

Details of Ph.D. thesis abstracts from January 31, 2023 to date

COLLEGE OF AGRICULTURE:

Genetics and Plant Breeding

1. Title of thesis	:	Stability analysis for yield traits and association mapping of quality traits in oat (<i>Avena sativa</i> L.)
Name of the student	:	Sanjay Kumar Sanadya (A-2019-40-019)
Major Advisor	:	Dr. V.K. Sood

Salient findings

Population growth, hunger and climate change are the major problems in the world. Therefore, a paradigm shift in agriculture is required to explore neglected and underutilized crop species that possess agronomic, nutritional and climate-resilient traits. Harnessing diverse oat genetic resources and development of stable cultivars are the sustainable solution to overcome these problems to some extent. Therefore, experiment was carried out to identify yield stable oat genotypes in originically and conventionally managed fields in the North Western Himalayas using AMMI and GGE biplot analysis and facilitate genetic dissection of quality traits employing ddRAD based GWAS approach. Ninety six diverse oat genotypes were tested in fine environments (year-production system combinations) using 12 x 8 alpha lattice design with three replications. Pooled ANOVA showed significant genotypic, environmental and GEI effects, suggesting GEI can be assessed in this population. Conventional system had higher yield over organic system across years. Environment and GEI were the major source of variation for all traits except dry matter percentage. Seed yield per plant showed positive significant association with biological yield per plant and harvest and harvest index whereas green fodder yield per plant exhibited positive significant association with number of leaves per plant and dry matter yield per plant. Genotypes SKO-190, UPO-119, OS-92, HJ-8, Choripatti and EC- 523890 for seed yield per plant and HFP-878, HFO-502 and PLP-14 for green fodder yield per plant were found to be widely adapted. On the basis of polygon view of the GGE biplot, two mega-environments (MEs) were identified with winning genotypes ADG-96 and IG-03-205 in ME-1 and SKO-190, EC-605837, PO-1 and KUE in ME-2 for seed yield per plant whereas JPO-38, IG-03-205 and UPO-119 in ME-1 and SKO-28, RO-19, UPO-102 and JHO-99-2 in ME-2 for green fodder yield per plant. Genome-wide 35,262 SNP markers were used for the identification of genomic loci associated with five grain and forage quality traits phenotyped in different production systems across year. Distribution of SNPs ranging from 998 (chromosome 6D) to 2495 (chromosome 1A) with SNP density ranged from 1.94 per Mb to 5.60 per Mb window size. Population structure and kinship matrix analysis divided population into three groups with some admistures indicating sufficient genetic variation. Total 31 significant marker-trait associations (MTAs) were detected across twenty one chromosomes for five quality traits. Out of which, 6, 3, 9, 9 and 4 were identified for ADF, NDF, β -glucan content, crude protein content and crude

protein yield per plant, respectively and explained 0.18 to 17.87% of total phenotypic variation. Twenty putative genes were found to be associated with QTLs linked with quality traits (100 Kb either side). Out of 31 QTLs, 10 QTLs explained more than 10% of total phenotypic variation thus these can be considered as major QTLs indicating a potential for using these markers in genomic –assisted oat breeding programme.

2. Title of thesis	:	Genetic analysis of hybrid fertility and yield contributing traits in indica, japonica and wide compatibility genotype of rice (<i>Oryza sativa</i> L.)
Name of the student	:	Jeevanjot Kaur (A-2019-40-014)
Major Advisor	:	Dr. Neelam Bhardwaj

Salient findings

The present investigation entitled “Genetic analysis of hybrid fertility and yield contributing traits in indica, japonica and wide compatibility genotypes of rice (*Oryza sativa* L.)” was undertaken to get the information on nature and magnitude of gene action, combining ability and heterosis and thereby indentifying potetial parents and cross combinations for yield, cold tolerance and disease restistance that could support further improvements of rice productivity using indica japonica hybrids. Eight parents *viz*; SKUA 500, SKUA 538, SKUA 536-2, HPR 3106, HPR 2143, Bhrigudhan, Naggardhan and Varundhan were crossed following Griffing’s method 2, model I in a half diallel fashion. Experimental material comprising of eight rice parents and twenty-eight hybrids were evaluated in RBD with three replications during *kharif* 2021 and 2022 at Rice and Wheat Research Centre, Malan and for the cold tolerance in *rabi* 2020-21 at the experimental farm of the Department of Vegetable Science and Floriculture, CSK HPKV, Palampur. Under cold conditions spikelet fertility was observed in the order of japonica x japonica lines > japonica x wide compatible lines > indica x japonica lines > indica x wide compatible lines > indica x indica lines. The analysis of variance revealed significant differences among the genotypes for all the traits studied in all the environments, suggesting prevalence of wide range of genetic variability. Genotype x environment (G × E) interaction was significant for most of the traits except days to 75% maturity, plant height, flag leaf length, flag leaf width, spikelet fertility, length:breadth ratio and amylose content indicating a definite role of environment on the performance of genotypes. SCA variances were higher than the GCA Variances and average degree of dominance was more than unity, thus showing preponderance of non-additive gene action for all the traits except amylose content. Based on GCA effects, SKUA 500, HPR 2143 and HPR 3106 were the most promising general combiners for grain yield/plant and most of the yield components. On the basis of SCA effect and heterosis, the cross combinations SKUA 500x Naggardhan, SKUA 536-2 x HPR2143, HPR 2143 x Bhrigudhan, SKUA 536-2 x Naggardhan and HPR 2143 x Varundhan were found best in pooled environment. Positive correlation of grains/panicle, grain length, and harvest index with grain yield/plant in parents and hybrids along with positive direct effect in path analysis revealed importance of these traits for selection of high yielding genotypes.

3. Title of thesis	:	Molecular diversity analysis and genetics of some morpho-physiological and biochemical traits associated with moisture-stress-tolerance in bread wheat (<i>Triticum aestivum</i> L.)
Name of the student	:	Shubhanshu Anubhav (A-2016-040-016)
Major Advisor	:	Dr. (Mrs.) Vijay Rana

Salient findings

The present investigation entitled ‘Molecular diversity analysis and genetics of some morpho-physiological and biochemical traits associated with moisture-stress-tolerance in bread wheat (*Triticum aestivum* L.)’ was conducted to identify morpho-physiological and biochemical traits associated with moisture-stress tolerance and analyze genetic diversity at morphological and molecular level. Experimental material comprised of 56 genetically diverse wheat genotypes; including some high yielding, drought tolerant lines, synthetics, local collections, recombinant inbred lines of a drought tolerant cultivar C 306. These lines were evaluated for different traits under field and controlled conditions with three replications during *Rabi* 2017-18 and 2018-19 under irrigated (E_1) and moisture-stress (E_2) conditions. Significant genetic variability was observed for, days to 50% flowering, flag leaf area (FLA), specific leaf area (SLA), specific leaf weight (SLW), relative water content (RWC), grain growth rate I (GGR-I), grain growth rate II (GGR-II), stem reserve mobilisation (SRM), tillers/ plant, grains/ spike, 1000-grain weight, biological yield/ plant, dry matter accumulation (DMA), grain yield/ plant, harvest index and proline content. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) along with high heritability and moderate genetic advance were recorded for proline content under E_1 and E_2 . Grain yield/plant showed significant positive correlation with tillers/plant, 1000-grain weight, biological yield/plant, DMA and harvest index. Biological yield/plant and harvest index appeared to be the best selection indices for increasing grain yield owing to high direct and indirect effects of these traits in path analysis. Under E_1 first six principal components revealed 72.40 % and under E_2 first five components explained 71.6 % of total variability. Variation for proline content contributed the maximum to the observed genetic divergence under both conditions. Congruence between morpho-physiological and SSR data was observed under both the environments. Forty-six out of 56 test genotypes were common among molecular and morphological clusters under moisture-stress, whereas 39 genotypes were common under irrigated conditions. Genotypes SYN 105, IC 36737, HS 562, IC 594376 and VL 907 under irrigated conditions and genotypes *viz.* IC 322025, HS 490, VHC 6081, VHC 6127, SYN 103, VL 892, VHC 6413, C 306, VL 907, HPW 236 and SYN 117 under moisture-stress conditions were most diverse. STRUCTURE divided the experimental lines into two major populations. A modified TTC analysis comprising 48 progenies; t 16 lines and 3 testers was used to detect epistasis and estimates of additive and dominance components of variance for observed phenotypes. Mean squares due to epistasis were significant for all the traits except SLW and relative water content under irrigated conditions (E_1) and FLA under (E_2). Additive \times Additive (i) type interactions were significant for GGR-I and tillers/ plant under E_1 and E_2 conditions

while j+l type interactions were significant for all the traits except SLW and RWC under irrigated conditions (E_1) and RWC under E_2 . The average degree of dominance $(H/D)^{1/2}$ revealed similar gene action for 1000-grain weight and GGR-II under both E_1 and E_2 . The comparison of estimates of genetic parameters using Line \times Tester and Triple test cross indicated the role of over dominance in genetic control of traits namely, grains/spike, grain growth rate I and proline content under both the environments E_1 and E_2 . Combining ability analysis revealed VHC 6413, HS 562, NIAW 1415, WH1105 as good general combiners for FLA, GGR- II, grains/ spike, 1000-grain weight; Syntehtic 107 and NIAW 1415 for SRM; VHC 6081 and VHC 6127 for tillers/plant; HS 490, VHC 6127 and HS 507 for DMA; VHC 6127, HS 490, NIAW 1415 and NI 5439 for grain yield/plant; HS 562 and Synthetic 107 for harvest index; HS 507, Synthetic 107, Synthetic 112 and NIAW 1415 for proline content under both E_1 and E_2 . HPW 89 x VL 907 recorded positive significant SCA effects for GGR- II; HPW 349 x VL 907 and HS 562 x HPW 368 for stem reserve mobilisation and VHC 6127 x HPW 368 for grains/spike and dry matter accumulation. These crosses were found promising and could be utilized for developing high yielding drought tolerant lines.

4. Title of thesis	:	Induced mutagenesis and molecular characterization of elite mutants for grain quality in bread wheat (<i>Triticum aestivum</i> L.)
Name of the student	:	Amit Rana (A-2019-40-013)
Major Advisor	:	Dr. Vijay Rana

Salient findings

Present studies were conducted with four wheat varieties *viz.*, HS 490, HPW 89, HPW 360 and HPW 251, mutagenized using 175 Gy, 200 Gy, 225 Gy, 250 Gy, 275 Gy & 300 Gy of gamma rays (γ) and 0.3%, 0.5%, 0.7%, 0.9%, 1.1% & 1.3% of EMS to assess their mutation effectiveness and efficiency, spectrum of induced macro-mutations in M_1 and M_2 generation at the Experimental Farm, Rice and Wheat Research Centre, Malan during *Rabi* 2020-21 and 2021-22. Results showed similar trend of reduction in different parameters with increase in dose/concentrations of both mutagens under lab and field conditions in M_1 generation. The LD_{50}/LC_{50} values of four wheat varieties varied between 290-315 Gy and 0.90-1.35% in case of γ -rays and EMS under lab conditions whereas 240-290 Gy and 0.50-1.10% in case of γ -rays and EMS under field conditions. HPW 251 was found to be more sensitive to both mutagens whereas, HPW 89 emerged as relatively less sensitive to γ -rays and HS 490 to EMS. These results indicated higher sensitivity of semi-hard varieties to mutagens as compared to soft-textured varieties. In M_2 population of 18,862 plants, a broad spectrum of chlorophyll mutants (0.949%) and morphological mutants (4.135%) were observed. Mutagenic effectiveness and efficiency showed that highest estimates were found at higher concentrations, but the estimates changed non-linearly with increase in concentrations over all four varieties for both the mutagens. Overall, HPW 251 was found to be most sensitive for mutagenic treatments as compared to HPW 360, HPW 89 and HS 490. EMS caused higher shift in magnitude of all the

parameters studied as compared to γ -rays. Based on LD₅₀, three doses (250 Gy, 300 Gy & 350 Gy) of γ -rays were used for inducing mutations in wheat variety HPW 89. Five mutagenic generations viz., M₁, M₂, M₃, M₄ and M₅ of HPW 89 were raised and studied using *Rabi* seasons and off-seasons through 2019-2022 at the Experimental farm, RWRC, Malan; HAREC, Kukumseri and IIWBR Regional Station, Dalang maidan, L&S to select agro-morphologically superior, disease resistant and better-quality mutants. Presence of significant variation among 293 M₄ mutant lines indicated the scope of selecting desirable mutants for various agro-morphological and quality traits. High phenotypic coefficient of variation and genotypic coefficient of variation as well as high estimates of broad sense heritability coupled with high genetic advance for flag leaf length, flag leaf area, peduncle length, biological yield/plant and grain hardness that selection based on these traits would be effective and rewarding. Days to 50% flowering, days to 75% maturity, biological yield/plant, harvest index and grain hardness emerged to be suitable selection criteria for grain yield improvement on the basis of correlation and path analysis. Out of 108 semi-hard elite mutants, 8 mutants viz., Mut9, Mut17, Mut58, Mut104, Mut109, Mut126, Mut179 & Mut195 were found superior with higher grain hardness, better grain appearance score, sedimentation value and protein content as compared to parent variety HPW 89. These mutants can be further subjected to multi-location testing before channelizing them into the breeding programmes. Overall, two mutants viz., Mut9 and Mut17 were found promising for grain yield, resistance to yellow rust and powdery mildew and desirable quality parameters. Molecular characterization of 108 semi-hard mutants showed presence of both *pina* and *pinb* genes. However, mutants having higher grain hardness as compared to parent variety HPW 89 suggested mutations in one or both genes and may be confirmed through gene sequencing for allelic differences caused due to mutation in future programmes.

5. Title of thesis	:	Genetic analysis of seed yield and quality traits and molecular characterization for white rust resistance in Indian Mustard [<i>Brassica juncea</i> L.) Czern & Coss.]
Name of the student	:	Sunidhi Tiwari (A-2019-40-020)
Major Advisor	:	Dr. (Mrs) Vedna Kumari

Salient findings

The present study entitled “Genetic analysis of seed yield and quality traits and molecular characterization for white rust resistance in Indian Mustard [*Brassica juncea* L.) Czern & Coss.]” was carried out to congregate information on genetic architecture, combining ability, heterosis and inheritance of white rust resistance. The materials for the investigation comprised of 12 lines, three testers (RCC-4, Donskaja-IV and their F₁) and resulting 36 TTC hybrids. These progenies and their parents were grown in randomized complete block design with three replications during *rabi* 2021-22 at the Experimental Farm of the Department of Genetics & Plant Breeding, CSKHPKV, Palampur (HP). Analysis of variance indicated the significance of

mean squares due to genotypes for all the traits which revealed the presence of sufficient genetic variability in the existing material. Modified triple test cross analysis exhibited the presence of epistasis for all the traits namely, days to flowering initiation, days to 75 per cent maturity, plant height, reproductive phase, number of primary branches per plant, number of secondary branches per plant, siliquae per plant, length of main shoot, siliquae length, seed per siliqua, 1000-seed weight, seed yield per plant, biological yield per plant and harvest index except for days to 50 per cent flowering. Further, partitioning of epistasis revealed the importance of 'j+I' type of epistasis for almost all the traits except 50 per cent flowering whereas mean squares due to 'i' type interaction were non-significant for most of the traits except number of secondary branches per plant siliquae per plant, siliqua length, seeds per siliqua, seed yield per plant and biological yield per plant which shows the importance of both 'I' and 'j+I' type of epistasis. Relative magnitude of additive component (D) was predominant over dominance component (H) for most of the traits except reproductive phase, number of secondary branches per plant, siliquae per plant and biological yield per plant indicating the relative importance of fixable type of gene action in their heritance.

Analysis of variance for line x tester revealed the presence of substantial genetic variability. Analysis of variance for combining ability indicated significant differences among hybrids for all the traits studied. The genotype DRMR 2017 was found to be good general combiner for nine traits followed by RSPR-03 for eight traits and Pusa Mehak for seven traits. Five crosses viz., Pusa Tarak x Donskaja-IV, RSPR-03 x Donskaja-IV, DRMR 2017 x RCC-4 and Urvashi x Donskaja-IV exhibited higher *per se* performance, significant SCA effects and heterobeltiosis for seed yield per plant. Two crosses namely, Urvashi x Donskaja-IV and Pusa Tarak x F₁ showed low glucosinolate content (˜30µmole per gram of defatted seed meal) and only one genotype viz., Pusa Krishma showed low erucic acid (<2 per cent).

To study the inheritance of white rust resistance, two crosses (RCC-4 x Donskaja-IV and RCC-4 x Heera) were evaluated. In cross RCC-4 x Donskaja-IV, dominant, epistasis (12:3:1) was observed while in cross RCC-4 x Heera, complementary epistasis (9:7) was observed. Molecular characterization revealed that intron polymorphic (IP) markers viz., At5g41560 and At2g36360 were highly linked to white rust resistance Loci AcBI- A4.I and AcBI-A5.1 and could be helpful in marker assisted selection for white rust resistance in Indian mustard.

6. Title of thesis	:	Marker assisted introgression of blast resistance and earliness into basmati rice (<i>Oryza sativa</i> L.)
Name of the student	:	Pandit Praveen Kumar (A-2018-40-017)
Major Advisor	:	Dr. D.P. Pandey

Salient findings

The present investigation entitled "Marker assisted introgression of blast resistance and earliness into basmati rice (*Oryza sativa* L.)" had been undertaken to introgress the blast

resistance and earliness genes from different sources to popular basmati rice cultivar Pusa Basmati 1121. Pusa basmati 1509 and Pusa 1637 were used as donor parents for *hd2* (earliness) and *Pi9* (blast resistance) gene, respectively. Crosses were developed and advanced to BC₂F₃ generation using foreground and background selection. Molecular marker RM 1362 and RM 7601 tightly linked with *hd2* gene and marker Pi9-Pro tightly linked with *Pi9* gene were used in the present study for foreground selection. Thirty eight out of 249 SSR primers were used for background selection for both the crosses. The recurrent parent genome recovery was recorded up to 98.44 and 96.05 percent in cross Pusa Basmati 1121 × Pusa 1509 and Pusa Basmati 1121 × Pusa 1637, respectively. Plants with high RPG content along with morphological value of trait near to recurrent parent for traits except incorporated, were selected for further advancement. Another experiment involved the screening of 160 F₂ lines each of three crosses between *O. glaberrima* and different cultivars of *indica* for leaf and neck blast under natural epiphytotic conditions. The ratio for disease inheritance in all the crosses was found 37:26:01. In another experiment, forty six rice genotypes were evaluated for various agro-morphological and grain quality traits during Kharif, 2021 at Rice and Wheat Research Centre, CSKHPKV, Malan (HP) during Kharif 2021. Genotypes in present study were sown in replicates using Randomized Block Design. Data was subjected to estimation of genetic parameter, correlation coefficient, path analysis and comparison of mean performance. Analysis of variance for RBD revealed the existence of sufficient variability among the genotypes for all the studied traits. Grain yield per plant ranged from 13.51 g (HPR-7) to 18.94 g (HPR-1612 X Pusa Basmati- 1121) among the genotypes. High heritability couples with high genetic advance was found for Days to 50% flowering, Plant Height, Tillers per plant, Grain length, grain breadth, L:B Ratio and Grain yield per plant. Genotypic Correlation study showed the significant positive correlation with tillers per plant, grain length and 1000 grain weight. The selected genotypes based upon their better performance can be used in future rice breeding program to improve the desirable traits.

7. Title of thesis	:	Molecular marker mediated introgression of <i>Pita</i> R-gene complex basmati rice
Name of the student	:	Aparajita (A-2018-40-013)
Major Advisor	:	Dr. H.K. Chaudhary

Salient findings

In present study three blast resistance genes *Pita*, *Pb2* and *Ptr* present together in a linkage block near centromeric region of chromosome 12 were introgressed into a popular traditional basmati rice variety, ‘Ranbir Basmati’. The genotype RIL-4, which derives its resistance from a broad spectrum resistance genotype Tetep, was used as a resistance donor. Molecular marker based foreground and background analysis was combined with stringent phenotypic selection to select plants containing target genes and realize maximum recovery of the recurrent parent genome (RPG). Background analysis with genome-wide 50,051 SNP markers revealed 98.46 to 99.24 % recovery of recurrent parent genome in BC₅F₂ near-isogenic

lines (NILs). All the NILs were highly resistant to both leaf and neck blast suggesting the effectiveness of *Pi-taR* gene locus. All the lines were found to have reconstituted the major *fgf* gene and two other *QTLs aro-3-1* and *aro-4-1* related to aroma. Fourteen NILs viz., NIL-4, -5, -6, -7, -9, -14, -16, -19, -20, -23, -26, -27, -28 and -31 exhibited a significant yield superiority over Ranbir Basmati. The improved yield in these NILs primarily resulted from the improvement in number of spikelets/panicle and spikelet fertility compared to Ranbir Basmati. All the NILs except two viz., NIL-11 and -31, flowered 2 to 7 days late compared to both the parental genotypes and a great majority of them also had a longer culm length than both the parents. The delayed flowering in most of the NILs indicated the strong possibility of the presence of minor genes in the linked regions of the *Pi-ta* locus which have an effect of delaying flowering in the genetic background of Ranbir Basmati. The NILs introgressed with *Pi-ta* linkage block have shown resistance to leaf and neck blast disease and six of them also possess superior basmati quality traits of Ranbir Basmati. Besides, three of these lines, NIL-7, -27 and -31, have also shown superiority over Ranbir Basmati for grain yield. These NILs are the potential candidates for release as the improved versions of Ranbir Basmati. Their deployment is expected to cut the cost of fungicides used for blast disease control and mitigate the problem of fungicide residues in the grains.

8. Title of thesis	:	Molecular characterization of rice (<i>Oryza sativa</i> L.) germplasm and elite mutants for embryo size and its effect on nutritional quality and germination parameters under direct seeded condition.
Name of the student	:	Kaldate Supriya Bhimrao (A-2019-40-016)
Major Advisor	:	Dr. D.P. Pandey

Salient findings

The present investigation was conducted keeping in mind the global challenges of climate change and malnutrition with mutagenesis of two rice varieties, HPR 1068 and HPR 2795 with 0.1%, 0.3%, 0.5%, 0.7%, 0.9% & 1.1% of EMS & 150 Gy, 200 Gy, 250 Gy, 300 Gy & 350 Gy of gamma rays (γ) for endosperm/embryo size as well as varietal variation for endosperm/embryo size in 45 diverse genotypes and to evaluate its performance for agronomorphological traits under DSR through seedling vigor traits and quality traits at Experimental Farm, Department of Genetics and Plant Breeding, CSKHPKV, Palampur during *kharif* 2020-2022. Results in M_1 generation showed reduction in different parameters with increasing dose/concentration of mutagens under lab and field conditions. LD_{50} values varied between 0.60-0.83 % and 0.62-0.81 % for EMS and 253.84-299.56 Gy and 254.64-296.37 Gy for gamma rays under lab & field conditions, respectively. HPR 2795 among the varieties found more sensitive and EMS among the mutagens was more effective in terms of chlorophyll, morphological mutations and mutagenic effectiveness as well as efficiency studied in M_2 generation.

Total of 52 plants consisting of 41 agronomically superior and 11 academically important mutants were selected from 15,375 M₂ plants. These 11 mutants consisting of 2 enlarged embryos, 4 long, 2 short and 3 wrinkled grains were selected examining with naked eyes from de-hulled grains of 4680 plants of HPR 1068 from LD₅₀ values and based on screening of parents with *Le-1* marker. Molecular characterization of these mutants with *Le-1* showed lack of amplified fragment in M19 and M22 enlarged embryo mutants. Significant increase in embryo area and ratio was observed with reduced seedling vigor and increased micronutrient content in enlarged embryos, which showed that endosperm/embryo balance is not supported in HPR 1068 genetic background. These mutants can be further studied in different genetic backgrounds to exploit them economically in near future. Four mutants, M13 and M23 of long grain types and M37 and M42 of HPR 2795 found agronomically superior over the checks under TPR and DSR conditions. Large variation for endosperm/embryo size was observed in 45 diverse genotypes. Considerable effects of seed size on embryo area, ratio, seedling vigor traits and quality traits was observed in diverse germplasm. Molecular characterization with 3 endosperm/embryo specific markers indicated existence of *GOLIATH* and *LARGEEMBRYO* wild type loci. Therefore those genotypes can be used as parents for future mutation breeding for this trait. Based on these results, genotypes/mutants having long and bigger seeds with good seedling vigor with ability to tackle stress environment via different biochemical compounds are recommended for DSR system of cultivation.

9. Title of thesis	:	Molecular genetic diversity analysis of north-west Himalayan bread wheat landraces
Name of the student	:	Kulveer Singh Dhillon (A-2019-40-017)
Major Advisor	:	Dr. H.K. Chaudhary

Salient findings

The present investigation was undertaken to assess the genetic diversity amongst north-west Himalayan bread wheat landraces collected from six districts of Himachal Pradesh and Kishtwar district of Jammu & Kashmir using various morphological traits and SSR markers. The experimental material comprised of 104 landraces along with 6 checks viz., Him Palam Gehun-1 (HPW 360), Him Palam Gehun -2 (HPW 368), Him Pratham (DH 114), VL-829, VL-892 and C-306 were evaluated for different morphological traits in Alpha Lattice Design of 11 x 10 with three replications during *rabi* 2020-21, 2021-22 and 2022-23. DUS descriptors viz., lower glume: beak length followed by waxiness of blade (flag leaf), ear waxiness, waxiness of peduncle and grain shape contributed maximum towards divergence. Sufficient genetic variability was observed for seed yield and its components traits suggesting the scope of selection for these traits. High PCV was observed for seed yield per plant and harvest index whereas moderate PCV and GCV observed for plant height, and 1000-grain weight. High heritability coupled with high to moderate genetic advance was found for days to 50% flowering,

plant height, tillers per plant and 1000-grain weight providing scope for improvement of these traits through selection, Seed yield per plant showed significant and positive correlation with spikelets per spike, grains per spike, biological yield per plant and harvest index. Also, biological yield per plant and harvest index were observed as best selection index for increasing seed yield per plant. Principal component analysis revealed 76 per cent variation which was elaborated by the first four significant principal components. D² statistical analysis grouped genotypes into six clusters whereas molecular analysis delineated then into seven clusters. On the basis of mean performance, one landrace i.e. G84 was found superior for seed yield, whereas, G66, G72, G89, G90, G92, G97, G98 and G100 expressed high resistance against yellow rust and powdery mildew diseases. Four landraces i.e. G72, G92, G98 and G100 stand out as highly diverse and optimal choices due to their overall performance and robust disease resistance. These landraces can be used further in future breeding programs.

10. Title of thesis	:	Molecular mapping, genetics and introgression of yellow rust resistance in bread Wheat (<i>Triticum aestivum</i> L.)
Name of the student	:	Priyanka (A-2019-40-018)
Major Advisor	:	Dr. Vijay Rana

Salient findings

The present research work entitled “Molecular mapping, genetics and introgression of yellow rust resistance in bread wheat (*Triticum aestivum* L.)” was undertaken with the objectives to study genetics of yellow rust resistance in resistant mutants, molecular mapping of yellow rust resistance in F₂ progenies and introgression of yellow rust resistance in agronomically superior lines. The experiment was carried out to screen sixty-six elite wheat germplasm lines for yellow rust resistance various agro-morphological traits. Experimental lines were evaluated in six environments including RWRC, Malan under field conditions for three consecutive years and at major hot spot locations, HAREC, Kukumseri and ICAR-IIWBR, Dalang Maidan. These lines were also evaluated for Seedling Resistance Test (SRT) using four prevalent pathotypes of yellow rust. Out of these experimental lines, yellow rust susceptible lines, viz., HD 2967, HS 240 and HS 295 were crossed with yellow rust resistant lines viz., HPW 368, HS 562 and TYRM2 (resistant mutant of HD 2967) to create (S×R) cross combinations viz., HD 2967×TYRM2, HD 2967×HS 562, HS 240×TYRM2 and HS 295 × HPW 368. These four crosses along with their segregating generations (P₁, P₂, F₁, F₂, B₁, B₂) were evaluated to study the genetics of yellow rust resistance and generation mean analysis for various agro-morphological traits. Segregation pattern of yellow rust resistance in the segregating generations of HD 2967×TYRM2, HD 2967×HS 562 and HS 240×TYRM2 revealed the monogenic and dominant nature of yellow rust resistance in TYRM 2 and HS 562 and therefore, these genotypes may be successfully utilized in the breeding programme to develop yellow rust resistant lines. Mean data of six different generations i.e., P₁, P₂, F₁, F₂, B₁, B₂ from the four inter-varietal cross combinations viz., HD 2967×TYRM2, HD 2967×HS 562, HS 240×TYRM2 and HS 295 × HPW 368 were utilized for

generation mean analysis using compact family block design. The analysis of variance exhibited significant mean squares due to families or crosses along with significant differences between progenies in all the four families for all the traits. Majority of the crosses displayed the duplicate type of epistasis for the inheritance of flag leaf area, peduncle length, tillers / plant, biological yield / plant and grain yield / plant.

Looking at the extreme phenotype of parents HD 2967 (susceptible) and TYRM 2 (resistant), inter-varietal cross HD 2967×TYRM2 was used for molecular mapping of yellow rust resistance as this cross combination showed clear cut segregation for yellow rust resistance. Based on Bulk Segregant Analysis in F₂ population, SSR marker *Xgwm 273* known to be present on 1BS chromosome was found to be associated with yellow rust resistance from putative *R locus* at a distance of 7.2 cM. For further utilization of this marker in marker assisted selection, its fine mapping has to be done and validation of this marker is required. To introgress yellow rust resistance in the adapted susceptible wheat cultivar i.e., HD 2967 from TYRM 2, a total of 52 BC₁F₁ plants of cross HD 2967× TYRM 2 were genotyped using *Xgwm273*, out of which 22 were found to be positive for putative *R gene*, so presumed to be the heterozygous carrier for this gene. Therefore, these plants were found to inherit an allele from the donor parent. Recurrent parent genome recovery in BC₁F₁ generation of HD 2967 × TYRM 2 ranged from 63.82-73.51%. The highest genome recovery percent of 73.51 was found in HD 2967-5-20. In BC₂F₁ generation, recurrent parent genome recovery ranged from 84.06-88.41%. The highest genome recovery percentage was found in HD 2967-5-20-35. Based on yellow rust resistance and high genome recovery of more than 85% in BC₂F₁, plants HD 2967-1-5-2, HD 2967-1-5-11 and HD 2967-5-29-35, could be further utilized in breeding program for selection of high yielding and yellow rust resistant progenies. On the basis of multi-environment evaluation over six environments, genotypes viz., TYRM2, Unnat PBW 550, FLW 16, HS 562, PW 1908, HPW 368, WH 1270, HTW 9, HPW 469, HIKK 05 and HI 8173 can be used as a potential donor for yellow rust resistance in future hybridization programme.

11. Title of thesis	:	Genetic amelioration of biochemical constituents and induce earliness through mutagenesis in high yielding variety Him Palam Hara Soya 1 of soybean (<i>Glycine max</i> (L.) Merrill)
Name of the student	:	Vishva Deepak Chaturvedi (A-2018-40-018)
Major Advisor	:	Dr. Vedna Kumari

Salient findings

The present investigation entitled “Genetic amelioration of biochemical constituents and induce earliness through mutagenesis in high yielding variety Him Palam Hara Soya 1 of soybean (*Glycine max* (L.) Merrill)” was undertaken to estimate the extent of induced variation for earliness, seed yield and biochemical constituents to identify potential mutants in the genetic background of variety Him Palam Hara Soya 1 of soybean. The experimental material consisted of 425 mutant lines evaluated in augmented block design in M₂ generation. Out of these, 218

mutant lines were evaluated along with the parent as control in compact family block design with two replications in the experimental farm of the Department of Genetics and Plant Breeding, CSK HPKV, Palampur during *kharif*, 2021. Analysis of variance revealed that sufficient genetic variability was present among all the mutant lines for seed yield and related traits.

Based on mean performance, 173 mutant lines were found to be significantly superior to the control Him Palam Hara Soya 1. However, 45 mutant lines showed multiple disease resistance for the major 4 diseases i.e. frog-eye leaf spot, brown spot, pod blight and bacterial pustule and were statistically at par with the control for seed yield per plant. In M₂ generation, moderate PCV was observed for branches per plant, fertile nodes per plant, number of pods per plant and biological yield per plant. High heritability was reported for days to 50 percent flowering and days to 75 per cent maturity while the plant height exhibited high heritability along with high genetic advance indicating the predominance of additive gene action in the inheritance of this character. Seed yield per plant exhibited significant and positive correlation with all the traits studied except number of seeds per pod at genotypic level. Path coefficient analysis revealed the highest positive direct effect on seed yield per plant *via* harvest index followed by biological yield per plant. Based on genetic divergence, 218 mutant lines were grouped into 33 clusters in which the highest intra-cluster distance was observed for cluster XX followed by cluster VI, cluster III, cluster II and cluster I. Among all clusters, cluster XX showed desirable mean values for number of pods per plant and seed yield per plant suggesting that the mutant lines *viz.*, M₂-1-1(500 Gy), M₂-2-3(500 Gy), M₂-4-2(500 Gy), M₂-7-5(500 Gy), M₂-8-8(500 Gy), M₂-9-5(500 Gy), M₂-10-4(500 Gy) and M₂-12-2(500 Gy) could be selected for these traits. None of the mutant lines were found to be significantly superior and statistically at par with the control for oil content, total sugar, total phenols, flavonoids and tannins except protein content for which seventeen mutant lines *viz.*, M₂-9-2(100 Gy), M₂-6-3(200 Gy), M₂-9-8(300 Gy), M₂-3-2(400 Gy), M₂-14-8(500 Gy), M₂-4-3(0.5 % EMS), M₂-12-2(1.0 % EMS), M₂-9-2(100 Gy + 0.5 % EMS), M₂-10-4(100 Gy + 1.0 % EMS), M₂-7-3(200 Gy + 0.5 % EMS), M₂-10-3(200 Gy + 1.0 % EMS), M₂-6-4(300 Gy + 0.5 % EMS), M₂-4-5(300 Gy + 1.0 % EMS), M₂-9-6(400 Gy + 0.5 % EMS), M₂-9-2(400 Gy + 1.0 % EMS), M₂-5-7(500 Gy + 0.5 % EMS) and M₂-8-5(500 Gy + 1.0 % EMS) were found to be significantly superior. Overall, seven mutants *viz.*, M₂-7-6(200 Gy), M₂-11-1(300 Gy), M₂-12-3(300 Gy + 0.5 % EMS), M₂-5-3(300 Gy), M₂-11-3(200 Gy + 0.5 % EMS), M₂-4-3(200 Gy) and M₂-2-1(200 Gy) were found promising for seed yield, earliness, multiple disease resistance and quality parameters. These mutants may be utilized in future hybridization programme for the development of superior soybean varieties.

12. Title of thesis	:	Genetic analysis for yield and its attributing traits in buckwheat (<i>Fagopyrum tataricum</i> Gaertn.)
Name of the student	:	Vivek Singh (A-2020-40-019)
Major Advisor	:	Dr. Gopal Katna

Salient findings

The present investigation entitled “Genetic analysis for yield and its attributing traits in buckwheat (*Fagopyrum tataricum* Gaertn.)” was undertaken during the year 2020-23 in the Department of Genetics and Plant Breeding, CSKHPKV, Palampur. The research comprised of two different experiments, first having diallel analysis (excluding reciprocals) with five genotypes and second having stability analysis of 24 tartary buckwheat genotypes in five environments. In the first experiment, 10 crosses were made using hot water thermos/cup method to produce F₁ seeds in tartary buckwheat. Analysis of variance showed that the mean sum of squares due to genotypes was significant for all the characters except number of cluster per cyme. The mean value for seed yield per plant was 3.14 g and it ranged from 1.78 to 3.58 g. Significantly higher seed yield per plant was found in all the parents and significantly lower seed yield per plant was found in IC 318859. In the case of crosses, significantly higher seed yield per plant was found in all the crosses as compared to the check. However top three crosses showing significantly higher seed yield per plant were IC 341589 × Him priya (3.59 g), IC 258233 × Him priya (3.47 g) and IC 258233 × IC 341589 (3.42 g). The analysis of variance for combining ability showed a significant mean sum of squares due to GCA and SCA for all the traits except the mean sum of squares due to GCA for cluster per cyme. The estimates of genetic components for different traits concluded that SCA variance were higher as compared to the GCA variance except for number of leaf per plant, plant height, primary branches per plant, inflorescence length and harvest index. The estimates of GCA effects for seed yield per plant ranged from -1.03 (IC 258233) to 1.03 (IC 341589). The estimates of SCA effects for yield per plant ranged from 0.38 (IC 258233×Him priya) to 2.08 (IC 318859× Him priya). Comparison of the two criteria *i.e.* *per se* performance and GCA effects showed that genotype IC 341589 exhibited significant results in primary branches per plant, inflorescence length, number of seed per plant, yield per plant and biological yield per plant. Based on *per se* performance, SCA effect and standard heterosis the cross IC 318859 × Him priya exhibited significant results for days to 80 per cent maturity, number of cluster per cyme and seed yield per plant. Perusal of test of validity of assumptions for a diallel analysis and estimation of the degree of dominance revealed that t^2 was significant for inflorescence length and number of seed per plant. Traits like number of leaf per plant, plant height, primary branches per plant, inflorescence length and harvest index had high narrow sense heritability. The second experiment was performed to effectively understand the GEI effect that showed, seed yield per plant partitioned into four highly significant ($p < 0.01$) principal component axes (IPCA) contributing 73.3%, 20.7%, 4.4% and 1.6% of the total GEI variation, respectively. AMMI analysis identified three genotypes for seed yield per plant *i.e.* Shimla B1 (G1), Him priya (G2), IC 26755 (G3) which were superior in all the environments. AMMI2 biplot explained 94.0 per cent of the total GEI for seed yield per plant. Genotypes IC 318859 (G10), IC 341683 (G20), Chitkul (G24) and IC 341674 (G19) appeared near to origin indicating their wide adaptation for seed yield per plant. Standard deviation-generated GGE biplot explained 98.1 per cent of the total GEI variance, with the contribution of 91.6 per cent by component 1 and 6.5 per cent by component 2. The genotypes Shimla B1 (G1), IC 26755 (G3),

Him priya (G2), IC 109729 (G11), Sangla B 129 (G6), IC 109729 (G11) and IC46160 (G8) were the most stable as indicated by their placement near the AEC abscissa. Shimla B1 (G1) was the most stable and clear winner across all the environments as placed on the vertex of the respective environment sector.

13. Title of thesis	:	Molecular diversity and genetic analysis of seed yield components and disease resistance in soybean [<i>Glycine max</i> (L.) Merrill]
Name of the student	:	Ronika (A-2020-40-017)
Major Advisor	:	Dr. Vedna Kumari

Salient findings

The present study entitled ‘Molecular diversity and genetic analysis of seed yield components and disease resistance in soybean [*Glycine max* (L.) Merrill]’ was carried out to assemble the information on morpho- molecular diversity, combining ability, heterosis and inheritance studies. The experimental material for morpho-molecular diversity consisted of 247 soybean genotypes evaluated during kharif, 2021 and kharif, 2022 for yield component traits and a total of 59 SSR markers were used to determine the molecular diversity. For determination of combining ability, gene action and heterosis studies, 15 lines and three testers resulting in 45 TTC hybrids were grown in randomized block design with three replications during kharif 2021, 2022 and 2023 at Experimental Farm of Department of Genetics and Plant Breeding, CSKHPKV, Palampur (H.P.). The genetics of pod blight resistance was studied using different generations of two crosses namely, JS 335 × Himso 1685 and Cat 2086 × Himso 1685.

The pooled analysis of variance revealed significant differences among 247 soybean genotypes across both the seasons which highlighted substantial magnitude of variation among the genotypes for yield attributing traits. Mahalanobis D²-statistic grouped the genotypes into 24 clusters (6 polygenotypic and 18 solitary clusters). Five PCs exhibited >1 eigen value and explained 66.35% of cumulative variation. Out of 59 SSR markers, 21 showed polymorphism and confirmed the existence of molecular diversity among the genotypes. The marker Satt216 was highly polymorphic. The dendrogram, neighbor joining tree and population structure analysis categorized the genotypes into three groups. Modified triple test cross analysis revealed the presence of significant epistasis and ‘j+1’ type (additive × dominance and dominance × dominance) of interaction for all the traits except for days to 75% maturity. The line × tester analysis revealed preponderance of non-additive gene action in the manifestation of majority of traits except for days to 75% maturity. Based on GCA effects, Palam Early Soya 1 and Hara Soya each were good combiners for eight yield and related traits. Based on SCA effects, five cross combinations viz., AS 40 × Himso 1685, PS 1572 × JS 335, AMS MB 5-18 × JS 335, EC 241778 × Himso 1685 and Him Soya × Himso 1685 were found to be good specific combiners for seed yield per plant. Based on per se performance, SCA effects, heterobeltiosis and economic heterosis, the crosses Palam Early Soya 1 × JS 335, Hara Soya × JS 335, PS 1572 × JS 335 and

Palam Early Soya 1 × Himso 1685 were found desirable for earliness and various biochemical parameters. The cross PS 1572 × JS 335 also recorded significant amount of phosphorus, iron and manganese. Therefore, these crosses can be exploited to isolate superior and stable lines in segregating generations for development of high yielding and nutritionally superior soybean varieties. The significance of simple scaling tests in both the crosses confirmed the inadequacy of simple additive- dominance model and suggested more than one gene control in the inheritance of pod blight resistance. Further, the segregation ratio revealed the goodness of perfect fit to 9:7 indicating the pod blight resistance is governed by two genes with dominant complementary gene interaction.

14. Title of thesis	:	Line × Tester analysis for yield traits and factors influencing haploidy in oat (<i>Avena sativa</i> L.)
Name of the student	:	Gaurav Sharma (A-2020-40-014)
Major Advisor	:	Dr. V.K. Sood

Salient findings

The present study entitled “Line × Tester analysis for yield traits and factors influencing haploidy in oat (*Avena sativa* L.)” was undertaken to understand the nature and magnitude of gene action, combining ability and heterosis along with assessment of genetic diversity using molecular markers. Factors influencing caryopsis and haploid embryos development using chromosome elimination technique *via* wide hybridization were also undertaken. Ten lines, four testers and 40 F₁’s along with three checks were evaluated for various agro-morphological traits in three replications during *Rabi* 2022-23. Analysis of variance revealed sufficient genetic variability for all the traits studied. The magnitude of dominance variance was found higher than additive variance indicating that non-additive gene action played a major role in the inheritance of these traits. Genotype OS-6, EC-608834 and PO-1 exhibited significant GCA value for most of the traits. Cross combinations namely, PO-1×JHO-851, OS-377×JHO-851, RO-19×HFO-114, PO-1×PLP-1 and EC-608834×PLP-1 were found superior on the basis of *per se* performance, specific combining ability effects and standard heterosis which can be used in future oat improvement programme. Standard heterosis was recorded up to 44.49% for seed yield per plant, 117.78% for green fodder yield per plant and -9.50% for early flowering. Quality assessment revealed that parent (PLP-1) and crosses *viz.*, RO-19×PLP-1 and RO-11-1×UPO-212 outperformed for most of the traits. Sixteen out of total fifty SSR primers showed polymorphism among 14 parental genotypes. Dendrogram grouped the 14 genotypes into three major clusters. Principal coordinate analysis also grouped genotypes into five populations and percentage of variation explained by I, II and III axes were 33.02%, 23.39% and 17.86%, respectively thereby revealing that parents used in the study had sufficient genetic variability.

Oat × maize, oat × *Imperata cylindrica* and oat × wheat wide hybridization programme revealed that caryopsis formation frequency was 36.20%, 57.20% and 29.95%, respectively. Embryo formation frequency for oat × maize, oat × *Imperata cylindrica* and oat × wheat hybridization was 0.34%, 1.51% and 0%, respectively. The results depicted that *Imperata cylindrica* could be the best pollen source to develop doubled haploids in oat. Influence of growth regulators revealed that 100 ppm GA₃ outperformed among all studied phytohormone combinations for development of haploid embryos when directly injected into the pistil of an uncut floret.

15. Title of thesis	:	Genome wide association mapping for drought tolerance in bread wheat (<i>Triticum aestivum</i> L.)
Name of the student	:	Shubham Verma (A-2020-40-018)
Major Advisor	:	Prof. H. K. Chaudhary

Salient findings

Global climate change poses a significant threat to wheat productivity, with drought stress being particularly challenging and impeding crop production. In wheat cultivation, terminal drought during anthesis is a key concern, leading to further reductions in yield. Thus, it is important to identify wheat genetic resources with drought tolerance and high genetic yield potential. In the present investigation, three hundred and six diverse wheat genotypes including well characterized doubled haploids, potential landraces, elite exotic lines and popular Indian cultivars were tested under five different optimal and water stressed environments using 17×18 alpha lattice design with three replications across the North Western Himalayas. The genetic architecture of drought resilience was dissected employing ddRAD based GWAS approach. Perusal of the ANOVA revealed substantial variability and significant differences among genotypes for all the studied traits pooled over environments under both the conditions, indicating that these traits were significantly affected by drought stress. Under drought stress, the grain filling period was significantly shorter, and the average grain yield reduced to 2.81 t/ha compared to 4.28 t/ha under optimal conditions across different environments. Grain yield per plant showed significant positive correlation with flag leaf length, tillers per plant, spikelets per spike, grains per spike, thousand-grain weight, biological yield, harvest index, drought tolerance efficiency and proline content while, days to anthesis, days to maturity, grain filling period, drought susceptibility index and root fresh weight were negatively correlated with grain yield per plant. Under rainfed conditions, four genotypes viz., L 36, L 39, L 44 and L 81 sustained higher grain yields. The dual resistance towards stripe rust and powdery mildew under natural epiphytotic conditions was displayed by twenty genotypes across all locations. Genome-wide, 62,156 SNPs were identified, and after filtration with missing rates > 50% & MAF (minor allele

frequency) <0.05 , the number was reduced to 7,610 SNPs and were further used for the identification of genomic loci associated with phenotyped traits under different water regimes across environments. Under pooled irrigated and pooled rainfed environments, a total 13 and 14 SNPs, respectively, were found associated with traits studied. A total of 7 SNPs, on chromosome 1B (1), 3B (1), 5B (1), 7B (2), 4A (1) and 6D (1) were found consistently significantly associated under drought stress. Two SNPs S3B_2957 and S3B_3154 on chromosome 3B, were found associated with grain yield per plant and grain filling period. The study identified significant SNPs linked to yield traits under drought stress, and with further validation, donor lines possessing these favorable alleles can be used to improve the genetic architecture of current wheat varieties for drought tolerance and high yield potential.

16. Title of thesis	:	Heterosis and combining ability for grain yield along with genetic assessment of blast resistance in rice (<i>Oryzasativa</i> L.).
Name of the student	:	Nareshkumar V (A-2020-40-015)
Major Advisor	:	Dr. (Mrs) Neelam Bhardwaj

Salient findings

This study aims to assess the genetic mechanisms underlying yield, its associated traits and blast resistance in rice. Eight red rice lines were crossed with three testers using Line \times Tester mating design to identify promising cross combinations for future breeding programs. Twenty-four F₁ progenies were generated during *kharif*, 2021 & 2022. A total of 38 genotypes, comprising 11 parents, 24 F₁ progenies, and 3 checks, were evaluated in Randomized Block Design (RBD) with three replications during *kharif*, 2022 & 2023 at the experimental farm of RWRC, Malan. Significant differences were observed among genotypes, parents vs crosses in Line \times Tester and Lines, Testers and Lines \times Tester in combining ability analysis for both seasons, indicating the presence of a broad spectrum of genetic variability. Variances for all the traits were found to be homogenous, as verified by Bartlett's test. The prevalence of non-additive gene action was suggested by higher levels of specific combining ability (SCA) and dominance variance across all traits, with an average degree of dominance exceeding 1, indicating the presence of over-dominance. Parents, *viz.*, *Shimla Collection*, *Kalizhini*, *Gosha*, *LalNakanda*, Pusa Basmati 1637, and RB-13 were identified as good combiners for grain yield, while *Sukara Red* and *Jattoo* exhibited promising SCA effects for most of the biochemical traits. Crosses such as *Shimla Collection* \times Pusa Basmati 1637 and *Jattoo* \times Pusa Basmati 1637 demonstrated high positive SCA effects and heterosis for grain yield. Additionally, *Gosha* \times RB-13 recorded high positive SCA effects for most of the biochemical traits. Most cross combinations exhibited resistance to leaf blast and neck blast under field conditions, likely due to the inheritance of dominant resistance genes (*Pi9*, *Pi-42*, & *Pi-ta*) from testers, as supported by chi-square analysis of blast inheritance in the F₂ generation. In conclusion, crosses *viz.*, *Jattoo* \times Pusa Basmati 1637, *Shimla Collection* \times Pusa Basmati 1637, *Gosha* \times RB-13, *LalNakanda* \times DHR-9, and *LalNakanda* \times Pusa

Basmati 1637 showed promising performance in terms of mean values, SCA effects, and heterosis for maximum traits investigated. Hence, these crosses could be further utilized in rice breeding program for isolating transgressive segregants.

17.Title of thesis	:	Molecular makers-assisted introgression of powdery mildew resistance gene into agronomically superior oat cultivar.
Name of the student	:	khushbu (A-2018-40-015)
Major Advisor	:	Dr. V.K. Sood

Salient findings

The present investigation entitled “Molecular marker-assisted introgression of powdery mildew resistance gene into agronomically superior oat cultivation” was conducted in the Department of Genetics and Plant Breeding, CSKHPKV, Palampur during the year 2017 to 2023. The powdery mildew resistant Eg-5 gene was incorporated into genetic background of an agronomically superior and potential oat variety, ‘HJ-8’ from donor genotype JPO-46 using marker-assisted backcross breeding (MABB) with the aim to incorporate gene conferring resistance to powdery mildew in oat. SSR markers were utilized for the estimation of recovery of recurrent parent genome. About three hundred fifty SSR markers were used for screening of parental genotypes, out of which 53 were found polymorphic.

The genotypes HJ-8 and JPO-46 were crossed to develop the BC₁F₁, BC₂F₁ and BC₃F₁ generations, plants having target genes selected on the basis of foreground selection were subjected to background selection. Background analysis revealed the extent of the recurrent parent genome recovery of foreground selected progenies ranging from 38.88 to 75.00 percent for cross HJ-8* JPO-46 in BC₁F₁ generation whereas in BC₂F₁, background analysis indicated recovery percentage of recurrent parent genome ranging from 83.33 to 96.29 percent. Furthermore, in BC₃F₁ generation background analysis indicated range of the recovery of recurrent parent genome ranging from 83.33 to 98.14 percent, BC₃F₁ plants were subjected to selfing, advanced to BC₃F₂ lines and evaluated for agro-morphological traits.

Analysis of variance revealed significant variability for all the traits among BC₃F₂ lines except for leaves per plant. In comparison to the recurrent parent HJ-8, which had a high incidence of powdery mildew, all the BC₃F₂ lines exhibited a high level of resistance to the disease. Thirteen BC₃F₂ lines viz., HJO-1-28-17-22, HJO-80-28-47-44, HJO-80-28-47-44, HJP-81-29-61-57, HJO-80-29-55-60, HJO-80-29-55-61, HJO-80-29-55-64, HJO-80-29-78-67, HJO-80-29-96-69, HJO-81-29-103-70, HJO-90-41-134-79, HJO-90-41-137-83, HJO-90-41-137-86, HJO-91-48-185-102 out –yielded recurrent parent HJ-8 and exhibited superiority for other traits alongwith resistance to powdery mildew.

Agronomy

1. Title of thesis	:	Refinement of conventional integrated farming system model with natural farming
Name of the student	:	Gurpreet Singh (A-2018-40-004)
Major Advisor	:	Dr. Vinod Kumar Sharma

Salient findings

An experiment was carried out in rabi and kharif seasons of 2019-20 and 2020-21 to evaluate the productivity and profitability of integrated farming system under conventional and natural farming in mid-hill conditions of Himachal Pradesh at 1 hectare AICRP-IFS on station research farm (Bhadiarkhar) of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The objective of the study was to refine existing integrated farming system model with natural farming and to identify and optimize component linkages for profit maximization. Components under study were field crops (CS), vegetable crops, livestock, poultry and mushroom. Farm area between different components was allocated as, 0.65 ha to field crops (4875 m² under conventional farming, 1625 m² under natural farming), 0.175 ha to vegetable crops (1050 m² under conventional farming, 350 m² under natural farming), 0.10 ha to fodder crops (750 m² under conventional farming, 250 m² under natural farming), and 0.075 for livestock, poultry, mushroom and other enterprises (mature pit, vermicompost unit and fodder chopping unit). Comparisons were made on the basis of production and economic benefits of different enterprises. Results revealed that among field crops, “maize + soybean- gobhi sarson” and soybean- wheat” cropping systems performed better under conventional and natural farming, respectively. Among vegetable- based cropping system, “okra-radish-garlic” and “okra + soybean-pea” remained economically efficient under conventional and natural farming, respectively. Among different farming systems, integration of CS +Vegetable + Dairy + Mushroom + Poultry resulted in highest net returns under conventional farming; whereas under natural farming, combination of CS + Vegetable+ Mushroom + Poultry resulted in highest net returns under existing farm plan. Optimization of farming system was done using linear programming. With optimal resource allocation it was predicted that under conventional integrated farming system, maximum returns can be obtained with allocating maximum area and resources to farming system, maximum return can be obtained with allocating maximum area and resources to field crops and vegetable cropping systems components. Whereas, maximum return can be obtained by integrating and allocating vegetable resources to vegetable based cropping systems component and poultry component under natural farming. The study suggests that farm resources were not optimally allocated in existing plan. With modification in existing component combinations emanated from the linear programming net farm profit can be increased

2. Title of thesis	:	Effect of seed priming, nutrient management and tillage practices on productivity of rainfed maize-wheat system
Name of the student	:	Navneet Kaur (A-2019-40-005)
Major Advisor	:	Dr. Anil Kumar

Salient findings

A field experiment was conducted from *kharif* 2020 to *rabi* 2021-2022 at the Irrigation and Water Management Farm of Department of Soil Science, CSKHPKV, Palampur. (H.P.) to study the effect of seed priming, nutrient management and tillage practices on productivity of rainfed maize-wheat cropping system. The experiment was laid out in randomized block design with three factors *viz.*, tillage practices, seed priming and nutrient management practices and was replicated thrice. The treatments comprised of three tillage practices [Conventional tillage (CT), CT + mulch (CT+M) and Zero tillage+ mulch (ZT+M)]; two seed priming [Hydropriming and micronutrient priming (0.5%Zn and 0.1%Mn)] and two nutrient management practices [recommended dose of fertilizers (RDF) (120:60:40 in maize and 80:40:40 in wheat) and Integrated nutrient management(50% N through FYM + 50% N and rest of P and K through inorganic sources)]. An additional treatment of control (CT, No priming, RDF) was also kept for general comparison of results. The soil of the experimental site was silty clay loam in texture, acidic in reaction, medium in organic carbon, available phosphorus and potassium and low in available nitrogen. Results revealed that significantly higher growth and yield attributes, yield, nutrient content and uptake, system and water productivity and economic returns were obtained with conventional tillage + mulch followed by zero tillage + mulch amongst tillage practices, integrated nutrient management over RDF among nutrient management, whereas seed priming methods did not differ with respect to different parameters . As compared to initial status soil physical and chemical properties *viz.* bulk density, porosity, hydraulic conductivity, organic carbon, available nitrogen, phosphorus and potassium content at end of two years cropping cycle improved significantly under conventional tillage + mulch and integrated nutrient management practice followed by zero tillage + mulch and integrated nutrient management system. For obtaining higher crop and water productivity as well as economic returns in maize-wheat cropping system under rainfed condition, conventional tillage + mulch practice with integrated nutrient management and seed priming should be adopted.

3. Title of thesis	:	Studies on physio morphological attributes of crops and weeds as influenced by organic weed management practices in maize0-ea cropping system
Name of the student	:	Sarwan Kumar (A-2019-40-007)
Major Advisor	:	Dr. S. S. Rana

Salient findings

Studies were carried out in a long-term experiment in maize- peas cropping system under All India Coordinated Research Project on Weed Management (AICRP-WM) during October 2019 to September 2021 at Palampur. Ten weed control treatments based on T1- hoeing, T2 –Stale seed bed + hoeing, T3- raised stale seedbed + hoeing, T4- mulch 5t ha, T5-

stale seed bed + mulch, T6- raised stale seed bed + mulch, T7 – intercropping of soybean in *kharif* and fenugreek in *rabi*, T8- crop rotation (alternating soybean-mustard with maize-pea), T9- intensive cropping (additional crop of mustard in autumn and buckwheat in summer) and T10- chemical check (pendimethalin in *rabi* and atrazine in *kharif*) were evaluated in a randomized block design with three replications. The weed flora were comprising of 14 species in *rabi* 2019-20 and 13 in *rabi* 2020-21, 8 weed species during *kharif* 2020 and 14 in *kharif* 2021. There was considerable change in weed species composition during the second year as compared to the first year. Diversity and phytosociological analysis revealed diverse weed flora in the organic weed management treatments as compared to the chemical check. Phenological study revealed extended periods of germination/ emergence, flowering and fruiting. *Rabi* weeds emerged during October to January and *kharif* during May to August, flowered and bore fruits/ seeds during March (*rabi*) and September (*kharif*) respectively. Yield, net income and net energy were significantly higher under RSSB + Hoeing/ HW followed by crop rotation, however, chemical check was at par to this treatment in the second year. Crop rotation also gave higher profitability over the check. The growth analysis parameter viz., CGR, AGR and RGR found to be significantly more in intercropping and crop rotation.

4.Title of thesis	:	Ecology and control of <i>Alternanthera philoxeroides</i> (Mart). Griseb and <i>Synedrella vialis</i> (Less) A. Gray
Name of the student	:	Tamanna Bhalla (A-2019-40-008)
Major Advisor	:	Dr. Suresh Kumar

Salient findings

A filed experiment was conducted at the Research Farm, Department of Agronomy, CSKHPKV, Palampur during *kharif* 2020 and 2021 to study the ecology and control of *Alternanthera philoxeroides* (Mart). Griseb and *Synedrella vialis* (Less) A. Gray. Eleven weed control treatments viz. glyphosate 1000 g/ha, paraquat 1000g/ ha, 2-4D Na salt 1250 g/ha, 2-4D ethyl ester 1000g/ha, metsulfuron methyl 4g/ha, carfentrazone 25g/ha, glufosinate ammonium 500g/ha, bispyribac Na 20 g/ha, flumioxazin 200g/ha, diuron 500g/ ha and weedy check (control) were tested in Randomized Block Design with three replications. To study the ecology of both the weeds, experiments were conducted at three locations i.e. Research Farm, Department of Agronomy (Palampur), KVK (Berthin, Bilaspur) and on farmer's field (Kangra). *Alternanthera philoxeroides* recorded the highest shoot length (97.25 and 100.75 cm) and number of leaves per shoot (40 and 42) in the month of October and this weed did not flower throughout the duration of study at both the locations i.e. Palampur and Kangra. Whereas, *Synedrella vialis* exhibited a low growing mat forming habit with maximum shoot height (13 to 15.50 cm) and number of leaves per shoot (12) in August and September. This weed propagated vegetatively (runner) as well as through seeds since flowering occurred throughout the growth period at all the locations. Results of the weed control study revealed that the application of glyphosate 1000g /ha and metsulfuron methyl 4 g/ha behaving statistically alike were

significantly effective in reducing the count (No./ m²) and dry weight (g/ m²) of *Alternanthera philoxeroides* and *Synedrella vialis* during both the years of study. The bioassay study indicated that all the herbicides used for the control of these weeds did not retain any residue in the soil and thus, can be considered safe for use.

5. Title of thesis	:	Comparative performance of maize and wheat based intercropping systems under natural and organic farming practices
Name of the student	:	Raveena (A-2019-40-006)
Major Advisor	:	Dr. Rameshwar Kumar

Salient findings

A field experiment entitled “Comparative performance of maize and wheat based intercropping systems under natural and organic farming practices” was carried out at the Zero Budget Natural Farm (ZBNF), Department of Organic Agriculture & Natural Farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, from *kharif* 2020 to *rabi* 2021-22 to study the effect of natural and organic farming practices on the productivity, soil health and economics of maize and wheat based cropping systems. Soil of the experimental site was silty clay loam in texture, acidic in reaction, high in organic carbon and medium in available nitrogen, phosphorus and potassium. The experiment was laid out in randomized block design with three replications and thirteen treatments *viz.*, T₁- Maize + Lobia - Wheat + Gram and *jeevamrit* spray at 14 days interval, T₂- Maize + Lobia - Wheat + Gram and *jeevamrit* spray at 21 days interval, T₃- Maize + Lobia – Wheat + Gram and *jeevamrit* spray at 28 days interval, T₄- Maize + Soybean - Wheat + Lentil and *jeevamrit* spray at 14 days interval, T₅- Maize + Soybean - Wheat + Lentil and *jeevamrit* spray at 21 days interval, T₆- Maize + Soybean - Wheat + Lentil and *jeevamrit* spray at 28 days interval, T₇- Maize (sole) - Wheat (sole) and *jeevamrit* spray at 14 days interval, T₈- Maize (sole) - Wheat (sole) and *jeevamrit* spray at 21 days interval, T₉- Maize (sole) - Wheat (sole) and *jeevamrit* spray at 28 days interval, T₁₀- Maize + Lobia – Wheat + Gram (Organic), T₁₁- Maize + Soybean - Wheat + Lentil (Organic), T₁₂- Maize sole - Wheat sole (Organic) and T₁₃- Maize sole - Wheat sole (Absolute control). Significantly higher values of growth, yield attributes, grain and stover yield of maize were recorded under T₁ during *kharif* 2020 and T₄ during *kharif* 2021. Maize grain equivalent yield was significantly higher under T₄ during both the seasons (2020 and 2021). In case of nutrient uptake, significantly higher nitrogen, phosphorus and potassium uptake by grain/seed, stover/straw as well as total uptake was recorded under T₄ during *kharif* 2020 and T₁₁ during 2021. In case of wheat, significantly higher growth and yield attributes were recorded under T₁ during *rabi* 2020-21 and T₁₁ during *rabi* 2021-22. Significantly higher grain and straw yield of wheat were obtained under T₇ during 2020-21, while during 2021-22, it was higher under T₁₂. However, there was an increment in the wheat grain equivalent yield of T₁₀ and T₁₁ by 26.89% and 45.58 % in *rabi* 2021-22 as

compared to *rabi* 2020-21. Significantly higher nitrogen uptake by grain/seed, straw as well as total uptake was recorded under T₁₀ during 2020-21 and T₁₁ during 2021-22. However, highest phosphorus uptake by both grain/seed and straw as well as total uptake was recorded under T₇ during first season and T₁₁ during second season. In case of potassium, highest uptake by grain/seed was recorded under T₁₁ during both the seasons, whereas straw as well as total uptake was highest under T₇ during first season and T₁₁ during second season. Amongst different intercropping systems, maize + soybean – wheat + lentil intercropping system along with application of *jeevamrit* at 14 days interval (T₄) came out to be the best in terms of system equivalent yield (90.30 q/ha in 1st year and 82.53 q/ha in 2nd year) followed by organic farming practices, T₁₁ (85.69 q/ha in 1st year and 81.83 q/ha in 2nd year). Use of natural farming practices in maize + soybean – wheat + lentil intercropping system (T₄) also proved to be more economical and resulted in higher gross returns (249101 ₹/ha and 231759 ₹/ha), net returns (156061 ₹/ha and 132551 ₹/ha), B:C (1.68 and 1.34) and profitability (516.8 ₹/ha/day and 433.2 ₹/ha/day) of the system during both the years. Soil health was also significantly improved under organic farming treatment T₁₁ in terms of organic carbon, available nitrogen, phosphorus, potassium and microbial count, microbial biomass carbon and dehydrogenase activity.

6. Title of thesis	:	Evaluation of crop sequences under natural farming, organic and integrated nutrient management production systems
Name of the student	:	(A-2018-40-007)
Major Advisor	:	Dr. Pawan Pathania

Salient findings

A field experiment entitled “Evaluation of crop sequences under natural farming, organic and integrated nutrient management production systems” was conducted during *Kharif* 2019-20 to *Rabi* 2020-21 at the Research Farm of Agronomy Department, College of Agriculture, CSKHPKV, Palampur to explore the production potential of identified cropping sequences and to monitor the change in soil fertility, quality and economic viability of the crop sequences. The soil at the experimental site was silty clay loam with an acidic reaction, medium organic carbon content, available phosphorus and potassium and low available nitrogen. The experiment consisted with sixteen treatments and three replications were laid out in split plot design. The treatments consisted of four production system viz. integrated nutrient management, organic farming, natural farming, conservation agriculture in main plots and in sub plots, maize-wheat, maize-cowpea-wheat+gram, maize+soybean-radish-onion and okra+pole bean-cabbage+garden pea were undertaken. In different cropping sequences, okra+pole bean-cabbage+pea sequences in combination with integrated nutrient management came out to be best in terms of maize grain equivalent yield (33009 kg ha⁻¹) followed by organic farming system. However, integrated nutrient management in okra+ pole bean-cabbage _ pea sequence proved to

be more economical and resulted in low cost of cultivation (146095 ha⁻¹), high gross returns (523945 ha⁻¹) and highest net returns per rupee invested (377850 ha⁻¹) . In terms of quality, integrated nutrient management production system with maize- wheat cropping sequence proved to be high in carbohydrate yield, fat yield and in energy equivalents. Integrated nutrient management with maize+ soybean- radish-onion resulted in high protein yield. Application conservation agriculture in combination with maize + cowpea- wheat + gram cropping sequence resulted significant increase in organic carbon, available nitrogen, phosphorus, potassium and also improve soil health of the system as microbial population in the soil i.e., bacteria and fungi were highest under conservation agriculture production system.

7.Title of thesis	:	Studies on conservation tillage and NPK levels in soybean- <i>Gobhi sarson</i> cropping system
Name of the student	:	(A-2020-40-005)
Major Advisor	:	Dr. Janardan Singh

Salient findings

A field experiment was conducted from *Kharif* 2021 to *Rabi* 2022-23 at the Integrated Research Farm, Department of Organic Agriculture & Natural Farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (HP) to study the effect of different tillage practices and NPK levels on productivity, profitability and soil fertility in soybean- *Gobhi Sarson* cropping system. The experiment comprised of twelve treatment combinations including three tillage practices (minimum tillage, minimum tillage + crop residue and conventional tillage) and four NPK levels (50, 75, 100 and 125% of recommended dose of nutrients) were tested in split plot design. The soil of experimental site was silty clay loam in texture, acidic in reaction and medium in available nitrogen, phosphorus and potassium. Among different tillage practice, higher values of growth parameters, yield attributes, yield, energy indices, economics and improved soil properties (bulk density, water holding capacity, organic carbon and soil carbon sequestration and available NPK status in soil) were recorded under minimum tillage along with crop residue. Among different NPK levels, 125 and 100 per cent recommended dose of nutrients recorded significantly higher values of growth parameters, yield attributes, yield, energy indices (energy efficiency, energy output and net return of energy), improved soil physical (bulk density, particle density and water holding capacity) and chemical properties (pH, organic carbon, soil carbon sequestration and available NPK). Minimum tillage along with crop residue and 100 per cent recommended dose of nutrients was found to be more profitable treatment for soybean- *Gobhi Sarson* cropping system, respectively.

8.Title of thesis	:	Agronomic biofortification studies in redrice (<i>Oryza sativa</i> L.) - wheat (<i>Triticum aestivum</i> L.) cropping system using Nanofertilizers
-------------------	---	--

Name of the student	:	Rahul Sharma (A-2020-40-006)
Major Advisor	:	Dr. Sandeep Manuja

Salient findings

A field experiment was conducted from *kharif* 2021 to *rabi* 2022-23 at the Experimental farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur to study the effect of nano nitrogen (Nano N) and nano zinc (Nano Zn) application on growth, development, yield, soil health and economics of rice-wheat cropping system as well as their effect on nutritional quality of rice and wheat grains. The experiment was laid out in randomized block design (RBD) and comprised of fourteen treatments viz; T₁: 100% N, T₂: 100% N +1 spray Nano N, T₃: 100% N+1 spray Nano Zn, T₄: 100% N+ 1 spray Nano N and Nano Zn, T₅: 75% N, T₆: 75% N+2 spray Nano N, T₇: 75% N+2 spray Nano Zn, T₈: 75% N+ 1 spray Nano N and Nano Zn, T₉: 75% N+ 2 spray Nano N and Nano Zn, T₁₀: 50% N, T₁₁: 50% N+ 2 spray Nano N, T₁₂: 50% N+ 2 spray Nano Zn, T₁₃: 50% N+ 1 spray Nano N and Nano Zn, T₁₄: 50% N+ 2 spray Nano N and Nano Zn with three replications. The same treatments were applied in both rice and wheat with rice being cultivated under direct seeding. The varieties used in this investigation were HPR 2795 (*HimPalam Lal Dhan* 1) in rice and HPW 368 (*Him Palam Gehun* 2) in wheat. The soil of experimental site was silty clay loam in texture, acidic in reaction, medium in available nitrogen, phosphorus, potassium and adequate in zinc. The results obtained from the present investigation clearly indicated the significant influence of nitrogen levels as well as foliar application of nanofertilizers on the growth, development, yield attributes and yield as well as the quality of both rice and wheat. Application of 100% N along with single spray of nano N and nano Zn resulted in significantly higher values of growth parameters, yield attributes and yield of both the crops though this treatment was at par with the application of 75% N alongwith two sprays of nano N and nano Zn. Application of 50% N alone resulted in significantly lower values of growth parameters, yield attributes and yield in both the crops. Further two sprays of nano N at tillering and pre-flowering stages could substitute for about 25% of the recommended nitrogen in both the crops. Higher nitrogen content, zinc content and crude protein content was recorded with the application of 75% N application supplemented with two combined sprays of Nano N and Nano Zn at tillering and pre-flowering stages in both rice and wheat. Soil pH, EC and organic carbon (%) were not influenced significantly by respective treatments after the end of two years cropping system. Treatments in which 100% N was applied exhibited significantly higher available nitrogen content in soil after two years of cropping while significantly higher values of available phosphorus were observed in treatments in which 50% N was applied. No significant influence of treatments was observed on the available potassium content in soil as well as DTPA extractable zinc though values of these parameters declined as compared to their initial values at the end of two years of cropping. Application of 100% N along with one spray of nano N and nano Zn proved to be the most remunerative one giving higher

gross returns, net returns, and B: C ratio in both rice and wheat crop during both the years while lower B: C ratio was reported in 50% N with two sprays of Nano Zn alone. Thus, in rice and wheat for growth, yield, and yield attributes, application of 100% N alongwith single combined spray of Nano N and Nano Zn is found to be the best treatment which was at par with 75% N application with two sprays of Nano N and Nano Zn in combination during both the years. Two sprays of nano nitrogen increased the crude protein content in both rice and wheat grains which further increased when nano zinc was sprayed along with nano nitrogen. Similarly, foliar spray of nano zinc, either once or twice, resulted in significant increase in the zinc content of both rice and wheat grains with foliar application of nano zinc at pre-flowering stage proving it to be more beneficial. Hence, the present study revealed the importance of using higher levels of nitrogen as well as foliar application of nano N and nano Zn for obtaining higher productivity, enhanced quality of both rice and wheat. Enrichment of rice and wheat grains with protein and zinc by using agronomic biofortification can be used to alleviate the zinc deficiency in rice and wheat eating population of our country.

9. Title of thesis	:	Modelling crop water requirement of garden pea in North- Western Himalaya
Name of the student	:	Avnee (A-2020-40-002)
Major Advisor	:	Dr. Ranbir Singh Rana

Salient findings

A field experiment was conducted during the *rabi* seasons of 2021-22 and 2022-23 at the Research Farm, Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (HP) to model the crop water requirement of garden pea in the North-Western Himalaya. The experiment included fifteen treatment combinations, with five irrigation treatments in main plots and three sowing windows in sub-plots and was carried out in a split-plot design with three replications. The soil at the experimental site exhibited a silty clay loam texture, acidic reaction and medium levels of available nitrogen, phosphorus and potassium. Among various irrigation scheduling methods, full irrigation (six irrigations), spatial reference PET, ET₀ by Penman-Monteith modified and Penman temperature method resulted in higher values of growth parameters, yield attributes and yield compared to limited irrigations (two irrigations). Amongst sowing windows, the crop sown during the 42nd Standard Meteorological Week (SMW) (20th October) exhibited significantly higher values of growth parameters, yield attributes and yield. The weather model's estimation of PET and ET₀ was validated with the field water balance method and the RMSE values varied between 10.3 to 14.4 %. In the context of climate change, with an increase in temperature by +1°, 2° and 3°C, coupled with a 10 and 20% decrease in rainfall, crop water requirements showed a 3.7 to 13.2% higher demand. Conversely, a 20% increase in rainfall offset the impact of elevated temperatures with +1°C, while +2° and

+3°C with 10 and 20% increase led to higher crop water requirements. The correlation studies showed that all sowing dates displayed strong positive correlations of dry matter with rainfall and day length during both the study years whereas the linear regression model with dry matter and weather parameters also showed a good fit of the model. The estimation of crop water requirement using Penman-Monteith modified method with real-time weather data was proved to be the best for irrigation scheduling to reduce crop water footprints compared to other methods (14.6% and 13.8% less than full irrigation) of crop water requirement. The research distinctly demonstrates that the utilization of real-time weather data and weather models for estimating crop water requirement can effectively serve as valuable guidance for the farming community when coupled with weather forecasts.

10. Title of thesis	:	Comparative performance of forage based cropping systems under conventional, organic and natural farming.
Name of the student	:	Kunal Narwal (A-2018-40-005)
Major Advisor	:	Dr. G.D. Sharma

Salient findings

A field experiment entitled “Comparative performance of forage based cropping systems under conventional, organic and natural farming” was conducted, starting from *rabi* season 2019-20 to *khariif*- 2021 at Integrated Organic Farm, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Fifteen treatment combinations with five farming practices viz., F₀- Absolute control, F₁- Organic Farming, F₂- Natural Farming, F₃- Natural Farming + 10t FYM, F₄- Recommended fertilizers dose (RDF) in main plots and three forage based cropping systems viz., C₁-Oat-sorghum, C₂-Oat+ fodder Sarson-sorghum + pearl millet, C₃- Oat+ berseem-sorghum+ cowpea in sub plots, laid out in split plot design with three replications were evaluated for crop productivity, quality, soil properties and profitability. The soil of the experimental field was silty-clay loam in texture and slightly acidic in reaction with medium organic carbon. The soil was low in available nitrogen and medium in available in phosphorus and available potassium. Application of recommended NPK fertilizers resulted in highest system productivity i.e. highest total green fodder yield (80.22 tha⁻¹), on the basis on two years pooled mean, which was followed by natural farming + 10 t FYM ha⁻¹ (71.47 t ha⁻¹) and the latter treatment remaining at par with organic farming practices out yielded natural farming and absolute control treatments. Among the cropping systems, oat + fodder sarson-sorghum + pearl millet gave maximum total green fodder yield (75.47 t ha⁻¹) which was significantly higher than two cropping systems on two years pool basis. Farming practices significantly influenced acid detergent fiber (ADF) and neutral detergent fiber (NDF) content in oats and sorghum, with absolute control and natural farming approaches showing highest ADF and NDF content while recommended NPK fertilizers showed the lowest content. Incorporating leguminous component

is recommend for improved fodder quality. The application of 10t of farmyard manure (FYM) in conjunction with natural farming practices resulted in significant improvements in soil organic carbon, soil microbial biomass carbon, and reduced bulk density compared to other treatments. However, the highest available nitrogen, phosphorus, and potassium contents in soil were observed under recommended dose of NPK fertilizers application. Among cropping systems, oat + berseem-sorghum + cowpea cropping system demonstrated superior soil health indicators at the end of experiment. Economic analysis revealed that recommended NPK fertilizers followed by natural farming + 10t FYM ha⁻¹ application proved most profitable with highest gross returns, net returns and benefit-cost ratio during the two years of experimentation. Similarly, the organic farming + fodder sarson- sorghum + pearl millet cropping system exhibited the highest benefit-cost ratio (2.8) among cropping systems.

11. Title of thesis	:	Studies on method of rice establishment, residue retention and zinc application in rice-wheat cropping system
Name of the student	:	Akashdeep Singh (A-2020-40-001)
Major Advisor	:	Dr. A. D. Bindra

Salient findings

The field experiment was conducted from *khari*f 2021 to *rabi* 2022-23 under the mid-hill conditions of Himachal Pradesh at Experimental farm of Rice and Wheat Research Centre, Malan of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh to study the effect of different rice establishment methods, zinc application and residue retention on growth, development, yield, soil health and economics of rice-wheat cropping system. The experiment was laid out in split-plot design and comprised of six main plot treatments *viz.*, M₁: transplanting, M₂: wet seeding (line sowing under puddle condition), M₃: aerobic rice (dry rice cultivation), M₄: transplanting + soil application of ZnSO₄ @ 12.5 kg ha⁻¹ + foliar spray of ZnSO₄ @ 0.5% at flowering and early milk stages, M₅: wet seeding + soil and foliar application of ZnSO₄, M₆: aerobic rice + soil and foliar application of ZnSO₄, and three sub plot treatments *viz.*, S₁: no residue, S₂: 15 cm height of rice straw from ground and incorporation in soil and S₃: 30 cm height of rice straw from ground and incorporation with three replications. The varieties used in the investigation were HPR 1068 of rice and HPW 349 of wheat. The soil at the experimental site was silty clay loam in texture, acidic in reaction, medium in available nitrogen, available phosphorus and available potassium. The results obtained from the present investigation clearly indicated the significant influence of different establishment method with or without zinc on the growth, development, yield attributes and yield of rice and their residual effect had significant influence on the subsequent wheat crop. Transplanting method along with zinc application resulted in significantly higher values of growth parameters, yield attributes, yield and grain zinc content of rice whereas wheat crop sown after aerobic method along with zinc application

resulted in significantly higher growth parameters, yield attributes and yield of wheat. On the other hand, residue incorporation of 15 cm had significantly higher values for yield attributes and yield of rice and wheat crops. Soil pH and organic carbon were not significantly influenced by different treatments after the end of two years of study. Furthermore, treatments which included puddling along with no residue incorporation resulted in significantly higher values for soil bulk density and particle density. Soil porosity remained unaffected by the different treatments. The incorporation of residue significantly enhanced the microbial population, dehydrogenase and biomass carbon in soil. In terms of net returns and benefit cost ratio in rice, aerobic method of rice establishment without soil and foliar applications of zinc proved to be most remunerative during both years of study. Similarly, wheat crop grown after aerobic method of rice establishment along with soil and foliar applications of zinc proved to be most remunerative giving higher gross returns, net returns and benefit cost ratio. Incorporation of 15 cm of residue consistently resulted in higher gross returns, net returns and benefit cost ratio in both rice and wheat during both years of study. Hence, the present study revealed the importance of rice establishment methods along with application of soil-applied zinc and foliar sprays of zinc during growth stages, and residue retention for enhancing rice and subsequent wheat crop performance and productivity. Enrichment of rice and wheat grains with zinc through targeted agronomic practices, such as soil applications and foliar sprays, presents a viable solution to enhance the nutritional quality of staple crops.

12. Title of thesis	:	Nutrient management in <i>gobhi sarson</i> (<i>Brassica napus</i> L.)-maize (<i>Zea mays</i> L.) cropping system
Name of the student	:	Deekshith H N (A-2019-40-003)
Major Advisor	:	Dr. B. S. Mankotia

Salient findings

A field experiment was conducted during 2019-20 and 2020-21 at the CSKHPKV, SAREC, Kangra on nutrient management in *gobhisarson* - maize cropping system. Eleven treatments viz., T₁-Control; T₂-100% PK to both crops; T₃-100% NP to both crops; T₄-100% NK to both crops; T₅-100% NPK to both crops; T₆-150% NPK to both crops; T₇-100% NPK + S @ 35 kg ha⁻¹ to *gobhisarson* and 100% NPK to maize; T₈-100% NPK + Zn @ 25 kg ZnSO₄ ha⁻¹ to *gobhisarson* and 100% NPK to maize; T₉-100% NPK + B @ 1kg ha⁻¹ to *gobhisarson* and 100% NPK to maize; T₁₀-100% NPK + FYM @ 2.5 t ha⁻¹ to *gobhisarson* and 100% NPK to maize; T₁₁-SPNF (*Gobhisarson* + Pea) followed by Maize + Soybean, were tested in RBD. *Gobhisarson* significantly responded to the higher dose (T₆), FYM (T₁₀), sulphur (T₇), zinc sulphate (T₈) and boron (T₉). Significant residual effect of FYM was also observed on maize. The system productivity (*Gobhisarson* equivalent yield) was significantly more in T₆ (3356 kg ha⁻¹) being at par with T₁₀ (3220 kg ha⁻¹) over T₇ (3026 kg ha⁻¹), T₈ (3012 kg ha⁻¹) and

T₉ (2905 kg ha⁻¹) and T₅ (2819 kg ha⁻¹) and respective net returns of ₹. 109.2, 103.1, 94.9, 94.0 and 89.1 thousand ha⁻¹ with benefit cost ratio of 1.81, 1.73, 1.64, 1.62, and 1.55. Sulphur (T₇) along with the recommended dose (RDF) increased oil content percent and oil yield in *gobhisarson*. T₆ recorded more N, P, K, S, Zn and B uptake in cropping system followed by T₁₀, T₇, T₈ and T₉. The system productivity in SPNF practice (2395 kg ha⁻¹) was 15.0% less as compared RDF whereas net returns were less by 8.2%. Thus, for more productivity and profitability in *gobhisarson*- maize farmer should apply higher dose to both the crops. Application of 2.5 t FYM or 35 kg sulphur or 25 kg ZnSO₄ ha⁻¹ to *gobhisarson* should be done to realize more system productivity and profitability as compared to RDF to both the crops.

13. Title of thesis	:	Comparative efficacy of indigenous and exotic cattle based natural farming inputs on performance of legume based cropping systems
Name of the student	:	Arjun Singh (A-2021-40-004)
Major Advisor	:	Dr. Rameshwar Kumar

Salient findings

A field experiment entitled “Comparative efficacy of indigenous and exotic cattle based natural farming inputs on performance of legume based cropping systems” was carried out at Zero Budget Natural Farm, Department of Organic Agriculture and Natural Farming, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur from *kharif* 2022 to *rabi* 2023-24 to evaluate efficacy of indigenous and exotic cattle based natural farming inputs on performance of legume based cropping systems in terms of productivity, economics and soil health. Soil of the experimental site was silty clay loam in texture, acidic in reaction, medium in organic carbon, available phosphorus, available potassium and low in available nitrogen. The experiment was laid out in split plot design with two factors and replicated thrice. The treatments consisted of two cropping systems *viz.* soybean-sarson and finger millet-peas with bio-formulations prepared with inputs of seven different cattle breeds *viz.* Indigenous cow (*Pahari*) lactating, Indigenous cow (*Pahari*) dry, Indigenous cow (Sahiwal) lactating, Indigenous cow (Sahiwal) dry, Exotic cow (Jersey) lactating, Exotic cow (Jersey) dry, Indigenous bull (*Pahari*). Application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari*) dry recorded the highest growth and yield attributes of all crops in comparison to other cattle breeds. However, application of bio-formulations prepared from inputs of Indigenous cow (*Pahari*) lactating was at par with Indigenous cow (*Pahari*) dry. Application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari*) dry proved to be more economical and resulted in the highest gross returns, net returns and B:C of all crops. Use of bio-formulations prepared from the inputs of Indigenous cow (*Pahari*) dry lowered the soil bulk density at the end of the experiment and recorded significant increase in available nitrogen (271.1 kg/ha), phosphorus (20.0 kg/ha) and potassium (250.1 kg/ha) over the initial status. Application of bio-formulations prepared from the inputs of Indigenous cow (*Pahari*) dry came out to be the best in terms of effect on soil health of

the system as microbial population in the soil i.e., bacteria, fungi and actinomycetes were the highest.

14. Title of thesis	:	Enhancement of productivity and biofuel production potential of sweet sorghum-mustard cropping system under different nutrient management systems
Name of the student	:	Tarun Sharma (A-2020-40-007)
Major Advisor	:	Dr. Naveen Kumar

Salient findings

The field experiments were conducted from Kharif 2021 to Rabi 2022-23 at the Fodder Section, Department of Genetics and Plant Breeding, CSK Himachal Pradesh Krishi Vishwavidyalaya, to study the effect of various nutrient management systems on the productivity and biofuel production potential of sweet sorghum-mustard cropping system. The soil at the experimental site was silty clay loam in texture with acidic soil reaction (pH = 5.48), low available nitrogen (256.4 kg ha⁻¹), medium potassium (170.6 kg ha⁻¹), and phosphorus soil status (17.2 kg ha⁻¹). The experiment had fifteen treatments with combinations such as N₆₀ K₄₀ B₁, N₆₀ K₄₀ B₂, N₆₀ K₆₀ B₁, N₆₀ K₆₀ B₂, N₁₂₀ K₄₀ B₁, N₁₂₀ K₄₀ B₂, N₁₂₀ K₆₀ B₁, N₁₂₀ K₆₀ B₂, N₁₈₀ K₄₀ B₁, N₁₈₀ K₄₀ B₂, N₁₈₀ K₆₀ B₁, N₁₈₀ K₆₀ B₂, Recommended dose of NPK (120: 60: 40), Recommended dose of NPK + FYM @ 10 t ha⁻¹ and absolute control arranged in a completely randomized block design with three replications. The application of nitrogen, potassium, and boron at the rate of 180, 60, and 2 kg ha⁻¹ significantly improved sweet sorghum growth attributes, such as plant height (291.3 and 300.4 cm), stem diameter (2.13 and 2.21 cm), fresh stem weight per meter square (5.45 and 5.35 kg m⁻²), and dry matter accumulation per meter square (1.46 and 1.50 kg m⁻²). This treatment also resulted in the highest stem (53.8 and 52.8 t ha⁻¹), biological (66.2 and 64 t ha⁻¹), juice (20.3 and 20.8 Kl ha⁻¹), sugar (2567 to 2608 kg ha⁻¹), and juice ethanol yields (1669 and 1645 l ha⁻¹). The total soluble solids (18.1 and 18.0%), sugar (2428.3 and 2423.7 kg ha⁻¹), and juice ethanol yield (1563.7 and 1560.7 l ha⁻¹) were also significantly improved with application of nitrogen, potassium and boron at the rate of 60, 60, and 2 kg ha⁻¹. The highest gross (109.5 and 108 INR ha⁻¹), net returns (40.8 and 39.6 INR ha⁻¹), and benefit-cost ratio (1.59 and 1.58) were recorded with 180, 60, and 1 kg ha⁻¹ -based application of nitrogen, potassium and boron. For mustard, the residual effect of 180, 60, and 2 kg ha⁻¹ based application of nitrogen, potassium and boron resulted in the highest values for growth and yield attributes, including plant height (208.5 and 217.7 cm), dry matter accumulation per meter square (484.8 and 531.1 g m⁻²), number of primary branches per plant (5.3 and 6.2), number of siliquae per plant (473.3 and 460.4), seed (1299.5 and 1486.6 kg ha⁻¹), stover (4452.1 and 4994.1 kg ha⁻¹), and biological yield (5751.6 and 6480.7 kg ha⁻¹). Increased soil fertility reduced glucosinolates (76.7 and 76.2 μmole g seed⁻¹) and fatty acid content, with the highest values in the control and at par with 60, 40, and 1 kg ha⁻¹. The highest gross (73.4 and

84 INR ha⁻¹), net returns (36.9 and 47.5 INR ha⁻¹), and benefit-cost ratio (2.01 and 2.30) for mustard were also recorded with residual influence based on application of nitrogen, potassium and boron at the rate of 180, 60, and 2 kg ha⁻¹. The highest available soil nitrogen (260.1 kg ha⁻¹) was recorded with 180, 60, and 1 kg ha⁻¹, while the highest available phosphorus (23.1 kg ha⁻¹) was with 60, 40, and 1 kg ha⁻¹ application of nitrogen, potassium and boron. The highest available soil potassium content (180.0 kg ha⁻¹) was found with the treatment based on application of FYM @ 10 t ha⁻¹ plus recommended NPK (120:60:40), and the highest available boron (0.420 mg kg⁻¹) was with 60, 40, and 2 kg ha⁻¹-based application of nitrogen, potassium and boron.

14. Title of thesis	:	Studies on rice establishment methods and crop management practices in red rice-wheat cropping system.
Name of the student	:	Gaytri Hetta (A-2020-40-003)
Major Advisor	:	Dr. G D Sharma

Salient findings

A field experiment was conducted at integrated nutrient management Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya at Holta, Palampur during kharif 2021 to rabi 2022-23, to evaluate the effect of different rice establishment methods and nutrient management practices in red rice-wheat cropping system. The field experiment consisting of twelve treatment combinations viz. three crop establishment methods (transplanted rice, system of rice intensification and aerobic rice system) were kept in main plots and four crop management practices (Organic farming, natural farming, Integrated nutrient management and control) were allotted to sub-plots in a split-plot design, replicated thrice. The soil of the experimental field was silty clay loam in texture, acidic in reaction, high in organic carbon, medium in available nitrogen and potassium and high in phosphorus content. SRI and transplanting method resulted in significantly higher values of growth parameters in terms of plant height, LAI at heading, dry matter accumulation and shoots per square meter owing to higher growth parameters which resulted in significantly higher grain yield of rice in SRI (2522.0kg ha⁻¹) which was statistically at par with transplanted rice (2476.0 kgha⁻¹). The grain yield of rice was 12.7 and 10.6 % higher with SRI and puddle transplanted rice, respectively over aerobic method of rice establishment. Straw yield and biological yield followed a similar trend during both the years of study. In terms of crop management practices, the highest yields were consistently obtained with integrated nutrient management (INM) and grain yield with integrated nutrient management was 43.9 % higher than control, while organic farming and natural farming practices were higher by 34.4 and 18.7 %. Significantly lower yield was obtained with aerobic method of rice establishment (2237.5 kg ha⁻¹) during both the years of study and in case of succeeding wheat crop sown after

aerobic method, it resulted in significantly higher growth parameters, yield attributes and yield of wheat. The highest input energy was recorded with the transplanted rice method (M1) in both years (11,278.5 MJ kg⁻¹). The SRI method (M2) had the highest energy output, with 86,658.1 MJ kg⁻¹ in 2021-22 and 75,803.4 MJ kg⁻¹ in 2022-23. SRI and transplanting methods yielded higher gross returns than aerobic methods, while integrated nutrient management, organic farming, and NF showed the highest net returns, despite a slight decline in 2022. In case of wheat, it was found that wheat sown after aerobic method of rice cultivation significantly increased grain yield, straw and biological yields in the second year i.e. 12.1% and 21.0% higher than SRI and puddle transplanted methods in the first year and 12.8% and 20.6% higher in the second year. Higher yields were recorded with INM, followed by organic and natural farming practices. The aerobic method (M3) consistently provided the highest gross and net returns and the best benefit-cost ratio, making it the most economically efficient method. In nutrient management, natural farming (C2) yielded the highest economic returns. The aerobic method (M3) showed the highest system productivity but the lowest profitability. SRI (M2) balanced high productivity with the highest profitability. Combining M3 with C2 i.e. aerobic with natural farming maximized economic returns, highlighting the importance of optimized practices for improved productivity and profitability in wheat. In case of rice, SRI under INM and OF was found suitable and remunerative for farmers with less land holdings as in the state of Himachal Pradesh.

Soil Science

1. Title of thesis	:	Effect of continuous application of target yield based fertilizers and organic manure in maize-wheat cropping system on soil properties, nutrients uptake and productivity of maize in an acid Alfisol
Name of the student	:	Anjali Thakur (A-2019-40-027)
Major Advisor	:	Dr. S.P. Dixit

Salient findings

The present study on the effect of continuous application of target yield based fertilizers and organic manure in maize-wheat cropping system on soil properties, nutrients uptake and productivity of maize was carried out during *kharif* 2020 and 2021 in a long term experiment on soil test crop response studies at the experimental farm of Department of Soil Science, CSKHPKV, Palampur. The experiment consisted of eight treatments viz., control, farmers' practice, general recommended dose, soil test based fertilizer application, chemical fertilizers for 30 q ha⁻¹ target yield with and without FYM, chemical fertilizers for 40 q ha⁻¹ target yield with and without FYM, in a randomized block design. The soil was silty clay loam, acidic in reaction (pH 5.2), 7.2 g organic carbon ha⁻¹, 236, 41 and 272 kg available N, P and K ha⁻¹, respectively. Soil samples from 0-0.15 m depth were collected before and after the harvest of maize (*kharif* 2020 & 2021) and analyzed for the physical, chemical and biological properties. Grain and

stover samples were also analyzed for nutrients concentration and nutrients uptake was determined. Grain quality parameters were also analyzed. Continuous application of 30 and 40 q ha⁻¹ target yield based fertilizers with FYM improved the physical properties of the soil significantly over control and chemical fertilizers- alone treatments. Soil organic carbon, CEC, available N, P, K, S, exchangeable Ca and Mg, DTPA extractable Fe, Mn, Zn and Cu, microbial biomass C, N, P, S, and enzyme activity were highest in STCR-IPNS treatments, however, soil pH did not vary significantly within the treatments. Integration of FYM and 40 a ha⁻¹ target yield based chemical fertilizers improved the maize grain quality resulting in highest crude protein, crude fat, crude fibre, ash, total carbohydrates, starch, reducing and non-reducing sugar content but it was at par with 30 q ha⁻¹ target yield + FYM treatment. Target yield based chemical fertilizers application for 30 and 40 q ha⁻¹ with FYM significantly increased the grain and stover yield as well the N, P, K, S, Na, Mg, Fe, Mn, Zn and Cu uptake by maize over farmers practice, general recommended dose and soil test based fertilization application. The highest B:C was recorded in 40 q ha⁻¹ target yield treatment (3.02 and 3.04), followed by 40 q ha⁻¹ target yield + FYM (2.87 and 2.80) and lowest in control (1.30 and 1.19) during kharif 2020 and 2021 respectively.

2. Title of thesis	:	Effect of chemical fertilizers, organics and lime on fractions of micronutrient cations under continuous maize-wheat cropping in an acid Alfisol
Name of the student	:	Deepika Suri (A-2018-40-027)
Major Advisor	:	Dr. Raj Paul Sharma

Salient findings

The present investigation was carried out in an on-going long-term fertilizer experiment, initiated during 1972 at experimental farm of Department of Soil Science, CSK HPKV Palampur, to study the effect of chemical fertilizers, organics and lime on fractions of micronutrient cations under continuous maize-wheat cropping in an acid *Alfisol*. The experiment was laid out in a randomized block design with twelve treatments. The soil of the experimental site was silty loam and classified taxonomically as “*Typic Hapludalf*”. Soil samples were collected after wheat (*rabi*, 2019-20 and 2020-21) harvest from the surface (0-0.15 m) and sub-surface (0.15-0.30 m) layer. Soil samples were analyzed for various chemical, physical and microbiological properties using standard analytical procedures. Different fractions of Zn, Cu, Mn and Fe were determined in surface and sub-surface soil samples collected after wheat harvest (*rabi*, 2019-20) and soil samples drawn from adjacent buffer plots. The grain and stover/straw yield of maize and wheat was recorded. The nutrient concentration was determined in grain and stover/straw samples of maize & wheat and uptake was calculated. Continuous use of chemical fertilizers, organics and lime under maize-wheat system in an acid *Alfisol* brought out marked depletion in the pools of all the micronutrient cations as compared to buffer plots. The content of different fractions of Zn, Cu, Mn and Fe in sub-surface layer was less than that in surface layer. However, the treatment wise trend was almost similar to that under surface layer. Highest grain

yield of maize (54.77 and 44.91 q ha⁻¹ during 2019 and 2020, respectively) and wheat (28.11 and 24.67 q ha⁻¹ during 2019-20 and 2020-21, respectively) was recorded under 100% NPK + FYM treatment which was at par with 100 % NPK + lime. FYM and lime treatments resulted in significantly higher uptake of all the nutrients by both the crops compared to other treatments. Most of the fractions of Zn, Cu, Mn and Fe correlated negatively and significantly with pH and positively and significantly with OC and CEC. Simple correlation and regression studies revealed that organically bound and exchangeable fractions were found to play major role in the nutrient supply, crop productivity and nutrients' uptake.

3. Title of thesis	:	Effect of foliar bio-nano P and K applications on nutrient optimization and soil productivity in maize-wheat cropping in an acid Alfisol
Name of the student	:	Devanshi Baghla (A-2018-40-028)
Major Advisor	:	Dr. V.K. Sharma

Salient findings

In modern agriculture, nano fertilizer use is being popularized throughout the world because of their higher nutrient use efficiencies in comparison to non nano/ conventional fertilizers. To assess the possibility of using bio-nano P and K fertilizers alone or in combination with conventional fertilizers and their impacts on fertilizer nutrient economy/ optimization and soil health attributes in maize-wheat sequence, a field experiment was conducted in acid *Alfisols* during 2019-20 and 2020-21 with fourteen treatments and three replications in Randomized Block Design. The treatment comprised of basal conventional P and K fertilizer applications, each at three levels (0, 50 and 100 per cent of their recommended levels), with and without two post-emergence bio-nano fertilizer sprays. In addition, there were two treatments to assess the compatibility of bio nano P and K sprays at 50 and 100 % of recommended levels of both nutrients. Natural farming practice was also applied as a check treatment. Through statistical analysis of year-wise and pooled data, it was observed yield attributing characters (plant height, cob/ spike length, no. of grains per cob/ spike and test weight), grain yields and nutrient uptake of maize and wheat increased significantly with increasing levels of P and K application through conventional fertilizers alone or along with bio-nano foliar sprays. Lowest and highest values of each were found with natural farming and P₁₀₀K₁₀₀ + bio-nano P & K sprays treatment, respectively. Further, treatment combinations viz., P₅₀ & P₀ + bio-nano P, P₁₀₀ & P₅₀ + bio-nano P, P₅₀ & K₀ + bio-nano K, K₁₀₀ & K₅₀ + bio-nano P and P₅₀ K₅₀ + bio-nano P & K & P₁₀₀ K₁₀₀ were found at par with each other in above mentioned parameters, which highlighted the effectiveness of bio-nano sprays as an effective nutrient supplying source to maize and wheat and for optimizing fertilizer nutrient requirement to the extent of 50% of the recommended dose of P and K. Assessment of leaf nutrient status of maize and wheat during their critical growth stages supported that finding also. Like non-nano P and K fertilizers, their bio-nano foliar sprays have a positive effect on soil attributes affecting soil health. There was a significant improvement in bulk density, water holding capacity, water stable aggregates (> 0.06 mm), organic carbon, CEC, available nutrient status, MBC, dehydrogenase activity and microbial population. These attributes increased significantly with increasing levels of P and K application through conventional fertilizers alone or along with bio-nano foliar sprays. Similar

results were also observed on saloid-P, AI-P and Fe-P build-up in soils but with non-nano P fertilizer application and on water soluble, exchangeable and non-exchangeable K build up but with non-nano K fertilizer application. However, bio-nano K application showed no significant effect on any inorganic and K fractions. The cost of cultivation of maize and wheat with fertilizer treatments involving non-nano fertilizer application alone were considerably lower than those with bio nano sprays at all the levels of P and K. Since, cost of spraying of bio-nano sprays is considerably higher, fertilizer treatment involving non-nano fertilizer application. Fertilizer treatments involving non-nano fertilizer application resulted in more net profits and B:C ratio. Highest B:C ratio was observed with P and K applications through non-nano fertilizers at recommended rates. Keeping in view the above-mentioned figures and facts it may be concluded that bio-nano sprays alone or in conjunction with conventional fertilizers optimized fertilizer P and K requirements of maize and wheat equivalent to 50 per cent of their basal application. However, this nutrient management intervention is less economically viable as compared to conventional fertilizers at current prices of bio-nano P and K fertilizers.

4. Title of thesis	:	Molybdenum status and its critical limits for french bean and cauliflower in acid soils of Himachal Pradesh
Name of the student	:	Hemali Bijani (A-2019-40-029)
Major Advisor	:	Dr. Pardeep Kumar

Salient findings

Molybdenum (Mo) an ultra-micronutrient plays key role in plants as an essential nutrient besides its significance in regulating nitrogen availability. It is emerging as a deficient nutrient especially in acid soils. As in Himachal Pradesh (HP), a significant area is under acid soils, likely to exhibit Mo deficiency. Since, no systematic study has been conducted on Mo status and its critical limits in soils and plants for french bean and cauliflower. Therefore, an investigation entitled "Molybdenum status and its critical limits for french bean and cauliflower in acid soils of Himachal Pradesh" was conducted from 2019 to 2022. The study involved the random collection of a total of 200 surface soil samples, analysed for soil pH, soil organic carbon (SOC) and available Mo through best extractant. The average soil pH was found to be 5.86, indicating slight acidity, while the mean SOC was determined to be 10.2 g kg⁻¹. Four extractants *viz.*, Ammonium Oxalate (AO), EDTA, AB-DTPA, and Aqua Regia, were compared to assess their efficiency in extracting Mo on 40 segregated samples based on pH and SOC (20 each). Among these, Aqua Regia extracted pseudo-total Mo, exhibited the highest extraction rate with an average value of 0.41 mg kg⁻¹. Among rest of the three extractants, AO exhibited the highest extraction rate with an average value of 0.120 mg kg⁻¹ followed by EDTA and AB-DTPA. The effectiveness coefficients of the extractants varied depending on the pH and SOC classes, with AO showing highest effectiveness at highest pH (>6) and SOC (>10.0 g kg⁻¹) class. AO exhibited positive correlations with pH (0.334*), SOC (0.573**), N (0.526**), and P (0.461**), indicating a significant association between AO and soil properties. Spatial mapping of available Mo using the AO extraction method revealed a mean content of 0.122 mg kg⁻¹. The analysis indicated that

majority of the samples exhibited latent deficiency of Mo (43%), followed by low (28.5%) and very low (6.5%).

To establish critical limits of molybdenum (Mo) in soil and crops, a controlled pot experiment was conducted in a glasshouse. Ten different bulk soils (L1-L10) were selected, and six levels of Mo (0, 0.5, 1.0, 1.5, 2.0 and 2.5 mg kg⁻¹) were applied to study their impact on the growth and yield of french bean (var. Falguni) and cauliflower (var. Pusa Snowball-K1). The experiment followed a completely randomized design with three replications. The results indicated that for cauliflower, increasing Mo levels up to 2.5 mg kg⁻¹ was statistically at par with 2.0 mg kg⁻¹ and resulted in improved growth parameters, yield attributes, yield, and nitrate reductase activity (NRA). Similarly, for french bean, Mo levels up to 2.0 mg kg⁻¹ which was statistically at par with 1.5 mg kg⁻¹ resulted in improved growth parameters, yield attributes, yield, and NRA. An increase in soil pH from 4.89 to 6.58 (L1-L5), and an increase in SOC from 2.90 to 15.1g kg⁻¹ (L6-L10), resulted in a significant and comparable improvement in crop yield in the Mandi (L4) and Hamirpur (L9) locations, whereas Sujjanpur (L6) demonstrated the lowest performance with an SOC content of 2.90 g kg⁻¹. The post-harvest soil nutrient status showed that the effect of Mo levels were non-significant for available N, K, Mg and DTPA extractable micronutrients. Among locations, all the nutrients showed significant relationship. Critical limit for Mo in soil was worked out as 0.147 and 0.143 mg kg⁻¹ for cauliflower and french bean, respectively. Critical limit of Mo for cauliflower and french bean in plant was figured out as 4.12 and 6.16 mg kg⁻¹, respectively. In conclusion, the study provided valuable insights into the distribution of available Mo in acid soils of Himachal Pradesh. The findings emphasized the importance of Mo for crop production and the established critical limits shall serve as a useful guideline for stakeholders.

5. Title of thesis	:	Effect of weed management practices on yield, nutrient uptake and soil properties under organic maize – pea cropping system in an acid Alfisol
Name of the student	:	Neha Chauhan (A-2018-40-029)
Major Advisor	:	Dr. Sanjay K. Sharma

Salient findings

The present study was carried out in an ongoing experiment under All India Coordinated Research Project on Weed Management (AICRP WM) since 2016 at the research farm of Department of Agronomy, CSK HP Krishi Vishvavidyalaya, Palampur during *kharif* 2019 to *rabi* 2020-21 with the objective to assess the effect of weed management practices on yield, nutrient uptake and soil properties under organic maize-pea cropping system. The experiment consisted of ten treatments *viz.*, T₁ - Hoeing, T₂ - Stale seed bed + Hoeing, T₃ - Raised stale seed bed + Hoeing, T₄ - Mulch, T₅ - Stale seed bed + Mulch, T₆ - Raised stale seed bed + Mulch, T₇ - Intercropping, T₈ – Crop rotation, T₉ - Intensive cropping and T₁₀ - Chemical check, replicated thrice in a randomized block design. The results indicated improved growth and yield attributing characters in chemical check (T₁₀). Crop productivity and nutrients uptake were recorded highest

in intensive cropping (T₉) followed by inter-cropping (T₇) and the lowest were recorded in mulch treatment (T₄). Physical, chemical and biological properties of soil were assessed using standard methods of analysis. The treatment RSSB + mulch (T₆) recorded the lowest value of bulk density and highest value of porosity, water holding capacity, saturated hydraulic conductivity and mean weight diameter. However, no significant effect of weed management practices was observed on the particle density. Similarly, among chemical soil properties, weed management practices had no significant influence on soil pH. Treatment chemical check (T₁₀) recorded the highest available N, P, K and S contents in soil (kg ha⁻¹) followed by RSSB + mulch (T₆) while the lowest were recorded in intensive cropping. The exchangeable Ca and Mg and DTPA extractable Cu, Fe, Mn and Zn contents were highest under RSSB + mulch (T₆) and the lowest were recorded in intensive cropping (T₈). The microbiological soil properties were significantly higher in the treatment RSSB + mulch (T₆) while chemical check (T₁₀) recorded the lowest values. Treatment intercropping recorded the highest B:C ratio (2.03 and 2.13) followed by chemical check (1.58 and 1.62) and intensive cropping (1.41 and 1.51) in maize-pea cropping system during 2019-20 and 2020-21, respectively. Soil physical properties did not correlated significantly with crop yield and nutrient uptake except porosity which correlated significantly with nutrients uptake. The soil chemical properties correlated significantly with yield and nutrient uptake whereas, among microbiological properties, only microbial biomass carbon and nitrogen showed significant correlation with yield and nutrient uptake.

6. Title of thesis	:	Effect of farming practices on maize-wheat productivity, nitrogen dynamics, carbon sequestration and soil health in an acid Alfisol
Name of the student	:	Sakshi Vishvamitera (A-2019-40-031)
Major Advisor	:	Dr. Sanjay K Sharma

Salient finding

Imbalanced and sole application of chemical fertilizers has been found to adversely affect the crop productivity as well as the soil health. There is a ample scope to improve the production potential by manipulating nutrient management systems in such a way that these are more effective, environmental-friendly, and largely acceptable. Therefore, the present study was undertaken to evaluate the effect of farming practices on productivity of maize and wheat, nitrogen dynamics, carbon sequestration and soil health. The experiment consisted of eleven treatments replicated thrice in a completely randomized block design, involving recommended NPK dose, 100% NPK+FYM@ 10 t ha⁻¹, 100% NPK+lime, organic farming practices, three natural farming systems involving formulations prepared using excreta of *desi* and *crossbred* cows, and *buffalo*, and their integration with 25% of recommended NPK dose. Application of 100%NPK + FYM@ 10 t ha⁻¹ resulted in better crop growth and yield attributes, and registered the highest grain and stover/straw yield of maize and wheat, but these were statistically similar to 100% NPK + lime during both the years. For comparison of different treatments, maize grain

equivalent yield and wheat grain equivalent yield were computed as NFS treatments included intercrops. Grain and stover/straw equivalent yield of maize and wheat were significantly higher under 100% NPK+ FYM@ 10 t ha⁻¹, which were however, statistically similar to 100% NPK+lime during both the years. Application of 100% NPK+ FYM@ 10 t ha⁻¹ recorded 51.7% and 113.9% higher mean maize grain and stover equivalent yield, respectively, and 23.0% and 57.6% higher mean wheat grain and straw equivalent yield, respectively, than NFS-Desi cow. Integration of 25% NPK in these treatments significantly enhanced the yield over pure organic/natural farming treatments. The NPK and cationic micronutrient uptake by grain and stover/ straw of maize and wheat was highest in 100%NPK + FYM@ 10 t ha⁻¹, and lowest in NFS-*Buffalo* treatment. Application of 100% NPK + lime increased the soil pH. Water holding capacity, mean weight diameter, organic carbon, available S, microbial count, microbial biomass carbon and nitrogen and enzyme activities were recorded highest in organic farming + 25% NPK treatment, however, available NPK were recorded highest under 100% NPK+FYM@ 10 t ha⁻¹, at both 0-0.15 m and 0.15-0.30 m soil depth. The highest content of inorganic N fractions were recorded under 100% NPK+FYM, while organic farming+ 25% NPK recorded the highest organic N fractions, and mean weight diameter at both the soil depths. Carbon sequestration was highest under 100% NPK+ FYM, while lowest was recorded under 100% NPK. Integration of 25% NPK with organic /natural farming systems significantly improved the soil physico-chemical properties at both soil depths over pure organic/natural farming systems. Among natural farming systems, NFS-*Desi* cow performed better in all the parameters as compared to NFS-*Crossbred* cow and NFS-*Buffalo*. Therefore, there was a notable effect of farming practices on maize-wheat productivity, nitrogen fractions, carbon sequestration and soil properties in an acid Alfisol, with conventional integrated nutrient management system giving the better results for most of the parameters under study.

7. Title of thesis	:	Effect of cropping systems on nutrient dynamics and soil health in an acid Alfisol
Name of the student	:	Deeksha Choudhary (A-2019-40-028)
Major Advisor	:	Dr. Naveen Datt

Salient findings

The field experiment entitled “Effect of cropping systems on nutrient dynamics and soil health in an acid Alfisol” was undertaken at Bhadiarkhar experimental farm, Department of Agronomy, College of Agriculture, CSK HPKV, Palampur (H.P.) during 2019-2020 and 2020-21. The experiment consisted of ten cropping sequences *viz.*, maize-wheat, maize-gobhi sarson + toria, dhaincha-early cabbage-french bean, sunhemp-vegetable pea-french bean, maize + soybean-chickpea + linseed, rice-wheat + gram, hybrid sorghum + hybrid bajra-oats + sarson, hybrid sorghum + hybrid bajra-ryegrass + berseem, babycorn-broccoli-french bean and maize-turnip-tomato in randomized block design which were replicated thrice. The soil of the site was acidic in nature (pH=5.5), silty clay loam in texture, medium in available nitrogen (350.6 kg ha⁻¹) and

potassium (147.3 kg ha⁻¹) and high in available phosphorus (44.2 kg ha⁻¹). Soil samples from 0-0.15 m depth were collected before and after the harvest of each cropping cycle (2019-2020 and 2020-21) and analyzed for various physical, chemical and biological properties. In addition, different forms of nitrogen, phosphorus and potassium were also determined following standard analytical procedures. Maize-turnip-tomato recorded significantly higher maize grain equivalent yield, net returns and BC ratio. The total uptakes of N, P, and K in a cropping system were highest in sunhemp-vegetable pea-french bean while Fe, Mn, Zn and Cu uptake were maximum under maize-turnip-tomato. The cost of cultivation was highest for babycorn-broccoli-french bean cropping system due to labour intensive nature of vegetable crops in the sequence. The incorporation of green manures significantly improved the soil organic carbon content, cation exchange capacity, available N, P, K, S, exchangeable Ca and Mg, DTPA extractable Fe, Mn, Zn and Cu, microbial count of bacteria, fungi, actinomycetes, microbial biomass C, dehydrogenase acid phosphatase, urease and soil respiratory activity. Among N fractions, serine + threonine-N, total hydrolysable-N and Nitrate-N exhibited maximum correlation with total N uptake. Amongst P fractions, NaOH-Po, HCl-P and H₂O-P for P uptake were found important. In case of K, water soluble-K and exchangeable-K were the dominant fractions. The N, P, K uptake and MGEY were found to be positively and significantly correlated with pH, SOC, CEC, MBC, dehydrogenase, acid phosphatase and SRA.

8. Title of thesis	:	Effect of drip irrigation and <i>jeevamrit</i> application schedules on water and crop productivity of tomato under protected environment
Name of the student	:	Kishor Kumar Sahu (A-2019-40-030)
Major Advisor	:	Dr. Sanjeev K. Sandal

Salient findings

The present study was conducted during spring summer (2020) and autumn winter (2020-2021) on tomato (*Lycopersicum esculentum*) as test crop in a naturally ventilated polyhouse at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur with the objectives of evaluating the effect of drip irrigation and *jeevamrit* application schedules on soil water, plant water content and water productivity and to evaluate the effect of drip irrigation and *jeevamrit* application schedules on crop productivity, plant nutrient uptake and soil health. The treatments comprised of two drip irrigation schedules (40 % of Pan Evaporation = 0.4 PE and 80 % of Pan Evaporation = 0.8 PE), five *jeevamrit* fertigation schedules *viz.*, (3 days interval of fertigation = 3 DF, 1 week interval of fertigation = 1 WF, 2 weeks interval of fertigation = 2 WF, 3 weeks interval of fertigation = 3 WF and 4 weeks interval of fertigation = 4 WF) and control. The eleven treatment combinations *viz.*, (a) 0.4PE3DF (b) 0.4PE1WF (c) 0.4PE2WF (d) 0.4PE3WF (e) 0.4PE4WF (f) 0.8PE3DF (g) 0.8PE1WF (h) 0.8PE2WF (i) 0.8PE3WF (j) 0.8PE4WF and (k) control (1.0 PE and recommended doses were applied as basal (25 % RDF) and through fertigation (75 % RDF)). The result indicated that the drip irrigation applied @ 0.8 PE on daily basis was the most suitable treatment having higher soil moisture content, plant height, relative leaf water content leading to higher yield as compared to 0.4 PE. Also, this treatment had higher net returns and B: C ratio. Among the *jeevamrit* fertigation scheduling, 3 DF treatment was the most suitable treatment compared to other treatments since it had better plant growth and higher biological

yield with higher nutrient uptake, better fruit quality which may be due to higher available nutrients, better soil hydro physical and biological properties. Further, the drip irrigation applied @ 0.4 PE resulted higher root growth, higher water use efficiency and lower water use as compared to other irrigation schedules.

9. Title of thesis	:	Effect of surface and sub-surface drip irrigation and fertigation using organic and inorganic sources on productivity of tomato and cucumber under protected environment
Name of the student	:	Bhawna Babal (A-2020-40-025)
Major Advisor	:	Dr. Sanjeev K. Sandal

Salient findings

In the realm of modern agriculture, optimizing the use of water and nutrients stands as a pivotal challenge, particularly under the constraints of environmental sustainability and increasing global food demands. The study delves into the realm of precision agriculture, focusing on the efficacy of water and nutrient use in the cultivation of tomato and cucumber crops within a protected environment with the specific objective to explore the potential of advanced irrigation and fertigation techniques to enhance the productivity and quality of these crops. The experiment was laid out in factorial completely randomized design having two irrigation treatments viz., I₁: surface drip @ 60% of pan evaporation (PE) for first two months and 80% of PE, thereafter and I₂: sub-surface drip @ 30% of PE for first two months and 40% of PE, thereafter and five nutrient management treatments viz., F₁: soil application of FYM @ 15 t ha⁻¹ + compost tea fertigation @ 75 ml m⁻² at 3 days intervals, F₂: soil application of vermicompost @ 7 t ha⁻¹ + vermiwash through fertigation @ 75 ml m⁻² at 3 days intervals, F₃: soil application of FYM @ 10 t ha⁻¹ + 75 % NPK (1/4 as basal + 3/4 through fertigation) + compost tea fertigation @ 75 ml m⁻² at seven days intervals, F₄: soil application of vermicompost @ 5t ha⁻¹ + 75% NPK (1/4 as basal + 3/4 through fertigation) + vermiwash fertigation @ 75 ml m⁻² at seven days intervals and F₅: soil application of FYM @ 10 t ha⁻¹ + 100% NPK (1/4 basal + 3/4 through fertigation) 7 days interval. Key findings include the significant efficacy of sub-surface drip irrigation in enhancing yield and water productivity, with an increase of 15.7% in tomato and 14.9% in cucumber yield, alongside a notable reduction in water use of 50%. The fertigation treatment combining compost tea with 75% recommended dose of fertilizers (RDF) emerged as the most effective, improving crop growth, yield, and water productivity, and saving 25% of water- soluble fertilizers. This treatment showed a yield increase of 16.0% in tomato and 14.7% in cucumber over the standard practice of 100% RDF. Quality assessment indicated superior produce quality under sole organic fertigation, followed by integrated organic- inorganic approaches. The study also revealed improvements in soil properties, particularly when organic sources were used, as opposed to sole water- soluble fertilizers. Sub-surface drip fertigation with compost tea and 75% RDF was identified as the most profitable treatment in terms of economic return for both crops, through the highest benefit-cost ration varied between the crops and treatments. The research underscores the benefits of

combining modern irrigation techniques with balanced fertigation practices, particularly in resource management and optimization of crop yield and quality under protected cultivation systems. The findings offer valuable insights for sustainable agriculture practices, emphasizing the potential of integrated irrigation and nutrient management strategies.

10. Title of thesis	:	Effect of continuous application of fertilizers, FYM and lime on chemical, microbial and biochemical properties of soil under maize-wheat system
Name of the student	:	Isha Thakur (A-2020-40-026)
Major Advisor	:	Dr. R.P.Sharma

Salient findings

The present study was carried out in an on-going long-term fertilizer experiment, initiated during 1972 at Research farm of Department of Soil Science, CSK HPKV Palampur, to study the effect of continuous application of fertilizers and amendments on different soil properties under maize-wheat system during 2021-2023. The experiment was laid out in a randomized block design with twelve treatments. The soil of the experimental site is silt loam in texture, belongs to the order *Alfisol* and sub-group *Typic Hapludalf*. The data on grain and stover/straw yield were recorded after the harvest of maize (kharif, 2021 and 2022) and wheat (rabi, 2021-22 and 2022-23). The nutrient concentration in maize and wheat biomass and their uptake was computed using standard methods. The surface and sub-surface soil samples were collected after harvesting of each crop. Soil samples were analyzed for various chemical, microbial and biochemical properties using standard methods. The correlation between different soil properties and yield (grain and stover/straw) of maize and wheat was worked out and interrelationship among different soil properties was computed. The results revealed that highest grain yield of maize (64.02 and 61.39 q ha⁻¹ during 2021 and 2022, respectively) and wheat (23.89 q ha⁻¹ and 27.78 q ha⁻¹ during 2021-22 and 2022-23, respectively) was recorded under 100% NPK + FYM treatment which was at par with 100 % NPK + lime. The application of 100% NPK with FYM or lime resulted in significantly higher nutrients' uptake by both crops compared to other treatments. Conjoint application of 100% NPK with FYM or lime enhanced SOC, CEC and available nutrients' content. The application of lime raised the soil pH to neutrality. The highest population of bacteria, fungi and actinomycetes was recorded in soil under 100% NPK+ FYM, 100% N and 100% NPK + lime, respectively. The use of 100% NPK with manure, lime and manual weeding positively influenced soil microbial biomass C, N, P and S, soil respiration, dehydrogenase, β -glucosidase, cellulase, urease, protease, acid phosphatase and arylsulphatase over rest of the treatments. Soil properties exhibited a positive and significant relationship with crop yield and with each other, except Fe, Zn and fungal population. Hence, understanding and managing these soil chemical and biological properties with adequate fertilization and amendments could help in optimizing the soil conditions for improved agricultural production. The study indicated that application of chemical fertilizers in conjunction with FYM and lime improved chemical and microbial characteristics of soil and

maintained the crop productivity without causing any deleterious effect on soil health.

11. Title of thesis	:	Mapping and characterization of agriculturally important microbes in potential rajmash (<i>Phaseolus vulgaris</i> L.) growing pockets in dry temperate zone of Himachal Pradesh.
Name of the student	:	Varun Parmar (A-2020-40-029)
Major Advisor	:	Dr. Naveen Datt

Salient findings

The pulse-growing areas in dry temperate regions of Himachal Pradesh harbor specialized microbial communities adapted to such unique ecological niches. These microbial communities being sensitive to various agricultural management practices could serve as principal indicators of edaphic environmental variations and ecosystem sustainability. The present study was carried out during *kharif* 2022 in dry temperate regions of Lahaul & Spiti and Kinnaur districts of Himachal Pradesh to characterize agriculturally important microbes and to generate spatial variability maps of different soil properties in rajmash growing pockets. Geo-referenced, 100 representative surface soil samples were collected near harvest of rajmash crop and analyzed for soil physical, chemical, and microbial properties using standard protocols. The soils in the study locations were found to be predominantly sandy loam in texture. Sand (%), silt (%) and clay (%) ranged from 48 to 61, 23 to 33 and 10 to 22 in Lahaul, 49 to 68, 21 to 32 and 9 to 16 in Spiti, 21 to 64, 23 to 50 and 10 to 31 in Kinnaur. Soil bulk density was observed to be maximum at high altitudes and minimum at low altitudes with average values of 1.31, 1.39 and 1.32 Mg m⁻³ in Lahaul, Spiti and Kinnaur, respectively. Soil porosity and particle density were found to be identical across all the three locations, largely ranging between 46 to 47 per cent and 2.5 to 2.6 Mg m⁻³, respectively. Water holding capacity varied inversely with altitude with identical retention capacities at Lahaul and Kinnaur (32%) and 30 per cent in Spiti. Lahaul soils were near neutral in reaction (pH=6.99) whereas, Spiti soils were alkaline in nature (pH=7.57) and soils of Kinnaur were moderately acidic (pH=6.41). Regardless of the sampling sites, the soils of dry temperate regions of Himachal Pradesh exhibited high build-up of OC i.e. 18.3 g kg⁻¹ in Lahaul, 18.8 g kg⁻¹ in Spiti and 16.8 g kg⁻¹ in Kinnaur. The cumulative mean values of CaCO₃ suggested that Spiti soils possessed maximum CaCO₃ levels of 14.3 per cent followed by Lahaul at 7.1 per cent and Kinnaur at 4.9 per cent. Further, the soils of dry temperate regions were low to medium in available N, P and S, high in K and sufficient in exchangeable Ca and Mg with per cent deficiency of 52, 7, 74 in Lahaul, 87, 14, 60 in Spiti and 42, 0 and 40 in Kinnaur with respect to N, P and S, respectively. Whereas, Fe and Mn were sufficient in all locations but, Zn and Cu were found to be deficient in Lahaul (65 and 42%) and Spiti (74 and 40%) soils and sufficient in Kinnaur soils. Across all sampling sites, MBC and MBN increased with decreased in altitude with maximum values observed in Kinnaur soils (329 and 49 µg g⁻¹) followed by Lahaul soils (305.8 and 44.0 µg g⁻¹) and least in Spiti soils (220.4 and 30.4 µg g⁻¹). Furthermore, the results revealed that the maximum fungal, actinomycetes and *Azotobacter* count were predominately found in Kinnaur soils (37.7 x10⁴, 45.1 x10⁵ and 44 x10⁴ CFU g⁻¹). While, the bacterial, *Rhizobium* and PSB count were maximum in Lahaul soils (151.3 x10⁵, 24.0 x10⁴ and 14.2 x10⁴ CFU g⁻¹). Soil biochemical properties viz., dehydrogenase and phosphatase were

maximum in soils of Lahaul region ($2.22 \mu\text{g TPF g}^{-1} \text{hr}^{-1}$ and $405.6 \mu\text{g PNP g}^{-1} \text{hr}^{-1}$) while the sulphatase activity was more prominent in Kinnaur soils ($53.9 \mu\text{g PNS g}^{-1} \text{hr}^{-1}$). Of the 402 morphotypes selected, 76 per cent exhibited siderophore production. Likewise, 20, 13 and 10 per cent solubilized Zn, P and K respectively. Irrespective of sampling location and altitude, there were significant positive as well as negative correlations between different soil properties, indicating the existence of dynamic equilibrium among them. Among all sampling locations, soil physical and chemical properties exhibited better correlation with altitude. However, within microbial properties, solely microbial biomass was found to be significantly correlated with altitude. Microbial population across all the locations were found to be highly correlated with pH, OC and available N. A diverse array of plant growth-promoting microbes were identified from rajmash growing areas in the dry temperate regions of Himachal Pradesh. In Lahaul, 6 were bacteria and 3 belonged to the Actinomycota phylum. In Spiti, 5 were bacteria and 1 was an actinomycete. In Kinnaur, 23 were bacteria and 4 belonged to the phylum Actinomycota.

12. Title of thesis	:	Land use impacts on boron dynamics in acid soils of Himachal Pradesh
Name of the student	:	Pratibha Thakur (A-2021-40-040)
Major Advisor	:	Dr. Pardeep Kumar, Principal Scientist (Soil Science)

Salient findings

Boron (B) has emerged as the most deficient micronutrient in the soils of Himachal Pradesh that sparked the thought whether the soils are inherently deficient in B or the deficiency developed over time due to continuous cultivation. It was hypothesized that the well-developed, undisturbed natural systems have nearly optimum soil properties while the cultivated lands might be facing nutrient deficits. As B deficiency is more prevalent under acidic conditions therefore four locations with acid soils were selected to test the above hypothesis. Across the selected locations, three predominant land uses (agriculture, horticulture and natural systems) were chosen and examined by considering cereal, legume and fodder cultivation under agricultural systems, orchards and vegetable cultivation under horticultural systems, while forests and grasslands were part of the natural systems. Surface and sub-surface soil samples from seven land use practices were collected with three replicates of each from four locations. The data generated was analyzed statistically in randomized complete block design. Soil properties and nutrient availability varied across locations as well as land uses. The variation across locations can be attributed to topographical, climatic and mineralogical differences. Across land uses, the physical, chemical, and biological properties (bulk density, particle density, porosity, water holding capacity, pH, electrical conductivity, soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, and soil respiration) under natural systems were more favorable for crop production compared to cultivated ones (agriculture and horticulture). However, the nutrient availability, except B, was significantly higher in cultivated systems (specifically under cereal, legume, fodder and vegetable cultivation) compared to natural systems. Unlike other nutrients, B availability was higher in natural systems ($0.36\text{-}0.81 \text{ mg kg}^{-1}$ in surface soils) compared to

cultivated ones (0.26-0.61 mg kg⁻¹ in surface soils). Natural systems accounted greater amounts of all B fractions, except oxide bound-B (Ox-B), compared to cultivated systems. Half of the tested samples from natural systems recorded readily soluble-B (RS-B) above 0.40 mg kg⁻¹, specifically adsorbed-B (SA-B) above 0.96 mg kg⁻¹, while the median values for organically bound (Org-B) and residual-B (Res-B) were 1.22 and 7.36 mg kg⁻¹, respectively. The highest Ox-B was recorded in vegetable cultivated soils across all the locations. On average, 89.6-91.9 per cent of the total-B (T-B) was constituted by Res-B and the contribution of various fractions followed the trend: Res-B > Org-B > Ox-B > SA-B > RS-B. All the B fractions were highly correlated with each other and with available B ($\rho \leq 0.01$). The regression equations showed that SA-B and RS-B were the best predictors of B availability in the soil. The results pertaining to the soil properties were in line with the hypothesis but nutrient availability strongly contradicted it. The abundant B pools and its availability in natural systems showed that the soils were not inherently deficient in B and it is most likely the result of land use practices and intensities of cultivation.

13. Title of thesis	:	Effect of drip line placement, organic layering and fertigation on productivity of tomato and cucumber under protected conditions
Name of the student	:	Varsha Rattan (A-2020-40-028)
Major Advisor	:	Dr. Sanjeev K Sandal

Salient findings

Study was conducted at experimental farm at CSKHPKV, Palampur during 2021 and 2022 with the objectives of evaluating the effect of drip line placement, organic layering and fertigation on soil water content, plant water content and productivity of tomato and cucumber under protected conditions. The treatments comprised of a) Gravity fed drip irrigation scheduling based open pan evaporation (PE) schedule - Surface drip with 40 per cent PE (0.4PE) for first two months and 80 per cent (0.8 PE) thereafter and Sub surface drip with 30 per cent PE (0.3 PE) for first two month, 40 per cent PE (0.4PE) for second month and 50 per cent PE (0.5 PE) for third month and 60 per cent PE (0.6 PE) thereafter, b) Fertigation - Compost tea fertigation at 3 days interval, vermiwash fertigation at 3 days interval and 100 per cent NPK fertigation at 7 days interval and c) Organic layering - Farmyard Manure and vermicompost layering. The tomato (Palam Tomato Hybrid-1) was transplanted on April 12th 2021 (crop I) and April 10th 2022 (crop II) and cucumber (Him Palam Kheera-1) was transplanted on September 13th 2021 (crop I) and September 26th 2022 (crop II). The experimental results indicated that the soil water content was higher under sub surface drip line placement which led to significantly higher relative leaf water content, crop growth attributes, root growth attributes, nutrient uptake, marketable yield and WUE as compared to surface drip line placement. Among the organic and inorganic fertigation, the organic fertigation comprising of vermiwash enhanced the root growth parameters, quality parameters, soil physical properties and soil microbial biomass carbon followed by compost tea. However, the crop growth attributes, available macronutrients, nutrient uptake were higher under

inorganic fertigation. The vermicompost showed slightly superior results in improving soil moisture retention, crop growth, development and soil microbial biomass carbon compared to farm yard manure layering. The combination of sub surface drip irrigation, inorganic fertigation and farm yard manure layering showed a higher benefit-to-cost ratio. The study concluded that the sub surface drip irrigation along with sub surface organic layering with vermicompost and NPK fertigation (100%) was the suitable option for obtaining higher productivity of tomato and cucumber under protected conditions. Further, the study focused on the combination of irrigation technology interventions, high efficiency and precise fertigation alongside organic manure layering, ensuring judicious use of water resources and maximizing crop production. This approach supported sustainable agricultural practices, enabling year-round cultivation of profitable crops like tomatoes and cucumbers under protected conditions, addressing concerns about land scarcity and excessive water use.

14. Title of thesis	:	Simulation and predicting the effect of long-term application of fertilizers and amendments for maize-wheat yield and soil fertility in an acid <i>alfisol</i>
Name of the student	:	Rushali Katoch (A-2020-40-027)
Major Advisor	:	Dr. Narender K. Sankhyan

Salient findings

The present study was carried out on a pre-established long-term experiment with an ongoing maize-wheat cropping sequence since rabi, 1972-73 at the experimental farm of Department of Soil Science, CSKHPKV Palampur in order to simulate and predict the effect of long-term application of fertilizers and amendments for maize-wheat yield and soil fertility in an acid *alfisol*. The study employed randomized block design with eleven treatments and three replications. The soil texture at the experimental site was silty loam and was classified as “*Typic Hapludalf*” subgroup based on taxonomic classification. The grain and stover/straw yield of maize and wheat during the 50th cropping cycle (kharif 2022 and rabi 2022-23) was recorded after their harvest. Grain and stover/straw samples of both the crops were also analyzed for nutrient concentration and nutrient uptake was determined. After the 50th wheat harvest, the soil samples were collected at two depths (0.015m and 0.15-0.30 m) and analyzed for various physical, chemical and biological properties. Principal Component Analysis (PCA) was employed to reduce soils attribute data to a minimum data set, facilitating the calculation of the soil Quality Index (SQI). To determine the long-term trends in soil fertility, periodical per cent changes were calculated and analyzed. For simulating crop yields and soil organic carbon dynamics, the DSSAT model was calibrated and validated for different nutrient management practices. The result indicated that the long-term balanced application of nutrients enhanced nutrient uptake and crop productivity, whereas the imbalanced fertilization did not have the similar effects. The application of optimal fertilizer doses (100% NPK) integrated with FYM or lime resulted in significantly higher maize and wheat productivity as well as nutrient uptake compared to other treatments. Balanced fertilization improved the physical, chemical and biological properties of soil contributing to a higher SQI. The SQI after 50 years of balanced fertilization (100% NPK + FYM) reached 1.00 and 0.99 at 0-0.15m and 0.15-0.30m soil depths, respectively, highlighting

the positive impact on overall soil health. The periodical assessment of soil fertility demonstrated that combining FYM with optimal fertilizer application effectively supported long-term soil health. The DSSAT-CERES model accurately simulated the days to anthesis and physiological maturity for both maize and wheat. Additionally, the model demonstrated good to excellent performance in predicting grain and stover/straw yields, nitrogen content and total nitrogen uptake. When calibrated and validated for soil organic carbon, the model also showed a close match between observed and predicted values, thereby highlighting its potential as a powerful decision-support tool in optimizing nutrient management practices for sustainable agriculture.

Entomology

1. Title of thesis	:	Bioefficacy studies of biorational approaches against <i>Leucinodes orbonalis</i> Guenee on brinjal in Himachal Pradesh
Name of the student	:	Nitika Negi (A-2018-40-010)
Major Advisor	:	Dr. Prem Chand Sharma

Salient findings

Studies were carried out to know the incidence of *Leucinodes orbonalis* on brinjal in agro-climatic zone I and II of Himachal Pradesh and data on the incidence of *L. orbonalis* were recorded at monthly interval during 2019 and 2021. The crop was found to be infested with *L. orbonalis* at all the locations during both the years. Incidence of *L. orbonalis* appeared early in the month of May and remained up to the end of the season. The peak incidence of *L. orbonalis* was recorded in the month of July and August on shoots and fruits of brinjal during both the years. Among all the locations, Una district had a maximum shoot and fruit infestation (25.33 and 28.83%, respectively) during 2019, while in 2021 the maximum shoot infestation was recorded in Hamirpur district (26.50%) and fruit infestation in Kangra district (28.64%). The intrinsic toxicity studies against neonate larvae of *L. orbonalis* revealed emamectin benzoate as most toxic with LC₅₀ value of 0.0043 ppm followed by spinosad (0.0303 ppm), *Bacillus thuringiensis* (3.989 ppm), azadirachtin (8.847 ppm), *Brahmastra* (24203.194 ppm) and *Agniastra* (29795.95 ppm). The field experiments were undertaken during the *khari* season of 2020 and 2021 at the Experimental Farm of the Department of Entomology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. For the management of *L. orbonalis*, different approaches were evaluated under three modules, cultural & mechanical methods (M₁), natural products & biopesticides (M₂) and insecticides (M₃). In Module 1, amongst seven treatments, minimum mean shoot infestation (9.33%) and fruit infestation (number as well as weight basis i.e., 12.68 and 13.86%) was recorded in neem cake (NC) + clipping of shoots. In Module 2, out of nine treatments, application of Bt resulted in least mean shoot infestation (13.56%), whereas fruit infestation on the number basis was minimum in neem cake + Azadirachtin; on the weight basis, neem cake + Bt recorded lowest per cent fruit infestation (15.27%). In case of Module 3, shoot

infestation was minimum (6.40 %) in emamectin benzoate followed by neem cake + emamectin benzoate (6.70%) and spinosad (6.87%). On the basis of fruit infestation (number and weight), neem cake + application of emamectin benzoate resulted in lowest fruit infestation (9.39 and 8.85%) followed by emamectin benzoate (9.61 and 8.88%). On the basis of incremental output input ratio of two years, emamectin benzoate (27.27) was the most economically viable treatment followed by spinosad (10.82). After two applications of insecticides, the average initial deposits of emamectin benzoate (@10 g a.i./ha) were 0.307 ppm, whereas the average initial deposits of spinosad (@75 g a.i./ha) were 0.489 ppm. A waiting period of 4 days for emamectin benzoate and 2 days for spinosad was suggested for safe consumption of brinjal fruits.

2.Title of thesis	:	Studies on novel approaches for the management of greenhouse whitefly, <i>Trialeurodes vaporariorum</i> (Westwood) on tomato under protected environment
Name of the student	:	Ekta Kaushik (A-2019-40-009)
Major Advisor	:	Dr. Ajay Kumar Sood

Salient findings

Present investigations were carried out in the laboratory, outdoor insect rearing facility and naturally ventilated polyhouse at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2020-22. Studies on the effect of different levels of recommended dose of fertilizers (nitrogen, phosphorus and potassium) on growth and development of green house whitefly reared on tomato revealed the duration and survival in different developmental stages was influenced adversely by decreased nitrogen and increased potassium levels. Total development period during first generation lasted for 23.33 to 27.33 days at $28 \pm 2^{\circ}\text{C}$ temperature and $70 \pm 5\%$ relative humidity in thirteen evaluated treatments, being maximum in treatment comprising 200% NK+100% P, 25% N+100%PK and 200%K+100%NP of RDF, respectively. Whereas during second generation it varied from 19.67 days to 28.67 days, maximum duration corresponded to the treatment having higher levels of K, 200% K+ 100%NP of RDF followed by 25%K+ 100%NP of RDF. Total survival to adult stage during G_1 ranged between 25.67 to 58.67%. Whereas, in G_{II} survival to adult stage ranged between 25.67 to 64.67% being more in treatments comprising higher N levels i.e. 200%N+100%PK being at par to 150% N + 100% PK of RDF. The minimum survival was recorded in treatments having lower level of N25%N 100% PK of RDF. Plant nutrition also influenced the pupal length and breadth significantly which varied from 0.665 to 0.732 mm and 0.362 to 0.461 mm, respectively in G_{II} and was maximum in 200% N + 100%PK. The minimum mean length and breadth was recorded in treatment comprising 25% NK + 100% P during both the generations. Effect of plant nutrition on fertility parameters of greenhouse whitefly adults assessed during G_{II} revealed increasing K and decreasing N nutrition levels influenced the fertility parameters adversely. It was observed that increased level of K (200%K+ 100%NP, 150%K +100%NP) resulted in reduction in gross reproductive rate (GRR), net reproductive rate (R_0), true intrinsic rate of population increase r_m),

finite rate of increase (λ) and increased the doubling time (DT) as compared to increased N levels. Amongst thirteen fertilizer treatments evaluated for population buildup of GHWF adversely and cropping season 2021 revealed treatment comprising 25% NK +100%P influenced the population buildup of GHWF during autumn resulted in minimum count of immature (36.13 immature/ leaf) as well as adult population (10.19 adult/ leaf) and 22.63 adult/ leaf. During summer season crop, 2022 effect of eight selective fertilizer treatments on population buildup of GHWF under two fertigation frequencies i.e. once and twice per week, showed that the population of immature of GHWF was significantly minimum (43.91 immature/ leaf) in 150%K + 100% NP. The maximum population (101.80 immature/leaf) corresponded to 150%N+100%PK. Frequency of fertigation also influenced the population levels which were significantly minimum when fertigation was applied twice per week. The fruit yield under different fertilizer levels revealed that treatments comprising higher K resulted in highest yield of 1549g/ plant and was significantly higher when fertigation was done twice per week, whereas fruit yield in treatments comprising higher N levels declined significantly and recorded 1006g/plant fruit yield. In different fertilizer treatments the sooty mould severity recorded on 120 DAT was at its minimum in 150%N+100%PK, when applied twice per week whereas, it was minimum in the treatment having 150%K+100%NP applied twice per week. Amongst different insecticidal treatments evaluated during autumn crop of tomato (2020), soil application of imidacloprid (0.009%) proved most efficacious in reducing GHWF adult population and resulted in significantly mean minimum population (1.24 adults/ leaf). It was followed by the treatment comprising foliar application of cyantraniliprole (0.02%). In summer crop of tomato (2022), treatment comprising foliar application of cyantraniliprole (0.02%) at 15 days intervals proved most efficacious and resulted in significantly mean minimum adult count (2.06 adults/ leaf) as compared to all other treatments. It was followed by alternate foliar application of spiromesifen (0.02%) & thiamethoxam (0.008%) at 15 days intervals and foliar as well as soil application of imidacloprid. The marketable fruit yield was significantly higher (1931g/plant) in treatments comprising alternated application of vermiwash (10%) & *Tamarlasi* (10%) and was followed by yield obtained in foliar application of cyantraniliprole (0.02%) at 15 days interval (1928g/plant). Benefit cost ratio worked out was maximum for soil application of imidacloprid (0.009%) during both the seasons. Persistence of cyantraniliprole residues on tomato grown under naturally ventilated polyhouse studied during summer cropping seasons of 2021 and 2022 revealed residues of cyantraniliprole persisted up to 7 and 15 days on tomato fruits at recommended and double the recommended dose, respectively and residue dissipated to half in 1.7 to 2 days (RL_{50}). Based on dissipation pattern, a pre harvest intervals/ safe waiting period of 8-10 days was suggested under protected environment.

The findings lead to the conclusion that modulating plant nutrition, incorporating natural and organic farming plant protection products, selective use of CIB&RC recommended insecticides can manage GHWF effectively in tomato grown under protected environment.

3. Title of thesis	:	Insect pests of rice and their management under natural farming
Name of the student	:	Aarushi Sharma (A-2020-40-008)
Major Advisor	:	Dr. Pawan K. Sharma

Salient findings

The study entitled "Insect pests of rice and their management under natural farming" was conducted to investigate the arthropod fauna associated with rice under natural farming conditions in Himachal Pradesh, India. Through extensive field surveys conducted across five diverse localities, a total of 88 arthropod species were documented, comprising fifty-one pestiferous and thirty-seven beneficial species. Notably, three previously undocumented flea beetle species, *Chaetocnema nigrica*, *C. gracilis*, and *C. congnate*, were identified, enriching the regional biodiversity database. Palampur had the highest species count with *Oxya fuscovittata* emerging as the most prevalent pest species. While, Sundernagar exhibited the highest association of beneficial fauna within rice ecosystem, being dominated by the spider group across all the localities. Seasonal analysis revealed varying degrees of infestation, across different growth stages and localities in the state. Pest activity across all recorded species was notably higher in 2022 compared to 2023 in all surveyed localities. Grasshoppers posed a significant threat around the heading stage, particularly evident in Jogindernagar, with a leaf infestation of 25.63 per cent and an adult catch of 15.38 adults/5 sweeps in 2022. Leaf folder infestation peaked during maturity, with higher leaf infestation levels of 16.46 per cent and an adult catch of 15.75 adults/5 sweeps, being recorded in Sundernagar in 2022. Flea beetles exhibited peak activity during the tillering stage, with Palampur experiencing infestation levels as high as 4.53 per cent in 2022. Stem borers showed a gradual increase in infestation from the booting stage to maturity, with Nurpur witnessing the highest infestation of 2.26 per cent during maturity in 2022. Chaffer beetles, peaked during the heading stage, with maximum activity recorded at Shahpur, where infestation level reached 3.63 per cent in 2022. The average population count of hopper complex was observed to be highest at Shahpur with peak population of WBPH, WLH and GLH being observed during tillering, booting and heading stages, respectively. However, infestation by whorl maggot, was maximum in Palampur locality peaking during booting stage. Weather variables such as temperature, rainfall, and humidity were found to influence pest abundance significantly, with regression analyses elucidating intricate correlations. Among all the pests recorded, grasshoppers and leaf folder emerged to be of significant concerns during crop maturity, being predominant in Palampur, where management measures were carried out. Laboratory evaluations (lethal toxicity, repellence, feeding deterrence and ovipositional deterrence) of natural products *viz.*, *Agniastra*, *Brahmastra*, *Darekastra*, *Dashparni ark* and *Neemastra* revealed *Dashparni ark* and *Neemastra*, to have moderate insecticidal activity against *Cnaphalocrocis medinalis*. Field evaluations further confirmed the effectiveness of *Dashparni ark* in reducing infestations of *C. medinalis* (62.82 and 66.49 %) and

grasshopper (60.90 and 64.77 %) over untreated control during both the years, respectively and increasing grain yield, making it the most cost-effective treatment. In conclusion, this study supports the adoption of natural farming principles as an effective strategy for managing pest pressures while simultaneously mitigating adverse environmental impacts.

4. Title of thesis	:	Studies on biointensive management of <i>Tuta absoluta</i> (Meyrick) in tomato
Name of the student	:	Devika Sharma (A-2020-40-009)
Major Advisor	:	Dr. Surjeet Kumar

Salient findings

Investigations entitled "Studies on biointensive management of *Tuta absoluta* (Meyrick) in tomato" were conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the summer of 2022 and 2023. Population dynamics revealed that the pest appeared during 21st and 19th SMW during 2022 and 2023, respectively. Trap catch showed peak moth catches at 25 moths per week in 2022 and 21 moths per week in 2023. Egg and larval densities correlated significantly with adult trap catch ($R^2=0.674$ in 2022, $R^2=0.857$ in 2023) and mine densities ($R^2=0.772$ in 2022, $R^2=0.803$ in 2023), respectively. Maximum leaf infestation reached 32.68 per cent in 2022 and 29.71 per cent in 2023, while fruit infestation peaked at 12.33 and 9.09 per cent, respectively during crop maturity. Weather variables such as temperature, rainfall, and humidity were found to significantly influence pest abundance, with regression analyses elucidating intricate correlations. Laboratory bioassays identified emamectin benzoate as the most toxic insecticide against second instar larvae with an LC_{50} value of 0.27 ppm, followed by spinosad (0.45ppm) and chlorantraniliprole (0.71ppm). Among biopesticides, *Bacillus thuringiensis* (9.02×10^6 cfu/ml) showed the highest toxicity. Biocontrol studies demonstrated that the predator, *Chrysoperla zastrowiisillemi* successfully completed its developmental and reproductive biology on the pest with an overall survival rate of 37.72 per cent, which was significantly lower than that on the factitious prey, *Corcyra cephalonica* (50.96%). Feeding potential of the predator on the eggs of *T. absoluta* showed that a total of 49.60, 103.80 and 483.40 eggs were consumed by first, second and third larval instars, respectively. The extent of parasitization by *Trichogramma achaeae* on the eggs of *T. absoluta* within the glass vials varied from 38.67 to 71.33 per cent with the increase in the number of parasitoid from 1 to 8, whereas it was 11.11 to 64.44 per cent inside the glass cages when the parasitoid number varied from 8 to 128 per cage. A Type-II functional response was observed for *T. achaeae* on varying densities of *T. absoluta* eggs, with a handling time of 1.209 h and an attack rate of 0.046. Field evaluations of biointensive pest management modules indicated that alternate spraying of azadirachtin with chlorantraniliprole and flubendiamide significantly reduced leaf infestation by up to 72.67 per cent and fruit infestation by up to 76.74 per cent over untreated control. In polyhouse conditions, alternate sprays of azadirachtin and indoxacarb was the most effective treatment, reducing leaf infestation by up to 76.13 per cent and fruit infestation by up to 81.06 per cent. These modules

also resulted in the highest yields, with incremental output-input ratios highlighting their cost-effectiveness. Overall, the study supports integrating these bio-intensive management strategies into sustainable pest management programs for tomato cultivation to reduce *T. absoluta* infestations and increase yield. Further field-based validations and potential incorporation of the bioagents into integrated pest management systems is recommended for providing an effective and environment friendly pest control in various agricultural settings.

Plant Pathology

1. Title of thesis	:	Characterization of variability in <i>Cercospora sojina</i> Hara causing frog-eye leaf spot and identification of resistant sources in soybean.
Name of the student	:	Abhilasha Sharma (A-2018-40-023)
Major Advisor	:	Dr. Amar Singh

Salient findings

The present investigation entitled “Characterization of variability in *Cercospora sojina* Hara causing frog-eye leaf spot and identification of resistant sources in soybean” was undertaken during Kharif season to study pathogen isolation and culture production techniques, development of differential set, pathogen variability (morpho-cultural, pathogenic and molecular), mating type distribution, evaluation of resistant sources, inheritance of resistance, and biochemical basis of resistance against *Cercospora sojina*. Frog-eye leaf spot of soybean (*Glycine max* (L) Merrill) caused by *Cercospora sojina* Hara emerged as most destructive disease in Himachal Pradesh as PDI recorded was ranged between 0.00 to 95.56 per cent. Thirty isolates of *C. sojina* were collected from different locations of five districts (Kangra, Mandi, Solan, Hamirpur and Bilaspur) representing 3 agro-climatic zones of Himachal Pradesh. Isolations were done by using three different methods viz; inoculation by bits, inoculation by using moist-chamber technique and inoculation by using toothpick method. Out of these, moist chamber technique was the most reliable as most of the isolates were recovered by using this technique. Thirty isolates were identified as *Cercospora sojina* based on symptomatology, morphological characters and confirmed with molecular characterization. Culture technique for *C. sojina* was also standardized as the fungus was slow growing in nature. Among nine tested media, PCDA (Potato Cellulose Dextrose Agar) was found best with 4g concentration of cellulose whereas FRCA (Flat Rice Cellulose Agar) media (4g cellulose) was found best at $25 \pm 1^\circ\text{C}$ to produce long conidia. The pathogen was found variable on the basis of morpho-cultural variability. A differential set was finalized to study the virulence structure of *C. sojina*. Initially sixty soybean lines were selected from 200 genotypes and tested against six isolates, out of which 25 soybean lines were selected as pre-differential set which was tested against all the 30 isolates of *C. sojina* and finally a differential set of 10 lines was developed. On the basis of disease reaction on differential set *C. sojina* isolates were grouped into 10 pathotypes. Virulence analysis of the pathotypes (PCP 1 – PCP 10) revealed that PCS 1 and PCS 2 were highly virulent whereas PCS 3, PCS 8 and PCS 10

were least virulent. Variability studies on morpho-cultural, pathogenic and molecular characters categorized 30 isolates of *C. soja* into 11, 10 and 6 groups, respectively. There is no or less correlation among the three types of variability studies. Molecular variability was also studied and analyzed with POPGENE analysis software which revealed that thirty isolates were divided into 2 populations on the basis of geography (Latitude and longitude) and there is substantial gene flow among the two populations. There was occurrence of maximum variability within the population i.e.>90 per cent as PhiPT value ranged between 0.004 - 0.127. Mating type distribution of 30 isolates of *C. soja* was studied using MAT1-1 and MAT1-2 primers which revealed the presence of both the idiomorph (MAT1-1 & MAT1-2) found in CSH09 isolate revealed that population in Himachal Pradesh probably undergoing sexual reproduction. Out of a total two hundred lines evaluated under field conditions 30 lines found resistant which were screened against diverse pathotypes (PCP1-PCP-10) and four resistant lines viz.; Harder, JSM 285, CAT 195 and GP465 were identified as highly resistant against all pathotypes. Biochemical basis of resistance was also studied in a resistant line ‘Himso 1685’ and a susceptible line ‘Shivalik’ revealed that the tested enzymes i.e., Phenols, PPO and PO had no or less role in defence as there may be other enzymes which can affect the defence mechanism upon infection in soybean against *C. soja*. Inheritance of resistance for *C. soja* studied and results revealed that the inheritance was controlled by single-dominant gene.

2.Title of thesis	:	Diversity analysis of <i>Pseudocercospora griseola</i> populations causing angular leaf spot of common bean and identification of resistant sources
Name of the student	:	Khushwinder Kaur (A-2019-40-025)
Major Advisor	:	Dr. Amar Singh

Salient findings

The present investigation entitled “Diversity analysis of *Pseudocercospora griseola* populations causing angular leaf spot of common bean and identification of resistant sources” was undertaken during 2019-2023 to identify pathogen, standardization of culture technique, variability in *P. griseola* and evaluation of common bean germplasm for resistance sources. Angular leaf spot of common bean caused by *Pseudocercospora griseola* emerged as most destructive disease in Himachal Pradesh as 21.3 to 76.2 per cent disease severity was observed. Fifty isolates of *P. griseola* were collected from different locations of six districts (Chamba, Kangra, Kullu, Kinnaur, Mandi and Shimla) representing three agro-climatic zones of Himachal Pradesh. Isolations were done by using four different methods viz., by infected leaf bits, sterilized toothpick, moist chamber method and by picking up synnemata from diseased leaves. Out of these methods, picking up synnemata from infected leaves was found most efficient with 58.0 per cent recovery efficiency. Total 40 isolates were recovered by using different isolation methods. These isolates were

identified as *Pseudocercospora griseola* based on morpho-cultural characters and were confirmed further with molecular techniques. Among culture techniques, V8 juice agar medium at 24°C temperature with pH level 6 and relative humidity levels of 85 to 90 per cent supported the maximum mycelial growth and sporulation. The pathogen was found variable on the basis of morpho-cultural characteristics and isolates were categorized into 8 groups i.e. PG-MV1-PG-MV8. The virulence structure and pattern of 40 isolates was studied on 9 differential lines and on basis of pathotype designation, *P. griseola* isolates were grouped into 5 pathotypes i.e. PPG1-PPG5. Among 5 pathotypes PPG1 was found highly virulent which gave susceptible reaction on 8 out of 9 differential lines used whereas PPG5 was least virulent which gave susceptible reaction against only 3 differential lines. PPG5 pathotype was found most frequently distributed which constituted of 23 isolates. Pathogen population was also characterised on molecular basis by using ISSR and RAMS markers. In POPGENE analysis, among all populations Kullu district population was found most diverse with highest Nei diversity (0.3161), Shannon information index (0.4763) and percentage of polymorphic loci (92.48). ISSR markers had exhibited high genetic diversity in pathogen population and categorized the test pathogen population in 2 clusters that were further grouped into 7 groups while RAMS markers categorized the population in 3 groups. It was observed that in molecular variability analysis, some of the isolates were grouped according to geographical region while some isolates collected from distant regions were also grouped in single cluster indicating genetic variability had no or less correlation with pathogenic and morpho-cultural variability studied. Out of two hundred twelve common bean lines along with 3 checks i.e. Hans, Jwala and Contenderevaluated under field conditions, 18 lines and variety Hans were found highly resistant. These identified highly resistant sources were screened against diverse pathotypes (PPG1-PPG5) under *in-vivo* conditions and four lines *viz.*, IC 243195, EC 500423, EC 500821, EC 405219 and variety Hans were confirmed to be highly resistant. Biochemical basis of resistance was studied in Hans (highly resistant) and the increased level of phenol and peroxidase after infection indicated their role in disease resistance. Inheritance of resistance for *P. griseola* was studied in Jwala x Hans crosses and results revealed that the inheritance was controlled by single-dominant gene.

3. Title of thesis	:	Studies on variability in major pathogen causing root rot of okra and its integrated disease management
Name of the student	:	Vakul Sood (A-2019-40-026)
Major Advisor	:	Dr. Amar Singh

Salient findings

The present investigation entitled “Studies on variability in major pathogen causing root rot of okra and its integrated disease management” was undertaken to ascertain the status of root rot, etiology, pathogen morpho-cultural and pathogenic variability, evaluation of resistant sources and biochemical basis of resistance against the major pathogen causing root rot of okra in Himachal Pradesh. Root rot was prevalent as a major disease in all the six districts (Mandi, Bilaspur, Hamirpur, Una, Kangra and Chamba) surveyed and causing 12.50-61.05 % overall disease incidence. Three pathogens viz., *Fusarium solani*, *F. oxysporum* and *Rhizoctonia solani* were found associated with root rot of okra with 36.61, 15.94 and 15.95 per cent frequency. So, the major associated pathogen was *F. solani* thus, considered for further studies. The pathogen was found variable on the basis of morpho-cultural variability. A differential set of 12 genotypes showing the characteristic differential reaction was developed and used for analyse virulence in pathogen population. On the basis of disease reaction on differential set *F. solani* isolates were grouped into 19 pathotypes. Virulence analysis of the pathotypes (FPG-1 – FPG-19) revealed that FPG7, FPG11, and FPG13 were highly virulent among all the pathotypes, which gave susceptible reaction on 8-9 out of 12 differential genotypes whereas FPG7, FPG11, and FPG13 were least virulent which gave susceptible reaction to only 5 differential genotypes. Out of a total sixty genotypes evaluated under field conditions 15 genotypes found resistant which were screened against diverse pathotypes (FPG-1 – FPG-19) and three genotypes viz., Hissar Unnat, VRO-4 and SKBS-11 were identified as highly resistant against maximum 11 pathotypes. Relatively high activity of Phenols and enzymes; PPO and PO in a resistant genotype ‘Hissar Unnat after inoculation revealed the biochemical basis of host resistance. Under *in vitro* conditions, thirty isolates of *Trichoderma* spp. isolated from okra rhizospherewere evaluated where *Trichoderma* sp.-29 was found best with 61.11 per cent mycelial inhibition, the potential bio-agents found effective for their efficacy of volatile metabolites and non-volatile metabolites of culture filtrates on mycelial growth of *F. solani*. Among different botanicals (*Azadirachta indica*, *Eucalyptus* sp., *Lantana camara*, *Eupatorium adenophorum*, *Dodonaeaviscosa*, *Justicia adhatoda* and *Ageratum conyzoides*) and organic formulations (Jeevamrit, Beejamrit, Ghanjeevamrit, Vermicompost, Eupatorium ark, Neemastra, Darekastra and Brahmastra)evaluated against *F. solani*, *Dodonaeaviscosa* with 53.66 per cent mycelial inhibition @ 25% concentration, Brahmastra (organic formulation) with 100 per cent mycelial inhibition @15, 20 and 25% concentrations were found best under *in vitro* conditions. Under *in vivo* conditions, seed treatment with potential bio-agent, botanical or organic formulation alone was proved better than soil and drenching application. An integrated treatment viz., seed treatment with Brahmastra (organic formulation) followed by soil drenching with *Trichoderma* sp-29 (bioagent @5kg/l) was found most effective giving 69.02 and 68.12 per cent disease control during *Kharif* 2021 and 2022, respectively for eco-friendly management of root rot of okra under field conditions.

Vegetable Science and Floriculture

1. Title of thesis	:	Response of different varieties to diverse nutrient management practices in chilli-garden pea sequence
Name of the student	:	Rafiullah Noori (A-2019-40-032)
Major Advisor	:	Dr. Akhilesh Sharma

Salient findings

The present investigation was undertaken to assess the response of different nutrient management practices on different varieties of garden pea and chilli. The field experiment comprised of 15 treatments which was conducted in chilli-garden pea sequence during two consecutive growing seasons of 2020-21 and 2021-22 following split plot design, replicated thrice. The main plot treatments consisted of five nutrient management practices (75, 100 and 125% of recommended NPK, organic farming and natural farming) while sub-plot treatment comprised of three varieties each of chilli and garden pea. Different nutrient management practices and varieties significantly influenced yield and majority of its attributes in both the crops alongwith NPK uptake and available N, P and K content in soil. The interaction effects between nutrient management practices and varieties were also significant for yield (fresh/ red ripe/ dry in chilli and fresh/ seed in pea), many important traits, N, P and K uptake monitory gains in respective crops and chilli equivalent yield. Application of 20 tonnes/ ha + 125% NPK resulted in significantly higher mean marketable green, red ripe and dry fruit yield of 254.22, 209.64 and 57.30 q/ha with net returns of Rs. 2.89, 3.27 and 6.62 lakhs/ ha, respectively over years in chilli. Similarly, this treatment when applied in pea genotype DPP-SP-6 also resulted in maximum average pod and seed yield of 166.64 and 27.25 q/ha along with net returns of Rs. 2.53 and 1.60 lakh/ ha, respectively in pooled data over years. Natural farming practice showed least performance for all the traits in both the crops while organic farming practice found better than natural farming. The maximum N, P and K uptake was recorded in treatment supplemented with 20 tonnes of farmyard manure + 125% of recommended NPK in both the crops. At the end of the experiments, treatment supplemented with 125% NPK increased available N, P and K levels in the soil by 55.96, 8.05 and 44.14 kg/ha over the initial status of the soil. Application of 125% NPK resulted in significantly highest chilli equivalent yield of 510.48 q/ ha in Him Palam Mirch 2 mean over years with an increase of 8.3% over recommended practice of 100% NPK in the same variety. Therefore, it can be concluded that treatment supplemented with 125% NPK resulted in maximum yield advantage and economic returns in chilli-garden pea sequence while organic farming performed better than natural farming.

2. Title of thesis	:	Genetic analysis of fruit yield, component and quality traits in tomato (<i>Solanum Lycopersicum</i> L.)
--------------------	---	---

Name of the student	:	Shaina Sharma (A-2019-40-022)
Major Advisor	:	Dr. Sanjay Chadha

Salient findings

The present investigation entitled “Genetic analysis of fruit yield, component and quality traits in tomato (*Solanum lycopersicum* L.)” was carried out at Vegetable Research Farm of the Department of Vegetable Science and Floriculture, CSKHPKV Palampur with the objectives to study the nature and magnitude of gene action of fruit yield, component and quality traits of triple test cross progenies, and to identify the potential parents and cross-combinations on the basis of combining ability and heterosis in tomato. The experimental material comprised of 24 triple test cross hybrids derived by mating 08 lines with three testers namely 12-1, Palam Pride and their single cross F_1 (12-1× Palam Pride). 24 cross combinations, 11 parents along with standard check- 1 (Avtar) were evaluated in Randomized Complete Block Design with three replications during summer-rainy season of 2021. Tester F_1 i.e.12-1× Palam Pride was identified as promising cross combination at CSKHPKV, Palampur during the past years and was also used as standard check -2 for the estimation of standard heterosis. Susceptible checks (Punjab Chhuhara and Roma) were included at every 11th row alternatively to ensure the presence of uniform distribution of bacterial wilt disease inoculum. The observations were recorded on five competitive plants marked at random in each entry over the replications on different quantitative traits viz. plant survival on the basis of bacterial wilt disease incidence, days to 50 per cent flowering, days to first harvest, average fruit weight (g), fruit shape index, pericarp thickness (mm), total fruits/plant, marketable fruits/plant, marketable yield/plant (kg), total yield/plant (kg), locules/fruit, plant height (cm), duration of fruit harvest (days). Data were recorded on some visual traits fruit shape, fruit colour, fruit shape at pedicel area, fruit shape at blossom end and blossom end scar. Biometrical analysis was done for the characters TSS (⁰Brix), ascorbic acid (mg/100g), lycopene content (mg/100g), titrable acidity, dry matter content, pH content, moisture content, carotenoid content (mg/100g) and TSS- AR ratio. Epistasis was discovered to be a crucial component of genetic variation for majority of the traits including marketable fruit yield/ plant. Epistasis has been found to be invariably present for all the examined attributes except days to first harvest. Both (i) and (j+l) type of interactions were significant for days to 50 per cent flowering, plant height, total fruits/ plant, gross yield/ plant, marketable fruits/ plant, marketable yield/ plant, locules per fruit, pericarp thickness, fruit length, fruit shape index, TSS, titrable acidity, carotenoid content, dry matter content, moisture content and TSS-AR ratio. Additive component was more pronounced than dominance component for all the traits except pericarp thickness, locules per fruit, dry matter content and moisture content. Degree of dominance was in the range of incomplete dominance for all the traits except pericarp thickness, locules per fruit, dry matter content and moisture content. Genetic variance revealed from triple test cross progenies can be exploited by intermating selected individuals in early segregating generations with delayed selection in later generations, diallel selective mating/biparental mating or recurrent selection followed by pedigree method to exploit both additive and non-additive

components as well as epistasis. Line \times tester analysis revealed the preponderance of non-additive gene effects for most of the traits viz. days to 50 per cent flowering, days to first harvest, duration of fruit harvest, plant height, fruit length, fruit width, fruit shape index, pericarp thickness, locules/fruit, total fruits/plant, marketable fruits/plant, total yield/plant, TSS, ascorbic acid content, titrable acidity, pH, carotenoid content, dry matter content, moisture content and TSS-AR ratio while additive gene effects for marketable yield per plant. Lines DPT 4 and DPT 1 were found to be good general combiners for most of the traits. The cross-combinations DPT 1 \times 12-1, DPT 1 \times Palam Pride, DPT 4 \times 12-1 and 2015/TOINVAR-4 \times 12-1 exhibited high heterosis, SCA and per se performance for majority of traits, therefore were rated as potential crosses. As a result, it would be helpful to exploit tomato hybrids, particularly those that showed high SCA in the current study for the development of hybrids.

3.Title of thesis	:	Molecular genetic diversity and gene action studies in bell pepper (<i>Capsicum annuum</i> L. var. <i>grossum</i> Sendt.)
Name of the student	:	Shaina Sharma (A-2019-40-021)
Major Advisor	:	Dr. Sonia Sood

Salient findings

The present investigation entitled “Molecular genetic diversity and gene action studies in bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.)” was conducted at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK HPKV Palampur with the aim of gathering information on genetic diversity, nature and magnitude of gene action, and the identification of potential parents and cross-combinations on the basis of combining ability and heterosis. Visual, morphological and molecular characterizations (SSRs) were employed to assess the diversity in parental material. Out of 82 SSRs, 47 were found to be polymorphic and PIC value ranged from 0.057 (CAMS 162) to 0.861 (CAMS 880) with an average of 0.630. Thirty six cross-combinations developed by crossing 12 female lines and three diverse testers in triple test cross fashion were evaluated along with two standard checks in Randomized Complete Block Design with three replications during Summer-rainy 2021 (E₁) and Summer-rainy 2022 (E₂). The data were recorded on different phenological and structural traits, fruit yield and yield attributing traits, quality traits and disease incidence of bacterial wilt. Sufficient genetic variability was recorded for all the traits in all environments. Significant genotype \times environment interactions were recorded for most of the traits indicating the role of environment on the performance of genotypes and cross-combinations. Epistasis has been found to be invariably present for all the studied traits. Both ‘i’ type and ‘j + l’ type interactions were present for harvest duration, lobes per fruit, fruit length, pericarp thickness, fruit shape index, marketable green fruits per plant, marketable green fruit yield per plant, marketable fruit yield in q/ha, capsanthin content, TSS and ascorbic acid content, implying that epistatic component could not be

overlooked as this would lead to biased estimates of the additive and dominance components of variance. Dominance component (H) was predominant than additive (D) component for most of the traits except lobes per fruit, fruit length, pericarp thickness and ascorbic acid content, revealing the importance of non-additive gene action. The degree of dominance was in the range of over dominance for most of the traits except lobes per fruit, fruit length and ascorbic acid content. The kind of genetic variance revealed from triple test cross can be exploited by intermating selected individuals in early segregating generations with delayed selection in later generations, diallel selective mating/ biparental mating or recurrent selection followed by pedigree method to exploit both additive and non-additive components alongwith epistasis. Lines ‘HPB-7’, ‘HPB-2-16’, ‘HPB-6-1’, ‘HPB-AC-49’, ‘HPB-HY-22’ and ‘HPB-29’ were found to be good general combiners for marketable green fruit yield per plant and related traits. ‘HPB-7 × California Wonder’, ‘HPB-29 × HPB-39’, ‘HPB-2-16 × HPB-39’, ‘HPB-6-1 × California Wonder’, ‘HPB-1 × California Wonder’, ‘HPB-3-10 × HPB-39’, ‘HPB-AC-48 × HPB-39’, ‘HPB-22 × HPB-39’ and ‘Kandaghat Selection × HPB-39’ were the most promising cross-combinations on the basis of SCA effects for yield and component traits. A large variation in magnitude and direction of heterosis was observed for most of the traits studied. Hybrids ‘HPB-7 × California Wonder’, ‘HPB-2-16 × HPB-39’, ‘HPB-6-1 × California Wonder’, ‘HPB-29 × HPB-39’ and ‘HPB-2-16 × California Wonder’ were the most promising crosses exhibited significant desirable standard heterosis for fruit yield and related traits. Based on *per se* performance, SCA effects, standard heterosis, morphological traits and disease incidence, ‘HPB-29 × HPB-39’ and ‘HPB-6-1 × California Wonder’ were the most promising cross-combinations for developing superior progenies. ‘HPB-29 × HPB-39’ exhibited high TSS and ascorbic acid content along with green fruit colour, blocky shape, cordate pedicel end, sunken blossom end, pendent fruit position and resistance to bacterial wilt. On the other hand, ‘HPB-6 × California Wonder’ had significant amounts of capsanthin and ascorbic acid content. This cross was characterized by yellow-green fruit colour, blocky shape, lobate pedicel end, sunken blossom end, intermediate fruit position and moderate resistance to bacterial wilt under field conditions. Thus, these cross-combinations can be released as hybrids after further field testings or can be utilized in future breeding programmes.

4. Title of thesis	:	Molecular characterization of CMS inbred lines of mid-late/late cauliflower and their utilization in heterosis breeding
Name of the student	:	Alisha Thakur (A-2020-40-020)
Major Advisor	:	Dr. Akhilesh Sharma

Salient findings

The present investigation entitled "Molecular characterization of CMS inbred lines of mid-late/late cauliflower and their utilisation in heterosis breeding," was conducted at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSKHPKV,

Palampur. The objective of investigation was to assess the genetic diversity among inbred lines using molecular markers and to examine the combining ability and heterosis to identify potential hybrids for marketable curd weight and related traits using 'Line \times Tester' mating design. The study involved the evaluation of 4 CMS lines, 9 testers and their 36 cross combinations, along with the standard checks 'PSB Hybrid 1', 'Pusa Hybrid 301' and 'Maharani' in α -RBD with three replications for two successive winter seasons of 2021-22 and 2022-23. Genetic diversity using morphological traits through Mahalanobis D^2 -statistic grouped 13 cauliflower genotypes into five clusters in both the environments. Out of 98 SSR and mitochondrial markers, 70 showed polymorphism and had PIC values ranging from 0.239 to 0.835 with an average of 0.645. Heterotic grouping by morphological and molecular marker analyses showed that inbred lines were diverse. Yield and its related traits also revealed enough genetic diversity over the years based on analysis of variance. The floral characterization showed that 'DPCaCMS-1' was superior to the other CMS lines and showed uniformity with its maintainer 'Palam Uphar' for almost all the flower traits. Further, 19 mitochondrial DNA specific markers were used to identify the CMS system present in the 4 CMS lines and out of which 6 primers validated the presence of *Ogura* system with *Orf 138* target location. The Line \times Tester analysis showed significant differences for most of the traits during the respective years in both the environments displaying considerable diversity in the experimental material. 'DPCaCMS 1' and 'DPCafCMS 4' among lines and 'DPCaf W4', 'DPCaf W131', 'DPCaf SP1' and 'DPCaf SP2' among testers were the good general combiners as they showed significant GCA for marketable curd weight and other related traits. On the basis of SCA effects, 'DPCafCMS 4 \times DPCaf 29', 'DPCafCMS 4 \times DPCaf SP2', 'DPCaCMS 3 \times DPCaf SP1', 'DPCaCMS 1 \times DPCaf S121', 'DPCaCMS 2 \times DPCaf 18', 'DPCaCMS 2 \times DPCaf 13', 'DPCaCMS 3 \times DPCaf 18', 'DPCafCMS 4 \times DPCaf 13', 'DPCaCMS 2 \times DPCaf W131' and 'DPCaCMS 1 \times DPCaf W131' were the most promising cross combinations for marketable curd weight and other related traits and one of the parents of these crosses revealed either good or average or poor general combining ability indicating the presence of non-additive gene action. Different traits indicated the preponderance of either additive or dominance variance. The majority of traits revealed variations in the magnitude and direction of heterosis. The promising hybrids for economic heterosis across the environments for gross plant weight, marketable curd weight, net curd weight and other important economic traits were 'DPCaCMS 1 \times DPCaf W4', 'DPCaCMS 1 \times DPCaf W131', 'DPCaCMS 1 \times DPCaf 18', 'DPCaCMS 1 \times DPCaf S121', 'DPCaCMS 1 \times DPCaf SP2', 'DPCaCMS 1 \times DPCaf 5', 'DPCaCMS 1 \times DPCaf SP1', 'DPCaCMS 2 \times DPCaf W131', 'DPCafCMS 4 \times DPCaf W131', 'DPCafCMS 4 \times DPCaf SP2' and 'DPCafCMS 4 \times DPCaf 29'. Based on *per se* performance, SCA effects and heterosis, it can be concluded that 'DPCaCMS 1 \times DPCaf W4', 'DPCaCMS 1 \times DPCaf-S121', 'DPCafCMS 4 \times DPCaf SP2', 'DPCaCMS 1 \times DPCaf 18', 'DPCaCMS 1 \times DPCaf W131', 'DPCaCMS 1 \times DPCaf 5' and 'DPCafCMS 4 \times DPCaf 29' were revealed as promising hybrids for gross plant weight, marketable curd weight net curd weight along with some other important traits. Therefore,

utilization of CMS based system in cauliflower has eased the hybridization process accompanied with the development of highly heterotic cross combinations for curd yield and other important traits which will be remunerative to the farmers in the near future.

5. Title of thesis	:	Line × tester analysis for yield and its components in broccoli (<i>Brassica oleracea</i> L. var. <i>italica</i> Plenck)
Name of the student	:	Shivam Sharma (A-2020-40-022)
Major Advisor	:	Dr. Viveka Katoch

Salient findings

The present investigation entitled “Line × tester analysis for yield and its components in broccoli (*Brassica oleracea* L. var. *italica* Plenck)” was carried out at the Research Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur and Research Farm of Research Sub Station (RSS) Berthin, District Bilaspur, Himachal Pradesh during *rabi*, 2022-23. The experimental material comprised of 15 cross combinations obtained by crossing three CMS lines and five testers. Fifteen cross combinations, eight parents along with standard check (Palam Samridhi) were evaluated in Randomized Complete Block Design with three replications during *rabi*, 2022-23. The observations were recorded on five competitive plants marked at random in each entry over the replications on different quantitative traits viz., days to first harvest (days), marketable yield per plant (g), terminal head weight (g), gross weight per plant (g), no. of spears per plant, head size index (cm²), plant frame (cm²), leaf size with leaf stalk (cm²), leaf size without leaf stalk (cm²), plant height upto longest leaf (cm), plant height upto head (cm), stalk length (cm), weight of spears per plant (g) and harvest index (%). Biochemical analysis was done for the characters TSS (°B), dry matter (%), ascorbic acid (mg/100g), total sugar (%), moisture content (%), iron (mg/100g), calcium (mg/100g), zinc (mg/100g), phosphorus (mg/100g) and potassium (mg/100g). Analysis of variance for the experimental design with respect to total entries revealed mean sum of squares due to genotypes were highly significant for all the horticultural and quality traits studied except for leaf size with leaf stalk, plant height upto longest leaf, plant height upto head, dry matter and moisture content in environment E1 while days to first harvest, dry matter and moisture content in environment E2. This indicates that genotypes differed among themselves and there existed a considerable variability irrespective of the effect of environments on the characters studied. Pooled analysis of variance revealed that mean sum of squares of genotypes were significant for all the traits studied indicating the presence of considerable genotypic variability among the genotypes. Based on mean performance cross combinations namely, DPBH-12, DPBH-18, DPBH-11, DPBH-13, DPBH-22, DPBH-15, DPBH-20, DPBH-10, DPBH-23 and DPBH-24 in E1, all cross combinations in E2 and overpooled environments, except for DPBH-14 over pooled environments exhibited significant superior performance with respect to marketable yield per plant when compared with standard check variety, Palam Samridhi. Based on performance, SCA effects, heterobeltosis and standard heterosis cross

combinations viz., DPBH-12, DPBH-11, DPBH-13, DPBH-22 and DPBH-15 in E1, DPBH-18, DPBH-13, DPBH-21, DPBH-16 and DPBH-22 in E2 appeared as best cross combinations as they exhibited high SCA effects, heterobeltiosis and standard heterosis for marketable yield per plant. However, on pooling top five cross combinations viz., DPBH-23, DPBH-12, DPBH-22, DPBH-13 and DPBH-18 exhibited high SCA effects, heterobeltiosis, standard heterosis and surpassed the performance of standard check variety, Palam Samridhi with a significant increase of 78.55 %, 76.84 %, 75.73 %, 70.25 % and 64.21 % for marketable yield per plant. The ratio of $\sigma^2GCA / \sigma^2SCA$ was found to be less than unity indicating that the gene effects were predominantly non-additive type for majority of the traits studied over pooled environments, environment E1 and E2 suggesting that heterosis breeding would be more effective in improvement of such traits. Epistasis was found to be an integral part of genetic variation for majority of the traits studied. However, on pooling additive (fixable) type of gene action was important for marketable yield per plant, terminal head weight, gross weight per plant and leaf size with leaf stalk.

Agricultural Economics

1. Title of thesis	:	Structure for farm credit in Himachal Pradesh and role in agricultural development
Name of the student	:	Kanika Mehta (A-2018-40-002)
Major Advisor	:	Dr. Rajesh Kumar Thakur

Salient findings

Credit plays a vital role in capitalizing the farmers to enhance farm productivity by increasing investment in quality inputs and efficient technologies. With the commercialization and modernization of agricultural practices, the credit needs in Himachal Pradesh are increasing. Therefore, the present study was conducted to comprehend the trends in the allocation of agricultural credit, extent of financial inclusion and its impact on farm investment, productivity and income levels of the farmers in Himachal Pradesh. Two-stage random sampling was used to select two blocks from each district in the first stage and a total sample of 200 loanee farmers in the second stage of sampling by proportional allocation method. The farmers were then classified into small (n=109) large (n=91) categories based on the total land holding size. Both primary and secondary data were employed in accordance with the objectives of the study. The state's dependency on Regional Rural Banks (RRBs) and co-operative banks for agriculture credit disbursement (through bank branch network position and ATMs) was high, particularly in rural areas. However, over the years, growth in these rural financial institutions was substantially lower than in the private sector banks. The amount sanctioned for the agricultural term loan, agricultural infrastructure and agricultural ancillary activities had declined over the years and was considerably lower (21.53%) than the short term crop loan (78.47%). The overall PCA score of the Financial Inclusion index was 0.41, reflecting a medium-level of financial inclusion in the

study area. The geographical penetration, affordability, usage financial literacy and quality of financial products and services provided by formal institutions were in the medium range of PCA scores. However, the accessibility and case components of the Financial Inclusion indexed were observed at a lower range of PCA scores in the study area. The cultivated land on overall farms was significantly increased by 1.12 per cent due to the diversion of credit towards the increase in leased-in land holdings (4.49%) in the study area. The financial aid led to a significant shift from cereal and fodder crops to vegetable cultivation. The use of hybrid seeds, fertilizers, pesticides and hired labour increased after the financial aid.. Due to this, the total cost of cultivation (Cost C₃) for all the *kharif* and *rabi* seasons crops was substantially increased. The increase in the use of quality inputs led to an increase in the productivity levels of all the major crops in the study area. The gross farm income on overall farms was significantly increased by 39.99 per cent after availing the farm credit. The income from vegetable cultivation increased by the highest proportion on both the small and large farms, constituting on overall increase of 73.74 per cent. The scale of the amount sanctioned to the sample farms varied positively with the land holding size, while the repayment of credit was lower on small farms that the large farms in the study area. Most sample farmers attained credit from the scheduled banks via KCC, followed by the private moneylenders and Primary Agricultural Credit Societies (PACS). With the increase in the size of cultivated land holding and dependency on agriculture as the primary source of income, the probability of credit acquisition from private moneylenders increased on sample farms. The asset status and the gross farm income of the farmers has a significantly negative impact of the odds of being a delinquent or a defaulter. The interest rate charged by the financial institutions reflected a positively significant relationship with the probability of being a defaulter or a delinquent in the study area. The lack of collateral security, insufficient credit limit offered by banks and fear of losing agriculture land were major problems for credit acquisition through institutional sources. Whereas, the increasing input costs and rising household expenditures negatively impacted the repayment and use of credit. Based on the findings, the Panchayat-level identification of farmers was suggested as a measure to restrict the diversion of credit towards non-agricultural purposes.

2.Title of thesis	:	A study of economics and price behaviour of vegetables in Himachal Pradesh
Name of the student	:	Diksha Sethi (V A-2018-40-001)
Major Advisor	:	Dr. Virender Kumar

Salient findings

Vegetables are integral part of Indian agriculture and nutritional security owing to their higher yield potential, nutritional richness, better economic returns and provisioning more employment opportunities. Agriculture bears great significance for hilly states like Himachal Pradesh where around 90 per cent of the population lives in rural area. Perceptible proportion of

the cultivated area in the state is being shifted from cereals to vegetable crops as the state has different agro-climatic conditions which provide a great scope to farmers for profitable vegetables production. Therefore, the present research was carried out to study the economics and price behaviour of vegetables in two agro-climatic zones (Zone II and III) of the state. The study was based on both secondary and primary data. The secondary data on vegetables for the period 1995-96 to 2021-22 were collected from different publications of Government of HP and Government of India. Further, the data were grouped in three periods viz. period I (TE 1997-98 to 2008.09), period II (TE 2009-10 to 2021-22) and overall period (TE 1997-98 to 2021-22). Primary data were collected through survey method from 200 farmers selected using proportional allocation technique. The proportion of area under green pea (27.53%) was found maximum in 2021-22 followed by tomato (14.93%). The proportion of cabbage area to the total area has declined from 6.22 per cent in 1997-98 to 0.54 per cent in 2021-22. The share of production was high for tomato (27.80 %) followed by green pea (16.31%). It was observed that the growth rates in area, production and yield under all vegetables was 5.47, 6.64 and 1.12 per cent per annum during the study period. The findings of the study showed that the increase in production was mainly on account of area (expansion) effect and partly due to yield effect though the interaction effect was negative for tomato crop. The instability in area under different vegetable crops was found low, however, medium to high instability was found in production in the vegetables in the state as well as across districts. Total cost (cost C_3) of cultivation was observed to be maximum Rs. 486382/ha for tomato followed by cauliflower (Rs. 445244/ha) in both Zones. The net returns over total cost were recorded to be Rs. 206368/ha for tomato and Rs. 60793/ha for cabbage. The results of regression analysis revealed that factors like seed, FYM and fertilizers significantly increased the yield of tomato, green pea and cabbage whereas further increase in human labour significantly decreases the yield. The factors like seed, FYM and fertilizers significantly affected the yield of cauliflower and capsicum. The farm income contributed about 75 per cent and non farm income to about 25 per cent, respectively. The trends in market prices showed significant increase over period of 12 years (2010-11 to 2021-22) in case of tomato, cauliflower and cabbage crop in all the markets. The arrivals and prices for all the vegetables showed inverse relationship for all the vegetables. The high degree of seasonal variations for arrivals and prices were found in the study markets. The market prices for vegetable commodities was found to be significantly influenced directly lagged prices and inversely by current arrivals. For cauliflower, the variability in the market arrivals was more pronounced in Bhuntar than the remaining markets. The price variability was, however, more marked in Takoli. The highest average price was observed in the month of October-November when the arrivals were supposed to be the lowest with moderate to low variability in tomato. The variability in the prices of cabbage and green pea was noted low to moderate, while it was moderate to high for market arrivals. The results of the study have confirmed the negative relationship between market arrivals and prices in terms of correlation coefficients over the years and across months in all the markets, though there were several instances of positive relationship. Forecasting of prices was done using time-series monthly wholesale prices from April 2010 to

March 2022 for tomato, green pea, cauliflower and cabbage in selected markets. Different set of Autoregressive Integrated Moving Average models were used to forecast prices. The models were validated for accuracy with Mean absolute percentage error (MAPE) in the range of 16-35 per cent which is acceptable in fresh produce markets. These models can facilitate the farmers and wholesalers in effective decision making. Therefore, the market infrastructure facilities like warehousing, transportation, processing, etc should be promoted more which would help the growers to store their excess produce during production and eliminate the seasonality in market arrivals of vegetables and minimize the price volatility of the vegetables.

3. Title of thesis	:	Study on adoption process and comparative economics of natural and conventional farming in Himachal Pradesh
Name of the student	:	Komal Sharma (V A-2019-40-001)
Major Advisor	:	Dr. Manoj Gupta

Salient findings

Natural farming is a one –of-a-kind chemical-free farming method that helps in preserving and protecting the valuable natural resources by minimizing the use of synthetic fertilizers, pesticides and chemicals. Present research was carried out to study the adoption process and comparative economics of natural and conventional farming in Himachal Pradesh. The study was based on both primary and secondary data. Primary data were collected through survey method from 240 farmers while the secondary data were collected from various published and unpublished sources. Natural farming has been since its launch, PK3 Yojna has witnessed success among the smallholder farmers of the hilly state. Natural farming has gained prominence across all development blocks and districts of the State, despite constraints imposed by the hilly terrain, and is being practiced by the farmers in almost all the panchayats of the state. Presently, about 1.71 lakh farmers have started practicing natural farming on about 9422 ha of land across all agro-climatic zones of the State. 76.67 per cent of farmers were following the pattern of mixed pattern farm while 9.17 per cent of farmers were still growing the monocrop under natural farming system. Overall adoption index was 0.75, indicating that majority of the farmers have partially adopted the SPNF practices. On the average, farmers had 0.8413 ha/ farm in SPNF and 0.7197 ha/ farm in CF system and around 60 per cent of total land was under cultivated land in both the farming system. There were five major crop combinations under natural farming i.e. Maize-pulses, Maize-Vegetable, Vegetables-wheat-pulses, Vegetable-pulses and Tomato-other vegetables in *Kharif* season, whereas Wheat-pulses, Wheat-vegetables, Vegetables-wheat-pulses, Vegetables-pulses and Cauliflower-other vegetables in *Rabi* season. In various components of natural farming inputs, use of *Jeevamrit* was highest in all the crop combinations. In *Kharif* season, under NF, cost C₃ ranged between Rs. 1,01,447/ ha (Maize-Pulses) to Rs. 1,77,300/ ha (Vegetable-pulses), whereas in CF, it ranged between Rs. 1,14,112/ha

(Maize) to Rs. 2,26,176/ha (Tomato). In *Rabi* season, under NF, cost C₃ ranged between Rs. 1,01,824/ ha (Wheat-pulses) to Rs. 1,68, 472/ha (Cauliflower-other vegetables), whereas in CF, it ranged from Rs. 1,15,562/ha (Wheat) to Rs. 2.07,889/ ha (Cauliflower). Percent change in yield in NF over CF was observed maximum in Maize-vegetables (50.68%) followed by Maize-pulses (24.59%) in *Kharif* season, whereas in *Rabi* season, it was maximum for wheat-vegetables (17.39%) followed by wheat-pulses (10.46%). In *Kharif* season, percentage reduction in cost of cultivation under NF over CF was maximum in Tomato-other vegetables (22.33%), followed by Vegetables-pulses (22.61%). Vegetable-maize-pulses (17.19%), Maize-pulses (11.10%) and in *Rabi* season, it was highest in Cauliflower-other vegetables (18.96%) followed by Vegetable-wheat-pulses (12.77%), wheat-pulses (1081.01%) in *Rabi* season. The results of regression analysis revealed the factors like *Beehamrit*, *Jeevamrit*, *Ghanjeevamrit*, *Agnistra*, *Khatti lassi* and labour were significantly increased the gross returns. Around 45-50 per cent of vegetables were marketed through channel-III involved commission agent-cum- wholesaler as the main market functionary. The channel 1 (involving producers and consumers) was found to be most efficient in the study area from the view point of higher net price received by farmers and higher marketing efficiency index. Perception of farmers revealed that majority of farmers were convinced that natural farming leads to crop diversification, decline in pest attack and decrease in the cost of production. 76.67 per cent of farmers felt that natural farming is labour intensive and only 27.50 per cent of farmers agreed that SPNF can be adopted on large scale under present conditions. Factors like experience in farming, total farm size, total family member, number of indigenous cow, high cost of chemical fertilizers, training attended and social participation were found significant variable for adoption of natural farming. Labour intensive technique, shortage of skilled labour, high wage rate, lack of market information and non-availability of specialized market were some of the constraints faced by farmers in the study area. To up-scale the PK3Y, government policy needs to focus on training and awareness camps, regular handholding of the NF farmers, certification programme, market intervention schemes, financial assistance during the initial years of adoption alongwith focus on development of seed banks, natural fertilizer production facilities, marketing and distribution networks for natural farm products.

4.Title of thesis	:	Economic of natural and conventional crop production systems in Himachal Pradesh
Name of the student	:	Minam Gamoh (A-2019-40-002)
Major Advisor	:	Dr. Brij Bala

Salient findings

The introduction of green revolution has led to indiscriminate use of fertilizers and pesticides in order to maximize production hence making the soil dead. Moreover, increasing costs of chemical fertilizers and pesticides led to farmer’s indebtedness and their suicides. Therefore in mid 1990s natural farming (NF) was introduced where nothing has to be purchased from outside. Himachal Pradesh (HP) is one of the states in India where there is less

use of agro-chemicals and has the potential to follow natural farming. Hence, the present study “Economics of natural and conventional crop production systems in Himachal Pradesh” was carried out in HP. Two stage random sampling technique was used for the selection of blocks and farmers. Zone-1 and Zone-II were selected purposively and 160 farmers practicing natural crop production and conventional crop production were interviewed. Secondary data revealed that Chamba covered the highest area (391.38 ha) under NF and Lahaul Spiti the least (19.16 ha). Kangra had the highest number of farming families (13386 nos) that received training for NF. Primary data revealed that during *Kharif* season combination of Maize+pulses+ oilseeds (M+P+O) (26%) covered the maximum area in Zone-1 and Maize+Pulses (M+P) (9.739%) in Zone-II. During *Rabi* season , Wheat+Pulses (W+P) covered the maximum area in Zone-I (56%) and Zone-II (39%). The highest cost incurred during *Kharif* season was for M+O+V in Zone-1 and Zone-II i.e. Rs. 67711 and Rs. 66593, respectively. During *Rabi* season maximum cost was incurred for V+P in Zone-I and Zone-II i.e. Rs. 143380 and Rs. 142931, respectively. Under conventional farming (CF) in *Kharif* season the total variable cost incurred in the cultivation of maize was Rs. 43605 in Zone-I and and Rs. 43252 in Zone-II. The Crop Equivalent Yield (CEY) in the NF system was higher that the CF system for all crop combinations. In *Kharif* season M+O+V resulted in maximum returns with net return of Rs. 150322 followed by M+P+O (Rs. 102907) in Zone-1. In Zone-II, M+P yielded highest returns (Rs. 148799) followed by M+O+V (Rs. 94209). In *Rabi* season, net returns were highest for V+P (Rs. 159832) in Zone-I followed by W+P+O (Rs. 130706). In Zone-II, V+P (Rs. 214722) remained at highest followed by W+P+O (Rs. 111846) and W+P the lest (Rs. 61322). Cobb-douglas production function revealed that, value of bioformulations (0.74) and human labour (0.06) were positive and significant under NF affecting the gross returns. Under CF, value of chemical fertilizers (0.67) was positive and significant. Age, education, subsidiary occupation and ownership of cow were the significant factors affecting the adoption of NF. Difficulty in management of weeds/ insect-pests, high wages of labour, lack of package of practices of natural farming , high transportation cost were the major problems faced by the farmers practicing NF in the study area. Creation of effective bio-pesticides/ formulations, proper package of practices, separate markets for natural produce with premium pricing and formation of Farmers Producer Organizations (FPOs) would encourage natural farming in the state.

II. COLLEGE OF VETERINARY AND ANIMAL SCIENCES:

Animal Nutrition

1.Title of thesis	:	Evaluation of Nutritional requirements of low input technology (LIT) birds for increased economic returns in different rearing systems.
Name of the student	:	Sunidhi (V-2020-40-001)
Major Advisor	:	Dr. Shivani Katoch

Salient findings

The present study was conducted to analyze the effect of feeding diets containing different levels of Developed Supplement Feed (DSF) on egg quality and egg production traits in low Inputs Technology (LIT) bird viz. Him-Samridhi (HS) under 4 systems of rearing i.e. deep litter system (DL), open scavenging system (OS), confined scavenging system (CS) and cage system (CG). A total of 288 HS birds (23 weeks of age) were randomly divided into 4 traits with 72 birds in each trail. 72 birds in each trails. 72 HS birds (23 week of age) were randomly divided into 3 dietary treatments with 3 replicates having 8-layer birds in each replicate. Dietary treatments were BF, DSF¹⁰& DSF²⁰ in CG and DL system whereas, BF^{cn}, DSF¹⁰& DSF²⁰ in OS and CS system. BF group was supplemented with basal layer feed 2120b/bird group, BF^{cn} group was supplemented with basal corn feed @20g/bird, while the treatment groups DSF¹⁰ & DSF²⁰ were supplemented with 10g and 20g/bird DSF respectively along with scavenging for open and confined scavenging, for a period of 42 weeks. External egg quality parameters, internal egg quality parameters, egg yolk and albumen mineral profile; and egg production traits were recorded using standard methods. Result showed that DSF supplementation significantly (P<0.05) improved the external egg quality trait i.e. shape index in all rearing systems except DL system. DSF supplementation had non-insignificant (P>0.05) impact on internal egg quality parameters of rearing system, however numerically egg production (HDEP) was significantly (P<0.05) high in DSF supplemented treatment groups in all rearing systems of all age groups examined (23,40,52 and 64 week of age). The mineral profile of egg was markedly significantly increased the albumin and total protein (TP) content in all systems of rearing. The normal concentration of ALT and AST in all four systems of rearing indicates healthy liver status. The DSF supplementation significantly (P<0.05) reduced serum concentration of total cholesterol. Serum Ca & P concentrations were within their normal ranges with DSF supplementations. Perusal of the results revealed highest profit margin in open scavenging in DSF²⁰ treatment whereas lowest profit was recorded in deep litter in birds offered basal feed. It was thus concluded that DSF supplement has the potential to improve egg quality traits, egg production, egg mineral profile and seems to be a potential feed supplement in LIT bird HS for producing designer eggs and increase profit margins.

Veterinary Surgery and Radiology

1.Title of thesis	:	Clinical application of CO2 Laser and Electrosurgery in the management of soft tissue affections in animals
Name of the student	:	Sara Kaushal (V-2021-40-001)
Major Advisor	:	Dr. Adrash Kumar

Salient findings

The present investigation aimed to standardize various parameters and derive optimal power settings for CO2 laser and electrosurgery when making a skin incision. The standardized settings were used in various soft tissue interventions in client-owned clinical cases to achieve the best surgical outcomes. The standardization phase involved fresh tissue specimens or cadavers to standardize different settings of CO2 laser and electrosurgical units in different modes and at different power settings to record and analyze various parameters, including time, depth of tissue cut, post-incision length and degree of carbonization. The investigation revealed that continuous mode achieved optimal skin incision depth and minimal carbonization at 10-12 W power settings. Conversely, the repeat pulse mode proved ideal for ablation procedures and efficient cutting at higher power settings. The superpulse mode emerged as a versatile option for both skin incision and ablation procedures. Notably, both modes exhibited minimal carbonization even at higher power settings i.e., 12-18 watts. The pure cut mode of monopolar electrosurgery delivered effective skin incision at 25-20 Watts, however, increased carbonization was observed at higher power settings. For minimal carbonization while maintaining incision efficacy, the low-cut mode and blend cut mode as preferable options with power settings range of 25-35 W. In the clinical application phase, a total of 145 cases were presented and were divided into two categories i.e., Group I- CO2 laser and Group II- Electrosurgical unit. In both groups, various intra-operative parameters such as mode, power, degree of bleeding and degree of carbonization were recorded. During the postoperative period, various parameters such as pain scoring, degree of exudation/oedema, degree of swelling, degree of bleeding, clinical outcome, cosmetic appearance and complications (if any) were recorded and analyzed. The Leather punch technique for treating aural hematoma with CO2 laser power settings of 6-13 watts in continuous mode was optimal for making circular incisions and tissue welding that facilitated less operative time, good cosmetic appearance and faster healing. A comparative evaluation of both these modalities was done which revealed the CO2 laser proves a compelling option in cases where minimizing scarring, bleeding, and recurrence rates is paramount due to its versatility. It excels in precise ablation, managing cutaneous lesions effectively, and treating specific periodontal conditions. Electrosurgery, on the other hand, remains a valuable tool for large-scale surgeries demanding extensive tissue manipulation and vessel sealing. Its benefits include reduced blood loss, shorter operating times, and potentially faster patient recovery.

III. COLLEGE OF COMMUNITY SCIENCES:

Food Science Nutrition and Technology

1. Title of thesis	:	Standardization and evaluation of oilseed/ pseudo cereal based nutritious bar for geriatric
--------------------	---	---

Name of the student	:	Mamta (A-2020-40-002)
Major Advisor	:	Dr. Anupama Sandal

Salient findings

Maintaining a healthy diet and engaging in regular, physical activity are essential for reducing the negative effects of ageing and enhancing life quality. As it keeps older individuals healthy and functional, good diet is also considered to be a critical component of effective and active ageing. Over the course of a lifetime, the metabolic rate declines and can drop by up to thirty per cent. Men 60 to 75 years old should consume an average of 2000-2800 Kcal per day, while women in the same age range should consume 1400-2000 Kcal. Calorie needs are reducing approximately parallel to the age, and the needs of many nutrients such as protein, vitamins and minerals, are not reduced by the same percentage. They also need good amount of antioxidants to prevent age-related degenerative diseases. Flaxseed, sesame seed and quinoa seed are the primary source of phytonutrients such as omega-6 fatty acids, flavonoid, phenolic anti-oxidants, vitamins, minerals and dietary fiber with potential anti-cancer as well as health promoting properties. The present experimentation was under taken with the objective to standardize the processing techniques and to analyze the nutritive aspects of the developed nutritious bar. The flaxseeds (*Surbhi*), sesame seed (*Brajeshwari*) and quinoa seed were given treatments viz. soaking, soaking roasting and germination and germination roasting. Bars were standardized and formulated by using Response Surface Methodology software and the selected percentage (10, 20 and 12 percent) were incorporated for the development of nutritious bar. Germination and germination roasted treatment increased the amounts of crude protein, crude fibre, as well as higher levels of DPPH inhibitory activity, total phenolic and flavonoid content. All treatments decreased the carbohydrate content, crude fat, energy and oxalates and phytic acid in comparison to raw seeds. Mineral content (Zn and Mg) also increased after all the treatments. Similar trend was observed in the formulated bars. The mean scores for overall acceptability of the developed nutritious bars were in acceptable range (6.68-8.92 score) at different levels of incorporation of seeds. Total viable count showed no visible growth and no growth of microbes was detected after the storage period after 24-48hrs of incubation. The free fatty acid and peroxide value were within the safe limit. The results indicated their long shelf life, accessibility, and affordability, thus making them suitable for geriatric, delivering essential nutrients in a convenient and economical form. Overall, these nutritious bars present a promising solution for promoting healthier snacking habits worldwide.

2. Title of thesis	:	Effect of processing and storage on quality and functional characteristics of Amla (<i>Emblica officinalis</i>) based Herbal Nutraceuticals
Name of the student	:	Diksha Sharma (A-2020-40-001)
Major Advisor	:	Dr. Radhna Gupta

Salient findings

Wild amla (*Emblica officinalis*) available in abundance in district Kangra has moderate acceptability because of its sharp acidic and astringent taste. Characterized by abundance of variable phytochemicals and commendable therapeutic properties, an attempt by blending it with extracts of six herbs/ medicinal plants to formulate three herbal nutraceuticals was done. Physico-chemical characteristics and proximate composition of amla berries and herbs were analysed. Functional properties emphasized a potent antioxidant potential of amla being rich in ascorbic acid, tannins, and total phenols, with a strong DPPH radical scavenging activity. Antimicrobial assay done demonstrated the remarkable potential of amla juice, ranking it as the most effective agent against human pathogenic bacterial strains. Following closely in order were mulethi root, umre bark, amla powder, bana leaf, and bhavadi leaf. The herbal extracts were standardized for incorporation into products, with optimal acceptability achieved for 2:15 proportion of herbs and water for both herbal extract 1-cold extract- leaves of kadipatta, bhavadi, bana and herbal extract 2- decoction- mulethi root, milk thistle seeds, umre bark. Using wild amla as base, three herbal nutraceuticals i.e., amla-herb syrup, amla-herb appetizer, and amla-herb preserve were standardized utilising 5, 10, 15, 20 per cent of both extracts with 20 per cent having maximum acceptability. Visible elevated trend in pH, TSS and sugar content and a significant inverse relationship in titrable acidity was noted amla- herbal nutraceuticals with the progression in designated storage duration of six months. All the functional attributes exhibited a significant decline with advancement in shelf period. No microbial growth was detected in products even at sixth month. Sensory scores of amla-herb syrup and amla-herb appetizer experienced a slight and corresponding reduction with storage period. Amla- herb preserve on other hand exhibited a marginal acceptance in sensory attributes during the 2nd and 4th months of storage. At 180 days of storage of amla-herbal formulations, all variants were palatable and acceptable to the panel of judges and were “liked moderately” when expressed on hedonic scale and therefore, can be safely stored at ambient temperature for the defined period.

3.Title of thesis	:	Development and evaluation of low glycemic index multigrain mixes for pro-diabetes.
Name of the student	:	Nivedhika Rai Vaid (A-2017-40-001)
Major Advisor	:	Dr. Ranjana Verma

Salient findings

In the present study efforts were made to formulate five different Ready to Use (RTU) multigrain mixes having low glycemic index that could be beneficial for patients suffering from pre-diabetes and diabetes. These RTU multi grain mixtures were standardized using wheat flour supplemented with different food ingredients viz. barley flour, horse gram, soybean, Bengal gram, bottle gourd, cabbage, *kasturi methi* and cinnamon in varying

proportions. These food sources are known to have the properties of minimizing spikes in blood glucose levels after consumption. Results of the study revealed that these low glycemic index RTU multigrain mixes had excellent physico-chemical, functional and nutritional characteristics. The antioxidant activities assessed by the DPPH method revealed that these mixes possessed higher radical scavenging properties, especially RTU-5 which consisted of soybean rich in isoflavones. The beta carotene, soluble, insoluble and total dietary fibre were also recorded highest in this mixture because of the presence of soybean that possessed highest amount of these components. The scanning electron micrographs of the mixes revealed oval to spherical morphology and somewhat distorted morphology was observed in RTU-5 due to the presence of fibre particle and proteins adhering to the surfaces of the starch granules. All the five formulations of RTU mixes were stored in different packaging materials viz. stainless steel, polypet jar and laminated pouches for six months and were evaluated for microbial safety. The polypet jar was adjudged as the best packaging material for storage of RTU mixes. Further, the RTU mixes were utilized to prepare products viz. *chapatti*, *bhaturu*, *babroo* and *prantha* and the sensory evaluation of the products was done and it was observed that scores of the sensory parameters of these products were highly acceptable. The glycemic index of the RTU mixes was also assessed and intervention was also imparted to the selected prediabetic subjects (70) for four months in Kandwari village of Palampur, district Kangra and impact of nutrition education was assessed in control and intervention group consisting of equal subjects. The awareness provided to the intervention group regarding health, pre-diabetes and benefits of low GI food as well as lifestyle management proved to be beneficial as evident from significant gain in knowledge of intervention group. A significant difference in pre and post testing of HbA1c, blood glucose and lipid profile in the selected subjects was observed.

