

RESEARCH ACHIEVEMENTS OF PUNJAB AGRICULTURAL UNIVERSITY (July 1, 2020 to June 30, 2021)

Research programmes primarily addressed crop improvement along with complementing crop production and protection technologies; farm mechanization for rapid, timely, economical and labour saving farm operations; value addition through appropriate post-harvest processing, storage and food engineering interventions, agribusiness, value chain analysis and efficient marketing approaches. Subsidiary or allied occupations were other important constituents of the research plan. Research programmes were aligned to address the broader challenges of climate change, environmental pollution, depleting groundwater, etc.

Crop Improvement

Besides focusing on productivity and stress resistance, crop improvement programmes addressed crop diversification, quality and capturing premium market segment. Diversification crops predominated the varietal output. The University developed/released 34 varieties of different crops. These included vegetable crops (5), flower crops (4), oilseeds (two of *raya* and one each of *gobhi sarson* and sunflower), pulses (one each of lentil, *moong* and chickpea), fodder crops (two oat and one ryegrass), sugarcane (4), *mentha* (1), maize (2), wheat (7), and *Basmati* rice (1).

Varieties developed/released by the PAU

Vegetable crops	CH 52 (chilli), PKH 11 (cucumber), Punjab Sarda (muskmelon), and PCP 2 and PCY 2 (carrot)
Flower crops	Punjab Antirrhinum 1, Punjab Antirrhinum 2, Punjab Antirrhinum 3 and Punjab Antirrhinum 4
Oilseeds	RCH 1 and PHR 26 (<i>raya</i>), PGSH 1707 (<i>gobhi sarson</i>), and PSH 2080 (sunflower)
Pulses	LL 1373 (lentil), ML 1808 (<i>moong</i>), and PBG 8 (chickpea)
Fodder crops	OL 13 and OL 14 (oat), and Punjab Ryegrass 2
Herb oils	CIM Kranti (<i>mentha</i>)
Sugarcane	Co 15023, CoPb 95, CoPb 96, and CoPb 98
Maize	PMH 13 and JC 4
Wheat	HD 3226, DBW 222, DBW 187, Sunehri, PBW 771, PBW 757, and PBW 1 Chapati
Rice	Punjab Basmati 7

- Eleven varieties (five of oat, and one each of chickpea, sugarcane, American cotton, wheat, *berseem* and ryegrass) have been identified at national level, two in zones which do not include Punjab. Out of the 11 varieties identified at the national level, six have been notified for release in different zones.

Crop	Variety
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Wheat	PBW 757*
Chickpea	GL 13001 (PBG 9)*
Oat	OL 1861*, OL 1869 -I (OL 13)*, OL 1874, OL 1896, and OL 1876-2
<i>Berseem</i>	PC 91
Ryegrass	Punjab Ryegrass 2*
Sugarcane	Co 14185 (CoPb 98)
American cotton	PBH 115, PBH 116 and F 2662

* Notified at national level

GERMPLASM ACQUISITION AND UTILIZATION

To diversify genetic pool and tap desirable traits, around 11, 000 accessions of various vegetable, floriculture, agroforestry and field crops were acquired from various international and national institutes, besides local sources. The germplasm material constituted vegetable crops (cucumber, brinjal, bittergourd, pumpkin, garlic, onion, beetroot, pole type Frenchbean, bush type Frenchbean, carrot, tomato, muskmelon, pea, Pak-choi, turnip, chilli, *palak*, okra, potato, cowpea, Dolichos bean, broccoli and bell pepper), flower crops (*Hippeastrum hybridum* and Gerbera), bamboo, oilseeds (sesame and groundnut), pulses (chickpea, rajmash, pigeonpea and mungbean), millets (sorghum and pearl millet), soybean, cotton, maize, wheat and rice.

BIOTECHNOLOGY

Crop	Research activities
Guava	<ul style="list-style-type: none"> • Genome assembly has been generated by sequencing guava genome on various next generation platforms. • Indigenous guava genome database has been generated by integrating in-house information. • High density linkage map has been constructed in F₁ population of Allahabad Safeda x Arka Kiran guava.
Muskmelon	<ul style="list-style-type: none"> • A gene for <i>Fusarium</i> wilt resistance has been mapped on chromosome 5. Male sterility, <i>ms-1</i> gene, has been fine-mapped to 400 Kb using whole genome re-sequencing.
Bittergourd	<ul style="list-style-type: none"> • High density SNP based linkage map has been developed and three QTLs have been identified for yellow mosaic disease resistance.
Onion	<ul style="list-style-type: none"> • Mitochondrial genome has been sequenced and assembled for 97A line.

Pulses	<ul style="list-style-type: none"> • Mapping of Ascochyta blight and Botrytis gray mold resistance gene(s)/QTLs in F₂ population derived from an intraspecific chickpea cross using SSR markers is underway. • Mapping of important agronomic traits using SSR markers is being carried out in population derived from an intraspecific pigeonpea cross.
Maize	<ul style="list-style-type: none"> • Drought resistance QTLs have been fine-mapped. • Nutritionally enriched maize inbreds have been developed by pyramiding QPM and beta-carotene genes.
Wheat	<ul style="list-style-type: none"> • Mapping populations have been generated and evaluated for new genes for stripe rust, leaf rust, powdery mildew and for Karnal bunt resistance. • Leaf rust (1) and stripe rust resistance (1) genes from <i>Ae. triuncialis</i> have been mapped on chromosome 7B. • Six QTLs for stripe rust resistance and 5 QTLs for powdery mildew from <i>Ae. speltoides</i> have been mapped. • Stable lines with secalin negative (Sec -) and GluB3 positive alleles have been evaluated and selected in stripe rust resistant version of PBW550 and DBW17. • A set of rapidly evolving effector and pathogenicity genes has been identified from in-house whole genome assembly of three races of <i>Puccinia striiformis</i>.
Rice	<ul style="list-style-type: none"> • Brown plant hopper resistance genes have been identified, mapped and pyramided from <i>Oryza nivara</i> and <i>O. rufipogon</i>. • Sheath blight resistance genes/QTLs have been mapped from <i>O. nivara</i> and <i>O. rufipogon</i> resistance sources.

	<ul style="list-style-type: none"> • Genome wide association study (GWAS) has been performed for sheath blight disease in a panel of <i>O. rufipogon</i> accessions. • <i>CEN3</i> gene has been allelized in N22 mutant population. • Bacterial blight resistance gene <i>xa-45</i> (t) from <i>O. rufipogon</i> has been fine mapped using BC-RIL population. • Nematode resistance QTLs have been identified and mapped from <i>O. glaberrima</i> and transferred into the background of PR121. • Differential gene expression has been identified from transcriptome data of rice anther and pollen tissue. • Introgression lines of <i>O. rufipogon</i> with higher phosphorus use efficiency have been developed. • <i>Oryza punctata</i> introgression lines with higher yield potential, earliness and resistance to bacterial blight have been developed. • Donors and genomic when sown deep under direct seeded rice (DSR) have been identified. • Evaluation of genomics-assisted derived advanced breeding lines developed at International Rice Research Institute (IRRI) involving 12 parents possessing a range of desirable traits has been conducted under direct seeded rice (DSR) environment and promising lines have been identified.
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SEED AND NURSERY PRODUCTION

- During the year, the University produced 659 q seed of vegetable crops and 60,916 q seed of field crops, besides providing 5,360 q propagation material of turmeric and potato (see the following Table).
- More than 7 lakh fruit tree nursery plants were provided to the farmers.
- About 82,000 agroforestry seedlings were provided to the farmers.

CROP PRODUCTION TECHNOLOGIES

Horticultural crops

Strawberry cultivation: complete package of practices

- A complete package of practices detailing soil and climatic requirements and recommended varieties has been recommended for strawberry cultivation in Punjab.

Orchid cultivation under high-tech polyhouses: package of practices

- Package of technologies has been recommended for orchid cultivation in Punjab under high-tech polyhouses.

Tomato in soilless media

- Cultivation practices, with respect to planting media, microirrigation-fertigation and fruit thinning, in case of indeterminate tomato grown in soilless media under naturally ventilated polyhouse were recommended.

Leaf sampling technique in litchi for nutrient assessment

- To assess nutritional status of litchi plantations and calibrate fertilizer regimes, 4-5 month old autumn flush leaves collected from second and third pair of leaflets from terminal shoots of litchi just prior to or at the panicle initiation stage are suitable for sampling.

Potassium nutrition for *Kinnow*

- In Central Alluvial Plains Zone and Sub-mountainous zone of Punjab, for better growth, yield and fruit quality in *Kinnow*, potassium should be applied in addition to the other recommended fertilizers.

Root pruning and trunk girdling in pear

- Studies performed on the effect of gridling (trunk girdling, limb girdling and sub-limb girdling) and root pruning on Punjab Beauty variety of pear revealed that the shy bearing behavior of Punjab Beauty can be managed by pruning the root 60 cm away from the trunk at 40 cm depth and girdling trunk for improvement in fruit set, quality and yield.

Field Crops

Seed rate and spacing

- Higher seed rate (18 kg/acre in place of existing 12-15 kg/acre) in respect of LL 1373 variety of moong has been recommended.
- Recommended seed rate (8 kg/acre) in case of maize was revised upward (10 kg/acre).
- Wider row spacing (30 cm) and hence lower seed rate (15 kg/acre) have been recommended for seed crop of fodder oat.

Organic production technology

- New production technology involving use of farmyard manure (FYM) and *neem* extract along with optimized plant spacing (67.5 cm X 10 cm) has been recommended for organic production of *gobhi sarson*.

Irrigation technology

- Irrigation through sub-surface drip system in cotton at 80% ET_c with 112 kg N/ha in 10 equal splits at 10 day interval starting from 30-35 days after sowing gave 26% higher yield than obtained under conventional surface-flooded with 100% recommended dose of fertilizers (RDF) and 9.4% higher than the surface drip system with 100% RDF.
- Mulching with paddy straw @ 30 q/acre in spring maize at the time of sowing helps save irrigation water in spring maize.

Agronomic biofortification

- In chickpea, foliar application of zinc heptahydrate (21% Zn) @ 0.5% along with urea @ 2% at flowering and pod formation stages has been recommended for achieving higher grain Zn content.

Direct seeded *Basmati* rice

- Pusa Basmati 1718 and Punjab Basmati 7 have been found suitable for direct seeding. The varieties matured 3-4 days earlier under direct seeding environment.

Intercropping

- *Rabi* onion can be grown as an intercrop in autumn sugarcane for deriving higher net returns.
- One row of tomato crop can be planted as an intercrop in autumn sugarcane for enhancing farm income.

Nutrient management

Biofertilizers

- Biofertilizers, worth 60,242 acres, for 16 crops were distributed among farmers.
- Application of biofertilizer consortium in sugarcane helped save FYM @ 10t/ha.

Nitrogen management

- In rice-wheat fields involving straw management through retention or incorporation, nitrogen fertilizer dose in wheat crop can be decreased by 25%.
- Nitrogen fertilizer rate in oat seed crop has been standardized at 20 kg N/acre.

Secondary and micro-nutrients

- Application of gypsum @ 225 kg/ha in two equal splits, first at sowing and second at flower initiation stage, along with 25 kg N and 30 kg P₂O₅/ha has been recommended for higher productivity and quality.
- Bentonite sulphur (90% S) can be used in place of other commonly used sulphur sources in wheat crop grown on S-deficient soils.
- Deficiency of iron in soybean can be made up by foliar application of 0.5% Ferrous Sulphate solution at 30 and 60 days after sowing.

Characterization of microbial germplasm for plant growth promoting potential

- Five bacterial strains isolated from different parts of the cotton plant were classified using *16SrRNA* gene sequencing and evaluated for their plant growth promoting potential.

CROP PROTECTION

Fruits

- Citrus foot rot/gummosis can be managed by using biocontrol agent *Trichoderma asperellum*.
- Litchi fruit bunches can be covered with white/pink polypropylene non-woven bags at 25-30 days after fruit set for better fruit quality.
- An integrated module has been developed for managing chafer beetle in grapes.
- Powdery mildew in mango can be managed by using Contaf 5EC (hexaconazole) @ 1ml/litre.

Vegetable crops

- Use of mustard cake @ 1t/ha+neem cake @ 1t/ha+FYM@ 2.5t/ha has been recommended for non-chemical management of root knot nematode in organic cultivation of cucumber under poly/net houses.
- Management of whitefly, *Bemisia tabaci*, in brinjal with PAU Homemade neem extract (@ 1,200 ml/acre) has been recommended.
- Jassid, *Amrasca biguttula biguttula*, in okra can be managed with neem-based formulation Ecotin (azadirachtin 5%) @ 80 ml/acre.
- Whitefly, *Bemisia tabaci*, in brinjal can be managed by employing homemade botanical solutions like extracts of maize, bajra and sorghum @ 1,500 ml/acre.
- Economic Injury Level (EIL) and Economic threshold level (ETL) of jassid, *Amrasca biguttula biguttula*, were worked out
- Economic Threshold Level (ETL) of whitefly, *Bemisia tabaci*, in brinjal was worked out to be nine adults per leaf.
- Whitefly, *Bemisia tabaci*, has been identified as an emerging pest of cucurbits in Punjab state. Use of PAU Homemade neem extract @ 1,200 ml/acre has been found effective in its control.
- Whitefly, *Bemisia tabaci*, in okra can be managed with neem-based commercial formulation Ecotin (5%) @ 80 ml/acre and with PAU Homemade neem extract @ 2 litres/acre.
- Jassid, *Amrasca biguttula biguttula*, in okra can be managed by using PAU Homemade neem extract @ 2 litre/acre.
- Economic Threshold Level (ETL) for spotted bollworm, *Earias spp.*, in okra has been found to be 1.0 per cent.

Oilseeds and pulses

- Gram caterpillar, *Helicoverpa armigera*, in chickpea can be managed with bacterial biopesticide *Bacillus thuringiensis kurstaki* (DOR Bt-1) @ 800 g/acre.

Maize

- Demonstrations using *T. chilonis* against maize stem borer, *Chilo partellus*, were carried out at farmers' fields over an area of 60 acres in Hoshiarpur, Jalandhar, Shaheed Bhagat Singh Nagar and Gurdaspur districts. Two releases of *T. chilonis* @ 1,00,000/ ha at 10 and 17 days old crop resulted in 55.1 per cent reduction in dead hearts incidence over control as compared to 84.1 in chemical control.

Sugarcane

- An integrated pest management package has been recommended for early shoot borer (ESB), *Chilo infuscatellus*, in sugarcane.
- Top borer, *Scirpophaga excerptalis*, can be managed by following integrated module involving use of pheromone traps @ 10/acre along with *Trichogramma japonicum*.

Cotton

- Economic Injury Level (EIL) and Economic Threshold Level (ETL) of thrips, *Thrips tabaci*, in cotton were worked out as 15.7 thrips/leaf and 11.8 (~12) thrips/leaf, respectively.

Wheat

- Non-chemical management of aphids in wheat using PAU homemade *neem* extract @ 5 litre/ha has been recommended.
- Economic Injury Level (EIL) and Economic Threshold Level (ETL) for managing gram pod borer (*Helicoverpa armigera*) 2.19 and 1.64 larvae per metre row, respectively, were identified.

Rice

- Rice stem borers and leaf folders in conventional and organic *Basmati* and *Parmal* rice can be managed with a *neem* based biopesticide Ecotin 5% (Azadirachtin) @ 80 ml/acre.
- Rice stem borers and leaf folders under organic cultivation of *Basmati* and non-*Basmati* rice can be managed with use of *neem* based biopesticide, *Neem* Kavach 0.15% (azadirachtin) @ 1 litre/acre.

Weed control

- Paddy straw mulch @ 30 q/ha in *Kharif* maize provides effective control of weeds at par with Laudis 420SC (tembotrione) @ 105 ml/ha.
- Paddy straw mulch (@ 4t/acre) and black-silver polythene mulch have been found effective in controlling weeds in marigold.

Pesticide residue analysis

- Out of the 530 vegetable samples collected from the market, 7 (1.3 %) samples had pesticide residue above maximum residue level (MRL). Out of 389 vegetable samples collected from farmgate, one sample exceeded the MRL. In case of *Basmati* rice, 9 (16.4%) out of 55 samples were found to be contaminated and 2 (3.6%) samples were found to have pesticides above MRL. In case of 361 farmgate samples, 10 (2.8%) were found to be contaminated

and 9 (2.5%) exceeded the MRL. No contamination was reported in 21 milk samples, 34 fruit samples and 8 water samples during this period.

Rodent, bird and vertebrate pest management

- Integrated rodent management module has been recommended in pea crop.

FOOD SCIENCE AND TECHNOLOGY

Liquid jaggery from sugarcane juice

- Liquid jaggery, potential sweetener with high nutritive value without any harmful chemicals, was developed using juice from sugarcane varieties CoJ88, CoJ 64 and CoPb 93.

Shelf stable chilli products

- Value added products such as chilli paste and honey chilli sauce with enhanced shelf stability were developed from Punjab *Sindhuri* and CH 27 chili varieties.

Pasta from Quality Protein Maize

- Quality Protein maize pasta was developed using HQPM 1 flour. The pasta prepared by using 100% QPM flour with 3% guar gum followed by steam treatment for 25 minutes had the highest overall acceptability.

Yellow pea flour

- Yellow pea flour was successfully used to prepare some traditional Indian food products such as *missi roti*, *pinni*, *pura* and *pakora*.

Honey based amla products

- Honey was used to completely or partly replace sugar for preparation of amla candy, amla *murabba* and amla nectar.

FOOD AND NUTRITION

Vitamin D enriched mushroom powder for food supplementation

- Exposure of button and oyster mushroom to UV-B radiation at 60 cm for 30 minutes caused manifold spike (228 times in button and 141 times in oyster) in vitamin D content.

Beetroot powder as a natural bakery colorant

- Beetroot powder can be used as a natural colorant for functional bakery products.

Gluten free biscuits

- Gluten free biscuits supplemented with quinoa flour (40% level) had good nutritional profile in terms of protein, minerals and amino acids.

PAU Bacteriological Food Testing Kit

- It is a portable solution for easy, rapid and precise detection of indicator and emerging pathogens in food commodities. The kit was prepared by adding the

defined concentrations of components of the BFTK in serum bottles, which were sterilized and rubber-stoppered.

POST-HARVEST TECHNOLOGY

Refractance Window drying system

- A continuous refractance window drying system has been developed for dehydrating fruit and vegetable purees into flakes.

Sterilization system

- Evaluation of a high capacity, compact ozonation treatment system developed for effective sanitization of fresh produce showed that aqueous ozone-treated samples had a significantly better shelf life as compared to chlorine-treated samples.
- Vacuum-assisted ozone treatment system has been designed for ozonation treatment of fresh produce and food products.
- An ultraviolet (UV-C) radiation based disinfectant system for fresh food/packed commodities at household level has been developed.

Packaging

- In a comparative evaluation of different packaging materials for storage and transportation of marigold flowers, thermocol and corrugated fibreboard boxes (CFB) provided better storage, upto three days, the CFB boxes, however, being more economical.
- BioFreshPak compostable films blown using 30% starch-biodegradable polymer blend extended shelf life of fresh white button mushrooms for seven days.
- Pectin-based coatings for shelf life enhancement of fresh guava fruits under retail marketing conditions were developed and evaluated.
- Process of manufacturing chemical free and iron fortified jaggery has been standardized.

Storage and shelf life enhancement

- A two-tonne capacity on-farm evaporatively cooled store has been designed and constructed for short term storage of fresh produce.
- In order to control *Callosobruchus maculatus* in stored moong grain, 1% canola oil, 0.5% *Kinnow* peel powder alongwith 0.05% treated Deltamethrin bags proved to be the best.

FOOD FERMENTATION

- Metabiotic lacto-fermented functional beverages, pickles and salad dressing were prepared from powder and rhizomes of turmeric (*Curcuma longa* Linn), and Indian Gooseberry (*Phyllanthus emblica*) using functional lactic acid bacteria starter culture.
- A safe and economical fermentative bioprocess for kojic acid production using a novel isolate, *Aspergillus nomius*, along with the fermentative bioprocess was optimized. The process has been sent for an Indian Patent.
- Kojic acid application @ 8mM for five minutes has been observed to delay/prevent pericarp browning of litchi fruit, and delay melanosis for up to nine days.

Handholding for agro-processing

- Six new agro processing complexes were established by the farmers with technical guidance from the PAU.

ENVIRONMENTAL ASSESSMENT

- Water samples collected along the course of River Beas (samples from Talwara, Mukerian, Bhet, Tanda, Dhilwan, Goindwal and Harike) were analyzed for various microbiological quality parameters. Water quality varied significantly with respect to change of season at Mukerian, Dhilwan and Harike.
- A survey in the environs of Buddha Nala was conducted (along about 50 km stretch) to study the heavy metal and other elemental composition of the vegetation.
- Seasonal epidemiological surveillance database of water-borne and food-borne pathogens for the quality of water and fresh-cut salads has been generated using Bacteriological Water Testing Kit (BWTK) and Bacteriological Food Testing Kit (BFTK).
- Study of faunal diversity in and around rural ponds in villages Jhammat and Malakpur, district Ludhiana and sewage treated water pond situated at Punjab Agricultural University (PAU) campus, Ludhiana revealed the presence of one species from a range of phyllums like Annelida, Arthropoda and Mollusca, and from classes Amphibia, Reptilia, Aves and Mammalia.

AGRO-FORESTRY

Intercropping

- Six onion varieties were transplanted at four times under poplar. PRO 7 variety recorded the significantly higher bulb yield and the mid-December planted crop yielded better.
- Intercropping performance of five potato cultivars was evaluated under 4-year-old poplar plantation. MS 1947 significantly outyielded.
- *Gobhi sarson* and *raya* intercrops performed better in *eucalyptus* plantations established at 8m x 2m spacing.

Soil fertility assessment of poplar and eucalyptus-based agroforestry systems

- Different tree based agroforestry systems resulted in significantly higher content of available N, P and K in all soil depths as compared to sole fodder-wheat, sole citrus and fallow land systems. Fodder-wheat system under poplar or *eucalyptus* fared better than citrus with poplar or *eucalyptus* in all the soil depths.

Evaluation of agroforestry germplasm

- Nine clones of *Casuarina* from the Institute of Forest Genetics and Tree Breeding, Coimbatore were evaluated for cultivation under Punjab conditions. At four years of age, IFGTB CH 2, CH 5 and CH 1 were found promising clones.
- The trees grown under semi-arid areas of Punjab had more Azadirachtin content than irrigated plain region of Punjab. The content ranged from 0.92-1.12%.

- Fourteen seed sources of *Moringa oleifera* were evaluated for biomass, nutritional value, mineral content, fodder quality and anti-bacterial potential under subtropical conditions of Punjab.

BEEKEEPING

Pollination under protected conditions

- Bee pollination resulted in reduction in empty seeds over hand pollination and seed germination improved over hand pollination in muskmelon under protected conditions.
- *Apis mellifera* colonies placed inside polyhouse inhabiting capsicum crop showed the highest darting behaviour during the first three days, which decreased thereafter. Fruit setting in *Apis mellifera* pollinated crop was 4.5 per cent more than the crop excluded from bees.

Hiving of new pollinator bee species

- Three hiving structures viz. *A. mellifera* mating nuc, plastic pipe and wooden hive (Kerala centre) were evaluated for their utilization in hiving *Tetragonula iridipennis*. All these structures were useful in successful hiving of this bee species.
- Results of a study aimed at evaluating the effect of colony strength (5, 8 and 10 bee-frame) on pest and disease, showed that higher strength i.e. 10 bee-frames encountered more mite and disease attack, whereas, lower strength colonies had more wax moth attack than 10 bee-frame colonies.

Nutrition, hygiene and byproducts

- Comparative evaluation of various pollen substitutes suggested that corbicular pollen had the highest consumption.
- Selective breeding for hygienic behaviour in *A.mellifera*, involving ten F1 daughter colonies reared from the two highly hygienic colonies, raised the mean hygienic behaviour from 87.7% in F1 to 90.7% in F3.
- A comparative evaluation of various bee venom extractors showed that summer season yielded the highest quantity of bee venom followed by spring, monsoon, autumn and winter seasons.

LAC CULTURE

- To conserve genetic resources of lac insect, regular surveys were conducted for collecting the information on lac insects and their host plants in six districts of Punjab. Eleven lac insect samples were collected from five host plants.
- Studies on diversity of natural enemies associated with the lac insect under Punjab environment showed that *Eublemma* was the predominant species under Punjab conditions.

MUSHROOM CULTIVATION

Strain evaluation

- Cultivation of *Volvariella volvacea* was evaluated on paddy straw. Out of five *Volvariella volvacea* strains, VV 20-203 and VV 20-205 showed the highest yield.

- Ten strains of *Calocybe indica* were evaluated on wheat straw. The Ci 20-08 yielded the highest.

Casing soil preparation

- Neem, castor, natural sugarcane vinegar, *Bacillus thuringiensis* based commercial formulation Dipel 8L, and *Beauveria bassiana* based commercial formulation Biojaal 1.15% SC were evaluated for preparation of casing soil for *Agaricus bisporus*. The highest yield was obtained in 1.5% neem powder followed by *Bacillus thuringiensis* @3.5%.

Germplasm characterization

- Eight mushrooms were collected during July and August 2020. The species were identified and accessioned as DMRX 1852 to DMRX-1859.

FARM MACHINERY

Super Seeder

- The tractor mounted machine for direct sowing of wheat in combine harvested paddy field developed by the private sector was approved upon evaluation.

PAU Smart Seeder

- It manages the paddy straw by partial incorporation in a narrow band and retains the remaining straw as surface mulch and thus combines the advantageous features of Happy Seeder and Super Seeder.

Tractor operated seeder for mat type paddy nursery

- This machine can raise mat type paddy nursery for about 180-200 acres in one day. As a result, labour can be saved by 93-94% over the conventional nursery raising method.

Refinement of Lucky Seed Drill

- Lucky Seed Drill has been refined by fitting it with press wheel attachment of 5.5-6.0 inch wide wheels of 14 inch diameter for enhanced weed control efficiency, better profile moisture conservation and better *krand* control in direct seeded rice.

Testing and quality control

- During the period under report, 39 machines were tested for adherence to the laid down standards. The activity generated a revenue of Rs 20.08 lakh.

Renewable Energy

Paddy straw as a substrate

- Co-digestion of paddy straw (PS) with green potato waste (GPW) in different concentrations (20-40%) indicated that PS + GPW (40%) produced 29.6% more biogas as compared to PS alone.
- Process of extracting lignin and silica from paddy straw has been optimized.

- Co-culturing various microalgal cultures with bacteria paced up biomass productivity.
- A potent fungal strain of *Saccharomyces cerevisiae* was identified with hydrolytic efficiency of 78%, having potential for fermentation of paddy straw and bagasse for ethanol production.
- Immobilized cellulase was tested for saccharification of paddy straw and high hydrolytic efficiency (52.6%) for pre-treated straw was noted.

Ethanol production

- Fermentation of sugarcane juice of CoPb 92 cultivar with *S. cerevisiae* produced 6.31% (v/v) ethanol.
- Screening of different sugarcane varieties/clones for ethanol production identified CoPb 92 variety as the most promising candidate.

Solar energy

- Advanced domestic solar dried sample also exhibited maximum greenness ($a = -7.53$) and high ascorbic acid (24.29 ± 1.81 mg/100 g dw) retention in coriander leaves in comparison to conventional domestic solar dryer and open sun drying.

DRUDGERY REDUCTION

- Thermo-cervical collar has been developed in order to manage severe cervical pain.
- Vegetable harvesting bag was designed and developed using ergonomic approach.

AGRICULTURAL ECONOMICS AND SOCIOLOGY

Economics of direct seeded rice

- Results from the study titled “Comparative economics of direct seeded rice technology and transplanted rice in Punjab” revealed that direct seeded rice is a feasible alternative to conventional puddled transplanted rice. It has good potential to save water, reduce labour requirements and mitigate greenhouse gas emissions.

Market analysis

- Results of a field survey regarding adoption of Electronic National Agricultural Market (e-NAM) suggested that there was a difference in the prices received by the adopters and non-adopters of e-NAM for all the crops covered under the study.
- A study was undertaken to analyze the market imperfections in output and input markets, access to credit and coping strategies of farmers. The survey covered 300 farm households from Moga, Bathinda and Hoshiarpur districts.

Farmer suicides

- An intensive survey of all the villages of six districts, namely, Barnala, Bathinda, Ludhiana, Mansa, Moga and Sangrur of Punjab revealed that 7,303 agricultural labourers committed suicides in these districts during the period of 2000-2018.

Of the victims, 88 per cent were males and remaining 12 per cent were females. Around 79 per cent of these suicides were ascribed to heavy debt burden.

Economic analysis of Punjab farmers

- A study was conducted to examine the dynamics of land holding structure, cropping pattern, farm investment details, income and expenditure pattern and their distribution among different categories of Punjab farms. For the year 2018-19, the average size of operational holding was 3.89 ha, out of which leased-in land formed 20 per cent and had direct relationship with the farm size. The herd size varied directly with farm size (average 4 animals/household).

Growth and performance index – A new measure of growth

- The 'Growth and Performance Index' for agricultural productivity has been proposed as an alternative to the currently used growth indicators. Two Composite Indices have been suggested, one based on two parameters, namely growth indicator (change in productivity over the year) and performance indicator (initial absolute productivity level) to replace the year on year growth rate and the second one combining stability indicator with growth and performance indicators to replace the Compound Annual Growth Rate (CAGR) over a number of years.

TECHNOLOGIES COMMERCIALIZED

- During the report period, 34 Memoranda of Agreement (MoA) were signed to commercialize a host of technologies.

RANKING

- The Punjab Agricultural University secured the first position among State Agricultural Universities and the second position among Agricultural Universities and Institutes in the ranking of Agricultural Universities 2019 by the ICAR, New Delhi. Dr Baldev Singh Dhillon, Vice Chancellor, PAU received the ranking certificate on December 5, 2020.