AICRP-SOYBEAN

Objectives

1. Collection, evaluation, maintenance, documentation and utilization of exotic and indigenous soybean germplasm.
2. Breeding for
   (a) High yielding with wider adaptability
   (b) Early maturing, photo and thermo-insensitive, suitable for both *Kharif* and *Rabi* (summer season) for plains as well as hilly regions.
   (c) Disease resistance (particularly yellow mosaic, bacterial pustules, *Rhizoctonia* aerial blight, *Cercospora* leaf spot, rust and bacterial leaf blight).
   (d) Insect resistance (specifically for hairy caterpillar, tobacco caterpillar, stem fly, white fly, girdle beetle, green semi looper, green stink bug and ass weevil).
   (e) High germinability and better seed longevity (comparable to T 49/ Kalitur/ Bhatt).
   (f) High oil and protein content (>20 % and >40 %, respectively).
   (g) Bold seed size and resistant to seed damage.
3. To evaluate the yield potential of pre-released soybean varieties under recommended agronomic management.

Soybean (*Glycine max* (L.) Merril) has a prominent place among modern agricultural commodities, as the world's most important seed legume, which contributes about 25% to the global edible oil production, about two thirds of the world's protein concentrate for livestock feeding and is a valuable ingredient in formulated feeds for poultry and fish. It is also an important commodity for food manufacturers, pharma industry and many more industrial uses. It is therefore no surprise that global soybean demand is increasing rapidly. After the record world production of soybean during 2016-17, it is expected to marginally decline this year on account of expected decline in Brazil and Argentina. The estimates of world soybean area, production and productivity for 2017-18 are 126.64 million ha, 346.31 million tons and 2.74 t/ha, against the 2016-17 figures of 121.10 million ha, 348.85 million tons and 2.88 t/ha. This shows an increase in area to the tune of 4.57%, whereas decline of 0.73 and 5.07% in production and productivity in 2017-18 over 2016-17.

In India, the major initiative on soybean cultivation was undertaken after independence (during 1963-64) under the aegis of G. B. Pant University of Agriculture and Technology, Pantnagar and JNKVV, Jabalpur in collaboration with University of Illinois, USA. The cultivation was further picked up after the researchers took advantage of yellow seeded material to develop high yielding varieties they suited Indian conditions. As a result, In 1967, Indian Council of Agricultural Research (ICAR) launched interdisciplinary multi-location trial in All India Coordinated Research Project on Soybean (AICRP-Soybean) with cooperating centers spread all over the country. The success of AICRP-Soybean in identification and development of high yielding varieties (> 110 at present) and standardization of production technology suitable for different agroclimatic conditions of the country was phenomenal which resulted in

substantial increase in negligible area in 1968 (3000 ha) to about 2.2 million hectare by 1991to about 11.4 mha at present. The ICAR also launched a soybean processing and utilization project at Bhopal in 1983-84 under Indo-US agricultural sub-commission on agriculture. Once convinced about the bright prospects of soybean in India and initiation of systematic research through these establishments, the research information started flowing in on various aspects of production and crop improvement and the area under soybean increased at a spectacular growth rate. All India Coordinated Research Project (AICRP) on soybean was launched at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, in 1967 as a special centre on soybean to carry out basic and strategic research on Soybean with following mandate and objectives:

A. Soybean Breeding

1. Sognificant Achievements:

A. Varieties developed and released

1. The total 24 high yielding varieties with wider adaption of soybean have been developed so far from Pantnagar centre for various agro ecological conditions including Central India, South India, North India, plains of U.P. and U.K. as well as hilly areas of Uttarakhand which are highest in number from any other AICRP Centers and SAUs in India

2. Development of resistant varieties to YMV, rust and fungal complex have been exclusive achievement of the centre. The varieties *viz*. PK 416, PK 564, PS 1042, PS 1347 ,PS 1225, PS 19, PS 20, PS 21, PS 22 and PS 24 are resistant to YMV, Ankur, PK 1029 and PS 1024 and PS 1042 tolerant to rust and PS 1241, PS 1242 are resistant to fungal complex disease.

B. Varieties/ Germplasm Registered for special character in N.B.P.G.R., New Delhi

3. Germplasm PK 515 (*Glycine soja* derived lines) has registered under NBPGR as resistant strain to YMV and moderately resistance to hairy caterpillar.

C. Varieties Developed and registered under Plant Variety Protection & Farmer Right's Act 2001.

4. Three varieties namely, Pant Soya 1092, Pant Soybean 1347 and Pant Soybean 1225 registered under PVP& FR Act 2001 as extant varieties.

D. Other commendable achievements

5. Three varieties of soybean viz., Ankur, Shilajeet and PK 472 recognized as landmark varieties of India by The *Indian Society of Genetics & Plant Breeding (ISGPB),* New Delhi, on 11 February, 2017.

6. Release proposals are to be submitted of two improved genotypes namely, Pant Soybean 1556 and Pant Soybean 1572 identified for North Hill Zone and North Plain Zone, receptively (47th and 48th AGM of AICRP on Soybean).

7. The detailed germplasm catalogue of five thousands of Germplasm accession has been developed (as per NBPGR soybean descriptor) after the screening for 18 morphological and agronomical traits including early, late, medium maturity and vine type etc. (Ram *et al*., 1988). Through systematic screening, large number of germplasm lines were identified as donor and are being utilized for soybean improvement programme and also distributed to various AICRP centers.

8. Through systematic screening of germplsam UPSM 534 (PI 1711443) and wild species i.e. *Glycine soja* (*Glycine formosana*) were identified as immune to yellow mosaic. The resistance in PI 171443 is controlled by 2 pairs of recessive genes rym_1, rym_2. The resistance in wild species appears to be controlled by one dominant gene i.e. *Rym*.

9 The genetic data on segregation for resistant and susceptible plants indicated that resistance to rust was controlled by a single dominant gene. Ankur is a first variety released in 1974 from this University apart from having other desirable features was resistant to rust and later on varieties

like PS 1024, PS 1029 were also released to have rust tolerance.

10 The preliminary inheritance data indicated that resistance for Bihar hairy caterpillar in *Glycine soja* (wild species) is controlled by one dominant gene. One variety i.e. PS 1225 having the background of *Glycine soja* derived line i.e. PK 515 was released in 2007.

11 Three indigenous soybean varieties namely, T49, Bhatt and Kalitur and one improved variety i.e. Ankur were identified as donors to improve seed storability and germinability.

12 More than 1650 PS breeding lines have been generated which are resistant to biotic and abiotic stresses and having high yield potential. More than 12000 cross combination among the divers parental line have been attempted to generate the voluminous the breeding material to achieve desired recombinant for yield and yield components.

13 The 21 genotypes viz., EC 11740, EC13006, EC 36372, EC 39225, EC 93320, EC 93320, EC 93404, EC 172621, EC 241868, EC 251330, EC 251874, EC 11739, V 14, V 19, V 61, TGX 342367, L 586, WT 10, WT 60, WT 129 and WT 189 were identified as superior lines for seed storability and germinability through systematic breeding soybean germplasm.

14 Developed Multi parental Advanced Generation Intercross (MAGIC) populations for further genetic studies in soybean to fulfill the mandate of the soybean breeding programme.

15 Through the assistance of graduate students, basic studies on different aspects on soybean are being conducted during every crop session as usual. The material developed and results obtained from these experiments are utilized in the ongoing soybean breeding programme.

16 Nucleus and Breeder seed of improved varieties of soybean released at National and state level and notified is produced at NEBCRC and Seed Production Centre, GBPUA&T, Pantnagar to meet the requirement of DAC Ministry of Agriculture Government of India to cater the need of soybean growers. From 2008 -2018, Pantnagar centre has produce 1688.12 q of breeder seed of soybean promising varieties.

E. Extension Material/Booklets etc. Published

17. More than 110 full length research papers on soybean breeding research have been published in various reputed national and international journals and more than 80 popular articles have been published in various reputed magazines for the welfare farming community.

18. Six research bulletins namely:

- Ram, H.H.; Pushpendra; Verma, V.D. and Singh, K. 1987. Soybean Breeding. In: Soybean Research at Pantnagar Directorate Experiment Station, G.B. Pant University of Agriculture & Technology, Pantnagar – 263 145. Experiment Station Technical Bulletin. 114: 5-18.
- सोयाबीन उत्पादन की वैज्ञानिक तकनीक, गो0ब0 पन्त कृषि एवं प्रौद्योगिक विश्वविद्यालय, पन्तनगर, पेज न- 18, 1995.
- बृजवीर सिंह, श्रीराम, एस.एन. विश्वकर्मा, पुष्पेन्द्र, कामेन्द्र सिंह, सुभाष चन्द्र सक्सेना, नरेन्द्र कुमार और नीता गौड़ 2007। सोयाबीन फसल उत्पादन की वैज्ञानिक तकनीक, पन्त कृषि एवं प्रौद्योगिक विश्वविद्यालय, पन्तनगर, पेज न- 18
- Singh K., Pushpendra, Shukla P.S. and Gupta M.K. 2015. Nucleus and Breeder Seed Production of Soybean. Bulletin no. 204. Pp. 1-22.
- Pushpendra, Kamendra Singh, K. P. Singh, P. S Shukla, J.P. Singh, K.P. Raverkar, Neeta Gaur, Pratima Awasthi. 2015. सोयाबीन उत्पादन की वैज्ञानिक तकनीक. Bulletin No. 203. Pp. 26.
- Pushpendra, Kamendra Singh, S. C. Saxena, Narendra Kumar, K. P. Singh, K. P. Raverkar, P. S. Shukla, Neeta Gaur and Ajay Srivastava (2017). Five Decades of Soybean Research at Pantnagar. Bulletin no. 214. Pp. 1-104.

19. Two germplasm catalogue have been published from Pantnagar centre.

2. Research Publications:

1. Singh, B.B., Hadley, H. H. 1967. Distribution and inheritance of fatty acids in soybeans. Paper presented at the Annual Meeting of the American Society of Agronomy held at Washington. D. C. Agron. Abs. 1967: p. 19.

2. Singh, B. B., Haldey, H. H., Collins, F. I. 1968. Distribution of fatty acids in germinating soybean seeds. *Crop sci*. 8: 171-173.

3. Singh, B. B., Hadley, H. H. 1968. Maternal control of oil synthesis in soybeans. Glycine max. (L.) Merrill. *Crop Sci.* 8: 622-625.

4. Bernard, R. L. Singh, B. B. 1969. Inheritance of pubescence type in soybeans: glabrous, curly, dense, sparse and puberulent. *Crop Sci*. 9: 192-197.

5. Singh, B. B., Hadley, H. H., Bernard, R. L. 1971.

SOYBEAN VARIETIES DEVELOPED AT PANTNAGAR

Sl. No.	Variety	Pedigree	Year of release	Notification No.	Maturity (q/ha)	Yield	Disease Resistance	Area of Adaptation
1.	Bragg	(JACKSON x 1969 ** D-49-2491)	-	120	20-25	Bacterial pustules	All India	
2.	Ankur	A COMPOSITE OF 1974 ** 22 CROSSES	SO 786	135 2/2/1976	20-25	Bacterial pustules & Rust tolerant	Central India	
3.	Alankar	(D-63-6094 x D-61-4249) x BORR-CHETT	1977 **	SO 13 19/12/1978	120	20-25	Bacterial pustules	Northern Plains
4.	Shilajeet	SINGLE PLANT 1979 ** SELECTION FROM EC 9309	SO 470 E 1980 *	110 19/2/1980	20-25	YMV tolerant	Northern	Hills
5.	PK 262	UPSM-97 x HARDEE 1982 *	SO 499 E	125 8/7/1983	25-30	Bacterial pustules	Northern	Plains Lower Hills
6.	PK 327	UPSM-82 x SEMMES 1982 **	SO 2 E	105 3/1/1983	25-30	Bacterial pustules	Northern	Hills & Plains
7.	PK 308	TYPE-31 x HARDEE 1984 **	SO 295 E	115 9/4/1985	20-25	Bacterial	Northern pustules	Plains
8.	PK 416	UPSM-534 x 1985 * ANKUR (S 38)	SO 258 E	120 14/5/1986	25-30	Yellow Mosaic & Bacterial pustules	Northern	Plains
9.	PK 472	HARDEE x PB-1 14/5/1986	1986 ** YMV tolerant	SO 258 E 100	25-32	Bacterial pustules & &	Central India Bundelkhand	
10.	PS 564	(UPSM-534 x ANKUR) x BRAGG	1990 *	SO 793 E 120 12/11/1991	25-30	YMV and BP	Northern	Hills & Plains
11.	PS 1024	PK-308 x PK-317	1994 *	SO 307 E 1/5/1997	120	30-35	YMV, BP, Rust tolerant	Northern Plains
12.	PS 1042	BRAGG x PK-416	1996 **	SO 307 E 1/5/1997	120	32-35	YMV, BP, Soybean Mosaic & Pod Blight	Northern Plains
13.	PS 1029	PK-262 x PK-317	1997 **	SO 647 E 9/9/1997	95	30-35	YMV, BP & Rust tolerant	Southern India

14.	PS 1092	PK-327 x PK-416	1999 *	SO 821 E 13/9/200	115	30-35	YMV, Bacterial pustules & CLS	*Tarai Bhabar* and hill Region of Uttarakhand
15.	PS 1241 17/10/2018	PK-1039 x PK-327	2003 *	SO 161 E	121	30-35	YMV, BP & Fungal complex	*Tarai Bhabar* Region of U.P. and U.K.
16.	PRS 1	-	2004*	-	100	18-20	CLS, tolerant	U.K. Hills
17.	PS 1347	PS-1024 x PK-472	2006**	SO 2458 E 16/10/2008	123	>35	Yellow Mosaic, B. P., & Pod Blight	Northern Plains
18.	PS 1225	PK-515 x PK-327	2007*	SO 449 E 11/2/2009	121	30-35	Multiple disease resistance	Uttarakhand plains (*Tarai Bhabar*)
19.	PS 19	PK 416 x PK 695	2010*	SO 952 E 10/4/2013	125	30-35	YMV, BP and moderately resistance to RAB	Plains and lower hills of Uttarakhand
20.	PS 20	PS 1241 x PS 1042	2015*	-	121	30-36	YMV, BP and moderately resistance to RAB	Plains, *Tarai Bhabar* area of Uttarakhand
21.	PS 21	PS 1029 x PS 1241	2015*	3-54/ 2017 SD IV	126	30-38	YMV, BP and moderately resistance to RAB	Plains, *Tarai Bhabar* area of Uttarakhand
22.	PS 22	PS 1029 x PS 1241	2015*	-	116	30-35	YMV, BP and moderately resistance to RAB	Plains, *Tarai Bhabar* area of Uttarakhand
23.	PS 23	PS 1029 x PS 1241	2015*	3-54/ 2017 SD IV	114	30-40	YMV, BP and moderately resistance to RAB	Plains, *Tarai Bhabar* area of Uttarakhand
24.	PS 24	JS 335 x PS 1024	2017**	3-54/ 2017 SD IV	116	30-35	YMV, BP and moderately resistance to RAB	NPZ including UP and Uttarakhand

* Released from State Varietal Release Committee ** Released from Central Varietal Release Committee

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132. Aditya J. P., Anuradha Bhartiya, Pushpendra and Kamendra Singh (2013). Transgressive Segregation for Yield Traits in F_2 and F_3 Generation of soybean [*Glycine max* (L.) Merrill] Crosses. *Soybean research.* 11:1-7.

133. Kamal Pandey, Kamendra Singh, B. V. Singh, Pushpendra, M. K. Gupta and Narendra Singh Yadav(2014). Genetic divergence study in advance breeding lines of soybean [*Glycine max* (L) Merrill]. *International Journal of Basic and Applied Agricultural Research*. 12(1):41-47.

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136. Gunjan Tiwari, Pushpendra, Kamendra Singh, Manoj Kumar Gupta and Aneeta Yadav 2014. Evaluation of F_1 Hybrids for Grain Yield Components in Soybean [*Glycine max* (L.)Merrill]. *Soybean Research.* 12(2): 54-62.

137. Pushpendra, Kamendra Singh, M.K.Gupta, Praveen Kumar and Priyanka Bhareti 2014. Breeding Strategies for Breaking Yield Barrier in Soybean Production in India. *Soybean Research.* 12(Special issue 2): 19-32.

138. Aneeta Yadav, Kamendra Singh, Puspendra, Vasudha Jadon and Gynendra Pratap Singh (2014). Predicting the best genotype from analysis of genotype-environment interaction in soybean (*G. Max* (L.) merill). In National Symposium on Crop Improvement for Inclusive Sustainable development. Nov, 7-9 at PAU, Ludhiana; 456-59. (short communication)

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development. Nov, 7-9 at PAU, Ludhiana; 656-59. (short communication)

140. Aneeta Yadav and Kamendra Singh 2015. Studies on genetic parameters for yield and quality traits in Soybean (*Glycine max* (L) Merrill). *International Journal of Basic and Applied Agricultural Research.* 13(1):17-21.

141. Gunjan Tiwari, Kamendra Singh, Pushpendra and N.K. Singh 2015. Stability analysis for various quantitative traits in soybean [*Glycine Max* (I.) Merrill]. *Legume Research-An International Journal*(Accepted)

142. Shukla P. S.; Singh Kamendra and Tiwari R. K. (2016). Harmonization of Seed Certification Processes for Global Seed Marketing. Published in souvenir AGRIVISION 2016 conducted JNU, Krishi Vishwavidyalaya, Jabapur (M.P.) dated 13-14 February, 2016. Pp 81-84.

143. Meenakshi Joshi, Kamendra Singh, Pushpendra and Anupam Barh (2016). Studies on F_1 and F_2 generation of soybean for correlation and path coefficient in tarai region of Uttarakhand. International Journal of Scientific Engineering and Applied Science (IJSEAS). Volume -2 (8) pp 277-292.

144. Anuradha Bhartiya, J. P. Aditya, Kamendra Singh, Pushpendra, J. P. Purwar and Anjuli Agrawal (2016). AMMI & GGE biplot analysis of multi environment yield trial of soybean in North Western Himalayan state Uttarakhand of India. Legume Research, LR-3562[1-7]

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146. Anchala Nautiyal, Neeta Gaur, Kamendra Singh and Preeti Sharma (2016). Effect of soybean plant phenols and flavonoid on the mean leaf area consumed by *Spodopteralitura* and *Spilosoma oblique* larvae. Journal of applied and Natural Science 8(4): 1931-1936.

147. Anita Rani, Vineet Kumar, B. S. Gill, Shruti Shukla, Pushpendra Rathi and R. K. Singh (2017). Linkage mapping of mungbean yellow mosic India virus (MYMIV) resistance gene in soybean. Breeding Science 67: 95-100.

148. Deepak Joshi, Pushpendra, Kamendra Singh and Sneha Adhikari. 2018. Study of Genetic Parameters in Soybean Germplasm Based on Yield and Yield Contributing Traits. *Int.J.Curr.Microbiol.App.Sci.* 7(01): 700-709

149. Deepak Joshi, Pushpendra, Kamendra Singh, Sneha Adhikari and Sunaina Rani (2018). Screening of soybean germplasm for important disease prevalent in North India. International Journal of Chemical Studies 2018; 6(2): 2731-2733.

150. Anita Rani, Vineet Kumar, B. S. Gill, Shruti Shukla, Pushpendra Rathi and R. K. Singh (2018). Mapping of Duplicate Dominant Genes for Mungbean Yellow Mosaic India Virus Resistance in *Glycine soja*. *Crop Science* vol. 58: 1-9.

3. Thesis Research:

M. Sc. Ag. Genetics & Plant Breeding

1. Arun Kumar Saha 1970. Extant of natural crossing in Soybean. to GBPUAT under supervision of Dr. B.B. Singh
2. Ram Kishore 1970. Inter vareital competition in Soybean. to GBPUAT under supervision of Dr. B.B. Singh
3. D. N. Choudhury 1971. The extent and Nature of Heterosis for yield and other Quantitative characters in soybean. to GBPUAT under supervision of Dr. B.B. Singh
4. B. Patil 1974. Genetic and cytological studies on male sterile mutant in soybean. to GBPUAT under supervision of Dr. B.B. Singh
5. K. C. Bhardwaj 1974. Inheritance of some quantitative characters in an interspecific cross in soybean. to GBPUAT under supervision of Dr. B.B. Singh

6. D. N. Chaudhury 1975. Studies on genetic divergence & phenotypic stability in soybean. to GBPUAT under supervision of Dr. B.B. Singh
7. A.S. Malik 1976. Inheritance of resistance to YMV in soybean. to GBPUAT under supervision of Dr. B.B. Singh
8. R.P.S. Rana 1977. Relationship of seed vigor with yield and yield components in soybean. to GBPUAT under supervision of Dr. B.B. Singh
9. A.N Jha 1977. Genetic and cytological studies on induced male sterility mutants in soybean. to GBPUAT under supervision of Dr. M.P. Pandey
10. A.K. Dwivedi 1979. Evaluation of induced quantitative mutants and characters association analysis in soybean. to GBPUAT under supervision of Dr. M.P. Pandey
11. Jai Prakash Shahi 1980. Genetic study of seed impermeability in soybean. to GBPUAT under supervision of Dr. P.S. Bhatnagar
12. Kamendra Singh 1983. Genetic divergence and and path coefficient analysis in new breeding lines in soybean. to GBPUAT under supervision of Dr.H.H. Ram
13. Hari Kumar 1988. Soybean cultivar identification by use of Electrophoretic pattern of seed proteins. to GBPUAT under supervision of Dr.H.H. Ram
14. N.S. Dhaka 1988. Stability analysis in the elite lines of soybean. to GBPUAT under supervision of Dr.H.H. Ram
15. N.S. Dhaka 1988. Stability analysis in the elite lines of soybean. to GBPUAT under supervision of Dr.H.H. Ram
16. Omleir 1989. Genetic variability and interrelationship in M5 progenies of soybean. to GBPUAT under supervision of Dr.H.H. Ram
17. P.K. Bhattacharya 1990. Growth stages and yield components in determinate Vs indeterminate soybean. to GBPUAT under supervision of Dr.H.H. Ram
18. P.T. Dao 1991. Visual selection and index selection index selection in soybean. to GBPUAT under supervision of Dr.H.H. Ram
19. Sanjoy Chauhan 1996. Extant of genetic variability and classificatory analysis in advance of breeding lines of soybean. to GBPUAT under supervision of Dr. Puspendra
20. Saurabh Shukla 1996. Studies on genetic diversity in the indieneous and exotic germplasm lines of soybean. to GBPUAT under supervision of Dr. Kamendra Singh
21. Praveen Siddhu 1997. Effecticness of early generation selection in interspecific crosses of soybean. to GBPUAT under supervision of Dr. Puspendra
22. Dhanpat Kumar 1998. Stability analysis in soybean over difference plant diversity. to GBPUAT under supervision of Dr. Kamendra Singh
23. Mukesh Kumar 2000. Estimation of variability, correlation and path coefficient for seed yield and its component in soybean. to GBPUAT under supervision of Dr. Kamendra Singh
24. Charan Singh 2000. Genetic variability and correlation studies for flower production, abscission rate, yield and yield components in soybean. to GBPUAT under supervision of Dr. Puspendra
25. Saswat Kumar 2001. Gama rays, ethyl methyl sulfonate and diethyl sulfonate induced variation for yield and yield contributing traits in soybean. to GBPUAT under supervision of Dr. Puspendra
26. Rahul Dev Pandey 2001. Genetic divergence, correlation and path coefficient analysis for seed yield, its component and quality traits in soybean. to GBPUAT under supervision of Dr. Kamendra Singh
27. Arun Kumar Agnihotri 2002. Studies on metroglyph components in mechanical diallele mixture in soybean. to GBPUAT under supervision of Dr. Puspendra
28. Shilpi Tiwari 2002. Studies on genetic variability

and correlation and seed longevity and its components in soybean. to GBPUAT under supervision of Dr. B.V. Singh

29. Jai Prakash Aditya 2003. Studies on residual heterosis and transgressive segregation for yield and its components in soybean. to GBPUAT under supervision of Dr. Puspendra

30. Bhawana Sharma 2003. Studies on genetic divergence on Indian varieties of soybean. to GBPUAT under supervision of Dr. B.V. Singh

31. Anuradha Bhartiya 2004. Residual heterosis and transgressive segregation studies for yield and its components in soybean. to GBPUAT under supervision of Dr. Kamendra Singh

32. Vikash Kumar 2004. Studies on genetic evaluation and correlation for nodulation and yield attributing traits in Rabi soybean.

33. Preeti Massey 2005. Transgressive segregation and residual heterosis in soybean. to GBPUAT under supervision of Dr. B.V. Singh

34. Narendra Singh 2005. Estimation of genetic diversity and characters association for seed yield and its components in elite lines of soybean. to GBPUAT under supervision of Dr. Kamendra Singh

35. Alpana 2005. Morphological characterization and genetic divergence studies in released varieties of soybean in India. to GBPUAT under supervision of Dr. Puspendra

36. Sunita Pandey 2006. Hydration treatment and its effect on generation of and other yield components in F3 generation of Birsa-Soya /Ds-71-05 crosses of soybean. to GBPUAT under supervision of Dr. Puspendra

37. Kamal Pandey 2006. Genetic divergence and correlation studies during winter and rainy season for yield and its components in soybean. to GBPUAT under supervision of Dr. Kamendra Singh

38. Hema Pandey 2006. Genetic divergence studies in Nigerian germplasm of soybean. to GBPUAT under supervision of Dr. B.V. Singh

39. Mamta Arya 2007. Heterosis correlation and variability studies for yield and its components in soybean. to GBPUAT under supervision of Dr. Kamendra Singh

40. Kalian Singh 2009. Studies on genetic variability and photosensitivity in advance breeding lines of soybean. to GBPUAT under supervision of Dr. Kamendra Singh

41. Kuldeep Singh 2010. Studies on genetic divergence and character association in elite lines of soybean. to GBPUAT under supervision of Dr. Kamendra Singh

42. Samant Pooja 2010. Heterosis and path coefficient analysis in soybean (*Glycine max* (L.) Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

43. Hitesh Pandey 2012. Genetic divergence and path coefficient analysis I soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

44. Kunduru Bharath 2016. Studies on Genetic Parameters for quantitative and qualitative traits I soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

Ph.D. Genetics and Plant Breeding

1. V.S. Chauhan 1976, Studies on heterosis combining ability …… in soybean. to GBPUAT under supervision of Dr. B.B. Singh

2. H.D. Upadhaya 1980, Studies on radiation stimulation and induction of genetic variability by physical and chemical mutagen in soybean .to GBPUAT under supervision of Dr. K. P. S. Chauhan

3. Jeet Singh Sandhu 1984, Studies of induced variability quantitative characters in soybean. to GBPUAT under supervision of Dr. P. S. Bhatnagar

4. Virendra Dev Verma 1985, Genetics of seed quantitative in soybean. to GBPUAT under supervision of Dr. H.H. Ram

5. Puspendra 1985, Genetics of quantitative traits and selection. to GBPUAT under supervision of Dr. H.H. Ram

6. Kamendra Singh 1987, Selecting parental cultivars and crosses and visual selection for seed yield in early generation in soybean. to GBPUAT under supervision of Dr. H.H. Ram

7. Rajat Saxena 1987, Stability analysis in soybean. to GBPUAT under supervision of Dr. P.S. Bhatnagar

8. S.K. Chaturvedi 1988, Studies on induced polygenic mutations in M3 &M4 generations of soybean. to GBPUAT under supervision of Dr. H.H. Ram

9. N.N. Pathak 1988, Genetics of vegetative and reproductive and their importance in inbreeding soybean. to GBPUAT under supervision of Dr. H.H. Ram

10. P.T. Dao 1995, Genetics and screening methods of seed longevity in soybean. to GBPUAT under supervision of Dr. H.H. Ram

11. Puspak Mani Bhardwaj 2009, Elucidating the genetics and physiology of seed longevity in soybean to GBPUAT under supervision of Dr. Puspendra

12. Rajneesh Kr. Singh 2009, Studies on inheritance of major quantitative traits in soybean. to GBPUAT under supervision of Dr. Puspendra

13. Ms. Gunjan Tiwari 2013, Stability analysis for various quantitative characters and assessment of molecular diversity in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

14. Mr. Praveen Kumar 2013, Study of genetic variability induced by gamma-rays and EMS and molecular characterization of mutants through SSR markers in Soybean (*Glycine max* (L.) Merrill). to GBPUAT under supervision of Dr. Pushpendra

15. Ms. Aneeta Yadav 2014, Stability analysis for yield and quality traits and assessment of diversity using SSR molecular marker in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

16. Ms. Nagma Kousar 2014, Genetic analysis for yield and its components in early generation and assessment of molecular diversity in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

17. Ms. Minakshi Joshi 2015, Studies on heterosis, transgrassive segregation selection index and determination of parental molecular diversity in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

18. Ms. Vandana Bhakuni 2016, Studies on seed longevity with packaging materials, genetic variability and molecular diversity of soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. P. S. Shukla

19. Ms. Minakshi Bisht 2018, Effectiveness of early generation selection based on F2 hertibility in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

20. Mr. Kumar Nishant Chourasia 2018, Studies on seed longevity based on biochemical, genetical and molecular in soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. Kamendra Singh

21. Mr. Narendra Singh Dhaka pursuing, Morphological and molecular genetic diversity study in soybean germplasm. to GBPUAT under supervision of Dr. Kamendra Singh.

3. Awards/Recognitions:

1. Received AICRP on Soybean Centre of **Excellence Award- 2017**, from IISR, Indore, ICAR, New Delhi during 47 AGM of AICRP on soybean held at Pantnagar, 2-4 May, 2017.

4. Future Thrusts:

Soybean is classified under least storable crop, highly sensitive to mechanical and thermo injury, bold seeds are poorer in compression to small seed for longevity**.** Thus, to minimizing the yield gap and enhance

the genetic potential of yield in soybean in spite of the global warming and other several biotic, abiotic stresses and shattering losses etc., To breed the varieties friendly to mechanical harvesting, thermo and photo-insensitive, long durability The following will be the future plan:

1. Stagnant potential for yield due to narrow genetic base of Indian Soybean varieties has been a major constraint for low productivity of soybean. To achieve these phenomena in terms of varietal improvement as well as basic genetic studies our main emphasis would be on productivity enhancement of soybean.
2. Consolidation, maintenance, documentation and utilization of soybean germplasm. (Collection of genetic resources particularly form Uttarakhand hills as well as North East region i.e. considered, as reservoir for soybean genetic resources).
3. Breed varieties for high yield with wider adoption for different agro-climatic zone of the country.
4. Breeding for photo insensitivity, enhanced seed longevity and resistance to mechanical damage.
5. Broadening the genetic base of Soybean varieties by infusing the diverse genetic resources as well as through inter-specific hybridization.
6. Breeding varieties for biotic (YMV, Rhizoctonia Aerial Blight, Hairy Caterpillar, Tobacco Caterpillar) and abiotic (drought) resistance / tolerance) stresses
7. Molecular breeding is another front area where impressive achievements have been made at global level but we are lagging behind. Initiating research in soybean molecular breeding particularly for identification and validation of molecular markers for YMV as well as other qualitative and quantitative traits of economic importance is a need of time for soybean improvement at this centre.
8. Genetic improvement of soybean genotype for yield and other traits of economic importance using marker assisted breeding approach.
9. Breeding varieties with added advantages of possessing these characters to suit the specific industry needs.
10. Nucleus and breeder seed Production of promising varieties of soybean to cater the need of quality seed of Soybean.

B. Soybean Agronomy:

Systematic research on soybean agronomy has led to timely development of production technology for new varieties and has led to increase in soybean area, production and productivity. Currently soybean has become leading oil producing crop in our country. The suitable package of practices of cultivation has been recommended from time to time which resulted from intensive research in Agronomy. The research is being intensified to remove various agronomic constraints of soybean production and to develop production technology for soybean based cropping systems.

1. Significant Achievements:

Time of Planting: Time of planting for any crop plays important role in producing higher quality and quantity of economic produce. Recommended time of planting of soybean is last week of June to second fortnight of July. Under north plane zone planting of soybean beyond second fortnight of July resulted in drastic decline of yield.

Evaluation of yield potential of pre-released soybean varieties under recommended agronomic management: The centre evaluates the pre released entries for their yield potential under Advance Varietal trials-II. Pre released entries for north plane zone are evaluated for their duration, yield potential, dry matter accumulation, relative crop growth rates and for biomass yield. Over the years evaluation of different pre released entries and their performance against different checks forms the basis for the release of these entries for the north plain zone condition. Latest varieties released after evaluation are PS19, PS20, PS21, PS22, PS23, PS24.

Evaluation of new molecules of herbicides: Management of weeds in *kharif* season is critical component in deciding yields of soybean. Yield losses can vary from 30-85 per cent if weed

growth is not managed. Continuous evaluation of new active ingredients and formulation is done to determine the effective control of broad leaf weeds, grasses and foe sedges under pre plant incorporation (PPI) pre emergence (PE) and post emergence conditions. In past years herbicides as Trifluralin, Fluchloralin, Tribunil, Oxadiazon, Pendimethalin, Metribuzin, Oxyflurofen, Alachlor, Aryloxyphenoxy propionate, Clomazone, Aacifluorfen, Sethoxydin, Anilophos, Metalachlor, Imazethapyr, Quizalofop-ethyl, Fenoxaprop-p-ethyl, Chlorimuron ethyl, Imazamox, Flumoxiazen, Haloxyfop-ethyl, Sulfentrazone, Fluthiacet methyl, were evaluated for control of different weeds at different stages.

Weed management. Critical crop weed competition period is identified up to 40-45 days after sowing. Two manual weeding at 20-25 days and at 40-45 days after sowing was found best practice for weed management in soybean. In the scarcity of labour and making soybean soybean production economical chemical weed management is an alternative options for weed management. Pre emergence herbicide (0-3 days after sowing) such as Alachlor @ 2.0 kgai/ha, Fluchloralin and Trifluralin @ 1.0 kg ai/ha (PPI), and Metalachlor, Pendimethalin, Clomazone@1.0 kg ai/ha were found effective in controlling the weed infestation in soybean. Post emergence (20-30 days after sowing) herbicide as chlorimuron ethyl@ 10 g ai/ha, Imazethapyr@ 100 g ai/ha, were found effective in controlling major monocot and dicot weeds in soybean whereas quizalofop ethyl@ 50 g ai/ha and fenoxyprop-p- ethyl@ 70gai/ha were found effective against grassy weeds in soybean. Use of weeds as mulch at 25-30 DAS gave effective weed control in soybean and also helped in soil and water conservation, least expensive than other methods of weed management. One hand weeding plus application of post emergence herbicide was found most effective and economical weed management practice in soybean during rainy season.

Nutrient management : Nutrient management play a crucial role in determining yield levels of soybean. For higher yield nutrients need to be applied at proper time in proper quantity and by proper method. Recommendation of 20: 60:40:: $N:P_2O_5:K_2O$ per hectare is developed for north plain zone. Among the secondary nutrients sulfur application @ 30 kg/ha as basal is found beneficial to obtain higher seed and oil yield in sulfur deficient soil. Among the micronutrients application of 5.0 kg Zn /ha and 0.5 kg Boron /ha as basal is recommended for higher yield in the area where these micronutrients are deficient in soil. Incorporation of crop residues @ 5 t/ha with FYM @5 t/ha + Zn @ 5kg /ha was recommended to improve soybean yield and soil physical /biological properties. Foliar application of N:P:K::19:19:19 @ 2 per cent at pod initiation stage resulted higher seed yield over control. Application of wheat straw mulch @ 5t/ha resulted in 21 per cent higher seed yield of soybean over no mulch application.

Growth Regulators: Growth regulators as Mapyquat chloride @ 250ppm, Biozyme granules @ 15 kg/ha, were evaluated for their performance over the years. Their application resulted in grain yield increase ranging from 2.4 per cent to 33.4 percent.

Front Line Demonstration: To demonstrate the latest production technologies at farmer's field front line demonstration were conducted every year in the soybean growing area. Front line demonstrations clearly indicate the yield advantage of the improved technology over farmers practice. In the last six 72 demonstrations of 0.4 ha each were conducted with improved technologies as latest varieties, Rhizobium inoculation, weed and nutrient management etc. The mean yield of last six year indicated that improved technologies (IT) resulted 20.4 per cent more grain yield over farmers practice and average incremental benefit cost ratio 1.90 was achieved. Farmers received Rs 5621/- per hectare/season additional return by adoption of improved production technologies.

Other Achievements

1. Soybean-wheat cropping system has been recommended for north plain zone as one of the most remunerative one as compared to Soybean lentil and soybean gram. Intercropping of soybean + pigeon pea was found to be more productive over Soybean+ maize and soybean + ragi.
2. Minimum tillage (two harrowing) is recommended

for soybean-wheat cropping system and it was found to be more productive and energy efficient.

3. Summer deep ploughing is recommended for effective weed and pathogen control for soybean cultivation during *Kharif* season.

4. In North plane zone area PS 1042 variety gives 15% higher yield at 30 cm row spacing than 45 and 60 cm row spacing.

5. Wheat yield in terms of SYE was significantly affected due to cropping system and nutrient management. 100% inorganic management of nutrients was at par with 50% organic + 50% inorganic and better than 100% organic system.

6. PS 1347 gave higher yield than SL 744, PS 1042 and SL 525 at varying levels of plant population (0.3 to 0.6 m plants /ha). After over a period of 7 years, 50% organic + 50% inorganic management system started showing higher soybean seed and wheat yield than other management practices and cropping systems.

7. Application of 125% RDF with FYM @ 5t/ha gave highest seed yield and also seed quality parameters like protein and oil content were also higher in it with PS 1347 variety of soybean under intensive cropping system.

8. Soybean seed yield was influenced due to varieties, spacing and seed rates. 45 cm gave higher seed yield than 30 and 60 cm with PS 1347 than SL 525. 75 kg seed /ha also gave maximum yield over 55 and 65 kg/ha.

2. Reasearch Publications:

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2. Chandel, A. S.; Singh, V. K. and Saxena, S. C. 1987. Suitability of soybean cultivars for maize + soybean intercropping. *Indian J. Agric. Sci.* 57(5):330-335.

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5. Chandel, A. S.; Pandey, K. N. and Saxena, S. C. 1988. Symbiotic nitrogen fixation and nitrogen benefits by nodulated soybean (*Glycine max* (L) Merrill) to interplanted crops in northern India. *Tropical Agriculture, 66:73-77.*

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14. Saxena, S. C. and Chandel, A. S. 1992. Effect of zinc fertilization on different varieties of soybean (*Glycine max* (L.) Merrill). *Indian Journal Agricultural Science.* 62(10):695-697.

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17. Surendra Singh; Chandel, A. S. and Saxena, S. C. 1995. Effect of phosphorus on total biomass, grain yield and nitrogen uptake in soybean (*Glycine max). Indian J. Agril Sci.* 65(6): 431-432.

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3. Thesis Research:

M.Sc. Ag. Agronomy

1. Hemant Singh Manral 1998, Effect of inorganic and organic sources of nutrients on growth and quality of soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr S.C.Saxena

2. Ashok Kumar Dey 2000, Response of soybean [*Glycine max* (L.) Merrill] + maize (Zea mays L.) intercropping to phosphorus nutrition under *Tarai* condition. to GBPUAT under supervision of Dr S.C.Saxena

3. Deepti 2002, Yield dynamic studies on plant population with respect to different varieties of soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr S.C.Saxena

4. Akanksha Gupta 2004, Intergrated weed management in soybean [*Glycine max* (L.) Merrill].to GBPUAT under supervision of Dr S.C.Saxena

5. Rajnish Singh 2005, Nutrient management in soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr S.C.Saxena

6. Vishar Kumar 2009, Evaluation of new herbicide molicules in soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr S.C.Saxena

7. Ashok Kumar Joshi 2011, Optimization of nutritional levels for newly released soybean [*Glycine max* (L.) Merrill] varieties under Tarai condition of Uttarakhand. to GBPUAT under supervision of Dr S.C.Saxena

8. Mukta Joshi 2012, Effect os seed rate , spacing and its economics of new released soybean varieties under Utarakhand. to GBPUAT under supervision of Dr S.C.Saxena

9. Nazim Hamid Mir 2013, Bio-efficacy of Flauzifop-P-Butyl 12.5% and Fomesafen 12.5% alone and in combination for total weed control in soybean. to GBPUAT under supervision of Dr Dheer Singh

10. Satendra Pratap Singh 2013, Integrated weed management in soybean. to GBPUAT under supervision of Dr S.C.Saxena

11. Debarati Datta 2016, Inpact of herbicides and mulch on weed and productivity of soybean under Tarai condition of Uttarakhand. to GBPUAT under supervision of Dr S.C.Saxena

12. Bandana Bhatt 2017, Effect of foliar nutrition on Soybean (*Glycine max.(L) Merril*) productivity under Tarai conditions of Uttarakhand. to GBPUAT under supervision of Dr S.C.Saxena

Ph. D. Agronomy

1. **1.** Rakesh Chandra Nainwal 2010, Evaluation of diclosulam and hayloxyfop for weed control in soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr S.C.Saxena

2. Priyanka Kabadal 2017, Nitrogen ans sulphur nutrition in Indian Mustard (*Brassica juncea*). to GBPUAT under supervision of Dr S.C.Saxena

4. Future Thrusts:

1. Evaluation of AVT-II entries of soybean for potential production under variable agronomic management practices. eg. Plant population, seed rate, spacing, date of planting, depth of sowing, sowing methods and nutrient requirement.
2. Screening of varieties for abiotic stress.
3. Weed management practices, integrated weed management practices and evaluation of new molecules for PPI, PE and PoE.
4. Use of plant residues as mulch for water and soil conservation.
5. Development of package and practices of soybean production technology with reference to lower /mid/high altitude of hill agriculture of Uttarakhand.
6. Production technology development of soybean under organic mode.
7. Studies on planting genotype and soybean based cropping systems.
8. Studies on micro and secondary nutrients of soybean under hill agriculture.
9. Studies on seed germination under variable environmental conditions.
10. Development of production technologies of various crops under soybean based cropping system.

C. Soybean Microbiology:

Soybean has occupied a unique place in the world for providing high quality protein and edible oil without extra application of nitrogenous fertilizer. It fixes atmospheric di-nitrogen in symbiosis with *Rhizobium japonicum/Bradyrhizobium japonicum* to meet most of its nitrogen requirement. The effective symbiosis depends upon the compatibility of host plant with rhizobia for the formation of effective nodules and fixation of atmospheric nitrogen for higher yield of soybean. To derive maximum benefit out of this association, it must be ascertained that sufficient number of nitrogen fixing bacteria are present in the soil, if not, then there is a need to inoculate the soybean seed with efficient strain of *Rhizobium japonicum* at sowing time. In 1966, at Pantnagar, it was found that the use of inoculants improved grain yield of soybean varieties. Once it had been established that inoculation was necessary for improving the yields, an all out effort was made to work on various aspects of soybean *R. japonicum* symbiosis. Research work on soybean microbiology at Pantnagar was started in mid-sixties with definite objectives in mind.

Objectives and mandate:

1. Evaluation of various *Rhizobium japonicum* strains on soybean varieties
2. To evaluate the performance of different composite cultures
3. To study the nitrate tolerance of rhizobial strains for nodulation in soybean
4. To study the influence of Arbuscular Mycorrhizal fungi (AMF), phosphorus solubilizing bacteria (PSB), plant growth promoting rhizobacteria (PGPR) and *B. japonicum* inoculation on nodulation, growth and yield of soybean
5. To evaluate the rhizosphere competence/ potentiality of AVT II entries of north plain zone for nodulation
6. To study the effect of integrated use of micro-nutrients and *B. japonicum* on nodulation and yield of soybean
7. To develop the multi-trait rhizobial isolates for soybean to harness the benefits under normal as well as abiotic stress conditions
8. To isolate and screen the PGPR especially fluorescent Pseudomonads to mitigate the abiotic stress

1. Significant Achievements:

- Seed treatment of soybean with *Bradyrhizobium japonicum* at sowing time was recommended for increased nodulation and yield of soybean

- Combined inoculation of *B. japonicum* either with PSB or AM-fungi enhanced soybean yield.
- Application of 40 kg P_2O_5/ha along with dual inoculation of *B. japonicum* either with PSB or AM-fungi was more beneficial.
- Inoculation of *B. japonicum* with micronutrients i.e. zinc @ 5 kg zinc sulfate/ha + B @5 kg borax/ha + Mo @ 4 g sodium molybdate /kg seed enhanced nodulation and yield of soybean.

2. Research Publications:

1. Pant, L. M.; Kumar, N. and Katiyar, A. K. 1990. Survival of single and composite strains of *Bradyrhizobium japonicum* on seed and soil. *Agril. Sci. Digest.,* 13: 163 – 165.
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6. Singh, M. and Kumar, N. 2007. Field evaluation of *Bradyrhizobium,* PSB and AM fungus on nodulation, nutrient uptake and yield of soybean. *Soybean Research,* 5: 14 - 20.
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8. Singh, M.; Kumar, N.; Mishra, A.; Sharma, V.; Raj, S. and Kumar, V. 2011. Effect of FYM, Vermicompost, Vermiwash and NPK treatments on growth, microbial biomass c and yield of soybean. *Journal of Farming Systems Research and Develompent,* 17: 137 - 144.
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11. Dwivedi, S. and Kumar, N. 2012. Effect of *Bradirhizobium japonicum* and PGPR inoculation on nodulation, growth and yield of soybean (*Glycine max* L. Merrill) in a Mollisol of Uttarakhand. *Pantnagar Journal of Research*, 10: 56 – 60.
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13. Singh, M. and Kumar, N. 2012. Effect of FYM, vermicompost, vermiwash and NPK on growth, microbial biomass and yield of soybean. *Soybean Research*, 10: 60 – 66.
14. Das, S.; Kumar, N. and Saxena, S. C. 2013. *In-vitro* effect of herbicides on the growth of *Bradyrhizobium japonicum* and phosphate solubilizing bacteria. *Pantnagar Journal of Research*, 11: 87 – 91.
15. Singh, M.; Kumar, N.; Kumar, S. and Lal, M.

2015. Effect of co-inoculation of *B. japonicum*, PSB and AM fungi on microbial biomass carbon, nutrient uptake and yield of soybean (*Glycine max* L. merril). *Agriways,* 3: 14 – 18.

16. Singh, M., Beura, K., A. K., Pardhan and Kumar, N. 2016. Efficacy of micronutrient application on potential of *Bradyrhizobium* in enhancement of growth and yield of soybean. *The Bioscan*, 11:309 - 314.

17. Singh, M., Beura, K., A. K., Pardhan and Kumar, N. 2016. 2015. Conjunctive organic and mineral fertilization- its role in nutrient uptake and yield of soybean under Mollisol. *The Bioscan*, 10: 1275 – 1279.

3. Thesis Research:

M. Sc. Ag. in Soybean Soil Science Microbiology

1. Mahendra Singh 2005, Influence of PSB and VA mycorrhizal inoculation on soybean–*Rhizobium* symbiosis. to GBPUAT under supervision of Dr. Narendra Kumar

2. Shalini Dwivedi 2006, Interactive effect of *B. japonicum* and PGPR on *Glycine max* - *B. japonicum* symbiosis and soil properties. to GBPUAT under supervision of Dr. Narendra Kumar

3. Babita Bhatt 2006, Symbiotic efficiency of native soilbradyrhizobia in soybean genotypes. to GBPUAT under supervision of Dr. Narendra Kumar

4. Gaurav Mishra 2010, Influence of fungicides and bio-agents on nodulation, growth, nutrient uptake by soybean grown on Mollisols. to GBPUAT under supervision of Dr. Narendra Kumar

Ph. D. Soybean Microbiology

1. Amit Mishra 2005, Organic was terse cycling through composting and their nutrient potential in soybean [*Glycine max* (L.) Merril]. to GBPUAT under supervision of Dr. Narendra Kumar

2. Mahendra Singh 2008, Effect of manures, fertilizers and micronutrients on nodulation, growth and yield of soybean [*Glycine max* (L.) Merril]. to GBPUAT under supervision of Dr. Narendra Kumar

3. Shrila Das 2011, Effect of nutrient management and post emergence herbicides on *Glycine max* – *Rhizobium* symbiosis and soil properties. to GBPUAT under supervision of Dr. Narendra Kumar

4. Future Thrusts:

1. Selection of promising multi-trait soybean rhizobial strains for wider range of soybean varieties.

2. Evaluation of rhizosphere competence/potentiality of AVT II entries of soybean for incorporation in breeding program for harnessing the microbes potential.

3. Isolation and screening of rhizobacteria capable of producing ACC deaminase antioxidant potential and phytohormones for developing inoculants to mitigate abiotic stress in soybean.

D. Soybean Entomology:

Soybean is an important crop of Uttarakhand. Its different varieties are grown in plains and hills of the state. To further aggravate the research in soybean entomology AICRP, soybean was started in G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, in 1967. The major pests of soybean in Uttarakhand are stem fly, tobacco caterpillar, Bihar hairy caterpillar, green semi looper, pod borer, leaf miner, whitefly, aphids and girdle beetle. The insect pests and diseases cause about s 32% yield loss to soybean. They infest the crop and cause damage from seedling to maturity stage. After analysing the alarming situation of insect pests on economy of soybean crops research program was started in Pantnagar with following objectives.

Objectives and mandate:

1. To study the seasonal incidence of insect pests of soybean.

2. Survey of insect pests and their natural enemies associated with soybean crop at farmers fields.

3. Collection and identification of insect pests and their natural enemies of soybean.
4. To develop an IPM module for insect pests of soybean.
5. To screen out the germplasm for identification of resistance source against insect pests of soybean.
6. To assess the economic losses caused by major insect pests to soybean.
7. To evaluate the efficacy of insecticides, entomopathogens and botanicals against major insect pests of soybean under field and laboratory conditions.
8. To study molecular diversity of soybean insect pests.
9. To study insecticide resistance in insect pests of soybean at farmers field.

1. Significant Achievements:

- A large variety of artificial diets have been developed for a variety of insects. This major breakthrough as incorporation of various chemical factors responsible for plant resistance in the diet which would indicate the behavior of these chemicals which would greatly help in developing high yielding resistant varieties either by direct breeding programme or through biotechnology.
- Intensive survey of insect mycopathogens in the major soybean growing areas of Kumaun region of Uttarakhand was carried out during 2014. The mycosised insect cadavers and soil samples from each location were collected during survey and brought to the laboratory, later on isolated and identified as *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi.* The prevalence of entomopathogenic fungi was maximum during August- November; mycosis was not reported in *rabi* season, 2014. The maximum mycosised insects recorded from various areas of Nainital district followed by Udham Singh Nagar and Almora districts. The occurrence of *B. bassiana* was observed on some beetles and defoliators of soybean. *T. orichalcea* was more susceptible to *N. rileyi* followed by *M. anisopliae*.
- **Stem fly resistant varieties:** Himso-558A, Himso-1509, MACS-94, MACS-176, JS-79-295, PK-327, MACS-410, JS 87-24, JS 87-59, PK 416, PK 1069, PK-1079, AMS-4-63, RKS-48, SL-443, MACS 212, JS 81-1625, JS 81-1625, JS8505, PK 1030, PK 1036, PS 564, PK 515, DS2705, DS 2708, JS 20-69, PS 1518, RVS 2007-6, MACS-1442, AMS 1003, MACS 1460, NRC 99, DSb 25, Himso 1685, JS 20-89, MACS 1370, MACS1410, NRC 97, PS 1518 NSO 81, KSO 245, MACS 1311, CSB 08-08, MACS 1336, TS 10 and SL 444.
- **Defoliator resistant varieties**

- Pubescence is one of the most important resistance factor in soybean crop and the genotypes resistant to Bihar hairy caterpillar and tobacco caterpillar were DS 2708, DSb 19, DSb 21, JS 20-41, JS 20-69, KDS 693, KDS 705, MACS 1407, MACS 1416, MAUS 612, MAUS 614, NRC 92, NRC 93, RKS 113, RVS 2001-18, SL 958, SL 979, SL 982, SL 688, PS 1092 and PS 1347. These varieties are having dense and pointed pubescence.
- The soybean genotypes namely JS 20-41, JS 20-69, KDS 708, MAUS 612, RVS 2001 -18, SL 979, SL 688, PS 1347, DS 2708, DSb 19, DS 2706, KDS 693 and PS 1518 contain high amount of phenols, flavonoids, antioxidants and protease inhibitors. They found resistant against *S.litura* and *S. obliqua.*
- The varieties resistant to girdle beetle were MACS1410, PS1283, DS 2207 and PS1042. The variety DSb 25 is resistant to pod borer.
- PS 1556 and PS 1572 showed **strong antixenosis** for *S. litura*.

- **IPM module**

Combination of maize as border crop, seed treatment with thiamethoxam 30FS@5ml/kg seed, foliar application of imidacloprid 17.8 SL @ 500ml/ha at 30-35 DAS and triazophos 40 EC @ 800 ml/ha

at 45-50 DAS recorded lowest mean whitefly population and highest grain yield in soybean.

2. Research Publications:

1. Bhatt, N. S. and Bhattacharya, A. K. 1976. Development of *Spodoptera littoralis* (Boisd.) (Lep., Noctuidae) at constant temperatures on two host plants. *Journal of Applied Entomology*, 80(1- 4): 201–206.
2. Bhattacharya, A. K.; Chaudhary, R.R.P. and Rathor, R.R.S. 1976. Susceptibility of several varieties of soybean to *Ephestia cautella* (Walker) (Lepidoptera: Phycitidae). *Journal of Stored Products Research*, 12(3): 143- 148.
3. Chaudhary, R.R.P.; Bhattacharya, A.K. and Rathore, Y.S. 1976. Use of systemic granular insecticides for the control of stem miner, *M. sojae* (Zehntner) and whitefly, *Bemisia tabaci* (Genn.). *Indian J. Ent*., 38: 207-209.
4. Bhattacharya, A. K.; Shri Ram and Chaudhary, R. R. P. 1977. Biology of *Thysnoplusia orichalcea* (Fab.) (Lepidoptera). *Sci. and Cul*., 43(4):173-174.
5. Chand, A. and Gaur, N. 2015. Comparative bioefficacy of neonicotinoid, synthetic pyrethroid and their mixture (Alika) against stemfly infestation in soybean, *Trends in Biosciences,* 8(11): 2975-2976.
6. Deshmukh, P. D.; Rathore, Y. S. and Bhattacharya, A. K. 1977. Studies on growth and development of Diacrisia obliqua Walker (Lepid.: Arctiidae) on sixteen plant species. *Journal of Applied Entomology*, 84(1-4): 431–435.
7. Chaudhary, R.R.P.; Bhattacharya, A.K. and Rathore, R.R.S. 1981. Usw of systemic insecticides for the control of stem fly *M. sojae* (Zehntner) and whitefly *Bemisia tabaci* (Genn.). *Indian J. Ent*., 43(2): 223-25.
8. Bhattacharya, A. K.; Rathore, Y. S.; Chaudhary, R. R. P.; Ram, S. and Rathore, R. R. S. 1986. Correlation between degree of damage caused by *Melanagromyza sojae* (Zehntner) and yield of soybean. *Indian J. Ent.*, 48(1): 1-6.
9. Kumar, S. and Bhattacharya, A. K. 1988. Influence of different row spacing on the incidence of some insects of soybean. *Indian J. Entomology*, 51: 1-7
10. Purwar, J. P. and Ram, S. 2004. Field efficacy of pest controlling agents from different origin against tobacco caterpillar, *Spodoptera litura* on soybean. *Indian J. Entomology*, 55(3): 382-385.
11. Purwar, J. P. and Yadav, S. R. 2004. Effect of bio-rational and chemical insecticides on stem borers and yield of soybean [(*Glycine Max* (L.) Merrill]. *Soybean Research,* 2: 54-60.
12. Purwar, J. P. and Yadav, S. R. 2004. Host ranges of Bihar hairy caterpillar, *S. obliqua*. *Indian J. Entomology,* 65(3): 382-385.
13. Neeta Gaur,J.P. Purwar and V.K Sharma(2005). Relative susceptibility of wheat germplasm to stored grain pests. *Indian J. Appl. Ent*,*19*(2), 118-122
14. N. Gaur & V. K Sharma (2006).Efficacy of some insecticides against wheat aphids. *Journal of Aphidology,20*(2),73-76.
15. Gupta, G. and Yadav, S. R. 2006. Cow Urine Efficacy Against Stem Borers And Cost Benefit In Soybean Production. *International Journal of Cow Science*, 2(2): 15-17
16. Neeta Gaur and Parul Chaudhary (2010). Bioefficacy of Lannate 40 SP (Methomyl) against leaf defoliators of soybean. *Ann. Pl.Protec Sci*.,18,510-511.
17. Neeta Gaur, Pooja Gangwar and Parul Chaudhary (2010). Insect pest complex associated with soybean (*Glycine max*) at Pantnagar. *Insect Environment*, 16(3), 110-111.
18. Gaur, N. and Chaudhary, P. 2010. Bioefficacy of methomyl 40 SP against leaf defoliators of soybean. *Annals of Plant Protection Sciences*, 18(2): 510-511.

19. Gaur, N.; Gangwar, P. and Chaudhary, P. 2010. Insect pest complex associated with soybean (*Glycine max*) at Pantnagar. *Insect Environment*, 16(3): 110-111.

20. Gaur, N.; Chaudhary, P; Kumar, J. and Pandey, A. K. 2011. Bioefficacy of Lannate 40 SP (Methomyl) against leaf defoliators of soybean. *Journal of Hill Agriculture,* 2(2): 224-226.

21. Pooja Gangwar, Neeta Gaur, and Parul Chaudhary(2011). Toxicity evaluation of Ememectin Benzoate against Tobacco caterpillar *Spodoptera litura* Fabricius. *Indian Journal of Entomology*,*25* (2), 107-109.

22. Parul Chaudhary, Neeta Gaur and A.K, Bhattacharya (2011). Age Specific life Table of *Samia Cynthia ricini* (Boisduval) on *Ricinus Communis*. *Indian Journal of Entomology,* 73(3),281- 282.

23. Gaur, N. and Chaudhary, P. 2012. Effect of indoxacarb against leaf defoliators of soybean. *Annals of Plant Protection Sciences*, 20(1): 210-211.

24. Parul Chaudhary and Neeta Gaur (2012). Rearing of eri silkworm on artificial diets. *Pantnagar Journal of Research* 10(2), 253-255.

25. Martoliya, H.; Gaur, N. and Chaudhary, P. 2013. Evaluation of germplasm against insect pests of soybean. *Bioinfolet*, 11(3): 464-465.

26. Pradeep Mishra and Neeta Gaur (2013).Effect of phosphorus, potassium and sulphur on yield attributes of linseed under the semi arid condition. *Pantnagar Journal of Research, 2*(3),461-463

27. Divyajyoti Pokhariyal, Neeta Gaur and Ranjeet Kumar(2013). Evaluation of novel insecticides against *Spilarctia oblique* under laboratory condition by leaf dip method, *Pantnagar Journal of Research,2*(3),464-465

28. Sharma Preeti and Gaur Neeta(2014). Role of Bio security in Plant Health Management, *Research Journal of Agriculture and Forestry Sciences, 2*(3), 1-4.

29. Gaur, N.; Sharma, P. and Nautiyal, A. 2015. Seasonal incidence of major insect-pests of soybean and their correlation with abiotic factors. *Journal of Hill Agriculture,* 6(1): 75-78.

30. Nautiyal, A; Gaur, N. and Sharma, P. 2015. Morphological parameters of soybean plant resistance to lepidopterous defoliators. *Journal of Hill Agriculture,* 6(1): 89-92

31. Nautiyal, A; Gaur, N. and Sharma, P. (2015). Morphological parameters of soybean plant resistance to lepidopterous defoliators. *Journal of Hill Agriculture, 6*(1), 89-92

32. PSharma, N Gaur, R Pandey (2015). Comparative study of medicinal plants on feeding behaviour of seven day old larvae of Tobacco caterpillar, *Spodoptera litura* (Fab.) and Bihar hairy caterpillar, *Spilarctia obliqua* (Walk.) *Journal of Applied and Natural Science*, *7* (1), 417-424.

33. Akanksha Chand and Neeta Gaur (2015). Comparative bioefficacy of neonicotinoid, synthetic pyrethroid and their mixture (Alika) against stemfly infestation in soybean. *Trends in Biosciences, 8*(11), 2975-2976

34. Bisht, K; Mishra, V. K. and Karnatak, A. K. 2015. Relative Resistance in Soybean Germplasms against Whitefly, (*Bemisia tabaci* Gennadius) and Yellow Vein Mosaic Virus Spread in Field. *International Journal of Agriculture, Environment and Biotechnology,* 8(4): 995-998.

35. Nautiyal, A; Gaur, N.; Singh, K. and Sharma,P. 2016. Effect of soybean plant phenols and flavonoid on the mean leaf area consumed by *Spodoptera litura* and *Spilosoma obliqua* larvae. *Journal of Applied and Natural Science*, 8 (4): 1931-1936

36. Mona Joshi, Neeta Gaur and Renu Pandey(2016). Suitability of different synthetic and non synthetic media for mass culture of entomopathogenic fungi, *Beauveria bassiana* (Balsamo) Vuillemin. *International Journal of*

basic and applied agricultural research, *14*(1), 20-23.

37. Nautiyal, A; Gaur, N.; Singh, K. and Sharma, P. (2016). Effect of soybean plant phenols and flavonoid on the mean leaf area consumed by *Spodoptera litura* and *Spilosoma obliqua* larvae. *Journal of Applied and Natural Science*, *8* (4), 1931-1936

38. Pandey, A.K. 2016.Evaluation of pre sown application of granular insecticides against white grub (*Holotrichia longipennis*) infesting soybean grown under rain-fed condition of uttarakhand hill. *J. ent. Res*., 40 (2):169-172.

39. Preeti Sharma and Neeta Gaur (2017). Detrimental effect and GC-MS analysis of some plant oils against Polyphagous pests *Spodoptera litura and Spilarctia obliqua*. *Legume Research*.

40. Swathi, M.; Gaur, N. and Mishra, P (2017). Bioefficacy of emamectin benzoate 1.9%EC against green semi looper, *Thysanoplusia orichalcea* (Fabricius) on soybean. *New Agriuculturist*, *28*(1), 79–82.

41. Swathi, M. and Gaur, N. (2017). Effect of border crops and insecticides on management of whitefly, *Bemisia tabaci* (Gennadius) transmitted Yellow Mosaic Virus in soybean. *International journal of current microbiology and applied sciences, 6*(5), 612-617.

42. Kalpana Bisht, Sunil Kumar Yadav, A. K. Karnatak and Neeta Gaur(2017). Resistance against whitefly *Bemisia tabaci* and yellow vein mosaic vius in soybean. *Indian Journal of Entomology, 79*(4),535-537.

43. Joshi Rashmi and Gaur Neeta(2018). Repellent Activity of Essential Oil from Tulsi Plant against Lesser Grain Borer, *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) and Red Rust Flour Beetle, *Tribolium castaneum* Herbst, (Coleoptera: Tenebronidae). *Int. J. Curr. Microbiol. App. Sci. 7* (02),157-160.

44. Neeta Gaur, Priyanka Kohli, Ashish Devrani, Rukesh Pramod KN and Renu Pandey (2018). Laboratory studies on antibiosis and antixenotic effect of soybean [*Glycine max* (L.) Merrill.] against *Spilarctia obliqua* (Walker). *Journal of Entomology and Zoology Studies* 2018; 6(2), 663-668.

45. P Suyal, N Gaur, A Devrani (2018). Seasonal incidence of insect pests and their natural enemies on soybean crop. *Journal of Entomology and Zoology Studies, 6* (4), 1237-1240.

46. M Joshi, N Gaur, R Pandey (2018). Compatibility of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* with selective pesticides. *Journal of Entomology and Zoology Studies, 6*(4), 867-872.

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48. K Nidhi, N Gaur, R Pandey (2018). A survey of the local isolates of entomopathogenic fungi in Uttarakhand region. *Journal of Entomology and Zoology Studies, 6*(1), 1725-1730.

49. Gaur, N and Swathi, M. (2018). Pests of wheat. In Omkar (Ed.),Pests and their management (pp. 81-97).Singapore: Springer.

50. Gaur, N and Swathi, M. 2018. Pests of Soybean. In Omkar (Ed.),Pests and their management (pp. 137-162).Singapore: Springer.

51. Neeta Gaur and Preeti Sharma. September, 2015. Rabi phasalo me keet vyadhi prabandan. *Khaad patrika*. 49-51.

52. Neeta Gaur, Kamendra Singh and Preeti Sharma. May, 2016. Soybean ke pramukh keet avam unka prabandan. *Kisan bhaarti*. 47(8): 30-31

53. Neeta Gaur, Preeti Sharma and Anchala Nautiyal. May, 2016. Soybean insect pests and their management. *Indian Farmer's Digest*. 49(5): 35-36

54. Manual "Field diagnosis of insect pests in crops".

2016. Department of Entomology, College of Agriculture, G. B. Pant university of Agriculture and Technology, Pantnagar.

3. Thesis Research:

M.Sc. in Entomology

1. Sathish Kumar 1981, Incidence of insects associated with soybean in different plant spacing and intercropping system. to GBPUAT under supervision of Dr. A. K.Bhattacharya
2. S.K. Sachan 1983, Susceptibility of soybean germplasm to cigarette beetle *Lesioderma cerrieone*(Fab). to GBPUAT under supervision of Dr. G.C. Sachan
3. Rehman 1985, Susceptibility of soybean germplasm to *Melanogromyza sojae*(Zehnter). to GBPUAT under supervision of Dr. M.S. Khalsa
4. A.K. Singh 1986, Efficacy of various insecticides against major insect-pests of soybean, *Glycine max* (L) Merril. to GBPUAT under supervision of Dr .V. K. Sharma
5. Sanjay Sharma 1993, Relative susceptibility of soybean varieties and soya products to *Lasioderma semicorne* (Fabricius) and developmental behavior of *Tribolium castaneum* on soya products. to GBPUAT under supervision of Dr. A. K.Bhattacharya
6. Arun Kumar Singh 1996, Efficacy of various insecticides against major insect pests of soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr. Shri Ram
7. Arbind Kumar 1997, Efficacy of neem based products in comparison to triazophos against major pest of soybean. to GBPUAT under supervision of Dr. Shri Ram
8. Abebe Megersa 1999, Comparison of newer and traditional methods to control the insect pests of soybean. to GBPUAT under supervision of Dr. Shri Ram
9. Raj Kumar 2000, Efficacy of different management strategies to control lepidopterous defoliators associated with soybean. to GBPUAT under supervision of Dr. Shri Ram
10. J.P. Purwar 2001, Evaluation of bio-rational pesticide against major insect-pest of soybean. to GBPUAT under supervision of Dr. Shri Ram
11. Garima Mangalik 2002, Field-efficacy of cow urine in comparison to chemical and bio-pesticide against major insect-pests of soybean . to GBPUAT under supervision of Dr. Shri Ram
12. Poonam Chialna 2003, Effectiveness of cow urine and its decoctions against major insect-pests of soybean. to GBPUAT under supervision of Dr. Shri Ram
13. Rohit Malik 2004, Comparison of newer and traditional methods to control the insect pest of soybean. to GBPUAT under supervision of Dr. Shri Ram
14. B. Mallangouda 2005, Field efficacy of cow urine and its decoctions as well as it's mixtures with triazophos against the insect pest of soybean. to GBPUAT under supervision of Dr. Shri Ram
15. Rachna Pandey 2006, Comparative study and compatibility of neem seed kernel extract with biopesticides and its efficacy with different additives against major insect pests of soybean. to GBPUAT under supervision of Dr. Shri Ram
16. K.K. Panda 2007, Efficacy of some insecticides against major insect pests of soybean and their impact on natural enemies. to GBPUAT under supervision of Dr. Shri Ram
17. V.V. Nisal 2007, Comparative Efficacy of some newer insecticides and *Bacillus thuringiensis* var. *Kurstaki* against major insect pests of soybean and their impact on natural enemies. to GBPUAT under supervision of Dr. R.S.Bisht
18. Pooja Gangwar 2010, Efficacy of some novel insecticides on major insect pest of soybean and their impact on natural enemies. to GBPUAT under supervision of Dr. Neeta Gaur
19. Hemlata Martoliya 2011, Evaluation of some

germplasm and novel insecticides against insect pests of soybean. to GBPUAT under supervision of Dr. Neeta Gaur

20. Divyajyoti Pokhriyal 2011, Comparative efficacy of some insecticides against insect pests of soybean under field condition. to GBPUAT under supervision of Dr. Neeta Gaur

21. Akanksha Chand 2012, Bioefficacy of some neonicotinoidorganophosphates and pyrethroids against insect pests of soybean. to GBPUAT under supervision of Dr. Neeta Gaur

22. Asha Vishwakarma 2013, Screening of some soybean germplasm against Pulse beetle ,Callosobruchus chinensis (Linnaeus). to GBPUAT under supervision of Dr. Neeta Gaur

23. Kalpana Bisht 2013, Population dynamics, relative resistance in soybean germplasm aginst whitefly (*Bemisia tabaci*) in field and pulse beetle (*Callosobruchus chinensis*, Bruchidae Coleoptera) infestation under storage conditions. to GBPUAT under supervision of Dr. A. K. Karnatak

24. Sandeep Kaintura 2014, Bioefficacy of Emamectin benzoate, indoxacarb and chlorantraniliprole against major insect pest of soybean and their ffect on natural enemies. to GBPUAT under supervision of Dr. A. K. Karnatak

25. Mona Joshi 2014, Studies on Entomopathogenic fungi against major Lepidopteran insect pest from Soybean growing areas of Kumaun Uttarakhand. to GBPUAT under supervision of Dr. Neeta Gaur

26. Kiran Negi 2014, Seasonal incidence of major insect pest and their natural enemies on soybean and Bio-efficacy studies of some novel insecticides against them. to GBPUAT under supervision of Dr. Neeta Gaur

27. Km.Nidhi 2015, Distribution, Occurrence and Genetic characterization of local isolates of Entomopathogenic Fungi in Uttarakhand region and their Pathogenicity to Lepidopteran pest. to GBPUAT under supervision of Dr. Neeta Gaur

28. Preeti Shrma 2015, Exploration of detrimental effect of plant products on *Spodoptera litura* (Walk.), *Spilarctia obliqua* (Walk.) and *Helicoverpa armigera* (Hub.). to GBPUAT under supervision of Dr. Neeta Gaur

29. Anchala Nautiyal 2015, Screening of soybean genotype against Lepidopteran pests through morphological, biochemical and molecular basis. to GBPUAT under supervision of Dr. Neeta Gaur

30. Ms. Swathi Mogalapu 2017, Studies on Transmission of Yellow Mosaic Virus and Management of its Vector Whitefly [*Bemisia tabaci* (Gennadius)] in soybean [*Glycine max* (L.) Merill]. to GBPUAT under supervision of Dr. Neeta Gaur

31. Ms. Deepshikha Karayat 2017, Morphological characterization îf gårmplasm and åffåctivånåss îf nåwår insåcticidås against whitåfly, *Båmisia tabaci* (Gånnadius) in Sîybåan [*Glycinå max* (l.) Mårrill]". to GBPUAT under supervision of Dr. Neeta Gaur

32. Priyanka Kholi 2017, Laboratory studies on antibiosis and antixenotic on soybean [*Glycinå max* (l.) Mårrill]"against *Spodoptera litura* (Fabricius) and *Spilarctia obliqua* (Walker). to GBPUAT under supervision of Dr. Neeta Gaur

33. Rukesh Pramod Continuing from 2015, Studies on resistance of Tobacco caterpillar (*Spodoptera litura* (Fab.)) collected from major districts of Uttarakhand to major insecticides. to GBPUAT under supervision of Dr. Neeta Gaur

34. Ms. Parul Suyal 2018, Studies on Seasonal incidence of insect pests and natural enemies and Evaluation of different IPM modules against major insect pests on Soybean at Pantnagar. to GBPUAT under supervision of Dr. Neeta Gaur

Ph.D. in Entomology

1. Shri Ram 1987, Effect of manual and insect

defoliation on the yield of soybean. to GBPUAT under supervision of Dr. A. K. Bhattacharya

2. Kuldeep Sharma 2003, Efficacy of insect growth regulators against major defoliators of soybean. to GBPUAT under supervision of Dr. Shri Ram

3. Vaibhav Mathu 2013, Seasonal incidence and screening of soybean cultivars and efficacy of chlorantrailiprole 18.5 SC against major insect pests. to GBPUAT under supervision of Dr. R. S. Bisht

4. Mona Joshi 2014, Studies on entomopathogenic fungi against major lepidopteran insect pests from soybean growing areas of Kumaun Uttarakhand. to GBPUAT under supervision of Dr. Neeta Gaur

5. Anchala Nautiyal 2015, Screening of soybean genotype against major lepidopteran pests through morphological, bio-chemical and molecular basic. to GBPUAT under supervision of Dr. Neeta Gaur

6. Swathi Mogalapu persuing, Studies on transmission of yellow mosaic virus and management of its vector whitefly [*Bemisia tabaci* (Gennadius)] in soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr. Neeta Gaur

7. Rukesh Pramod persuing, Survey and identification of gut micro organisms of *Spodoptera litura* (Gabricius) [Noctuidae: Lepidoptera] on soybean [*Glycine max* (L.) Merrill]. to GBPUAT under supervision of Dr. Neeta Gaur

4. Future Thrusts:

1 Survey and surveillance study of major insect pests of soybean in Uttarakhand.

2 Evaluation of AVT-II entries of Soybean for resistant against defoliators, *M.sojae* and yellow mosaic virus disease for their effective managaement in field conditions.

3 Development of forecasting module for major pests of soybean in Uttarakhand.

4 Studies on life cycle of menacing pests of soybean in Uttarakhand.

5 Antibiosis and antixenosis studies on major defoliators of soybean in Uttarakhand.

6 Development of integrated management practices against different insect pests of soybean.

7 Management of defoliators by using plant and animal derived products.

8 Studies on morphological screening, biochemical tests like phenol, flavonoid, antioxidant, trypsin inhibitor content using GC-MS analysis and RAPD analysis of the major cultivars for field resistance against major insect pests of soybean.

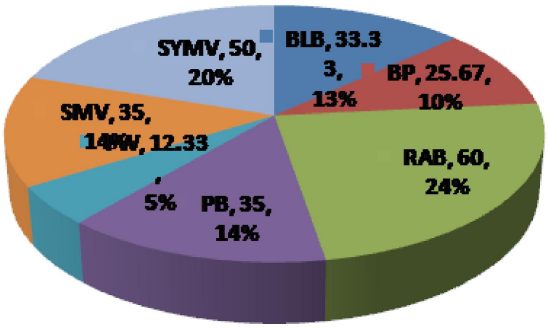
9 Molecular identification of different insect pests of soybean.

10 Insecticide resistance biochemical and molecular studies in different insect pests of soybean.

E. Soybean Pathology

1. Significant Achievements:

➢ Prevalence and severity of various important diseases of soybean growing areas of Uttarakhand during last fifty years from July to September. As can be seen in Fig. 1, the BLB, BP, RAB, PB, SMV and SYMV were found to be evenly spread in all the farmers' fields that were surveyed. The diseases like SMV, SYMV, BP, Fusarium wilt and RAB were appeared in 1st week of August to mid of August but BLB, Anthracnose pod blight and Charcoal rot were noticed in 1st week of September to mid of October. The first symptoms of SMV and SYMV were recorded on leaves in 2nd week of August



in unsprayed field. The incidence of SMV ranged between 30 to 40 per cent on foliage while SYMV was observed in between 45 to 55 per cent on leaves The RAB was found to be more prevalent and wide spread in all the soybean growing areas and its incidence was estimated maximum in susceptible cultivars which ranged from 15 to 60 per cent in Tarai region. Pantnagar was observed as the hot spot for RAB having maximum disease incidence and severity of 57.67 and 59.66 per cent which was significantly higher than other places of Uttarakhand. This disease is favoured by high temperature (>25ºC), high water table and relative humidity and these environmental conditions prevails in soybean growing areas in zone I of Uttarakhand (nine weeks after sowing), when the crop is at vulnerable stage for RAB. High temperature, cloudy conditions with high relative humidity are favourable for the development and spread of RAB. During last fifty years of survey report, RAB was observed to be a major problem in foot hill areas of Uttarakhand and Pantnagar has been considered as a hot spot of the disease. Not only now, it was found that the disease had gained attention since 1980's when its severity was high (AICRP, 1980). The disease like bacterial pustule, bacterial blight, and *Rhizoctonia* aerial blight were rapidly spread between Septembers to October in unsprayed field. Pod blight was noticed in 3rd week of September and spreads rapidly in the month of October.

- A large number of fungi like species of *Pythium, Phytophthora, Colletotrichum, Aspegillus, Fusarium, Macrophomina, Monilia etc.* and a few bacterial species of *Pseudomonas*, *Bacillus* etc. have been observed to be responsible for seed and seedling rots in soybean. These organisms are both, seed- and soil- borne in nature. *Fusarium*, *Pythium*, *Phytophthora* and *Rhizoctonia* are the most common of these early season pathogens. The early season soybean diseases can be managed by soil solarization for a period of 30 days during May-June under Pantnagar conditions which has been found significant in reducing the seed and seedling rots. The seed treated with Thiram 4.5 g/kg or Thiram 75 W.P + Bavistin 25 S. D. (1:1, w/w) @ 3 g/kg seed effectively controlled these rots and significantly improved seedling emergence crop stand and yield. Soybean seed treated with different fungicides and inoculated with *Rhizobium japonicum* planted at 0, 4, 24 and 48 h after treatment to observe the treatment effect on emergence, nodulation and yield exhibited significant increase in emergence and nodulation with Thiram, Bavistin, Difolatan and Dithane M-45. All fungicides used, enhanced the yield of soybean. Delay in planting of the fungicides treated and *Rhizobium* inoculated seeds, reduced the emergence and nodulation of soybean with the reduction depending on the fungicide used for seed treatment. Before sowing soybean seeds should be treated with fungicides, Thiram + Carbendazim (2:1 ratio) @ 3g/kg seeds or bioagents i.e. *Trichoderma harzianum* + *Pseudomonas fluorescens* (1:1 ratio) @ 10 g/kg seeds at least 12 hrs before planting of seeds for controlling seed and seedling rots and ensuing higher field emergence.

- Rhizoctonia aerial blight of soybean caused by *Rhizoctonia solani* Kuhn is a very common disease affecting most of the soybean cultivars in the warm humid 'Tarai' region of Uttarakhand and Uttar Pradesh. RAB was observed to be a major problem in foot hill areas of Uttarakhand. The disease development had three distinct phases i.e. establishment, progress and decline phases. The favorable time of RAB development was observed to be 35 SMW and after the 38 SMW the disease increased at a drastic rate and attained maximum disease at 42 SMW based on the presence of suitable environmental conditions for disease initiation and spread. The maximum progression was observed between R3 (Pod initiation) and R4 (Full pod) stage (60-74 days). The disease severity increased from 53 days at R1 (flowering) stage to 81 days when crop reached at maximum R6 (seed filling) stage and further to 95 days at R7 (physiological maturity) stage. The progress was slower in the beginning of September while it increased at a drastic rate

in the last week of September i.e. from 22nd to 29th September after which the increase was again at a slower rate. The rise in infection rate in the initial stage of disease was slow in the 1st and 2nd week of September. This was followed by rapid progress of the disease due to favourable weather conditions and reaches maximum in most of the cultivars but declined later due to reduction in temperature and fall in relative humidity and decrease in the hours of bright sunshine. The lowest disease severity of 3.20 per cent recorded on 53 days old plants while it was highest (52.02 %) on 95 days old plants. Among various environmental factors, maximum temperature, maximum relative humidity, rainfall and sunshine influenced the initiation and development of RAB. The high temperature (>32 ºC), RH morning (>88 %), rainfall (>14 mm) and sunshine (6.5 hrs) were most deciding factors for the development of RAB on all the varieties in developing the regression model during the mean values of several year data. The varieties JS-72-220, PK-262 and PK-472 were considered as moderately resistant to RAB whereas JS-7244, JS-7546, Bragg, Monetta, VLS-58 and JS-335 may have rate reducing components.

- Pyraclostrobin (0.1%), Pencycuron (0.1%) and Fluopyram (0.1%) were most effective in reducing RAB disease index while antagonist treatment with *T. harzianum, P. fluorescens* and *B. subtilis* were least effective in controlling *R. solani*. Chemical control with Strobulin and Triazole group of fungicides were most effective against *R. solani* in field but its efficiency was slightly influenced by the prevailing environmental conditions. Maximum yields were obtained from the plots receiving two sprays of Pyraclostrobin (29.30 q/ha), Fluopyram (29.21q/ha) and Pencycuron (29.10 q/ha) which was 43.56, 43.12 and 42.87 per cent more over the control. Cost benefit ratio of the treatment Pencycuron (0.07:1) was superior followed by Hexaconazole (0.08:1), Pyraclostrobin (0.12:1) and Chlorothalonil (0.13:1) suggesting their economic feasibility as chemicals effective for management of Rhizoctonia aerial blight. The maximum oil content was observed in Azoxystrobin (21.60%) and minimum in Myclobutanil (18.45 %) treated plots while highest protein content was recorded in Pyraclostrobin (37.95 %) and Myclobutanil (37.95 %). Strobulins have higher positive impact on the qualitative traits of the soybean seeds improving seed health by various mechanisms.
- Out of the nine soybean seed samples harvested from the field treated with different fungicides, Myclobutanil was found to have 0.21ppm residue in the sample while Axozystrobin had 0.0071ppm residue while the other fungicides were found to have residue below the detection limit. All the residues were below the permissible minimum residue limit (MRL) set by the international standards implicating their safe consumption. Elicitor compounds including chemicals, hormones and bioagents increased the accumulation of defense compounds viz. H_2O_2, APX, POD, PPO, SOD and PAL, initiating a whole array of defense mechanisms thereby inducing induced systemic resistance (ISR). All the elicitor biomolecules decreased the endogenous content of xylanase, laccase and cellulase to a greater extent, which have been reported as pathogenic determinants and assist pathogen attack. So reduction in their concentration strengthens the plant defense.
- Different Integrated Disease Management (IDM) modules were tested against RAB in which combined use of cultural practices (deep summer ploughing), chemical method (seed treatment with carbendazim @2g/kg seed + foliar spray of carbendazim @0.05% at 30 DAS + P.E. soil application of herbicide i.e. pendimethalin @ 1.0 kg a.i. /ha) + Use of organic matter as vermicompost under biosuppression have been proved a better combination for reduction of disease intensity of rhizoctonia aerial blight and to increase the yield of soybean. Sugarcane bagasse and Neem cake (De-oiled) amended soil extracts were found very effective against *Rhizoctonia solani*, causing aerial blight of soybean *in-vitro*. Neem cake amended soil, inoculated with *Rhizoctonia solani* gave

maximum percentage (91.47%) of seed germination and suppressed the seed and seedling rot caused by *R. solani* under green house conductions.

- Pod blight caused by *Colletotrichum truncatum* or *Colletotrichum dematium* (Pers, ex Fr.) Grove var. *truncatum* (Schw.) Arx or *C. dematium* var. *truncata* (schw.) Andrus and Moore is a very serious problem in varieties that mature during rainy period. The infected seeds colonized by fungus may appear dirty with irregular brown areas or small uneven grey areas with black speck. The symptoms appear on stems, pods and leaf petioles as irregularly shaped brown blotches. The disease was severe, leaf rolling, premature defoliation and plant look like stunted. Pods may be shriveled and contain less seed or no seed. The most conspicuous effect of the disease is the production of shrivelled, diseased, poor quality grains which is worthless as a seed material. Seed rot, seedling decay, stem blackening, leaf spot, pod blackening and blight are the major symptoms. Young pods shrivel and do not form good seed. Number of acervuli develops in rings on pod surface, ultimately lead to blackening. Among the fourteen varieties / cultivars screened against anthracnose, var. Kalitur has been identified as resistant and PK 1029 as moderately resistant. Removal of plant debris, deep summer ploughing and sanitation practices found effective in reducing the pod blight. Seed dressing with Thiram (3g) or Thiram (1.5g) + Carbendazim (1g) per kg seed is most effective against pod blight. Six weekly foliar sprays of Zineb (2.5 kg/ha) starting at 30 days after planting significantly reduced the disease but effect on yield was non-significant. The average reduction in seed yield, protein and fat to the tune of about 34, 13 and 3 percent, respectively in a susceptible cultivar (Shilajeet)**.** Crop rotation to non host crops is a proven strategy to reduce anthracnose inoculums in a field.

- Bacterial pustule disease caused by *Xanthomonas compestris* pv *glycines* and affects large number of soybean varieties. The disease reduces the yield up to 38 per cent as well as protein content in the grains. As the disease progresses, small brown-colored pustules form in the middle of the spots and the spots turn yellow. The spots may merge, forming large irregularly yellowing lesions. Bacterial pustule lesions are sometimes confused with the lesions caused by bacterial leaf blight. Bacterial leaf blight lesions appear water-soaked while the lesions of bacterial pustule do not. As in other bacterial diseases, if a soybean leaf with lesions due to bacterial pustule is cut and submerged in water, bacteria will stream out of the infected tissue. A coordinated chemical control field trial conducted for several years revealed that two high volume (1000 1/ha) foliar sprays, at 45th and 55th day after planting with a mixture of Blitox-50 (1.5 kg/ ha)+ Agrimycin-100 (150 g/ha) or Streptocycline (150 g/ha) + Copper sulphate (1 kg/ha) are adequate for the effective control of the disease with consequent yield increase. Two sprays of Copper oxychloride @ 0.2% + Streptocycline @ 0.01% at 45 and 55 DAS were also found effective against this disease.

- Charcoal rot is also called as dry root rot or dry weather wilt was one of the major constraint in soybean cultivation. It is a major root inhabiting fungal problem responsible for losses up to 70 per cent in Uttarakhand in early years, resulting in poor seed quality and yield in hot dry weather. Charcoal rot is soils borne root and stem disease of soybean that develops in the mid to late summer when plants are under stress, especially heat and drought stress. Infected plants may die prematurely and are often wilted and stunted. The tap root portion show light grey discolouration of epidermal and sub-epidermal tissues. After peeling off the skin of infected roots the black charcoal like powder with numerous microsclerotia and pycnidial fruiting bodies of *M. phaseolina* are visible. The fungus causes a reddish brown discolouration in the vascular tissue of the tap root and progresses upward. Among bioagent tested, *Trichoderma harzianum* was found to be more effective as compared to *T. viride* and *Gliocladium virens*. Integration of

Vitavax (0.1%) with *T. harzianum* (0.3 %) improves seedling emergence, plant population, number of branches per plant, number of buds/ plant, root nodulation, height of plant and increase in yield. Removal of plant debris, deep summer ploughing and sanitation reduces the disease incidence. Seed dressing with Thiram (4.0 g/Kg) or Thiram (1.5 g/ kg) + Carbendazim (1.5 g/kg) prior to sowing reduces seed borne inoculums and maintains good plant stand.

- Soybean mosaic virus (SMV) is seed borne in nature and caused by Soja virus-1. SMV can cause yield loss, affect seed quality, and reduce seed germination and nodulation. Yield reductions are generally low and infections late in the season cause little damage in Uttarakhand. Plants infected early in the season are stunted, with shortened petioles and internodes. Leaves are reduced in size, puckered and remain darker than the normal leaves. Dark green enations along the veins is a common feature. The common aphid species are *Myzus persicae* and *Myzus convolvuli solani*. The virus is also transmitted through seeds and can remain viable in seeds for at least two years. Higher activity or populations of aphids favor virus transmission. Infected pods remain small, flat, deformed with few mottled seeds which are brown to black in colour. Foliar sprays of Monocrotophos (0.1%) at 15-20 days interval to check the activity of aphids. Planting early in the season may be helpful in North Plain region. Roughing of infected plants in field and use of soybean mosaic free seeds.

- Soybean yellow mosaic virus **(SYMV)** was a major disease problem in this area when soybean project was started. Soybean yellow mosaic disease caused by the Mungbean Yellow mosaic virus (MYMV) is the most important disease of soybeans in the northern plain zone of India. The only means of its spread is by a small white-fly (*Bemisia tabaci* Genn.) during July-August when the white fly population is high. It is not transmitted through seed. Both, the virus and the insect vector are common in case of yellow mosaic disease of soybean and other *Kharif* pulses like urd, moong, arhar, etc. Soil application of systemic insecticide granules in two split applications, at planting and 1 month later were tried to simplify the chemical control. Both, Phorate 10 G (25 kg/ha and 12.5 kg/ha) and Furadan 3 G (17.5 kg/ha) gave significant control of disease and increased the yield also. Integrated Disease Management (IDM) module based on combined use of cultural practices i. e. barrier crop of maize on borders + use of chemicals i.e. seed treatment with Thiamethoxam 70ws @ 3g/kg seeds + spray of herbicide i.e. Imazethapyr 100 g a.i. /ha in soybean plots and on bunds at 25 DAS + vector management i.e. by use of sticky traps 15 DAS + spray of Quinalphos @ 2 ml/l of water at 30 DAS significantly reduced the white-fly population, disease intensity of soybean yellow mosaic and increased the yield of soybean.

- Bacterial blight (BLB) was observed on stem, petioles and pod but most conspicuous on leaves. Small, angular, translucent, water-soaked spots surrounded by a chlorotic halo appear on the leaves. The brown or black centers of these spots indicate that the tissue is dying. Typically these spots will enlarge and merge to form large, dead patches on the leaves. The centres soon dry out, turn reddish brown to black and are surrounded by a yellowish green halo. As the disease advances defoliation of leaves may occur. Large, black lesions develop on stems and petioles. Pod lesions are dark brown to black in colour, enlarge and coalesce to cover much of the pod. Seeds become infected and may eventually cover with a slimy bacterial growth. Seeds may shrivel and develop sunken or raised lesions or become slightly discolored. *Pseudomonas savastanoi* pv. *Glycinea*, the causal bacterium is motile, gram negative, rod-shaped with rounded ends, one to several polar flagella. The incidence of BLB have been observed from this area as 20 to 46 per cent depending on the environmental conditions. Foliar spray of Cu-based fungicides (0.3%) + Streptocycline (0.01%) at the time of disease appearance is effective against bacterial blight. Usage of resistant cultivars in the proper environment is therefore an effective way of

eliminating the impact of this pathogen.

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3. Thesis Research:

M.Sc. Ag. in Plant Pathology

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3. R.K. Malhotra 1971, Physiological and pathological studies with *Colletotrichum truncatum* causing pod blight disease in soybean. to GBPUAT under supervision of Dr. C. Chaturvedi
4. K.P. Singh 1973, Soybean rust: Symptoms, etiology and chemical control. to GBPUAT under supervision of Dr. P.N. Thapliyal
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6. N.N. Choudhary 1977, Chemical control of anthracnose (pod blight) of soybean caused by *Collectotrichum dematium* (Pres. Ex Fr. Grover var. truncate (Schw) Arx. to GBPUAT under supervision of Dr. P.N. Thapliyal

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10. S.P. Singh 1984, Studies on compatibility between seed treatment fungicides and *Rhizobium* inoculum in soybean. to GBPUAT under supervision of Dr. V.K. Agarwal

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14. Bijendra Kumar 2001, Studies on certain aspects of anthracnose of soybean caused by *Colletotrichum dematium* var. *runcate* (Schoo)Andrus & Moone. to GBPUAT under supervision of Dr. K.S. Dubey

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17. Sachin Tomer 2002, Variation in isolates of *Colletotrichum dematium* var. *trancata* the causal organism of soybean pod blight. to GBPUAT under supervision of Dr. P. Kumar

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19. Neetu Rani 2003, Studies on some aspects of bacterial blight of soybean caused by *Pseudomonas savastanoi* pv. *Glycinea*. to GBPUAT under supervision of Dr. P. Kumar

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23. Priyanka Mehta 2007, Chemicals, botanicals and bio-agents against *Fusarium oxysporum* the cause at seed rot of soybean. to GBPUAT under supervision of Dr. KarunaVishunavat

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27. Meenakshi Rana 2012, Anthracnose of soybean symptomology etiology and management. to GBPUAT under supervision of Dr. K.S. Dubey

28. Kalpna Gairolo 2013, Drechslera blight of Soybean Symptomology, Etiology and management. to GBPUAT under supervision of Dr. K.S. Dubey

29. Ms. Mamta 2014, Studies on mango diseases under Tarai region of Uttarakhand. to GBPUAT under supervision of Dr. K P Singh

30. Mr. V S Yadav 2015, Prevalence of guava wilt in Tarai regions of Uttarakhand and its management. to GBPUAT under supervision of Dr. K P Singh

31. Ms. Kumari Surbhi. 2017, Epidemiology and molecular characterization of soybean genotypes for identification of resistant sources against Rhizoctonia aerial blight. to GBPUAT under supervision of Dr. K P Singh

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2. K.S. Dubey 1988, Physiological and pathological studies on *Rhizoctonia solani* Kuhn causing aerial blight of soybean. to GBPUAT under supervision of Dr. P.N. Thapliyal

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4. R. Pant 1998, Biological control of seed and seedling rot complex of Soybean. to GBPUAT under supervision of Dr. A.N.Mukhopadhyay

5. G. P. Jastap 1999, Pod blight of soybean: variability in causal fungus *Colleto*trichum *truncatum* (Schw) Andrus and Moore and disease management. to GBPUAT under supervision of Dr. P.N. Thapliyal

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7. Anjana Ray, 2006, Studies on cultural and physiological characteristics of *Rhizoctonia solani* Kuhn and management of the aerial blight of soybean. to GBPUAT under supervision of Dr. P. Kumar

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9. Mamta Mathpa 2016, Epidemiology and management of Rhizoctonia aerial blight of soybean (*Glycine max* L. Merrill). to GBPUAT under supervision of Dr. K P Singh

10. Supriya Gupta 2016, Studies on epidemiology and post harvest management of Mango Anthracnose. to GBPUAT under supervision of Dr. K P Singh

4. Future Thrusts:

- Screening of germplasms / varieties / cultivars / land races of soybean against major diseases to identify the sources of resistance.
- Development of economically and ecologically sustainable management techniques against major diseases of soybean occurring in different agro-climatic regions of the state.
- Development of IDM modules for management of menacing diseases of soybean for the different regions of Uttarakhand.
- Variability studies on pathogens causing major diseases of soybean in the state.

- Development of forecasting module for major foliar diseases of soybean in Uttarakhand.
- Studies on life cycle / disease cycle of menacing diseases of soybean in Uttarakhand.
- Assessment of yield and nutrients losses due to major diseases of soybean in Uttarakhand.
- To conduct the survey and surveillance for soybean diseases to identify the disease free areas for seed production.