnagar centre is known as one of the leading centres for irrigated ecology. Every year, around 75-100 new crosses are being made that lead to generate a lot of segregating materials (F_2-F_6) generations for further evaluation and selection. On an average, 50-70 newly developed advance lines were evaluated and seed multiplied to provide 20-25 nominations every year in AICRP and State Trials.

8. ***Nucleus & breeder seed production:*** The centre has produced sufficient quantity of nucleus seed of different varieties to meet the demand of breeder seeds of the country. All the 26 varieties developed from Pantnagar are being maintained at the centre and nucleus seeds produced to meet the requirement of breeder seeds production in every year. Besides, breeder seeds of other rice varieties are being produced at centre as per DAC, allocation to meet the national requirement.

9. In the last 50 years, the centre has developed package of practices like age of seedling, planting date, plant geometry, nutrient management and weed management for transplanted and direct seeded rice of hills, *tarai* and plain of Uttarakhand and Uttarpradesh. For the first time Pantnagar invented that Zn is the most limiting micro-nutrient element in rice production in *tarai* which can be substituted with foliar spray of 0.5% ZnSO4 and 0.25% Calcium hydroxide.

10. Pantnagar has also investigated that yield decline of rice under rice-wheat cropping is related with soil depletion of nutrients which could be arrested by the application of balanced fertilizer (*i.e.* 120 kg N, 40 kg P_2O_5, 40 kg K_2O, 5 kg $ZnSO_4$ foliar spray + 50 quintal/ha). It has also been invented that integrated approach of nutrient management by green manuring with *Sesbaniarostrata* @ 35-40 t biomass followed by application of 5 t FYM/ha) or *S. aculeate* green manure (35-40 t biomass/ha) with recommended P, K and Zn may increase the yield of rice yield to more than 60 quintals/ha. Use of Azolla as green maunring with or without fertilizer N increased rice yield by about 25%.

11. Numerous basmati and non-basmati culture/varieties including national and local checks of early, mid-early and medium duration have been evaluated at low, optimum and high input nitrogen along with normal P and K.

12. Several new pre- and post-emergence herbicides have been evaluated under transplanted as well as direct seeded aerobic rice conditions and application of Anilophos + Ethoxysulfuron (0.375 + 0.015 kg ai/ha at 10 DAT or Bispyribac Sodium @ 0.025 kg a.i./ha) was economical and effective.

13. Rice physiology has addressed the major issues concerning physiological mechanisms such as grain filling process in hybrids and varieties, zinc nutrition, biofortification of iron and zinc, aerobic rice, photothermic indexing, nitrogen use efficiency, boron's effect on spikelet fertility, radiation use efficiency, heat tolerance , silicon solubilizers and multiple abiotic stress tolerance.

14. It has been investigated that terminal stage of phenology decides the adversity on yield

and yield components which are generated earlier during the course of ontogeny.

15. Studies have also revealed that Zinc accumulation is dependent on growth stages of rice.Rice cultivar Krishna Hamsa accumulates more zinc in tillering stage while rice cultivar Rasi shows higher zinc accumulation during flowering stage. In rice grain, iron and zinc contents are 40-60mg/kg and 20-30 mg/kg respectively.

16. Our studies have indicated that alternate wetting and drying can save five irrigations with slightly reduced yield and yield components.

17. Rice Pathology has contributed substantially over the years in terms of conducting trials and planting screening nurseries, viz. GSN, NSN, NSN-Hill, NHSN, DSN, IRBBN, false smut screening by way of which thousands of entries have been screened under open infection conditions and scores of promising disease resistant lines have been identified and reported.

18. Disease control/management modules for various important diseases such as bacterial leaf blight, sheath blight, grain discoloration, false smut and several other pandemic diseases, like blast and sheath rot have been standardized, by incorporating newer molecules, biocontrol agents and plant products.

19. Characterization of bacterial leaf blight pathogen (Xoo) revealed 21 haplotypes from among a collection of 193 strains.

20. Thousands of donors, elite breeding lines, cultures and varieties developed by national and international institutions have been evaluated for resistance against major insect pests in PHS, MRST, NSN I and II, IRSBN and IRBPHN in field and glass house condition and data generated is being used for the breeding of resistant varieties.

21. Several experiments have been conducted to access the losses due to stem borers and leaf folder under natural and simulated conditions and on the basis of extensive data collected for so many years ETL have been determined for borers and defoliators.

22. Development of resistance against insecticide is a major problem in the management of insect pests due to which continuous evaluation of new active ingredients and formulations of insecticides is of vital importance in controlling the pests outbreaks. In the last so many years, most of the new molecules have been evaluated against major insect pests of Uttarakhand and they are being recommended to the farmers. The centre has also studied the compatibility of various insecticides and fungicides.

23. Pantnagar centre is monitoring the insect pests and their natural enemies and conducting pest survey in rice growing area of Uttarakhand and concerned farmers are advised immediately to take up the control measures. The centre has also studied the effect of rice cultivation system and date of planting on the incidence of insect pests in *tarai* of Uttarakhand. All such information are regularly communicated to the farmers to adjust the time of planting, select the varieties, forewarn the pest damage and initiate the chemical control interventions.

24. Pantnagar centre has evaluated several IPM modules some of which are being used for the management of key insect pests of this region under organic and non-organic conditions.

25. The centre has also conducted front line demonstrations in more than one hundred hectare basmati rice to demonstrate the management of yellow stem borer of rice by pheromone based male annihilation technique.

Varieties released

Since 1969, 26 high yielding varieties of rice were released including 5 aromatic, 2 hybrids and 2 basmati varieties.

S. No.	Variety	Year of Release	Duration (Days)	Yield (q/ha)	Area of adaptation
1	IR 24	1972	120-125	55-60	Plains of Uttarakhand Valleys upto 500 m & Uttar Pradesh
2	Prasad	1978	120-125	50-55	Plains of Uttarakhand & Uttar Pradesh
3	Govind	1982 SVRC,	95-100	30-35	Uttar Pradesh, Uttarakhand, Madhya .Pradesh.
		1989 CVRC			Pondichery, Gujrat, Maharashtra
4	Pant Dhan 4	1983	126-130	55-60	Plains of Uttarakhand & Uttar Pradesh
5	Manhar	1985	115-120	50-55	Plains of Uttarakhand & Uttar Pradesh
6	Pant Dhan 6	1986	113-120	40-45	Transplanted Conditions of Uttarakhand Hills
7	Pant Dhan 10	1992	121-130	58-60	Transplanted Condition in Plains of Western Uttar Pradesh & Uttarakhand
8	Pant Dhan 11	1992	118-125	42-48	Transplanted Conditions of Uttarakhand hills
9	Pant Dhan 12	1994	113-122	55-58	Plains of Uttarakhand & Uttar Pradesh
10	Pant Sankar Dhan 1	1997	115-120	55-60	Plains of Uttarakhand &Uttar Pradesh
11	Pant Dhan 16	2001 CVRC	105-110	50-55	Bihar, West Bengal & Haryana
12	Pant Sugandh Dhan 15	2003	135-140	35-40	Plains of Uttarakhand & Uttar Pradesh

13	Pant Sankar Dhan 3	2004	130-135	65-70	Plains of Uttarakhand & Uttar Pradesh
14	Pant Sugandh Dhan 17	2004	135-140	35-40	Traditional basmati growing areas of Northern India
15	Pant Dhan 18	2007 CVRC	125-130	55-60	Andhra Pradesh, Kerala, Karnataka, West Bangal Tamil Nadu, Bihar, Chhattisgarh
16	Pant Dhan 19	2007 CVRC	120-125	55-60	Punjab, Haryana, Gujarat & Maharashtra
17	Pant Sugandh Dhan 21	135-140	2010	35-40	Plains of Uttarakhand & Uttar Pradesh
18	Pant Dhan 23	120-125	2015	47-50	Plains of Uttarakhand & Uttar Pradesh
19	Pant Dhan 24	130-135 CVRC	2014	55-60	States of Bihar & Orissa
20	Pant Sugandh Dhan 25	130-135	2015	36-40	Plains of Uttarakhand & Uttar Pradesh
21	Pant Dhan 26	115-118	2015	47-50	Plains of Uttarakhand& Uttar Pradesh
22	Pant Sugandh Dhan 27	120-125	2015	43-45	Plains of Uttarakhand & Uttar Pradesh
23	Pant Basmati 1	130-135CVRC	2016	45-48	Basmati growing area of Delhi, Uttar Pradesh & Uttarakhand
24	Pant Basmati 2	125-130CVRC	2016	48-50	Basmati growing area of Punjab, Haryana, Uttarakhand, & Uttar Pradesh.
25	Pant Dhan 22	120-125	2018	45-50	Plains of Uttarakhand, & Uttar Pradesh
26	Pant Dhan 28	128-130	2018	56-60	Plains of Uttarakhand & Uttar Pradesh

2. Research Publications:

Rongbai, Li, Qin Xueyi; Wei, Sumei; Pandey, M.P., Pathak, P.K. Huang Fenguan, Li Qing and Luo Shanyu. 2001. Inheritance of resistance to brown plant hopper in an *Oryza rufipogon* (Griff) derivative line in rice. Current Science. 80(11):1421-1423.

Virmani, S.S., Pandey, M.P., Singh, I.S. and Xu, Wei Jun. 2001. Classical and molecular concepts of heterosis. Presented in : Diamond Jubilee Symp. Organized by Ind. Soc. of Genet. Plant Breeding, Nov 6-9, 2001. New Delhi, India.

Pandey, V., Agrawal, V.K. and M.P.Pandey. 2000. Location and transmission of fungi in discoloured seeds of hybrid rice. Ind. Phytopathology 53(1) : 45-49.

Rongbai, Li and M.P. Pandey. 2000. Complexity of inheritance of thermosensitive genetic male sterility trait in rice, *Oryza sativa* L. Oral presentation in the 4th Intern. Rice Genetics Symposium. The International Rice Research Institute, Los Banos, Laguna, Philippines, 22-27 Oct, 2000.

Saxena, N. and M.P. Pandey, 1999. Exploitation of tropical japonica germplasm in heterosis breeding. Rice Biotech. Quarterly 40 : 21.

Dwivedi, D.K., Pandey, M.P., Pandey, S.K. and Li Rongbai. 1999. Combining ability over environments in rice involving indica and tropical japonica lines. Oryza 36 (2) : 101-107.

Rongbai, Li and M.P. Pandey. 1999. Genetic studies on in-vitro un-pollinated ovary culture derived populations of rice, *Oryza sativa L. Oryza* 36(1):28-31.

Pandey, M.P., Sharma, S.K., Dwivedi, D.K. and S.K. Pandey. 1999. *Oryza perennis* - a new source of resistance to bacterial blight in rice. Oryza 36 : 1999.

Dwivedi, D.K., Pandey, M.P., Pandey, S.K. and Rongbai L. 1999. Screening and genetics of wide compatibility in rice. Ind. J. Genet. 59(3): 281-94.

Pandey, M.P., Sharma, S.K., Singh, H. and Pandey, S.K. 1999. Sources of resistance to Pantnagar isolates of bacterial blight pathogen of rice. Oryza 36 : (2) : 188-189.

Pandey, M.P., Li, Rongbai. Mani S.C; Malik, J.P.S. and S. Singh. 1998. The identification and nature of new thrmosenstive genetic male sterile source, UPRI 95-140 TGMS in rice. Cereal Research Communication 26 (3) : 265 - 269.

Rongbai, Li and Pandey, M.P. 1998. Genetics and breeding behaviour of thermosensitive genetic male sterility in rice. J. Genet. & Breed. 53: 11-17.

Rongbai, Li; Pandey, M.P., Pandey, S.K. and D.K. Dwivedi, 1998. Agromorphological characterisation of ovary culture derived plants of rice. (*Oryza sativa L.).* Euphytica 106: 197-203.

Rongbai, Li. Pandey, M.P., Pandey, S.K., Dwivedi, D.K. and Ashima 1998. Exploiting the in-vitro ovary culture technique to breed rice hybrids. International Rice Research Notes, 23, (1) : 14.

Rongbai, Li, Pandey, M.P., Garg, G.K. Pandey S.K., Dwivedi D.K. and Ashima. 1998. Development of a technique for in-vitro unpollinated ovary culture in rice, *Oryza sativa* L. Euphytica 104 (3) : 159-166.

Dwivedi, D.K., Pandey, M.P., Pandey, S.K. and Li Rongbai 1998. Heterosis in inter and intrasubspecific crosses over three–environments in rice. Euphytica 99:155 -165.

Dwivedi, D.K., Pandey, M.P., Pandey, S. K. and Li, Rongbai. 1998. Heterosis over environments in crosses involving indica and tropical japonica rice cultivars. IRRN 23 (2) : 11.

Rongbai, Li and M.P. Pandey. 1998. Genetics of the thermosensitve genetic male sterility traits in rice. IRRN 23 (2) 1-5.

Mishra, Mannu and M.P. Pandey. 1998. Hererosis breeding in rice for irrigated conditions. Oryza 35 (1) : 8-14.

Rongbai, Li and Pandey, M.P., 1998. Development of a thermo sensitive genetic male sterile line for hybrid breeding through ovary culture in rice (*Oryza sativa* L.) J. Plant Biochemistry and Biotehnology 7: 103-106.

Pandey, M.P. and D.V. Seshu. 1998. Selection criterion for the basic seed production of rice cultivars. Oryza 35 (3) : 202-207.

Dwivedi, D. K., M.P. Pandey, S.K. Pandey and Li Rongbai. 1996. Studies on screening and genetics of wide compatibility in rice. (*Oryza sativa* L.) II International Crop Science Congress, Nov 17-24, 1996. New Delhi, India. Abst. No. P 1-003 : 4.

Rongbai, Li, M.P. Pandey, G.K. Garg and S.K. Pandey, 1996. Development of in-vitro un-pollinated ovary culture technique in rice)Abst.) II International Crop Science congress, Nov 17-24, 1996, New Delhi, Abst. No. 1-036 : 20.

Rongbai, Li and M.P. Pandey. 1996. Genetic studies on thermosensitive genetic male sterility trait in rice. Abst. Proceed of Third International Symposium on Hybrid rice held on Nov 14-16, 1996, Hyderabad, India, pp. 101-102.

Dwivedi, D.K., M.P. Pandey, S.K. Pandey and Li Rongbai. 1996. Heterosis over environments in crosses involving Indica and tropical japonica cultivars of rice. Abst. Proc. III International Symposium on Hybrid Rice, 14-16 Nov, 1996, Hyderabad, India, pp 36-37.

Rongbai, Li M.P. Pandey, S.K. Pandey, D.K. Dwivedi and Ashima. 1996. Exploitation of in-vitro ovary culture technique in breeding rice hybrids, (Abst), Proc. III International Symposium on Hybrid Rice, Nov 14-16. 1996, Hyderabad, India, pp. 111-112.

.Kumar, Rajendra and Mani, S.C. 1997. Chemical mutagenesis in Manhar variety of rice (*Oryza sativa* L.). Indian J. Genet., 57 : 120-126.

Sharma, J.P. and Mani, S.C**.** 1997. Analysis of biochemical parametersat boot stage in rice (*Oryza sativa* L.). Indian J. Genet., 57 (3) : 238-242.

Sharma, R.K. and Mani, S.C. 1997. Combining ability for cooking quality characters in basmati rice (*Oryza sativa* L). Crop Improv. 24 (1) : 93-96.

Verma, S.K. and Mani, S.C. 1997. Yield component analysis and its implications for early generation selection in rice. Oryza 34 : 102-106.

Mani, S.C., Verma, S.K. and Sharma, R.K. 1997. Genetic variability and character association for panicle traits in basmati rice. Agric. Sci. Digest. 17 (3) : 155-157.

Panwar, R.K., and Mani, S.C. and Pandey, M.P. 1998. Genetics of resistance to bacterial blight disease in rice. *Oryza,* 35 (1) : 61-64.

Verma, S.K. and Mani, S.C**.** 1998. Genetic components of variation in segregating generation of rice (*Oryza sativa* L.). Agric. Sci. Digest., 18(1) : 62-64.

Kumar, M.D. and Mani, S.C**.** 1998. Genetic analysis of some polygenic traits in rice. Oryza, 35 (2) : 106-108.

Sharma, R.K. and Mani, S.C. 1998. Combining ability analysis for physical grain quality in basmati rice. Oryza, 35(3) : 211-214.

Verma, S.K. and Mani, S.C**.** 1998. Character association and path coefficient analysis in F_3 generation of rice (*Oryza sativa* L). Crop research, 16(3) : 349-351.

Verma, S.K. and Mani, S.C. 1998. yield factor analysis in early segregating generations of rice. Oryza, 35(4) : 319-321.

Verma, S.K. and Mani, S.C. 1999. Correlation response to selection for yield components in segregating populations of rice (*Oryza sativa* L.). Indian J. Genet., 59(2) : 159-162.

Stobdan, T., Khanna, V.K., Singh, N.K. and Mani, S.C. 1999. DNA fingerprinting of Indian aromatic rice genotypes by RAPD. Rice Biotechnology Quarterly, 40 : 18-19. (Nov. 1999).

Verma, S.K. and Mani, S.C**.** 2000. Selection methods and response to selection in rice. Indian J. Genet., 60(4) : 477-482.

Shankhadhar, D., Shankhadhar, S.C., Mani, S.C. and Pant, R.C. 2000. In vitro selection for salt tolerance in rice. Biologia Plantarum 43(3) : 477-480.

Kumar, J., Agrawal, R.L., Mani, S.C**.**, Singh, Y., Pandey, I.D. and Kumar, A. 2001. Variability in seed storage proteins of sunflower. Physiol. Mol. Biol. Plants. 7 : 89-91.

Shankhadhar, S.C., Shankhadhar, Deepti, Sharma, H.C., Mani, S.C. and Pant, R.C. 2000.

Genotypic variation of Zinc-65 uptake and distribution in rice (*Oryza sativa* L.) J. Plant Biol. 27 : 253-257.

Shankhadhar, D., Shankhadhar, S.C., Pant, R.C., and Mani, S.C. 2001. Regeneration of rice (*Oryza sativa* L.) through somatic embryos. Phytomorphology 51(1) : 79-81.

Verma, S.K. and Mani, S.C. 2000. Effect of spacing and selection methods on genetic parameters in segregating populations of rice. Oryza 37(2) : 7-10.

Singh, H. 1999. Rice production constriants and strategy in U.P. paper presented in the national workshop/seminar on Rice Production Management held at CRRI, Cuttack on Aug. 23-24, 1999.

Sohane, R.K. Rahel, A., Singh, M. and Singh, H. 1999. Heterosis in chemical composition and digestibility of hybrid rice straw (abstract). International Conference on Sustainable Animal Production Health and Environment SSARM, CCS, HAU, Hissar, India, Nov 24-27, 1999.

Sohane, R.K. Rahel, A., Singh, M. and Singh, H. 1999. Effect of genetic variation on chemical composition and in Sacco digestibility in rice straw (abstract). International Conference on Sustainable Animal Production Health and Environment SSARM, CCS, HAU, Hissar, India, Nov 24-27, 1999.

Khan, M.A., Malik, S., and Singh, S. 2011. Identification of maintainers and restorers for development of potential rice (*Oryza sativa L.*) hybrids for *Tarai. VEGETOS (Accepted)*

Kumar, Aditya, Singh Surendra and Singh, S.P. 2011. Genetic analysis of yield and quality attributes in basmati rice (*Oryza sativa* L.). Book of abstracts. National seminar on "Contemporary Approaches to Crop Improvement", April 22-23, 2011 held at University of Agricultural Sciences, Banglore. Indian Society of Genetics & Plant Breeding, New Delhi-110012. Page: 217.

Kumar, Aditya, Singh, S. and Singh, S. P. 2012. Heterosis for yield and yield components in basmati rice. *Asian Journal of Agricultural Researc,* 6 (1) : 21-29.

Kumar, Aditya., Singh, Surendra and Singh, S.P. 2012. Heterosis for yield and yield components in basmati rice. *Asian Journal of Agricultural Research. 6 (1) : 21-29.*

Mondal, B., Singh, S.P. and Joshi, D.C.2011. DUS characterization of rice (*Oryza sativa* L.) varieties using morphological descriptors. Book of abstracts. National seminar on "Contemporary Approaches to Crop Improvement", April 22-23, 2011 held at University of Agricultural Sciences, Banglore. Indian Society of Genetics & Plant Breeding, New Delhi-110012. Page: 124.

Nautiyal, M.K., Mani, S.C., Singh, S., and Singh, S.P. 2011. Pant CMS-2A-new cytoplasmic genetic male sterile line. *Pantnagar Journal of Research* 9, 2, 311-314.

Pandey, I.D., and Singh, S. 2010. Designing strategies for basmati rice in changing climate. *National symposium on sustainable rice production system under changed climate,* 27-29 Nov. 2010, CRRI, Cuttack.

Pandey, I.D., and Singh, S. 2010. Farmer's participatory hybrid rice seed production. A case study *In National symposium on sustainable rice production system under changed climate.* 27-29, Nov. 2010, CRRI, Cuttack.

Singh, B.; Singh, S.P. and Kumar, J. 2011. Assessment of genetic diversity in aromatic rices (*Oryza sativa L.*) using morphological, physiochemical and SSR markers.*Indian J. Genet*. and plant breeding, 71 (3): 214-222.

Singh, S.P. 2009. Production potential of hybrid rice in the valleys of Uttarakhand. *In*: Agriculture in Uttarakhand hills, (ed.) by B.S. Bisht and D.P. Singh, Vol. 8: pp. 31-37.

Pandey, I.D. and Singh, S. 2010. Designing strategies for basmati rice in changing climate. *National symposium on sustainable rice production system under changed climate,* 27-29 Nov. CRRI, Cuttack.

Pandey, I.D. and Singh, S. 2010. Farmer's participatory hybrid rice seed production. A case study *In National symposium on sustainable rice production system under changed climate.* 27-29, Nov. CRRI, Cuttack.

Khan, M.A., Malik, S. and Singh, S. 2011. Identification of maintainers and restorers for development of potential rice (*Oryza Sativa L.*) hybrids for Tarai, WEGETOS Accepted

Pandey, I.D.; Mani, S.C. and Chandra, S. 1994. Evaluation and selection of rice (*Oryza sativa* L.) genotypes under direct sown rainfed conditions. *Agril. Biol. Res*. 10, 1&2, 22-26.

Pandey, I.D. and Mani, S.C. 1995. Quality indices of some upland rice genotypes. *Crop Improvement*. 22, 2, 267-270.

Kumar, Sudhir and Indra Deo. 2015. Studies on Genetic Variebility, Heritability and Genetic Advance in advanced lines of Kalanamak Aromatic Rice (*Oryza sativa* L.) *Ecology, Environment and Conservation* (Accepted/ InPress)

Rather,S.A. and Indra Deo, 2017. Relative Efficiency of Different Emasculation Methods in Rice (*Oryza sativa* L.) *Environment & Ecology* 35 (3B): 2205-2208.

Rather,S.A &. Indra Deo, 2016. Standard seed box screening for brown plant hopper resistance and agro-morphological evaluation of advanced breeding lines of rice (Oryza sativa L.) *Eco. Env. & Cons*.22 pp. (S17-S21) Copyright@ EM International ISSN 0971-765X.

Harsaha & Indra Deo. 2017. Assessment of Genetic Variability and Inter-Character Association Studies in Rice Genotypes (Oryza sativa L.) *Int.J.Curr. Microbiol. App. Sci* 6 (9): 2041-2046.

Panda, G.S., Pandey, I.D., Rather, S.A., Moharana, C. and Sharma, R.S.2018. Evaluation of rice grain quality of newly developed advanced rice (*Oryza sativa* L.) CMS lines and their respective maintainer lines. *Environment and Ecology* 35 (4), 2727-2732.

Preeti Massey, Singh,S. and I.D. Pandey 2016. DUS characterization of aromatic rice germplasm, *International Journal of Basic and Applied Agricultural Research*, Vol. 14 (2), 158-165.

Bansidhar & Indra Deo Pandey 2018. Phenotypic evaluation of leaf blast resistance in Kalanamak Rice (*Oryza sativa* L.) International Journal of Agriculture, Environment and ecology. Pp 959-962, special issue 2018.

System of Rice Intensification for Ecological, Food and Agricultural Security of the Nation by Indra Deo Pandey and H.S. Chawla. 2018. 130-145. In System of Rice Intensification by K.N. Bhatt and Pradeep Bhargava. Studium Press (India)) Pvt.Ltd

Khan, M.A., Malik, S., and Singh, S. 2011. Identification of maintainers and restorers for development of potential rice (*Oryza Sativa L.*) hybrids for *Tarai. VEGETOS (Accepted)*

Kumar, Aditya, Singh Surendra and Singh, S.P. 2011. Genetic analysis of yield and quality attributes in basmati rice (*Oryza sativa* L.). Book of abstracts. In National seminar on Contemporary Approaches to Crop Improvement, April 22-23, 2011 held at University of Agricultural Sciences, Banglore. Indian Society of Genetics & Plant Breeding, New Delhi-110012. p217.

Kumar, Aditya, Singh, S. and Singh, S. P. 2012. Hrterosis for yield and yield componentns in basmati rice. *Asian Journal of Agricultural Research,*6(1):21-29.

Mondal, B., Singh, S.P. and Joshi, D.C.2011. DUS characterization of rice (*Oryza sativa* L.) varieties using morphological descriptors.In National seminar on Contemporary Approaches to Crop Improvement, April 22-

23, 2011 held at University of Agricultural Sciences, Banglore. Indian Society of Genetics & Plant Breeding, New Delhi-110012. p.124.

Nautiyal, M.K., Mani, S.C., Singh, S., and Singh, S.P. 2011. Pant CMS-2A-new cytoplasmic genetic male sterile line. *Pantnagar Journal of Research,* 9(2):311-314.

Pandey, I.D., and Singh, S. 2010. Designing strategies for basmati rice in changing climate. In National symposium on Sustainable rice production system under changed climate*,* held at CRRI, Cuttack, 27-29 Nov. 2010.

Pandey, I.D., and Singh, S. 2010. Farmer's participatory hybrid rice seed production: A case study National symposium on Sustainable rice production system under changed climate*,* held at CRRI, Cuttack, 27-29 Nov. 2010.

Pandey, S., Pandey, I.D., Roy, C., and Singh, S. Nov. 2011. Improved technology for commercial hybrid rice seed production. *Indian Farmers Digest,*44:24-29.

Singh, B.; Singh, S.P. and Kumar, J. 2011. Assessment of genetic diversity in aromatic rices (*Oryza sativa L.*) using morphological, physiochemical and SSR markers.*Indian J. Genet. & Pl.Breeding*,71(3):214-222.

Singh, S.P. 2009. Production potential of hybrid rice in the valleys of Uttarakhand. *In*: Agriculture in Uttarakhand Hills, (eds.) B.S. Bisht and D.P. Singh, Vol. 8: pp.31-37.

Bisarya D, Singh D.K., Nautiyal M.K., Shankhdhar Deepti and Shankhdhar S.C.(2018) Effect of Organic inorganic and integrated Nutrient Sources on the yield and its attributes of two Basmati Rice varieties viz Type -3 and Taraori Grown in Tarai Regions of Uttarakhand India. Interantional Journal of Current Microbiology and Applied Sciences.Vol.7(10).Pp 3711-3726

Kandpal G, Nautiyal M.K., Kumar A. (2017) Role of Silicon Solabilizer for water stress tolerance in different genotypes of Rice (*oryza sativa L.*) Green Farming International of applied agricultural & horticultural sciences. Vol. 8(4). Pp 844-848.

Joshi.C. Hem, Joshi Babita, Guru S.K., Shankdhar S.C., Kumar A., Mahapatra B.S., Nautiyal M.K. and Singh Prashant (2017) Consequences of Integrated use of Organic and Inorganic Fertilizers on Yield and Yield Element of Rice. International Journal of Agricultural Science and Research (IJASR). Vol.7. pp 163-166.

Kumar Pardeep, Nautiyal M.K., Kumar Pankaj and Kumar Kuldeep (2016). Morphological and Molecular based characterization of different thermo- sensitive genetic male sterile (TGMS) lines in rice (*oryza sativa L.*) Vegetos- An International Journal of Plant Research 29:4. Pp 1-10.

Kumar Pardeep, Nautiyal M.K., and Kumar Kuldeep. (2016) Inter – relationship and path analysis of different traits of two line hybrid in rice (*Oryza sativa L.*). Journal of Applied and Natural Science 8 (4): 2016-2020 (2016).

Kumar Pardeep, Nautiyal M.K., and Kumar Pankaj. (2016) Gene action and component of genetic variance analysis in the thermo sensitive genetic male sterile (TGMS) line in rice (*Oryza sativa L.*). Journal of Applied and Natural Science 8 (4): 2011-2015 (2016).

Kumar Pardeep, Nautiyal M.K(2016) Two-Line Hybrid Production System and their Application in Rice. International Journal of Agriculture Sciences, ISSN:- 0975-3710 & E-ISSN: 0975-9107, volume 8, Issue 61, pp-3502-3504

Pandey G., Nautiyal M.K., and Chauhan P.(2016).Potential restorers and maintainers and SSR specific genetic diversity assessment among parental lines of rice. Green farming vol.7(6):1277-1282.

Pandey Geeta, Nautiyal M.K., Chauhan Priyamvada and Pant D.P. (2016) Evaluation of genotypes for fertility restoring and maintaining behavior for development of potential rice (*oryza sativa* L.) hybrids in Tarai region. Research on crops 17: 433-438.

Kumar Pardeep, and Nautiyal M.K., Singh N.K (2015) Analysis of combining ability& standard heterosis with different crosses of TGMS lines in rice (*Oryza sativa*) green Farming journal,vol.6(6):1223-1228.

Nautiyal M.K., Mani S.C., Singh Surender & Singh Samar Pal (2011) New Cytoplasmic Genetic Male Sterile Line in Rice (*oryza sativa* L.) Journal Pantnagar Journal of Research. 9 (2). Pp 311-314.

H. Chaudhary , D.C. Baskheti, D.R. Meena and Madhubala 2018 Assement of genetic variability parameters for yield and quqlity traits in aromatic rice (Oryza sativa L.) International Jouranl of chemical studies 6 (6):904-907

3. Thesis Research:

1. Birendra K. Pal. 2003. Refinement of certain agro-techniques for production of hybrid seed in rice, Oryza sativa L. Seed Science Technology submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

2. Amit Srivastava. 2003. Morphological and molecular diversity and their relationship with heterosis for yield in Rice submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

3. Shailesh K. Shukla. 2002. Studies on genetic divergence, combining ability and heterosis involving elite thermosensitive genetic make sterile lines of rice, (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

4. Shalini Gupta 2001. Genetic studies for wide compatibility trait in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

   Li. Rongbai 2000. Genetic analysis and molecular tagging of gene (s) for thermosensitive genic male sterility in rice submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

5. Naveen Saxena 1999. Genetic analysis and exploitation of modern and modified plant types over environments in breeding rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

7. Devendra K. Dwivedi (1996). Studies on wide compatibility genes and combining ability and heterosis involving Indica and tropical japonica rices, (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

8. Sudesh K. Sharma 1995. Genetics of resistance to bacterial blight (*Xanthomonas oryzae* pv. oryzae) and yield and other characters in rice, (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

9. Yograj Sharma 1993. Genetics of fertility restoration and combining ability and heterosis studies in rice, (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

10. Jaipal S. Malik 1986. Genetic analysis of resistance to white-backed plant hopper (*Sogatella furcifera*) in rice submitted for Ph.D. to GBPUAT under supervision of Dr. M.P. Pandey

11. Mayank Rai, 2000. Genetic analysis and heterosis for yield and its components in elite maintainer lines with Eui gene in rice submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

12. Ashima 1998. Transient expression of different reporter genes in rice transformation submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

13. Li Ronghi 1996. Ovary culture technique and its use breeding rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

14. Manu Mishra 1991. Studies on certain aspects of hybrid breeding in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

15. Dinesh C. Basketi 1987. Genetic analysis and heterosis for certain quantitative characters in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

16. Sunil K. Gupta 1986. Genetic divergence and yield component analysis for grain quality in rice (*Oryza Sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. M.P. Pandey

17. Akwan Ahmed , June 1980, Studies on variability, correlation and path coefficient analysis in segregating Population of rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

18. Indra Deo, 1993, Evaluation and selection of rice (*Oryza sativa* L.) Genotypes under Direct sown rainfed conditions submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

19. Neeraj Kaishreshtha , 1987, Triple test cross analysis for yield and yield components inn Rice (*Oryza sativa L.*) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

20. Vasudha Pandey , 1991, variation for the agronomic and quality characters in aromatic rice (*Oryza sativa* L.) Germplasam submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C Mani.

21. Prashant Bagade, 1991, Mutation Induced variability in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

22. Mandala Dharmendra Kumar, 1993, Genetic analysis of some quantitative traits in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.c. Mani

23. H.S. Jeena, 1987, Evaluation of rice (*Oryza sativa* L.) (Genotypes under Direct sown upland condition, submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

24. Surendra Prasad mishra, 1985, Variability heterosis and correlation studies in intervarietal crosser of rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

25. Jagdamba Prasad singh, 1984, Stability analysis for yield and quality characters in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

26. Arvind Chauhan , 1982,Effect of chemical mutagen and protectant in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

27. Manoj Kumar Tripathi, 1988, In heritance of quantitative characters in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

28. Shailendra Kumar, 1985, Studies on variability heterosis and correlation coefficient in intarvarietal crosses of rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C.Mni

29. Harsh Kumar Dikshit , 1987, Genetic analysis of yield an yield components in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. S.C. Mani

30. Shiv Datt, 2002, Genetic diversity and Bio chemical characterization of parental lines in hybrid of Basmati rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

31. Rajendra Kumar, 1991 Studies on chemical mutagenesis in Manhar variety of rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

32. Ravindra Kumar Panwar, 1990, Genetics of resistance to Bacterial Blight (*Xanthomenas compertris* pv. *Oryza*) and some quantitative characters in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mni

33. Rahul Dev Pandey , 2005, Morphological and molecular diversity in aromatic rice (*Oryza sativa* L.) varieties submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

34. Amaresh Chandel , 2005, Cytogenetic and molecular characterization of sterility mutants induced in IR 64 cultivar of rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

35. Vineet Kumar, 2003, Studies on morphology floral trails synchronisation of flowering and hybrid seed production in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

36. Jag Paul Sharma, 1988, studies on hybrid rice by utilising mala sterility fertility restoration system and its Bio chemical characterization submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

37. Manender Singh, 2007, Genetic Analysis and inheritance of bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) resistance and quantitative characters in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C. Mani

38. Ram Kumar Sharma, 1995, Efficacy of two factor mating Designs for estimation of combing ability in Basmati rice (Oryza sativa L.) submitted for Ph.D. to GBPUA&T under Supervision of Dr. S.C.Mani

39. Naveen Saxena ,1996, Studies on the thermosensitive Genetic mala sterile lines for fertility transformation and their agronomic traits in rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. J.P.S. Malik

40. Anita Rawat , 2002, Genetic analysis of grain yield and quality traits in advanced generation of rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. J.P.S. Malik

41. Ram Lakhan Verma, 2010, Refinement of Agrotechniques for Hybrid Seed Production and Assessment of their Purity in Rice. (*Oryza sativa*.L) submitted for Ph.D. to GBPUAT under supervision of Dr. Surendra Singh

42. Mohd. Arif Khan, 2011, Line x Tester Analysis in Two and Three Line Rice (*Oryza sativa*.L) Hybrids and Identification of Maintainers and Restorers for Development of Potential Hybrids. submitted for Ph.D. to GBPUAT under supervision of Dr. Surendra Singh

43. Naseer Mohammad, 2012, Genetic Assessment of Yield and Quality Traits in Basmati Rice (*Oryza sativa*.L) submitted for Ph.D. to GBPUAT under supervision of Dr. Surendra Singh

44. Aditya Kumar , 2009, Genetics Analysis of Yield and Quality Attributes in Basmati Rice (*Oryza sativa*.L) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Surendra Singh

45. Sunita Shah, 2010, Studies on Genetic Divergence and Variability in Rice (*Oryza sativa*.L) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Surendra Singh

46. Shilpi Malik, 2011, Studies on Heterosis and Combining Ability of Two and Three Line Hybrids in Rice. (*Oryza sativa*.L) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Surendra Singh

47. Deepankar Pandey, 2012, Evaluation and selection of rice (*Oryza sativa* L.) Genotypes Under aerobic condition submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Surendra Singh

48. Mahabala, 2014, Characterization of

kalanamak aromatic rice (*Oryza sativa* L.) landrace submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Indra Deo Pandey.

49. Gouri Shankar Panda, 2016, Characterization of CMS, maintainer and kalanamak lines of rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Indra Deo Pandey.

50. Banshidhar, 2018, Genetic evaluation for leaf blast resistance and DUS characterisation of advanced recombinant lines of kalanamak rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Indra Deo Pandey.

51. Shiva Nand Pandey, 2012 Selection indices for aromatic rice (*Oryza sativa* L.) submitted for M.Sc. Ag to GBPUAT under supervision of Dr. Indra Deo Pandey.

52. Chandan Roy,2013, Genetic study on CMS lines, fertility restoration, heterosis and combining ability in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. Indra Deo Pandey.

53. Visalakshi Chandra C, 2014, Studies on blast resistance, molecular diversity and stability analysis of rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. Indra Deo Pandey.

54. Harsha,2017, Genetic studies on agro-morphology, quality traits, blast resistance and QTL detection for iron and zinc contents in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. Indra Deo Pandey.

55. Sudhir Kumar, 2015, Studies on yield and yield parameters, quality characters, molecular markers and blast resistance in kalanamak lines of rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. Indra Deo Pandey.

56. Shoukat Ahmad Rather, 2017 Genetic analysis of brown planthopper resistance and assessment of relative efficiency of different emasculation methods in rice (*Oryza sativa* L.) submitted for Ph.D. to GBPUAT under supervision of Dr. Indra Deo Pandey.

57. Pooja Payal 2011. Evalution and identification of rice genotypes for combining ability and heterosis in rice (*Oryza sativa* L.) Submitted for M.Sc Ag to GBPUA&T under Supervision of Dr.M.K.Nautiyal

58. Meenakshi Joshi 2014 .Evaluation of elite germplasm for identification of potential restores and maintenance in rice (*Oryza sativa* L.) Submitted for M.Sc Ag to GBPUA&T under Supervision of Dr.M.K.Nautiyal

59. Pradeep Kumar 2016 .Morphological and molecular evaluation of Thermo sensitive genetic male sterile(TGMS) line and their heterotic combination in Rice (*oryza sativa* L.) Submitted for Ph.D. to GBPUA&T under Supervision of Dr.M.K.Nautiyal

60. Geeta Panday 2017. Identification of potential restorers and maintainers from elite line,their molecular diversity assessment and effect of GA_3 on seed yield and vigour in Rice (*oryza sativa* L.) Submitted for Ph.D. to GBPUA&T under Supervision of Dr.M.K.Nautiyal

61. Himanshu Chaudhry, 2018, Estimation of combining ability and heterosis for grain yield and components in rice (*Oryza sativa L.*) Submitted for M.Sc.Ag.. to GBPUA&T under Supervision of Dr.D.C.Baskheti

4. Future Thrusts:

1. Development of multiple resistant, high yielding varieties for irrigated ecosystem.
2. Development of early maturing drought and cold tolerant varieties for the hills.
3. Identification of sources of resistance against insect pests and diseases.
4. Development of varieties resistant/tolerant

to various biotic and abiotic constraints.

5. Integration of molecular markers in crop improvement to overcome bottle neck problems of conventional breeding.
6. DUS database of released varieties and advance lines.
7. Germplasm exploration, collection, characterization, utilization and storages, to make molecular database for important accessions.
8. Development of high yielding, medium duration, semi dwarf, BLB resistant varieties of aromatic and basmati rice through molecular breeding.
9. Development of new CMS lines, restorers and combinations, refinement of seed production of hybrid rice.
10. Development of hybrid rice suitable for hill agriculture.
11. Development of aerobic rice varieties suitable for direct sowing in rainfed and irrigated ecosystem.
12. Development of high yielding, well adopted varieties suitable for resilient climate.
13. Development of low input and high nutrient use efficient varieties for doubling the farmers' income.

B. Rice Agronomy:

1. Significant Achievements:

1. During past >50 years, large number of new culture and varieties (HYVs, Basmati, Hybrids and Direct Seeded aerobic rice, fortified and NIL rice cultures) were agronomically evaluated under low, optimum and high input management conditions and several varieties of rice have been released and adopted by farmers for cultivation. Recently, four varieties of coarse grain rice (Pant Dhan 22, Pant Dhan 23, Pant Dhan 26 & Pant Dhan 28) and two each varieties of basmati (Pant Basmati 1 & Pant Basmati 2) and scented rice (Pant Sugandh Dhan 25 & Pant Sugandh Dhan 27) from Pantnagar have been released by CVRC and SVRC.
2. Aerobic rice production technology has been developed and recommended for the farmers of nearby areas. Direct seeded crop yielded comparable to transplanted rice provided with good weed management practices adopted. Brown manuring with *Sesbania* along with integrated approach including chemical, organic and bio-fertilizers of nutrient management has positive response in smothering the weeds and increasing the yield of direct seeded rice.
3. Comparing different methods of establishments, productivity of wet direct seeded rice was at par to transplanted one. High yielding and hybrid varieties performed better under direct seeded rice. Recommended dose of NPK (120:60:40) along with FYM 5 t/ha is better that 150% of NPK in all the method of crop establishment.
4. For water economization, saturated conditions or AWD of water management practices proved to be better than continuous flooding.
5. Under resource conservation technology, direct seeded rice did not respond to conservation tillage either of zero tillage or minimum tillage however, wheat did well.
6. Under site specific nutrient management (SSNM) practices, nutrient expert based SSNM found superior in terms of productivity, nutrient use efficiency and profitability over, blanket recommendation, soil test crop response (STCR) and farmers fertilizer practice.
7. In long-term fertility experiment, yield

declined of rice under rice-wheat cropping was found related with soil depletion of nutrients especially miro-nutrients and could be arrested by the application of balanced fertilization i.e. 120-150 kg N, 40 kg P_2O_5, 40 kg K_2O, 0.5 $ZnSO_4$ + 5 t FYM ha^{-1} in rice and 150 kg N, 40 kg P_2O_5, 40 kg K_2O to wheat crop.

8. Different new herbicides like Almix, Clincher, Whipsuper, Pyrizosulfuron, Bispiryback Sodium, Rinskore etc have been evaluated and recommended for rice cultivation which is being adopted by farmers of the state.

Nitrogen and nitrogen use efficiency

Nitrogen is the most limiting nutrient element in rice production. Numerous new cultures (HYVs, Basmati, Hybrids and Direct Seeded aerobic rice) were agronomically evaluated under low and high input management especially nitrogen. Several cultures from Pantnagar i.e. Pant Dhan 16, Pant Dhan 18, Pant Dhan 19, Pant Sugandha Dhan 15, Pant Sugandha Dhan 17, Pant Sugandha Dhan 21, Pant Basmati 1, Pant Sanker Dhan 1 and Pant Sanker Dhan 3 and from other AICRP centres were released for cultivation.

Graded level of nitrogen increased grain yield significantly up to 120 kg N per ha in **Basmati cultures**, 120 kg N per ha in **early and medium early cultures** of HYVs and **180 kg N per ha in medium HYVs and hybrid cultures** .Agronomic efficiency (kg grain/kg N) decreases with the increase dosage of nitrogen.

Time of nitrogen application played a decisive role in realizing high yields from dwarf varieties. Early application (at planting and during tillering) promoted tillering and thus increased the number of panicles whereas later applications around or a week before panicle initiation increased the spikelet (grain) number. Therefore, nitrogen should be applied in three equal splits, one- third as basal, one- third at tillering (20-25 DAT) and remaining one- third at the time of panicle initiations (40-45 DAT).

In rice, the recovery of applied fertilizer N seldom exceeds 30-40 % and it is the lowest among cereals. Increasing the efficiency of fertilizer, N is a matter of great concern in modern days when prices of fertilizers (and not of rice produce) are increasing by leaps and bounds. Efforts were, therefore, intensified in this direction. Placement of N fertilizer in reduced soil layer has long been considered the best method to decrease N losers and thereby, increase fertilizer use efficiency in low land rice. The development of urea supergranule (USG) in recent times offers an opportunity of placing N in rice soil easily and economically.

Nutrient management in rice-wheat system:

On the basis of long –term fertility research experiences, yield declined of rice under rice-wheat cropping was found related with soil depletion of nutrients and could be arrested by the application of balanced integrated fertilization i.e. 120-150 kg N, 40 kg P_2O_5, 40 kg K_2O, 0.5 $ZnSO_4$ + 5 t FYM ha^{-1}

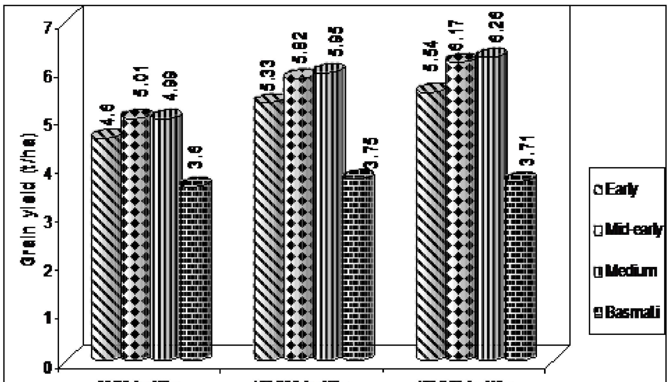


Fig. 1. Average(average of 5-6 years) grain yield (t/ha) of rice culturars at varying N levels

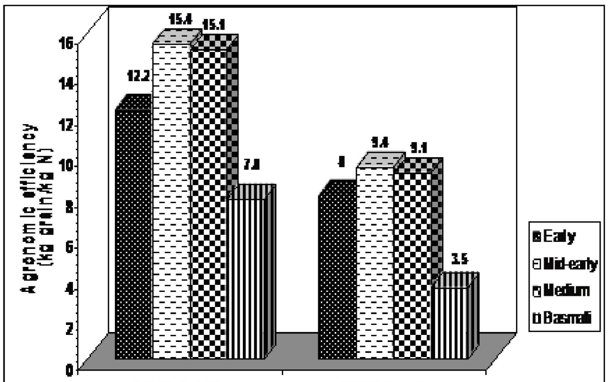
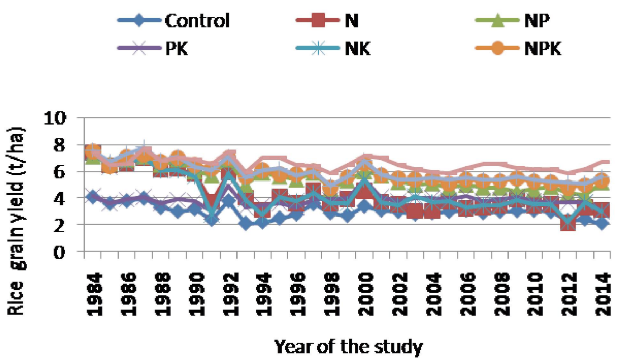


Fig. 2. Responseof rice varieties/genotypes to fertilizer N (base level of 60/50 kg N/ha)

in rice and 150 kg N, 40 kg P_2O_5, 40 kg K_2O to wheat crop. In the absence of P and K, the decline in response was more pronounce. Decline in rice yields are more where only N is being applied even as compared to control. Phosphorus turned out to be second most limiting nutrient element after nitrogen under rice-wheat cropping system.

Bio-fertilizer

Due to energy crises in modern times, efforts are being made to exploit the renewable source of energy for supplying N to rice through bio-fertilizers. The bio fertilizer viz., Blue-green algae (BGA), Azolla and other free living micro-organism in aerobic soil conditions have been recommended. Seedling dip in 1-2% solution of Azospirillum increased the rice yield but slightly (0.2 t/ha) both with and without chemical N. Application of Cyanobacteria (earlier known as blue green algae) @ 10 kg per ha with 25 kg urea N gave yield comparable to 50 kg urea N.



Zinc deficiency (*Khaira* disease) and its control

Zn is the most limiting micro-nutrient element in rice production in *tarai*. Zn deficiency in rice is locally known as *Khaira* diseased and Pantnagar is known for reporting in 1965 this disorder and its solution in lowland rice first time in the world. In fact, the rice research at Pantnagar got initiated with the *Khaira* problem in 1963 and that it could be corrected by spraying with 0.5% $ZnSO_4$ mixed with 0.25% Calcium hydroxide at 10 & 20 DAS in nursery and 10 DAT in main field.

Water requirement:

Water requirement of transplanted rice (from planting to maturity) in *tarai* is around 1000 mm, 40-60 % of which is met through irrigation (10 to 20 irrigations of 50 mm each). In addition to this, 200 mm water is required for land preparation. Raising seedlings in wet nurseries requires about 700 mm water (200 mm for land preparation and 500 mm for meeting the water need of seedlings).

Maintaining of 0-5 cm flooding adequately meets the water requirement of rice and also suppresses the growth of weeds. Flooding more than 5 cm water was uneconomical. Maintaining saturated conditions or AWD (2-3 days disappearance of pounded water) is better in terms of water economy and productivity of transplanted rice.

Direct seeded aerobic rice

Package and practices have been developed for direct seeded aerobic rice. Direct seeded crop yielded comparable to transplanted crop besides provided with good weed control. First fortnight of June sown direct seeded aerobic with 35 kg seed/ha and 150 kg N/ha with four equal split application ($^1/_4$ **each at basal, tillering, PI and flowering stages**). Two sprays of Fe and Zn @ 0.5% at 10 and 20 DAS is also recommended for aerobic rice. To control the weeds, pre-emergence application of Pendimathaline @1.0 kg a.i./ha followed by post emergence application of herbicides. Brown manuring with *Sesbania* has shown positive response in smothering the weeds and increasing the yield of direct seeded rice. High yielding and hybrid varieties performed better under direct seeded condition.

System of Rice Intensification (SRI)

Production technology of SRI has also been developed at Pantnagar. Improved varieties / hybrids with high tillering capacity, young seedling of 10 days old, 25 x 25 cm spacing and three mechanical weeding at 10 days intervals starts 14 days after transplanting with AWD of water management are responsible for higher productivity.

2. Research Publications:

D.K. Singh, P.C. Pandey, Gangadhar Nanda and Shilpi Gupta (2018) Long-term effect of inorganic

Brown manuring in DSR

fertilizer and farmyard manure application on productivity, sustainability and profitability of rice-wheat system in Millisols. *Archives of Agronomy and Soil Science* (DOI:1080/03650340.2018.1491032).

Bora R, P.C. Pandey D.K. Singh, S.K. Yadav and Chilwal, A. 2018. Assessment of soil fertility status under long-term balance fertilizer application on rice (Oryza sativa L.) . *International Journal of Chemical Studies* 6(5): 1696-1699.

Bora R., Chilwal, A., Pandey, P.C. and Bhaskar, R. 2018. Nutrient content and uptake in rice (Oryza sativa L.) under the influence of long-term balance fertilizer application. *International Journal of Current Microbiology and Applied Sciences.*7(9): 2011-2017.

Ashvin Kumar, D.K. Singh, P.C. Pandey and Gangadhar Nanda 2018. Growth, yield, economics and nitrogen use efficiency of transplanted rice (Oryza sativa L.) as influenced by different nitrogen management practices through neem coated urea. *International Journal of Chemical Studies* 6(3): 1388-1395.

Qureshi, A., D.K.Singh and S. Dwivedi. 2018. Nano-fertilizers: a Novel Way for Enhancing Nutrient Use Efficiency and Crop Productivity. *International Journal of Current Microbiology and Applied Sciences.*7(2): 3325-3335.

Qureshi, A., D.K.Singh and P. C. Pandey, P.K. Chandrakar and P.S. Makram. 2018. Demand driven nutrient management for enhanced nutrient use efficiency and productivity in rice and wheat under rice-wheat cropping system. *Green Farming.* 9(2): 296-300.

Qureshi, A., D.K.Singh and Amrendra Kumar. 2018. Climate Smart Management (CSNM) for Enhanced Use Efficiency and Productivity in Rice and Wheat under Rice- Wheat Cropping System. *International J. Current Microbiology & Applied Sciences* 7: 4166-4173.

D.K. Singh, P.C. Pandey, S.D. Thapaliyal and Gangadhar Nanda (2017) Yield and economics of rice as influenced by establishment methods and varieties under Mollisols of Pantnagar . *International J. Current Microbiology & Applied Sciences* 6(6): 297-306.

Seema, D. K. Singh and Pandey, P. C. (2017) Effect of Conservation Tillage on Wheat Yield and Soil Physical Properties in Rice-Wheat Cropping System. *Indian Journal of Ecology* 44(5):560-563.

Ajit Yadav, D.K.Singh, Sumit Chaudhary, Amit Kumar and Anil Nath. 2017. Growth and yield attributes of direct seeded aerobic rice *(Oryza sativa* L.) as influenced by seed rate and varieties. *International J. Current Microbiology & Applied Sciences* 6(2): 868-873.

Qureshi, A. D.K.Singh and P. C. Pandey 2017. Site-specific nutrient management for enhancing nutrient-Use efficiency in rice and wheat. *New Agriculturalist* 28(1): 289-296.

Qureshi, A., D.K.Singh and Amrendra Kumar. 2016. Soil Fertility Management: A Mirror to Sustainable Agriculture. *Progressive Research-An International Journal* 11(II): 1267-1272.

Qureshi, A, D.K.Singh, P.C.Pandey, V.P.Singh and K.P. Raverkar. 2016. Site specific nutrient management approaches for enhancing productivity and profitability in rice and wheat under rice-wheat cropping syatem. *International Journal of Agriculture Sciences*. 8(54): 2838-2842.

Qureshi, A., D.K.Singh and P. C. Pandey 2016. Site-specific nutrient management for enhancing nutrient-Use efficiency in rice and wheat. *Academia Journal of Agricultural Research* 4(8): 518-524.

D.K. Singh, P.C. Pandey, Shilpi Gupta and Dipti Bisarya (2015). Enhancing rice and wheat productivity through rhizosphere active high yielding technology microbial product. *The Bioscan* 10(3): 1269-1274.

D.K. Singh, P.C. Pandey, Priyanker, A. Qureshi and Shilpi Gupta (2015). Nitrogen management strategies for direct seeded aerobic rice grown in mollisols of Uttarakhand. *International J. of Applied and Pure Science and Agriculture* 01(7): 130-138.

D.K. Singh, P.C. Pandey, Naiyar Ali and Shilpi Gupta (2015). Stand establishment techniques of rice in conjunction with nutrient sources for soil health and productivity of rice-wheat under system. *Indian Journal of Agronomy* 60(1): 31-37.

Seema; Pandey, P. C.; Singh, D. K.; Thoithoi, M. (2015) Effect of weed management practices along with brown manuring on yield of aerobic rice and weed control efficiency at different nitrogen levels. *Environment and Ecology* Vol. 33 No. 2A pp. 819-822

Seema, D. K. Singh and P. C., Pandey (2015). Productivity and Economics of aerobic rice and soil bulk density under conservation tillage. *American International Journal of Research in Formal, Applied & Natural Sciences* 9(1):36-40.

S.K. Yadav, D.K. Singh and Manisha Rani (2014). Studies on nutrient uptake as influenced by different weed management practices and brown manuring at varying nitrogen levels in direct seeded aerobic rice. *International Journal of Basic and Applied Agricultural Research* 12(2):178-183.

D. K. Singh, P. C., Pandey and Shilpi Gupta (2014). Long addition of organics to sustain the system productivity of Rice (*Oryza sativa* L.) – Wheat (*Triticum aestivum* L.) under Indo-Gangatic Plain of India. *American International Journal of Research in Formal, Applied & Natural Sciences* 7(1):14-18.

S. K Yadav, D. K. Singh and M. Rani (2014). Interaction effect of weed management practices, brown manuring and nitrogen levels on yield of direct seeded rice and growth of weeds. *Green Farming* 5(1): 46-50.

D. K. Singh, M. Rani, P. Tripathi, S. K Yadav and A. K. Dubey (2013). Weed management practices in organic basmati rice based cropping systems under *Tarai* conditions of Uttarakhand. *Green Farming* 4(6):711-715

T. Paul, P.S. Bisht, P.C. Pandey, D.K. Singh and S. Roy (2013). Rice productivity and soil fertility as influenced nutrient management in rice-wheat cropping system. *Indian Journal of Agronomy* 58(4): 495-499.

Singh Sobaran, Pandey P.C., and Mishra Peeyush, 2011. Soil test based integrated fertilizer recommendation for targeted yield of wheat grown in Mollisols of Tarai region in Uttarakhand. Pantnagar Journal of Research Vol.9(1): 75-77.

Shyam Radhey, Mishra O.P, Sharma B.B. and Pandey P.C. 2010. Evaluation of Post Emergence Herbicides for Weed Control in Lentil (*Lens Culinaris* Medic.). Annals Agricultural Research New Series Vol. 31 (1&2): 63-64.

D.K. Singh, P.C. Pandey, P.S. Bisht and Shilpi Gupta (2010). Genotypic response of early, mid-early, medium duration and basmati rice (*Oryza sativa* L.) to low, optimum and high nitrogen dosage (Accepted in *Indian Journal of Agricultural Sciences* F.No.1-7D-138/ 2010-EEU)

Singh V.Pratap, Singh G., Pandey P.C, Singh R.K, Dyani V.C., Singh S.P., Sharma G., Kumar A., and Singh M.K., 2007. Efficacy of different herbicides alone and with follow up application of 2,4-D with regard to weeds and yield of zero tillage direct seeded rice. Pantnagar Journal of Research 5(1):1-5.

Bisht, P.S.; Puniya, R.; Pandey, P.C.; and, Singh D.K. 2007. Grain yield and yield components of rice as influenced by different crop establishment methods. ***Int. Rice Res. Notes,*** *32* (2): 33-34.

Puniya, Ramphool; Pandey, P.C.; and Bisht, P.S. 2007. Herbicide molecules for the management of weeds and their effects on grain yield of rice. *Oryza,* 44 (4) 340-342.

Puniya, Ramphool; Pandey, P.C.; and Bisht, P.S. and Singh, D. K. 2007. Nutrient Uptake by crop and weeds as Influenced by Trisulfuron, Trisulfuron + Pretilachlor and bensulfuron-methyl in transplanted rice (*Oryaza sativa* L.). *Indian J. of Weed Sci*. 39 (3&4): 120- 122.

Puniya, Ramphool; Pandey, P.C.; Bisht, P.S. and Singh, D.K. 2007. Nutrient uptake by crop and weeds as influenced by Trisulfuron, Trisulfuron + Pretilachlor and Bensulfuron-methyl in transplanted rice (*Oryza sativa L.)*. Indian J. of Weed Sci. 39 (3 & 4): 239-240

Bisht, P.S.; Puniya, Rmphool.; Pandey, P.C.; and, Singh D.K. 2007. Grain yield and yield components of rice as influenced by different crop establishment methods. *Int. Rice Res. Notes, 32* (2): 33-34.

Puniya, Ramphool; Pandey, P.C.; and Bisht, P.S. 2007. Herbicide molecules for the management of weeds and their effects on grain yield of rice. *Oryza*. 44 (4): 340-342.

Puniya, Ramphool; Pandey, P.C.; and Bisht, P.S. 2007.Performance of trisulfuron, trisulfuron + pretilachlor and bensulfuron – metyl in transplanted rice (*Oryaza sativa* L.). Indian J. of Weed Sci. 39 (182): 120- 122.

Bisht, P.S. 2006, Great opportunities for producing Basmati/scented rice organically in Uttaranchal. *Rice India*. 16 (10):13-14

Sachan, H.K; Bisht, P.S; Singh, V.K.and Singh, V.P. 2005. Effect of inorganic fertilizers and their integration with FYM on the productivity of rice in rice-wheat cropping system. J. Farming

System Research and Development. 11(2): 256-257. Singh, R. K.: John, Anurag, and Pandey, P.C. 2005. Weed management studies of wheat in rice- wheat cropping system. J. Indian Agric & Weed Sci. Vol. 3-4; 87-90.

Chaturvedi, S; Lal, P; Singh, A.P; Bhardwaj, A.K, and Bisht, P.S. 2004. Growth and yield performance of promising varieties of hybrid rice in mollisols of Uttaranchal *Tarai. J. Rural and Agric. Res.* 4 (42): 34-37.

Rathore, R.S.; Lal, P.; Pandey, P.C. and Bisht, P.S. 2004. Effect of longterm application of fertilizers and farmyard manure on soil fertility and rice productivity under rice- wheat system. *Oryza*. 41 (1& 2): 45-47.

Bisht, P.S., Pandey, P.C., Tiwari, S.N. and Mani, S.C. 2002. Great potential for the cultivation of Basmati rice in Uttaranchal. *Rice India.* June, 2002, 7-9.

3. Thesis Research:

1. Nanda, Gangadhar (2018). Studies on organic, inorganic and integrated modes of production under basmati rice based cropping in mollisols. Ph. D., G.B.P.U.A. & T., Pantnagar.

2. Bora reshama (2018). Effect of Long-term balance fertilizer application on rice productivity and soil health. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

3. Ashvin K. Meena (2017). Standardization of rate and scheduling of N application through neem coated urea in transplanted rice. M. Sc. Ag. Thesis, G.B.P.U.A. & T., Pantnagar.

4. Qureshi, A. (2016). Site specific nutrient management approach for enhancing their efficiencies and productivity of rice and wheat under rice-wheat cropping system. Ph. D. (Agronomy), G.B.P.U.A. & T., Pantnagar.

5. Thapaliyal, Shankar Dutt (2016). Performance of Rice Varieties under different establishment methods in Mollisols. M. Sc. Ag. Thesis, G.B.P.U.A. & T., Pantnagar.

6. Pant A. (2016). Evaluation of nutrient management practices and establishment methods for rice (*Oriza sativa* L.) cultivation.

7. Yadav, Ajit (2015). Optimizing the seed rate of hybrid and HYV of rice under direct seeded aerobic conditions. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

8. Priyanker (2015). Studies on nitrogen management in direct seeded aerobic rice M. Sc. Ag. Thesis, G.B.P.U.A. & T., Pantnagar.

9. Seema (2014). Tillage and residue management practices for augmenting soil and crop productivity of rice-wheat cropping system. Ph. D., G.B.P.U.A. & T., Pantnagar.

10. Madan, Saurabh (2013). Performance of Rice Varieties on Different Dates of Sowing under Aerobic Conditions. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

11. Bhimwal J. (2013). Performance of new herbicide molecules for weed control in transplanted rice.

12. Roy, Shyamashree (2012). Effect of age of seedling and weed management practices on productivity of rice under SRI. Ph. D., G.B.P.U.A. & T., Pantnagar.

13. Nath, C.P. (2012). Evaluation of new herbicides in direct seeded rice under puddle conditions. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

14. Garg, Ashish (2012). Performance of Rice (*Oryza sativa* L.) Genotypes under Optimum and Sub-optimum Level of Nitrogen. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

15. Nair Ali (2012). Effect of establishment methods and integrated nutrient management in rice (*Oryza sativa* L) Ph. D., G.B.P.U.A. & T., Pantnagar.

16. Seema (2011). Agronomic weed management practices with varying levels of N under direct seeded aerobic rice M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

17. Shah, Monobina (2011). Bio-efficacy evaluation of different herbicides for direct seeded puddled rice. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

18. Puniya, Ram Phool (2010). Long-term effect of nutroient management on crop productivity and soil quality under rice-wheat. Ph. D., G.B.P.U.A. & T., Pantnagar.

19. Yadav, Santosh Kumar (2010). Agro-techniques of Weed Management in Aerobic Rice at Varying Levels of Nitrogen. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

20. Yadav, Parth Brat (2009). Performance of Basmati rice genotypes under optimum and sub-optimum level of nitrogen. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

21. Suman, K.K. (2008). Performance of Pusa Rice Hybrid-10 with variable sources of manuring . M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

22. Indrajeet (2008). Effect of organic and inorganic source of nutrients on rice productivity and soil fertility in rice-wheat system. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

23. Thakur, Dheeraj Kumar (2008). Evaluation of Crop Establishment Methods for enhancing Rice Productivity. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

24. Puniya, Ram Phool (2006). Evaluation of new herbicide for weed control in transplanted rice. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

25. Pathak, V.K. (2004). Effect of NPK and Zn fertilizer with and without FYM on rice productivity and soil fertility in rivce-wheat cropping system. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

26. Joshi, A.C. (2004). Effect of integrated nutrient management on rice productivity and soil fertility in rice-wheat cropping system. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

27. Dubey, P.K. (2003). Control of weeds in transplanted rice by use of herbicides and management practice. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

28. Sachan, H.K. (2003). Effect of inorganic fertilizer and their integration with FYM after 18 years of rice-wheat cropping. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

29. Nishant, T.S. (2002). Effect of promising herbicide mixtures on weed and grain yield direct seeded (puddled) rice. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

30. Kumar, Jitendra (2001). Integrated use of organic and inorganic nutrient sources in transplanted rice. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

31. Kumar, Vineet (2000). Effect of inorganic fertilizer and FYM on productivity of rice and soil fertility. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

32. Rathore, R.S. (1998). Rice crop productivity and soil fertility as enfluenced by long-term use of fertilizer and FYM in rice-wheat cropping. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

33. Gupta, Chandra (1998). Integrated use organic manure with urea fertilizer in low land rice Ph. D.., G.B.P.U.A. & T., Pantnagar.

34. Gurrani Jitendra (1997). Performance of semi-dwarf aromatic varieties under different dates of transplanting. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

35. Sachan D. K. (1994). Integrated use of fertilizer N with *Sesbania* green manuring and FYM in rice based cropping system Ph. D., G.B.P.U.A. & T., Pantnagar.

36. Bhatt Ramesh Chand (1993). Lon-term effect

of fertilizers and FYM on rice productivity and soil fertility in rice based cropping system. M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

37. Garg Sanjay Kumar (1991). Crop productivity and soil fertility changes in long-term rice based cropping pattern (rice-wheat). M. Sc. Ag., G.B.P.U.A. & T., Pantnagar.

4. Future Thrusts:

1. Development and refinements of site specific package and practices for new of high yielding, hybrids and basmati varieties.
2. Development and promotion technology for direct seeded/aerobic rice.
3. Development and refinement of resource conservation techniques.
4. Management of micronutrients in deficient soils and more emphasis on INM.
5. Development of location specific crop production technology taking into consideration the farmers socio-economic and other factors of regional/ local importance.
6. Management of non-monitory inputs to minimize cost of cultivation.
7. Promotion and encouragement of SRI method of rice cultivation.
8. Promotion and development of organic farming module especially for basmati/ scented rice cultivation

5. Award / Honours:

1. Dr. D. K. Singh received Best Paper Presentation Award *In* 20th International Conference on Soil Science and Plant Nutrition held Jan. 25-26, 2018 at Paris (France).
2. Dr. D. K. Singh has been conferred Faculty Excellence Award -2017 College of Agriculture, G.B. Pant University of Agriculture & Technology, Pantnagar
3. AICRP Rice Agronomy has awarded ICAR-Best Center Award - 2016 by ICAR-IIRR, Hyderabad
4. AICRP Rice has been awarded Golden Jublee Award in 2015 by DRR, Hyderabad
5. Dr. D. K. Singh received Best Poster presentation award In National Symposium on ECM Technology for Safe, Secure and Profitable Food Production, 10-11 Oct., 2014 at GBPUA&T, Pantnagar.

C. Rice Physiology:

Rice physiology has initiated studies with physiological characters and mechanisms associated with hybrids and inbreds on the issues related to grain filling process, judicial application of nitrogenous fertilizers i.e., Nitrogen Use Efficiency, Zinc nutrition, Influence of silicon solubilizers and various kinds of abiotic stresses such as multiple abiotic stresses, terminal heat tolerance and low light stress tolerance .

Physiology of grain filling process: The grain filling process in rice showed that terminal stage of phenology decides the adversity on yield and yield components which is generated much earlier during the course of ontogeny. DRRH1 recorded the maximum weight of 1.6g/panicle at 20 days after panicle emergence and partitioned photosynthates from shoots to grains at a faster rate as compared to others. This genotype has phenotypic characters for the selection of high yielding rice varieties.

Studies on nutritional genomics (Biofortification)*:* To ensure quality food security to all those dependent on rice as a staple food crop through conventional and genetically modified technological tools. Several genotypes were screened for zinc uptake and its translocation which showed genotypic variations, some genotypes had good extractor of zinc but poor in partitioning. In general- grains of inbreds had more zinc content than hybrids. It was found that average content of Fe and Zn in the rice grain was 40-60 mg/

kg and 20-30mg/kg respectively in Mandyavi and Jaya. These could be a good genetic material for biofortification programme.

Studies on photothermic indexing: Plant phenotyping is a prerequisite to identify suitable donors indeveloping genotypes with wider adaptability. The wide adaptability of rice crop in a wide range of ecosystems such as semi deep, irrigated, upland and rainfed ecosystems. Selection of rice cultures offers strength for developing wider diversity in rice breeding program. By delaying sowings the number of days taken to attain Pi stage was reduced by 6 days while the reproductive and grain filling (ripening) period got increased by one day.

IET19569, IET20623 from early group and IET19972, IET 20524and IET19799 of medium duration group and hybrids recorded better yields than the means obtained under normal sowing conditions. Rice entries IET20924,IET 21113, IET21119, Jaya, Annada, PR113, Lalat and NDR359 are more consistent in their physiological response. Rice cultures IET20945, IET20901, IET 21100, Govind, Tulasi are relatively more sensitive to cumulative nyctoperiods. These rice cultures will be useful genetic material to breeders for the selection of rice genotypes insensitive to photoperiod.

Effect of boron on spikelet fertility: Boron deficiency is a problem in calcareous sodic and excessively permeable soils throughout the country. Application of boron at 0.4ppm significantly increased the grain yield (4-8%). Rice cultures IET 20979, 21007 and 21014 showed positive response to 0.4 ppm boron. A positive response to 0.4 ppm boron application on spikelet fertility was found in IET20979, IET21114 and IET21519.

Radiation use efficiency*:* Radiation use efficiency is the ratio of gross photosynthesis without respiration and photorespiration and root a period of crops complete life time. The above ground mass is generally converted to RUE i.e., the efficiency of capture of radiation that is intercepted by the crop.Radiation Use Efficiency was found to be highest at panicle initiation stage and lowest at flowering stage. IET21478, IET21479 and IET21476 had identified as genotypes with high biomass production and high RUE. These genotypes might be useful for breeders for the selection of high yielding varieties.

Physiological characterization of selected genotypes for multiple abiotic stress tolerance: Large amount of genetic diversity existing in rice provide ample avenue to breed and produce newer varieties which are more efficient in the ever multiple abiotic stresses. Rice cultures NS-1,NS-3,NS-4,AC39416 ,PHY-5 and Phy-6 were superior in coping with the multiple abiotic stresses when compared with other cultures of the experiment. These genotypes might be incorporated in breeding programme for the selection of multiple abiotic stress resistance.

Evaluation of Nitrogen Use Efficient (NUE) promising rice genotypes : Increasing NUE is imperative to future sustainable agriculture, not only for crop growth and yield but also for reducing production cost as well as environmental contamination. Since past four decades nitrogen fertilizer application increases 7 fold and increased application of N fertilizers may not necessarily increased grain yield always. Several rice genotypes had evaluated for NUE and amongst the tested genotypes for NUE PA 6444 were found to possess good responsiveness to N-levels coupled with higher yield closely followed by KRH 2, Ajaya, and BPT 5204. Among the varieties tested for NUE Kasturi, KRH-2 and Vasumati responded better than rest of the cultures, indicating their higher N use efficiency. Varadhan x BPT5204/10, Varadhan x BPT5204/6, Sampada x Jaya/3, Varadhan x MTU1010/2Varadhan and Jaya produced higher grain yield under 50 kg N ha^{-1}. These genotypes can be recommended as Nitrogen use efficient genotypes.

Evaluation of rice genotypes for terminal heat tolerance suitable for future climate : Climate change induced temperature and precipitation changes would affect crop production of countries. An increase in temperature due to climate change resulting in increased mean temperature during critical growth stage will reduce grain yield. It was estimated that rice grain yield may be reduced by 41% by the end of 21^{st}

century. Thus, identifying and developing high temperature tolerant cultivars are essential to meet the demands for food in future climate. The dry matter remobilization under high temperature was higher in rice genotypes IET 21577, IET 21415, IET 21404 Varadhan and PHB-71 IET 26778,IET26763, IET23356, IET23947,IET24705, IET24796, Somali and Gontra Bidhan3 be identified as most tolerant genotypes.

Influence of silicon solubilizers on induced stress tolerance in rice genotypes : Silicon accumulated rice genotypes were found to exhibit tolerance to biotic and abiotic stresses and also maintain nutrient balance. The ability of silicon accumulation depends on roots to take up and accumulates as high as 10% on dry weight basis. The efficiency of silicon solubility and availability can be enhanced by addition of carrier molecules or by application of sodium, potassium silicates silixol. They helped in better growth of rice crop with almost negligible disease and insect infestation.

Foliar application of 0.6% silixol reduced the incidence of blast, stem-borer and reduced impact of drought and thereby improve grain yield of rice more than 8%.

Screening of rice varieties for tolerance to low-light stress : Light is the main energy source for plant photosynthesis and is an environmental signal used to trigger growth and structural differentiation in plants. Low light stress has severely constrained rice yield in north eastern part of the country. Several rice genotypes were screened and amongst them Vivek Dhan 86, Tulasi, IET24192, IET26778, IET26763and Swarandhan identified as relatively moderately tolerant to light stress. These genotypes can be used by Breeders for the selection of rice genotypes tolerant to low light stress.

1. Research Papers:

Reddy, M., Shankhdhar, Deepti, and S.C. Shankhdhar 2007. Physiological characterization of rice genotypes under periodic water stress. *Indian Journal of Plant Physiology***.** 12(2):189-193.

Joshi R.,Mani,S.C., Shukla,Alok and Pant,R.C.2009. Aerobic Rice: Water Use Sustainability. *Oryza* 46:1-5.

Joshi, R., Shukla, Alok, Mani, S.C and Kumar, P 2010. Hypoxia induced non-apoptotic cellular changes during aerenchyma formation in rice (*Oryza sativa* L.) roots. *Physiol. Mol. Biol. Plants*. 16(1): 99-106.

Reddy, M., Shankhdhar, Deepti, S.C. Shankhdhar and SC Mani 2010. Effect of aerobic cultivation on yield, biochemical and physiological characters of selected rice genotypes. *Oryza.* 47 (1)**:** 22-28.

Joshi, R., Shukla, Alok and Sairam, RK 2011. *In vitro* screening of rice genotypes for drought tolerance using polyethylene glycol. *Acta Physiolgia Plantarum* 33(6): 2209-2217.

Pallavi Ghanshyala, Deepti Shankhdhar and S.C. Shankhdhar 2011. Physiological characterization of rice genotypes at different nitrogen levels. *Journal of Indian Botanical Society* 90**:**257-267.

Rao, P. Raghuveer Subhramaniyam ,D., Shialja, B.,Singh,.P., Ravichandran,V., Sudershan, G.V., Rao,Swain, Padmini,, Sharma,S.G., Saha, Somnath, Nadarajan,S., Reddy,P.J.R., Shukla,Alok, Dey,P.C., Patel, D.P., Ravichandran,S. and Voleti,S.R 2012. Influence of Boron on spikelet fertility under varied soil, conditions in rice (*Oryza sativa* L.) genotypes. *Journal of Plant Nutrition* 36:539-550.

Nitin Kumar, Bhupendra Mathpal, Ashish Sharma, Alok Shukla, Deepti Shankhdhar and S.C. Shankhdhar 2015. Physiological evaluation of nitrogen use efficiency and yield attributes in rice (Oryza sativa L.) genotypes under different nitrogen levels *Cereal Research Communications*. 43(1)**:**166-177. *DOI: 10.1556/CRC.2014.0032*

Narendra Kumar, Alok Shukla, S.C. Shankhdhar, and Deepti Shankhdhar 2015. Impact of terminal heat stress on pollen viability and yield attributes in different genotypes of rice (*Oryza* *sativa* L.). *Cereal Research Communications*. 43(4):616-626. *DOI: 10.1556/0806.43.2015.023*

Narendra Kumar, S.C. Shankhdhar and Deepti Shankhdhar 2015. Effect of foliar-applied boron on growth, chlorophyll, amylase, nitrate reductase activities and yield in rice (*Oryza sativa* L.). *Oryza* 52(2):123-130.

Narendra Kumar, S.C. Shankhdhar, Deepti Shankhdhar 2016. Impact of induced high temperature stress on antioxidants membrane stability in different genotypes of rice. *Indian Journal of Plant Physiology*. 21(1):37–43. DOI 10.1007/s40502-015-0194-z

Veena Pandey, Alok Shukla, S.C. Shankhdhar and Deepti Shankhdhar 2016. Effect of delayed sowing on quality and yield attributes of six rice (*Oryza sativa* L.) genotypes. *International Journal of Basic and Applied Agricultural Research* 14(3)**:**325-331.

Rakesh Sil Sarma, Deepti Shankhdhar**,** S.C. Shankhadhar and Pallavi Srivastava 2017. Effect of silicon solubilizers on growth parameters and yield attributes in diffeent rice genotypes. *International Journal of Pure Applied Bioscience***.** 5: 60-67.

Vinai Kumar, Geeta Kandpal, Bhawna Thakur, Dipti Bisarya and Gurdeep Bains 2017. Physiological and biochemical responses of different rice (*Oryza sativa* L.) genotypes under terminal heat stress. *International Journal of Chemical Studies* 5(6): 1422-1427.

Geeta Kandpal, M. K. Nautiyal and Atul kumar 2017. Role of silicon solubilizer for water stress tolerance in different genotypes of rice (*Oryza sativa* L.) *Green Farming* 8 (4):844-848.

Veena Pandey, Sanjay Kumar, S.C. Shankhdhar, and Deepti Shankhdhar 2018. Economic yield prediction in different rice *(Oryza sativa* L.) genotypes by applying Mamdani rule based fuzzy model. *Oryza* 55 (1)**:** 242-247.

2. Thesis Research:

1. Meghanatha Reddy (2005). Physiological and Biochemical characterization of rice (*Oryza sativa* L.) genotypes under periodic water stress. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

2. Pallavi Ghanshyala (2007). Effect of different nitrogen levels on the availability of micronutrients in rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

3. Rohit Joshi (2007). Physiological and molecular evaluation of field grown rice varieties and *Invitro* developed rice somaclones for aerobic situations. PhD Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

4. Smita Sundram (2008). Studies on micronutrients status of rice genotypes (*Oryza sativa*) at different nitrogen levels. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

5. Parminder Singh (2008). Elucidating the potential of different rice (O*ryza sativa* L.) varieties through photothermic indexing. PhD Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

6. Bhupendra Mathpal (2009). Physiological and biochemical characterization of iron efficient rice (*Oryza sativa*. L.) genotypes at different nitrogen level. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

7. Neelam Dhiwan (2009). Elucidating the photothermal benavior of different rice (*Oryza sativa* L.) varieties. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

8. Jyoti (2010). Elucidation of photothermic behaviour of different rice (*Oryza sativa* L.) varieties for yield and nutrient quality. M.Sc Thesis submitted to G.B.P.U.A. &T., under

guidance of Dr S.C. Shankhdhar.

9. Nitin Kumar (2010). Physiological characterization of nitrogen use efficiency in different genotypes of rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

10. Hukum Singh (2010). Physiological studies on nitrogen use efficiency in different genotypes of rice (O*ryza sativa* L.). PhD Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

11. Bhawna Pant (2011). Effect of Boron On Spikelet Fertility and Micronutrient Status in Different Genotypes of Rice (*Oryza sativa*. L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

12. Narendra Kumar (2011). Influence of foliar application of boron at flowering stage in different genotypes of rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Deepti Shankhdhar.

13. Vinai Kumar (2011). Physiological and biochemical basis of terminal heat stress tolerance in rice (*Oryza sativa* L.) genotypes. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Gurdeep Bains.

14. Veena Pandey (2012). Elucidating the response of different rice (O*ryza sativa* L.) varieties under early and late sown conditions. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

15. Geeta Kandpal (2013). Studies on photothermic variation through dates of sowing in different genotypes of rice(*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

16. Manish kumar Goyal (2013). Effect of silicon solubilizers on yield, pest and disease resistance in rice (*Oryza sativa* L.) genotypes. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

17. Anita Bharti (2014). Variation in morpho-physiological characteristics of rice (*Oryza sativa* L.) Under different sowing dates. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Gurdeep Bains.

18. Sukhdev Singh (2014). Influence of silicon solubilizers on induced stress tolerance in rice genotypes (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

19. Jitendra S. Karki (2014). To investigate the differences in the response of heat stress tolerance in elite rice genotypes. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

20. Narendra Kumar (2014). Physiological biochemical and molecular characterization of some rice (*Oryza sativa* L.) genotypes in response to terminal heat stress. PhD Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Deepti Shankhdhar.

21. Pallavi Srivastava (2015). Evaluation of photothermic behaviour of early, normal and late sowing dates in different genotypes of rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

22. Babita Joshi (2015). Influence of silicon solubilizers on yield and stress tolerance in rice genotypes (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C. Shankhdhar.

23. Ritika Yadav (2016). Evaluation of Drought tolerance in Different genotypes of rice (*Oryza sativa* L.) Under laboratory and field condition. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Gurdeep Bains.

24. Rukaiya (2016). Evaluation of physiological and biochemical parameters of rice genotypes (*Oryza sativa* L.)Under high temperature stress. M.Sc Thesis submitted to G.B.P.U.A.

&T., under guidance of Dr Deepti Shankhdhar.

25. Rakesh Sil Sarma (2016). Influence of silicon solubilizer on Physiological attributes pest and disease infestation in rice genotypes (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Deepti Shankhdhar.

26. Maneesh Lingwan (2016). Influence of high temperature stress on morpho-physiological Characteristics in rice genotypes (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Atul Kumar.

27. Sudeshna Das (2016). Physiological evaluation of NUE in rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C.Shankhdhar.

28. Geeta Kandpal (2017). Elucidating the role of silicon solubilizer in grouth dynamic, biotic and moisture stress tolerance in different genotypes of rice (*Oryza sativa* L.). PhD Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Alok Shukla.

29. Tanvi Chandra (2017). Evaluation of Physiological and biochemical parameters of rice (*Oryza sativa* L.)Genotypes under different nitrogen doses. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Deepti Shankhdhar.

30. Sadaf Ansari (2017). Physiological and biochemical parameters for tolerance to high temperature in some rice (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Gurdeep Bains.

31. Pratibha Rawat (2017). Physiological and biochemical characterization or rice genotypes for low light stress tolerance. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Gurdeep Bains.

32. Neeraj Joshi (2017). Influence of silicon solubilizers on physiological and biochemical attributes in rice genotypes (*Oryza sativa* L.). M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C.Shankhdhar.

33. Anuj Sharma (2018). Evaluation of Nitrogen Use Efficient promising rice (*Oryza sativa* L.) genotypes. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr Atul Kumar.

34. Rahul Tewari (2018). Physiological responses of rice (*Oryza sativa* L.) genotypes to low light stress. M.Sc Thesis submitted to G.B.P.U.A. &T., under guidance of Dr S.C.Shankhdhar

3. Future Thrusts:

1. Identification of high temperature tolerant high yielding genotypes
2. Evaluation of phosphorous use efficient genotypes by using different PGPRs
3. Physiological and biochemical characterization of rice genotypes for high value addition with respect to low anti-nutrient and high pro-nutrient compounds.
4. Physiological and molecular characterization of zinc and iron rich rice genotypes.

D. Rice Entomology:

Identification of resistant materials against major insect pests: The centre has evaluated thousands of donors, elite breeding lines, cultures and varieties for resistance against major insect pests such as Stem Borer, Brown Plant Hopper, White Backed Plant Hopper, Leaf Folder, Rice Hispa and Whorl Maggot in Plant Hopper Screening Trial, Multiple Resistance Screening Trial, National Screening Nursery I and II, Stem Borer Screening Trial, International Rice Stem Borer Nursery and International Brown Plant Hopper Nursery in agro-climatic conditions of *tarai* of Uttarakhand which is hot spot for majority of insect pests. Since long we are also evaluating PHS, MRST, NSN, NHSN and NSNH against BPH in the Glass House. The data generated is being used for the breeding of resistant varieties.

Assessment of losses due to insect pests and determination of Economic Injury Level (EIL) and Economic Threshold Level (ETL) *:* Economic Threshold Level of Insect pests is key factor in implementation of Integrated Pest Management (IPM) program. Several experiments have been conducted to access the losses due to stem borers and leaf folder under natural and simulated conditions and on the basis of extensive data collected for so many years, ETL has been determined for borers and defoliators. It has been estimated that each percentage of white ear caused by stem borers may result in 0.50-1.38 percent loss in yield in different varieties.

New Molecules of Insecticides: Development of resistance against insecticide is a major problem in the management of insect pests due to which continuous evaluation of new active ingredients and formulations of insecticides is of vital importance in controlling the pests outbreaks. In the last so many years most of the organochlorin, organophosphate, carbamate, pyrethroids, neonicotinoids, spinosyn, oxadiazine, pyrezole, diamide, neristoxin and growth regulators such as Acephate, Chlorpyrifos, Dichlorvos, Dimethoate, Monocrotophos, Oxydemeton-methyl, Phosphamidon, Phorate, Profenofos, Quinalphos, Triazophos, Benfuracarb, Carbaryl, Carbofuran, Carbosulfan, Fenobucarb, Bifenthrin, Cypermethrin, Fenvalerate, Lambda-cyhalothrin, Etofenprox, Spinosad, Indoxacarb, Ethiprole, Fipronil, Acetamiprid, Clothianidin, Imidacloprid, Thiamethoxam, Chlorantraniliprole, Flubendiamide, Cartap hydrochloride, Buprofezin, Dinotefuran, Flonicamid, Rynaxypyr, DPX-RAB 55 and Thiacloprid have been evaluated against major insect pests of Uttarakhand. On the basis of such evaluations, we are recommending safest and most effective active ingredients to the rice farmers of northern India. Our studies have revealed that use of pyrethroids for the control of insect pests in rice is very harmful as it leads to resurgence of brown pant hopper and white backed plant hopper. Recently these states have faced the severe outbreak of hoppers. However, due to continuous evaluation of new molecules, we have minimized its impact by recommending latest active ingredients.

Compatibility of insecticides and fungicides: Several combinations of insecticides and fungicides such as Acephate + Hexaconazole, Acephate + Tricyclazole, Dinotefuran + Hexaconazole, Dinotefuran + Tricyclazole, Spinetoram + Methoxyfenozide have been found compatible.

Monitoring of insect pests and their natural enemies: Pantnagar centre is monitoring the insect pests and their natural enemies for the past so many years under field condition as well as through light traps. Our long term studies have revealed that yellow stem borer, brown plant hopper, white backed plant hopper are the major pest of rice while Leaf Folder, Rice Hispa and Rice Bug are minor pest in *tarai* and plains of Uttarakhand. pink stem borer and white backed plant hopper are major pest in Almora district. Among natural enemies, *Telenomus* sp., *Tetrasticus* sp. parasitize the egg mass of YSB while several species of spiders feed on hoppers and leaf folder.

Pest oriented survey in Uttarakhand: Pest survey on insect pests and diseases and other production constraints are being conducted regularly from 2009 in all the rice growing areas of Uttarakhand and 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 and Technology for technical advice which is provided regularly.

Effect of rice cultivation system on incidence of insect pests: The centre has also studied the effect of rice cultivation system on the incidence of insect pests in *tarai* of Uttarakhand. Influence of rice cultivation methods and cultivars on the incidence of rice stem borer indicated that damage of rice stem borer was significantly low in direct seeded rice as compared to normal transplanted rice and among the cultivars the infestation was significantly high in hybrid KRH-2 than the high yielding variety HKR-47. Influence of rice cultivation methods and cultivars on the number of brown plant hopper revealed that overall population of BPH was higher in direct seeded rice as compared to transplanted rice, however, comparison of cultivars revealed that overall population of BPH was comparatively higher in hybrid KRH-2 as compared to high yielding variety HKR-47 in both the system of cultivation under field condition. In case of WBPH mean population was higher in transplanted rice as compared to direct seeded rice and more hoppers were seen in KRH-2 as compared to HKR-47. No significant difference was recorded in the total number of grains and weight of grain per hill in different methods or cultivars.

Effect of date of planting on incidence of insect pests: Infestation of stem borer was significantly higher in normal and late planted crop as compared to early planted crop while mean population BPH and WBPH remained more or less similar in different plantings.

Evaluation of IPM modules against key pests of rice: Pantnagar centre has evaluated several IPM modules some of which are being used for the management of key insect pests of this region under organic and non-organic condition.

Front line demonstrations on management of YSB through pheromone traps: Front line demonstrations conducted in basmati rice at large scale in farmer's field revealed that sex pheromone mediated male annihilation technique is highly effective in managing the population of yellow stem borer below economic injury level. In so many trials, no difference in yield has been recorded in pheromone trap installed and insecticide treated plots.

1. Research Publications:

Tiwari, S.N. (2004). Potential of sex pheromone in management of rice yellow stem borer, *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae) at farm level. *Pestology*. 28: 68-74.

Pushpakumari, A.S. & Tiwari, S.N. (2005). Management of yellow stem borer, *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae) in Rice through sex pheromone mediated mass trapping of male. *Pestology*. 29: 11-17.

Bhatt, N., & Tiwari, S. N. (2015). Identification of New Sources of Resistance against Brown Plant Hopper. *J Plant Sci Res*, 2(2): 126.

Hitendra, K., & Tiwari, S. N. (2010). New sources of resistance against rice brown plant hopper, *Nilaparvata lugens* (Stal.). *Indian Journal of Entomology*, 72(3): 228-232.

Rakesh, K., Kalmesh, M., Rakesh, S., & Tiwari, S. N. (2012). Evaluation of PHS-(09) entries to brown plant hopper, *Nilaparvata lugens* (Stal.) under glass house condition. *Environment and Ecology*, 30(3A): 629-631.

Soni, Vijay Kumar and Tiwari, S. N. (2016). Effect of planting dates on the incidence of rice insect pests. *Research in Environment and Life Sciences*. 9(11): 1364-1365.

Soni, Vijay Kumar and Tiwari, S. N. (2016). Effects of cultivation methods and cultivars on the incidence of major insect pest of rice. *International Journal of Plant Protection*. 9(1):21-25.

Soni, Vijay Kumar and Tiwari, S. N. (2016). Growth and development of brown planthopper, *Nilaparvata lugens* (Stal.) on rice genotypes having resistance and moderate resistance. *Progressive Research*. 11(Special -II): 859-863.

Soni, Vijay Kumar and Tiwari, S. N. (2017). Evaluation of resistance source against yellow stem borer Scirpophag incertulas (Walker) in Rice under field conditions. *Environment and Ecology*. 35 (4E): 3733-3737.

Soni, Vijay Kumar and Tiwari, S.N. (2014). Comparative efficacy of some new insecticides against brown planthopper, *Nilaparvata lugens* in rice. *Journal of Insect Science*. 135-138.

Soni, Vijay Kumar and Tiwari, S.N. (2014). Species composition of stem borer in irrigated rice agro ecosystem. *Journal of Environment, Empowerment and Economics*. 1(2):33-35.

Soni, Vijay Kumar; Tiwari, S.N. and Kushwaha, Ranjeet (2014). Glasshouse evaluation of entomopathogenic fungi Met-52EC against brown plant hopper in rice. *Hexapoda (Insect indica)*, 21 (1): 44 -49.

Vijay Kumar Soni and Tiwari, S.N. (2017). Comparative Efficacy of Different Trade Formulations of Buprofezin 25SC against Brown Plant Hopper in Rice. *Int. J. Curr. Microbiol. App. Sci*. 6(9): 124-128. doi: . https://doi.org/10.20546/ijcmas.2017.609.015

Vijay Kumar Soni and Tiwari, S.N. (2017). Glasshouse Evaluation of New Source of Resistance against Brown Plant Hopper *Nilaparvata lugens* (Stal) in rice. *Int. J. Curr. Microbiol. App. Sci*. 6(9): 1187-1192. doi: https://doi.org/10.20546/ijcmas.2017.609.143.

Kumar, H & Maurya, R.P. & Tiwari, S.N. (2012). Study on antibiosis mechanism of resistance in rice against brown plant hopper. *Nilaparvata lugens* (Stal.). *Ann. Plant Prot. Sci*. 20: 98-101.

2. Thesis Research :

1. Samiran Pathak. 2005. Estimation of yield losses in rice and evaluation of some IPM modules agaisnt *Scirpophaga incertulas* (Walker). Ph. D (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

2. Hitendra Kumar. 2008. Identification of new sources of resistance and evaluation of some IPM modules against major insect pests of rice. Ph. D (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

3. Vijay Kumar Soni. 2013. Sudies on host plant resistance and management practices against major insect pests of rice. Ph. D (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

4. Neha Bhatt. 2016. Identification of new sources of resistance and toxicity of insecticides against *Nilaparvata lugens* (Stal.). Ph. D (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

5. Him Prasad Pathak. 2002. Management of major insect pests of rice through insecticides and sex pheromone. MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

6. Aluthge Shyama Pushpakumari. 2004. Succession of insect pests and natural enemies of rice and management of yellow stem borer. MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

7. Jones Philip Andrew B. 2004. Assessment of crop losses due to rice insect pests and management of yellow stem borer through pheromone traps. MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

8. Rakesh Kumar. 2010. Monitoring of insect pests of rice and identification of sources of resistance against Brown Plant Hopper. MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

9. Anil Kumar Bairwa. 2012. Monitoring of insect pests of rice and management of yellow stem borer, *Scirpophaga incertulas* (Walker) by auto-confusion technique. MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

10. Chanda Mishra 2017. Screening and host plant resistance of some rice germplasm against

brown plant hopper . MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

11. Ankit Uniyal. 2018. Studies on new sources of resistance and pesticide compatibility against insect pests of rice (*Oryza sativa* L.). MSc Ag. (Entomology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. S.N. Tiwari.

3. Future Thrusts:

1. Monitoring and management of insecticide resistance in major insect pests of rice.
2. Evaluation and introduction of reduced risk pesticides in Uttarakhand.
3. Development of forecasting models for major insect pests and diseases of rice.
4. Development of IPM modules for different agro-ecosystem of Uttarakhand.

E. Rice Pathology:

Host Plant Resistance: Pantnagar has contributed significantly over the years by evaluating thousands of donors, elite breeding lines, entries and varieties under field conditions for resistance against major like; sheath blight, bacterial leaf blight (BLB), false smut etc. and promising disease resistant materials have been identified. Each year, more than 1000 entries under different nurseries viz; Germplasm Screening Nursery (GSN), National Screening Nurseries (NSN-I, NSN-II & NSN-Hill), National Hybrid Screening Nursery (NHSN), Donor Screening Nursery (DSN), International Rice Bacterial Blight Nursery (IRBBN), false smut screening, etc. were screened and sources of resistance identified are being used for the breeding of resistance varieties.

Disease Management Trials:

Evaluation of new fungicide molecules*:* Continuous use of fungicides for long period of time may pose threat of development of resistance in pathogens. Thus, products may become less effective - or even useless for controlling resistant pathogens. Identification of new molecules that are effective against target pathogen and rotating them with other available fungicides can be one of the methods to manage the fungicide resistance. Since, Pantnagar has been a hot spot of bacterial leaf blight, sheath blight, grain discoloration and false smut diseases. Over the years, several new fungicides such as Trifloxystorbin + Tebuconazole, Kresoxim methyl, Copper hydroxide, Hexaconazole, Tricyclazole, Propiconazole, Azoxystrobin, Pyroclostrobin, Thifluzamide, Fluopyram, Trifloxystrobin, tricyclazole alone and in combinations were evaluated against major diseases of rice in the region. On the same basis we are recommending the most effective, safest and latest molecules for the management of these dreaded diseases in the region.

Biological control of plant diseases: Over the years, Pantnagar has evaluated several fungal and bacterial formulations of bioagents and their methods of applications against major disease of rice in the region. When bioagents were applied in the combination of seed + soil + root dip + foliar sprays, maximum reduction in sheath blight severity and incidence was observed.

Effect of fertilizers on disease incidence*:* As long as sufficent 18 essential minerals are available, plants grow and reproduce in a healthful way. When not enough of one of the essential elements is supplied, a deficiency occurs and plants present symptoms. Mineral nutrient symptoms are considered abiotic disorders. There are however cases where excess or deficiency of elements can be predisposing to disease caused by pathogens. Some mineral elements do have a role in the development of disease caused by some pathogens. The centre has also studied the effect of nitrogen levels on the incidence of sheath rot of rice. It was found that the disease incidence increased with increase in the nitrogen level from 120 to 180 Kg/ha.

Monitoring of field virulence against Xanthomonas oryzae pv. oryzae*:* Bacterial leaf blight caused (BLB) by *Xanthomonas oryzae* pv. *oryzae (Xoo)* is one of the most serious constraints of rice in the region. In the past, severe BLB outbreaks causing total crop failure have been experienced. It was, therefore, necessary to monitor the field virulence or pathogenic variability of *Xoo* to develop effective breeding strategy for BLB resistance. Over the years studies showed that the existing population of *Xoo* in the region was highly virulent and genetically diverse.

Most of the single major resistance genes used in rice breeding program at IRRI were defeated by *Xoo* strains, at the same time effectiveness of Xa21 to all the pathotypes was encouraging. The potential of Xa21 alone or in combination with xa13 and xa5 could be exploited for pyramiding into well adapted rice cultivars for the effective management of the pathogen in this region.

Evaluation of Integrated Disease Management module against location specific diseases of rice: Pantnagar centre has evaluated several IDM modules which are being used by the farmers for the management of major location specific disease like; sheath blight and BLB, under organic and non-organic condition.

Survey and surveillance of rice diseases: Pantnagar centre is conducting extensive periodical survey for the past so many years in rice growing areas of the Uttarakhand. Our long term studies have revealed that sheath blight, bacterial leaf blight (BLB), are the major diseases of rice while false smut, panicle blight (*Burkholderia glumae*) and stem rot are some of the emerging diseases in *tarai* and plains of Uttarakhand, while, brown spot is a disease of minor importance usually appears late in the season.

Production oriented survey in Uttarakhand: production oriented survey have been conducted regularly in all the rice growing areas of Uttarakhand to study the practices and production constraints in rice cultivation and to minimize input costs by suggesting suitable remedial measures on the spot to solve farmers' problems. The university also offers technical advice regularly to the farmers of adjoining districts of Uttar Pradesh.

1. Research Papers:

Singh R.A. and Pavgi M.S. 1966. Stem rot of rice in Uttar Pradesh, India. *Phytopathology*. 57: 24-28.

Singh R.A. and Pavgi M.S. 1972. Cytology of teliospores germination and development of *Neovossia horrida*. *ILRI*. 21: 259-268.

Singh R.A. and Raju C.A. 1981. Studies on sheath rot on rice. *Int. Rice Res. Newsl.* 6(2):11.

Singh R.A. and Dubey K.S. 1984. Sclerotial germination and ascospore formation of *Claviceps oryzae-sativae* in India. *Indian Phytopath.* 37: 168–170.

Singh R.A., Dube K.S. and Verma R.K. 1985. Survival of *Claviceps oryzae-sativae*, the incitant of false smut of rice. *Indian Phytopath*. 38:442-446.

Mishra D.S. and Sinha A.P. 2000. Plant growth-promoting activity of some fungal and bacterial agents on rice seed germination and seedling growth. *Trop. Agric.* 77:188-191.

Singh A., Rohila R., Singh U.S., Savary S., Willocquet L. and Duveiller E. 2002. An improved inoculation technique for sheath blight of rice caused by *Rhizoctonia solani*. *Canadian J. Plant Pathol*. 24(1): 65-68.

Singh A., Rohila R., Savary S., Willocquet L. and Singh U.S. 2003. Infection process in sheath blight of rice caused by *Rhizoctonia solani*. *Indian Phytopath*. 56(4): 434-438.

Singh Rajbir and Sinha A.P. 2004. Comparative efficacy of local bioagents, commercial bioformulations and fungicide for the management of sheath blight of rice, under glass house condition. *Indian Phytopathol.* 57(4): 494-496.

Singh Rajbir and Sinha A.P. 2005. Effect of *Pseudomonas fluorescens* formulations on sheath blight of rice. *Ann. Pl. Protec. Sci.* 13(1): 159-162.

Singh Rajbir and Sinha A.P. 2005. Influence of application methods of *Pseudomonas fluorescens* for managing rice sheath blight. *Indian Phytopath* 58:474–476.

Singh Rajbir and Sinha A.P. 2005. Management of rice sheath blight by *Pseudomonas* *fluorescens* and grain yield. *Ann. Pl. Protec. Sci*. 13(2): 410-414.

Khan A.A. and Sinha A.P. 2005. Influence of soil and nutritional factors on the effectivity of *Trichoderma harzianum* against sheath blight of rice. *Indian Phytopathol*. 58(3): 276-281.

Khan A.A., and Sinha A.P. 2005. Comparative antagonistic potential of some biocontrol agents against sheath blight of rice. *Indian Phytopathol*. 58(1): 41-45.

Singh Rajbir, and Sinha A.P. 2005. Influence of time of application of *Pseudomonas fluorescens* in suppressing sheath blight of rice. *Indian Phytopath*. 58(1): 30-34.

Khan A.A. and Sinha A.P. 2006. Integration of fungal antagonist and organic amendments for the control of rice sheath blight. *Indian Phytopathol*. 59 (3): 363-365.

Khan A.A., and Sinha A.P. 2006. Influence of fertilizers on *Trichoderma harzianum* against sheath blight of rice. *Ann. Pl. Protec. Sci*. 14(2): 481-482.

Khan A.A., and Sinha, A. P. 2006. Influence of formulations, doses and time of application of fungal bio-agents on rice sheath blight. *Ann. Pl. Protec. Sci*. 14(1): 157-161.

Singh Rajbir and Sinha A.P. 2006. Effect of *Pseudomonas fluorescens* on sheath blight of rice in nursery. *Ann. Pl. Protec. Sci*. 14(1): 264-265.

Khan A.A. and Sinha A.P. 2007. Biocontrol potential of *Trichoderma* species against sheath blight of rice. *Indian Phytopathol*. 60(2): 208-213.

Singh Rajbir and Sinha A.P. 2007. Management of sheath blight of rice with *Pseudomonas fluorescens*. *J. mycol. Pl. Pathol*. 37(1): 18-21.

Singh Rajbir and Sinha A.P. 2008. Growth promoting activities of Pseudomonas fluorescens on rice seedlings. *Indian Phytopath*. 61(2): 264-267.

Singh Rajbir and Sinha A.P. 2009. Biological control of sheath blight of rice with *Pseudomonas fluorescens*. *Indian Phytopath*. 62(3):381–383.

Singh Rajbir and Sinha A.P. 2009. Biological management of rice sheath blight with antagonistic bacteria. *Ann. Pl. Protec. Sci.* 17(1): 107-110.

Singh Rajbir and Sinha A.P. 2009. Influence of some soil factors and organic amendments on *Pseudomonas fluorescens* and sheath blight of rice. *Indian Phytopath.* 62: 435-439

Bahuguna, R.N., Pandey, M., Nath, M., Kumar, J. and Shukla, A. 2009. Physiological evaluation of *Trichoderma harzianum* against sheath blight in rice. *Indian J. Plant Physiol.* 14: 205-208

Aswal J.S., Kumar J. and Shah B. 2010. Evaluation of biopesticides and plant products against rice stem bore and leaf folder. *J. Eco-friendly Agriculture*. 5: 59-61.

Gangwar G.P. and Sinha A.P. 2010. Comparative antagonistic potential of *Trichoderma* spp. against *Xanthomonas oryzae* pv. *oryzae*. *Ann. Pl. Protec. Sci.* 18(2): 458-463.

Gangwar G.P. and Sinha A.P. 2010. Evaluation of fluorescent pseudomonads against *Xanthomonas oryzae* pv. *oryzae* causing bacterial leaf blight of rice. *Ann. Pl. Protec. Sci*. 18(2): 532-534.

Singh, B., Singh, S.P. and Kumar, J. 2011. Assessment of genetic diversity of 50 aromatic rices (*Oryza sativa* L.) using morphological, physiological and SSR markers. *Indian J. Genetics & Plant Breeding*. 71(3): 214-222.

Sukla N., Awasthi R.P., Rawat L. and Kumar, J. 2012. Biochemical and physiological responses of rice (*Oryza sativa* L.) as influenced by *Trichoderma harzianum* under drought stress. *Plant Physiology and Biochemistry* 54:78-88.

Bahuguna, R.N., Joshi, R., Shukla, A., Pandey, M.

and Kumar, J. 2012. Thiamine primed defense provides reliable alternative to systemic fungicide carbendazim against sheath blight disease in rice (*Oryza sativa* L.). *Plant Physiology & Biochemistry*. 57: 159-167.

Gangwar, G.P. 2012. Efficacy of commercial formulations of bioagent against bacterial leaf blight of rice. *Ann. Pl. Protec. Sci*. 20(2): 389-391.

Gangwar G.P. and Sinha A.P. 2012. Comparative antagonistic potential of fungal and bacterial bioagents against isolates of *Xanthomonas oryzae* pv. *oryzae*. *Ann. Pl. Protec. Sci*. 20(1): 154-159.

Gangwar G.P. and Sinha A.P. 2012. Evaluation of *Trichoderma* spp. and fluorescent pseudomonads for the management of bacterial leaf blight of rice. *Indian Phytopath*. 65 (1): 89-91.

Rawat L., Singh Y., Shukla N. and Kumar J. 2012. Seed biopriming with salinity tolerant isolates of *Trichoderma harzianum* alleviates salt stress in rice (*Oryza sativa* L.): growth, physiological and biochemical characteristics. *Journal of Plant Pathology.* 94 (2): 353-365.

Shukla N., Awasthi R.P., Rawat L. and Kumar J. 2012. Biochemical and physiological response of rice (*Oryza sativa* L.) as influenced by *Trichoderma harzianum* under drought stress. *Plant Physiology and Biochemistry*. 54: 78-88.

Sharma Lalan, Nagrale D. T., Singh S. K., Sharma K. K. and Sinha A. P. 2013. A study on fungicides potential and incidence of sheath rot of rice caused by *Sarocladium oryzae* (Sawada). *J. Applied & Nat. Sci.* 5(1): 24-29.

Gangwar, G.P. 2013. Efficacy of different isolates of fluorescent pseudomonads against bacterial leaf blight of rice. *Afr. J. Agric. Res.* 8(37): 4588-4591.

Gangwar, G.P. 2013. Field efficacy of formulation of fungal bioagents against bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* (Uyeda and Ishiyama) Dowson. *J. Appl. & Nat. Sci.*, 5(2): 423-426.

Gangwar, G.P. 2013. Growth promotion of rice seedling by fungal and bacterial bioagents effective against bacterial leaf blight of rice. *J. Appl. & Nat. Sci.* 5(2): 430-434.

Ghatak A., Willocquet L., Savary S. and Kumar J. 2013. Variability in aggressiveness of rice blast (*Magnaporthe oryzae*) isolates originating from rice leaves and necks: a case of pathogen specialization? *PLoS ONE* 8(6):e66180. doi:10.1371/journal.pone.0066180.

Gangwar G.P. and Sinha A.P. 2014. Growth promotion of transplanted rice plant by bioagents effective against bacterial leaf blight disease of rice under glasshouse conditions. *J. Applied & Nat. Sci.* 6(1): 234-238.

Negi A., Vishwanath and Badoni S. 2014. Management of *Rhizoctonia solani* by using Antagonist, Botanicals and Essential oils. *The Bioscan.* 9(3):1317-1321.

Pandey S., Singh B and Kumar J. 2014. DNA typing and virulence determination of *Xanthomonas oryzae* pv. *oryzae* population for the management of Bacterial leaf blight of rice in Udham Singh Nagar. *European J. Plant Pathology*. 138: 847-862.

Balodi R. and Kumar J. 2015. PCR assay for rapid detection of *Magnaporthe oryzae* in rice (*Oryza sativa*) using primers specific to PWL gene family. *Journal Mycol. Pl. Pathol.* 45 (2): 144-155.

Shrisht Lingwal, Vishwanath, Ramanna Koulagi, Vijay Srinivasraghwan, 2015. Effect of sterilization on antifungal properties of various components of panchgavya-tested against *R. solani* causing sheath blight of paddy. *J. Pure and Applied Microbiol.* 9(4): 1201-1212.

Pandey V., Ansari M.W., Tula S., Sahoo R.K., Bains

G., Kumar J., Tuteja N. and Shukla A. 2016. *Ocimum sanctum* leaf extract induces drought stress tolerance in rice. *Plant Signaling & Behavior* DOI: 10.1080/15592324.2016.1150400

Singh B., Pandey, Singh S.P. and Kumar J. 2016. Linkage disequilibrium based association and inheritance of blast resistance in improved varieties and landraces of aromatic rice. *Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci.* DOI 10.1007/s40011-016-0764-5

Singh Omkar and Vishwanath. 2017. Evaluation of New Formulation of Fungicides for the Management of Sheath Blight of Rice (*Oryza Sativa* L). *J. Env. Bio. Sci.* 31(1): 241-245.

2. Thesis Research :

1. Mukherjee, P. 1977. Histopathological studies of bacterial leaf blight of rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

2. Pandey, G.N. 1979. Studies on the diseases of rice-grain. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

3. Monga, D. 1980**.** Studies on the factors affecting survival of *Xanthomonas oryzae* in infected rice seeds and its treatment. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

4. Srivastava, V. 1984**.** Studies on *Pyricularia oryzae* the causal agent of blast of rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

5. Saxena, A.K. 1987**.** Studies on uptakes, effects and binding of rice blast fungicide Pyrioguilon in rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. U.S. Singh.

6. Sadeed, S.M. 1987**.** Effect of some seed treatment with chemicals on the fungal and bacterial flora of rice seeds and development of Kresek phase of BLB. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

7. Sunder Lal, P.E. 1990**.** Studies on systemicity of Pyroquilon in rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. U.S. Singh.

8. Sachan, A. 1996**.** Studies on sheath blight of Rice: Relationship between host specificity and Anastomosis group of *R. solani*. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. U.S. Singh.

9. Sharma, M.K. 1996**.** Assessment of yield losses and chemical control of sheath blight of rice caused by *R. solani*. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

10. Mishra, D.S. 1998**.** Comparative efficacy of some biocontrol agents against *Rhizoctonia solani* kuhn, the cause of sheath blight of Rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

11. Sati, P. 1998. Studies on the survival of *Rhizoctonia solani* incitant of sheath blight of rice. M.Sc. Ag. (Plant Pathology) thesis

submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

12. Vaish, D.K. 2000. Antagonistic Potential of fungal isolates against *Rhizoctonia solani* Kuhn, the causal agent of sheath blight of rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A. P. Sinha.

13. Nagi , H. 2001**.** Certain aspects of seed discoloration of rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. B. Das.

14. Acharya, S. 2005**.** Studies on the management of bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *Oxyzae*. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

15. Chalavariya, R. and Sinha, A.P. 2005**.** Estimation of yield losses and botanical management of sheath blight of rice caused by *Rhizoctonia solani* (Khun). M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A. P. Sinha.

16. Tiwari, R. 2006**.** Studies on certain aspect of sheath rot at rice caused by *Sarocladium oryzae*. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

17. Prakash, N. 2009**.** Antagonistic potential of *Trichoderma* spp. and fluorescent Pseudomonads against *Sclerotium oryzae,* the incitant of stem rot of rice (*Oryzae sativa* L). M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

18. Rawat, R. 2011**.** Antagonistic potential of *Trichoderma* spp. And Fluorescent Pseudomonads against *Sarocladium oryzae*, the incitant of Sheath rot of rice (*Oryza sativa* L.). M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

19. Lingwal, S. 2014**.** *In vitro* evaluation of bio pesticides against sheath blight of rice caused by *Rhizoctonia solani* Khun. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. Vishwanath.

20. Singh, R. 2015**.** Management of sheath blight of rice (*Oryza sativa*) caused by *Rhizoctonia solani* Kuhn. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. Vishwanath.

21. Singh, O. 2016**.** Variation among rice and maize isolates of *Rhizoctonia solani* and management of sheath blight in rice. M.Sc. Ag. (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. Vishwanath.

22. Raju, C.A. 1978**.** Studies on sheath rot of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

23. Verma, R.K. 1979. Studies on *Claviceps oryzae sativae* the incitant of false smut of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

24. Srinivasan, N. 1980. Studies on kresek phase of bacterial leaf blight of rice and strain

variation in *Xanthomonas oryzae*. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

25. Kumar, A. 1985. Teliospore germination and variability in *Neovossia horrida*- the incitant of rice bunt. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

26. Bhatt, J.C. 1990**.** Inheritance of resistance to rice blast (*Pyricularia oryzae*) and its chemical control. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

27. Ali. Z. 1991**.** Studies on stem rot of rice caused by *Magnoporthe salvinii* (*Sclerotium oryzae*). Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. R. A. Singh.

28. Modgal, R. 1999**.** Variability in *Rhizoctonia* so*l*ani causing sheath blight of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. U.S. Singh.

29. Singh, A. 2000**.** *Rhizoctonia solani* in rice wheat cropping system. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. U.S. Singh.

30. Singh, R. 2003**.** Studies on factors affecting the Biocontrol Potential *Pseudomonas fluorescens* against sheath blight of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

31. Khalid, A. 2006**.** Variability in *Xanthomonas oryzae* pv. *oryzae* (Uyeda and Ishiyama) Dowson and management of bacterial leaf blight of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

32. Gangwar, G.P. 2009**.** Biological management of bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* (Uyeda and Ishiyama) Dowson. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

33. Tripathi, S. 2010**.** Variability in *Ustilaginoidea virens* (Cke.) Tak. and management of false smut of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

34. Pandey, S. 2010**.** Population structure of *Xanthomonas oryzae* pv. *oryzae*, the pathogen of bacterial blight of rice, from major rice growing areas of U.S. Nagar (Uttarakhand). Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. J. Kumar.

35. Sharma, L. 2010**.** Variability in *Sarocladium oryzae* (Sawada) Gams and Hawksw. and management of sheath rot of rice. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. A.P. Sinha.

36. Ghatak, A. 2013**.** Relationship between rice nick blast and leaf blast epidemics. Ph. D (Plant Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. J. Kumar.

37. Kumari, S. 2014**.** Studies on etiology, biology and management of false smut of rice caused by *Ustilaginoidia virens*. Ph. D (Plant

Pathology) thesis submitted to G.B. Pant University of Agriculture & Technology, Pantnagar, under the guidance of Dr. J. Kumar.

3. Future Thrusts:

1. Screening of germplasms and elite lines for multiple disease.
2. Developing facilities for artificial screening against diseases
3. Studying pathogenic variability of the pathogens causing major diseases in the area.
4. Studying ecology and epidemiology of emerging diseases like, false smut, panicle blight.
5. Identifying safer and effective chemical control measures for diseases of economic consequences.
6. Monitoring and management of fungicide resistance in major diseases of rice.
7. Evaluation and introduction of reduced risk fungicides in Uttarakhand.
8. Development of forecasting models for major diseases of rice.
9. Development of IPM modules for different agro-ecosystem of Uttarakhand.