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Need for Next Generation Technologies in Agriculture

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Agriculture sector needs infusion of new technologies which will strengthen the hands of our farmers to move to the next level of farm productivity and profitability. The Government of India has fast tracked this process of infusion of new technologies. The Artificial Intelligence for Agriculture Innovation (AI4AI) initiative was launched in August 2020 by the World Economic Forum's Centre for the Fourth Industrial Revolution India, in active collaboration with the Government of Telangana and support from the Ministry of Agriculture, the National Institution for Transforming India (NITI) Aayog and the Ministry of Electronics and IT. The initiative focuses on strengthening multi-stakeholder collaborations to analyze and exploit the opportunities and challenges of applying upcoming technologies to transform the agricultural landscape, in a way that is profitable and sustainable for farmers. Emerging technologies such as artificial intelligence (AI), blockchain, drones and the internet of things (IoT) has the potential to impact productivity and efficiency at all stages of the agricultural value chain. According to research by NASSCOM and McKinsey, there is a $65 billion opportunity to be realized through enhancing 15 agriculture datasets, including soil health records, crop yields, weather, remote sensing, warehousing, land records, agriculture markets and pest images.

Innovations and new technologies in science open new avenues across the different fields. While the first revolution in agriculture was possible due to mechanization, the second green revolution came with genetic modification. Precision Agriculture, which consists of the precision application of inputs when and where these are needed, has become the third wave of the modern agriculture revolution. There is an urgent need to adapt the next generation technologies to achieve higher productivity of crops using less energy, fertilizers, and pesticides while simultaneously lowering the levels of Green House Gases and coping with climate change. India needs next 'Green Revolution' and for that we have to go for a 'technology revolution'. Smart agriculture has all the technological inputs which can steer us from the problems of low productivity and labour constraints.

Armoury of new technologies like Cloud Computing, Internet of Things (IoT), Big Data, Blockchain, Robotics and Artificial Intelligence (AI) have taken the management of agricultural operations to much higher levels of technology. AI is used to combine automation, robotics, and computer vision. Drones with AI-enabled vision processing capabilities are being used to assess the real situation with respect to the condition of the crops in the ground. Autonomous drones and the data they provide can help in crop monitoring, soil assessment, plant emergence and population, fertility, crop protection, crop insurance reporting in real time, irrigation and drainage planning and harvest planning. Autonomous swarms combine the technology of swarm robotics with a blockchain-based back end. Swarm robotics is another application which involves multiple copies of the same robot, working independently in parallel to achieve a goal too large for any one robot to accomplish. By leveraging the benefits of both swarm robotics and blockchain, pesticides and fertilizers can be applied more efficiently.

Internet of Things (IoT) is another promising technology which in the agricultural context refers to the use of sensors and other devices to turn every element and action involved in farming into data. These can be “things” that can be embedded with technologies, software or sensors which further help in connecting or the exchange of data with other devices or systems via the internet or vice versa. Such technologies are bound to bring precision in the delivery of various inputs required in the crop production and application of crop management practices besides helping us to achieve increased yields, lower costs, and reduced environmental impact. It is estimated that with the infusion of new techniques like the IoT, there is a strong potential to increase agricultural productivity by 70% by 2050.

Our country is moving fast in the direction of preparing infrastructure to make agriculture smart. Globally, India is ranked second for the number of registered “agtech” start-ups. India has 3,116 registered start-ups in food and agriculture, and there has been 25-30% growth in this number year-on-year. Since 2014, $500 million has been invested in this area. Indian agri start-ups raised investments to the tune of almost USD 1 billion. According to a start-ups. India has 3,116 registered start-ups in food and agriculture, and there has been 25-30% growth in this number year-on-year. Since 2014, $500 million has been invested in this area. Indian agri start-ups raised investments to the tune of almost USD 1 billion. According to a report by the country's Ministry of Electronics and Information Technology and McKinsey & Company, India has a potential economic value of $50-65 billion through digital agriculture by 2025 translating to 23% addition to the current value of agricultural produce. Minister of Agriculture & Farmers Welfare has initiated Digital Agriculture Mission 2021–2025, and signed five memorandums of understandings (MoUs) with CISCO, Ninjacart, Jio Platforms Limited, ITC Limited and NCDEX e-Markets Limited (NeML), to forward digital agriculture through pilot projects. The Digital Agriculture Mission 2021–2025 aims to support and accelerate projects based on new technologies such as AI, block chain, remote sensing and GIS technology and the use of drones and robots.

Our University has taken a number of initiatives to upgrade the farming technologies with the infusion of new technologies. The University has installed 20 disease prediction systems in different parts of the State which are equipped with 12 different types of sensors to analyse real time data from the fields to regulate precisely the application of irrigation, fertilizers and pesticides. The University is also collaborating with multinational companies like Bayer Crop Science Limited for successful prediction of foliar diseases of apple. We are preparing to train scientific manpower for the use of drones in agriculture. Indian and foreign agritech players can play a vital role in supplying these advanced technologies to farmers. Though there are a few players in the market currently, catering to ~267 million farmers presents a huge opportunity for private and foreign entities to expand their footprint in the country.

Green Pesticides for Eco-friendly Crop Protection

Dr HR Gautam

The annual amount of synthetic pesticides used for crop protection is estimated at 2.5 million tons causing damages worth about $100 billion, due to residues in crops, soil and water, non-biodegradable properties, and high toxicity. Demand for pesticides is increasing in many developing countries including India, which together account for a quarter of global pesticide use. Industry lobby group Crop Life International has said that of 6,400 crop protection products sold by its members in 2015, 15 % were Highly Hazardous Pesticides (HHPs), as defined by the World Health Organization (WHO), one indicator of the extent to which dangerous pesticides still exist in great numbers. The detrimental effects of synthetic pesticides on the environment are well established as it affects animal and plant biodiversity as well as terrestrial and aquatic ecosystems. Other effects include toxicity, soil and groundwater pollution, and harmful residues that contaminate crops and food. It also affects non-target organisms and the excessive use of synthetic pesticides leads to increased resistance in pests. The negative effects of synthetic pesticides have created the need for a safer and more environmentally friendly substitute.

Today, the major challenge is to develop effective new chemistries that have minimal impact on the environment and health yet have durable efficacy due to a low risk of resistance development. But, there is progress in the development of green molecules and technologies which are fine tuned and being evaluated. Botanical pesticides are effective alternative but their usage is around 1 % of the total pesticides usage. Another area of crop protection that has enhanced focus is the development and exploitation of resistance elicitors. Such products are generally not toxic but prime or activate plant defences thereby enhancing resistance. They are often not as efficacious as conventional biocidal crop protectants but in the era of Integrated Crop Management these are beginning to find their niche and we need to better understand how they can be developed as an asset to sustainable crop protection. Plant immunity inducers can be derived from animals, plants, microbes or their metabolites, active molecules produced during interactions between plants and microbes, or natural/synthetic compounds. According to their chemical properties, plant immunity inducers can be classified into proteins, oligosaccharides, glycopeptides, lipids, lipopeptides, small molecule metabolites, and chemical compounds. The identification of these components has accumulated considerable resources for the development of plant immune-induced pesticides. Compared to chemical pesticides, plant immunity inducers have many advantages, such as their exceptionally low dosage, lack of damaging effects for humans and animals, lack of adverse effects on the environment, ability to induce substantial disease resistance, induction of long-term and broad-spectrum plant resistance, low risk for microbial resistance, and ability to reduce the use of chemical pesticides—this reduction can aid in environmental protection efforts.

There are number of plant immunity-inducing chemical compounds such as benzothiadiazole, 2,6-dichloro isonicotinic acid, probenazole, and dufulin are elicitors that activate plant immunity. For example, benzothiadiazole induces plant resistance to numerous diseases, consistent with its resemblance to salicylic acid. DL-β-aminobutyric acid can induce local and systemic resistance to *Colletotrichum coccodes* in pepper plants. Isotianil, which was identified by Bayer AG and Sumitomo Chemical Co., Ltd., induces the expression of plant pathogenesis-related genes; it can efficiently activate rice resistance to rice blast disease. Dufulin enhances defense enzyme activity, increases the chlorophyll content in tobacco leaves, and prevents tobacco viral diseases. The oligosaccharide.chain protein 6% (Atailing) is an innovative product developed independently by a research team headed by Qiu Dewen, the deputy chief of the Institute of Plant Protection (IPP) affiliated to the Chinese Academy of Agricultural Sciences (CAAS), taking into account the specific occurrences of plant disease and the plant resistance mechanism. The product is industrialized by Beijing Green Agricultural Science and Technology Ltd.

Many multinational companies are working on the development and evaluation of green pesticides. For instance, mefentrifluconazole and ipfentrifluconazole were discovered by the company BASF. They have shown good environmental compatibility and outstanding biological activity against fungi on field crops (e.g., corn, grain, and soybean), cash crops (e.g., green pepper, and grape), and lawn. It was made available in 2020 and became one of the pillar products of BASF. Quinofumelin is a novel active ingredient discovered by Mitsui Chemicals Agro, Inc. (MCAG). It has novel mechanism of action and shows broad-spectrum activity against pathogens that affect trees in orchard, leafy vegetables, oilseed crops, as well as rice. It provides a unique and attractive solution for the rotational component in fungicide resistance management. Quinofumelin is under the process of registration in Japan in 2020. Oxathiapiprolin is another novel active ingredient with ultra-high efficiency against oomycete diseases in potatoes, grapes, sunflowers, vegetables, tomatoes, etc. It affects intracellular sterol transport, signal transduction, and lipid metabolism by inhibiting Oxysterol Binding Proteins (OSBP). It displays good effects at all stages of the life cycle of pathogens. Its unique mechanism of action endows it with excellent efficiency against oomycetes. Oxathiapiprolin has been launched in the United States, the European Union, China, Mexico, Australia, and New Zealand. Many natural products, such as ferulic acid, chalcone, vanillin, matrine, drimane meroterpenoid, lycoris alkaloids, etc. have also been used to innovate fungicides. The matrine-based structures were found to possess high fungicidal activity against *Corynespora cassiicola*, *Phytophthora capsici*, *Sclerotinia sclerotiorum*, *Rhizoctonia solani*, and *Botrytis cinerea*.

The most recent and talked about innovation in the field of pest management is the exogenous (topical) application of dsRNAs as the most effective strategy for gene silencing. RNAi-based pesticides function by inhibiting the expression of a gene that is essential for the survival of the target crop pest through the RNAi effect, thereby suppressing vital biology of the pest and even causing death. Thus, such pesticides are also referred to as "RNA-induced gene silencing pesticides". RNAi effects by topical dsRNA application have also been studied to control the infection and proliferation of pathogens including fungi, viruses, and viroids in plants RNAi-based pesticides function by inhibiting the expression of a gene that is essential for the survival of the target crop pest through the RNAi effect, thereby suppressing vital biology of the pest and even causing death. Thus, such pesticides are also referred to as "RNA-induced gene silencing pesticides". RNAi effects by topical dsRNA application have also been studied to control the infection and proliferation of pathogens including fungi, viruses, and viroids in plants. Plants naturally secrete interspecific small-RNAs as part of their defense system to silence pathogens mRNAs, known as host-induced genes silencing (HIGS). Conversely, pathogens also send small-RNAs to repress host gene expressions related to plant immunity. The plant mRNAs are cargo of extracellular vesicles, a strategy to ensure safety avoiding degradation due to abiotic conditions or the presence of extracellular RNAse. Likewise, extracellular delivery of small-RNAs from bacteria, fungi, and protists are proposed to involve vesicles. In fact, CRISPR-edited Sicilian Rouge tomatoes with high concentration of γ-aminobutyric acid (GABA) were the first genome-edited crop (approval in December, 2020) that entered the market of Japan successfully by Sanatech. Understanding the mode of action and machineries involved in communication triggered by small-RNAs between plants and their pathogens is crucial to develop novel strategies in crop protection. One of plant strategies to repress virulence genes when combating fungal pathogenicity is by excreting sRNAs. A well-documented phenomenon in plant pathogenesis by *Botryris cinerea*, Phytophthora infestans and Phytophthora capsici. At the laboratory level, dsRNA targeting the actin-encoding gene of CPB resulted in almost 100% mortality with a dose equivalent to 0.96 g dsRNA/ha for the most susceptible sample species, although the least susceptible required approximately 7.5 times that amount of dsRNA. The amount of these pesticides required for use in practical situations has not yet been studied in detail, but recent estimates suggest that approximately 2–10 g of RNA per hectare may be needed. The production cost of RNAs has been decreasing year-by-year as manufacturing technology improves. A biotechnology company called RNAgri (formerly APSE) has developed a technology that can produce dsRNA at a cost of USD 1–2/g RNA. Their production system claims to be based on accumulation of target dsRNA in virus-like particles (VLPs) in E. coli.

At least 105 chemical pesticides have been launched during the past decade or are under development out of which 43 are fungicides. Most of them are safe to humans and environmentally friendly. The most developed fungicides are SDHI (succinate dehydrogenase inhibitors), DMI (demethylation inhibitors), QoI (quinone outside inhibitors), and QiI (quinone inside inhibitors). Due to the development of resistance to fungicides with existing modes of action, many fungicides possessing various novel modes of action have been launched or are under development. Syngenta developed four SDHI fungicides. Isopyrazam (Reflect®) is for foliar application to control rust and net blotch of wheat. Sedaxane (Vibrance®) is a seed-treatment fungicide for wheat, beans, and potatoes. Benzovindiflupyr (Solatenol™) is a rust-control fungicide for soybeans. Pydiflumetofen (Adepidyn™) is for the control of powdery mildew and *Alternaria* disease of vegetables, fruit trees, *etc.*, as well as wheat leaf blight and wheat scab.Bayer launched bixafen (Aviator® Xpro™, Siltra® Xpro™, *etc.*), penflufen (EverGol® Prime), and fluopyram (Luna®). Isoflucypram, under development by Bayer, exhibits efficacy for the control of leaf spot diseases on a large range of crops.

There are some other safe alternatives to chemical pesticides and among these green synthesis of nano-fungicides is also promising. These nano-formulations have been found 100- 10,000 times more efficacious in restricting the growth of the pathogens and also in the management of the diseases. Thus, based on advances at the intersection of chemistry, biochemistry, molecular biology and genomics, 'designer' fungicides may be developed that address some of these issues.

Multi-omics analysis on plant responses to global climate change

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Global climate change is an emerging threat to humanity. Not only human lives are being affected, but also other life forms including plants are affected by climate change. Carbon dioxide (CO_2) is a primary greenhouse gas and a major contributor to global climate change. The current atmospheric CO_2 concentration is 400 parts per million (ppm), and is predicted to increase 550–700 ppm by 2050, resulting in global warming. CO_2 acts as a primary reactant in a photosynthetic reaction that converts solar energy into chemical energy, which is stored in the form of carbohydrates. Therefore, elevated [CO_2] concentrations stimulate photosynthesis in C_3 plants, enhancing plant growth and productivity (fertilization effect). Also, high [CO_2] lowers stomatal conductance, stimulates respiration, alters flowering time, and lessens abiotic stress impact in plants by affecting stomatal (transpiration) and non-stomatal (e.g., photorespiration and antioxidants) processes. Elevated [CO_2] concentrations suppress photorespiration, resulting in less reactive oxygen species (ROS) formation and reducing oxidative pressure in plants. In contrast, elevated [CO_2] grown plants show higher antioxidant capacity due to enhanced C-fixation, which also contribute to the stress-mitigating effect of high [CO_2]. Thus, elevated [CO_2] levels not only affect plant growth and developmental processes, but also alter stress signaling and defense responses in plants.

Surging atmospheric [CO_2] levels are strongly associated with the rise in Earth's temperature. The intensity and frequency of heat stress events are predicted to become higher in the future climate. High temperature stress impairs chloroplast development and functioning, inhibits photosynthesis and growth, and has devastating effects on crop yield. Also, metabolic changes induced by heat stress lead to imbalances in redox homeostasis and elevated levels of ROS formation, causing oxidative stress in plants. Defense responses against heat stress include stomatal opening (transpiration cooling), induction of protective molecules (e.g., osmolytes, heat shock proteins, and antioxidants), and transcriptional reprogramming.

Plant responses to short-term (single generation) exposure to environmental perturbations such as high [CO_2] and heat stress are relatively well characterized. However, heritable responses to the environment are less studied in plants. Recent studies, however, documented the transgenerational effects of abiotic stresses in plants. These studies revealed that offspring of stressed plants cope-up with stress exposure more efficiently than the offspring of naïve parents. Such transgenerational effects originate from genetic (mutations), or epigenetic changes, affecting gene expression patterns and organismal processes. Because mutation rates are relatively low in nature, therefore heritable responses to environmental changes are not likely to be explained by genetic changes alone. Epigenetic mechanisms, including DNA methylation, histone modifications, and small non-coding RNAs are known to shape the phenotype of progeny via regulating gene expression.

Interaction of elevated CO_2 with drought and temperature

The growth-promoting effect of elevated atmospheric CO_2 is well established in plants (fertilization effect), but how elevated CO_2 affects plant responses to abiotic stresses remains unclear. To get mechanistic insights on plant responses to realistic future climate extreme conditions, we exposed *Arabidopsis thaliana* to a combination of heat and drought stress at ambient and elevated CO_2 concentrations. We observed that climate extremes negatively affected photosynthetic processes, and elevated CO_2 significantly mitigated the negative impact. We discovered that the stress-mitigating CO_2 effect operates through up-regulation of antioxidant defense metabolism, as well as by reduced photorespiration resulting in lowered oxidative pressure. Collectively, exposure to future climate extreme episodes will negatively impact plant growth and production, but elevated CO_2 is likely to mitigate this effect. Furthermore, plant metabolic responses to a complex climate change scenario comprising elevated CO_2, heat and drought were elucidated. We showed that concentrations of soluble sugars and amino acids increased transiently after 'short' exposure to climate extreme (combination of heat and drought), and readjusted to control levels under 'prolonged' stress. In contrast, fatty acids showed more persistent changes during the stress period. The stress impact on sugar and amino acid metabolism was reduced by elevated CO_2, but not on fatty acids. Further, multivariate analyses grouped metabolites on the basis of stress exposure time, indicating specificity in metabolic responses to short and prolonged stress. Taken together, the results suggest that dynamic metabolic reprogramming plays an important role in plant acclimation to climatic extremes.

Species-specific responses to elevated CO_2 and abiotic stresses

Global climate change factors may alter plant chemical composition and thereby their economic and ecological characteristics e.g., nutritional quality and decomposition rates. We compared biochemical attributes (carbohydrates, proteins, lipids and mineral contents and stoichiometric ratios) of four temperate grassland species i.e. grasses (*Lolium perenne*, *Poapratensis*), and the nitrogen (N) fixing legumes (*Medicagolupulina* and *Lotus corniculatus*) under climate change scenario (elevated temperature, drought and elevated CO_2) in a multifactorial experimental design system. It was concluded that quality losses would be less prominent in grasses than legumes under climate extreme and its combination with high CO_2 conditions. Proline (Pro) is a versatile metabolite, playing a critical role in plant protection against stresses. To gain a mechanistic understanding of the regulation of Pro metabolism under future climate conditions (drought, elevated temperature and CO_2), we compared four grassland species (two grasses and two legumes); and determined metabolite concentrations, enzyme activities and gene expression levels. Also, a computational modelling based pathway control analysis was implemented. We found that Pro accumulation occurs through different biochemical pathways in different species groups, wherein grasses activates 'glutamate pathway', and legumes activates 'ornithine pathway', which is possibly related to their differences in N-nutritional status.

Understanding the interaction between high CO_2 and elements is also crucial. The contamination of agricultural soils with arsenic (As) limits global crop productivity, while elevated CO_2 (eCO_2) boosts plant growth both under optimal and suboptimal growth conditions. However, crop-specific interactions between eCO_2 and soil arsenic exposure has been less explored at the whole plant, physiological and biochemical levels. We anlysed the effects of eCO_2 and soil as exposure on growth, photosynthesis and redox homeostasis in barley (C3) and maize (C4). Species-specific responses were observed wherein barley was more susceptible to soil as exposure at ambient CO_2 levels as compared to maize. Barley experienced more severe oxidative stress than maize. Interestingly, eCO_2 differentially mitigated As-induced stress in barley and maize. In barley, eCO_2 exposure reduced photorespiration, H_2O_2 production, and lipid/protein oxidation. In maize eCO_2 exposure led to an upregulation of the ascorbate-glutathione (ASC/GSH)-mediated antioxidative defense system. Our work highlights the differential impact of eCO_2 on the growth, physiology and biochemistry of C3 and C4 crops exposed to soil As pollution. In another study, we assessed the interactions between phosphorous (P) and elevated CO_2. P is essential to every form of life and plays a key role in controlling photosynthetic responsiveness to CO_2 levels. We systematically reviewed the interactive effects of high CO_2 and P on shoot and root-related processes, and compared them at growth, physiological, biochemical and transcriptional levels. Moreover, *insilco* analysis of the expression pattern of typical P responsive genes under high $CO_2$was analysed. The expression of P-starvation genes was induced under long-term exposure to high CO_2, suggesting that growth enhancement under elevated CO_2 result in higher P requirement, which require further investigation.

Epigenetic basis of global climate change adaptation

Epigenetic modifications facilitate adaptation to changing environments. As discussed above that the frequency and intensity of climate extremes is increasing. Thus, we tested whether and how such extremes induce long-term transgenerational changes in plants. *Arabidopsis thaliana* plants were exposed to extreme high temperature. The most resistant individuals were selected for three generations and compared to non-heat treated plants that were selected in parallel (control-selected). We observed that plants selected repeatedly under heat stress evolved to be heat resistant, as revealed by higher seed production and lower photosysnthesis inhibition, and lesser oxidative stress than the control selected plants. Genome-wide transcriptional profiling revealed differentially expressed genes, consistent with the reduced physiological impact. Interestingly, genome-wide methylome analysis (bi-sulphite sequencing) showed a higher number of methylation changes in response to heat stress. Together, results demonstrate that extreme heat stress induces epigenetic adaptations, reducing the stress impact.

In conclusion, elevated CO_2 mitigates the impact of abiotic stress in plants. Also, species-specific responses exist in responses to climate change that need to be considered while devising climate mitigation strategies. Epigenetic (e.g., DNA methylation) modifications are involved in the climate adaptation of natural populations. Hence, the role of epigenetic modifications should be further explored in plant adaptation. In the end, multi-omics analyses provide a clearer view of climate change impact on plants.

Weather-based epidemiology and forewarning system of diseases in crops – An Integrated Decision Support approach for Crop Protection Services

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Reliable and timely forecasts provide important and useful input for proper, foresighted and informed planning, more so, in agriculture which is full of uncertainties. Agriculture now-a-days has become highly input and cost intensive. Without judicious use of fertilizers and plant protection measures, agriculture no longer remains as profitable as before. Uncertainties of weather, production, policies, prices, etc. often lead to losses to farmers. New pests and diseases are emerging as an added threat to the production. Under the changed scenario today, forecasting of various aspects relating to agriculture are becoming essential. A well-tested weather-based model can be an effective scientific tool for forewarning insect-pests and diseases in advance so that timely plant protection measures could be taken up. In India, there are 127 agro-ecological zones, which would require weather data recording at least at ~1200 observatories apart from multi-year observations on pest epidemics / epizootics in those many locations. Such exercise would be time-consuming, labour-intensive in the country with difficult terrain and other constraints. Therefore, limitation of forewarning models for specific geographic locations could be overcome by use of satellite-based agromet data products. Therefore, forewarning models for major pests and diseases of crop using satellite-based agromet product and surface data could be developed for decision support system(s), which would reduce use of chemical pesticide on standing crop for risk mitigation. Various types of methodologies have been utilised for development of forewarning models. The simplest technique forms the class of thumb rules, which are based on experience. Though these do not have much scientific background but are extensively used to provide quick forewarning of the menace. Another tool in practice is regression model that represent relationship between two or more variables so that one variable can be predicted from the other (s). Linear and non-linear regression models have been widely used in studying relationship of insect-pests and diseases with time and weather variables (as such or in some transformed forms). With the advent of computers more sophisticated techniques such as simulation modelling, machine learning, approach have been explored. In view of changing climate, the devised and to-be-born models need to be oriented to dynamic mode as there is increase in the frequency of climate extremes, especially temperature and rainfall which are influence the distribution, epidemiology and management of plant diseases & insect-pests. Therefore, there is needs to generate strategic knowledge based on modelling approach in diseases and insect-pests dynamics with changing climate and accordingly crop protection strategies may be adapted which leads an Integrated Decision Support System (IDSS) for Crop Protection Services for value-added agro-advisory.

Novel approaches for detection and discovery of plant viruses affecting fruit crops

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Viruses/ viroids induce huge economic losses to production chain of fruit crops and most often these losses are overlooked. In fruit trees, viruses accumulate over the years, giving rise to mixed-infections. Viruses may or may not produce symptoms but their infection frequently result in slow growth, fewer, small sized fruits, alter the fruit quality, reduces the plant life period in different fruit crops. Twenty-one viruses belonging to nine families and twelve genera have been reported from various pome (apple, quince and pear) fruits. In apple alone, 19 viruses and 5viroids have been reported throughout the world. Similarly In grapevine, about 70viruses and 7 viroids have been reported. Only few viruses have been identified in fruit crops from India. Further, identification and characterization of these viruses are challenging due to the low titre, irregular distribution within the plant, inter- and intra-species mixed-infections, symptomless infections or fluctuation of symptom intensity across the seasons and the complex and heterogeneous nature of viral populations. Recent advances in the form of Next generation sequencing (NGS) technologies are powerful tools to detect and characterize the untargeted viral pathogens with known/unknown genomic sequences. These technologies have found increased applications in unraveling the phytovirome which contribute to disease phenotype of host plant. The NGS can help to optimize the existing detection assays by addressing one of the major shortcomings for the traditional methodologies, which is the high sequence variability present in fruit tree-infecting viruses. The virome study not only detects the viruses/viroids but also unravels the genome complexity, replication, mutation, recombination, nucleotide variations in virus/viroid genomes in certain situations. In fact, most of perennial fruit plants are being vegetatively propagated and are considered as store houses of large number of viruses/viroids. These technologies have opened new vistas for not only detection and identification of known viruses, but also novel, newly emerging and divergent viruses/viroids. It is ultimate tool for the production of virus-tested high-quality propagating material and can be efficiently applied in the fields of certification and phytosanitary control especially in perennial crops. Assessment of the new viruses identified will provide a thorough list of pathogens posing potential threats, and quarantine lists can be updated. The easy-to-use detection assays for identified viruses/viroids can be developed for certification programmes and production of clean planting material as use of virus free clean planting material is the best strategy for management of viral diseases in clonally propagated perennial fruit crops.

Burr knots on apple trees

Neelam Kumari and HR Gautam

What are burr knots?

Burr knots, sometimes also called burrs or burls, are root producing structures that develop on the aerial parts of some apple trees. These develop when adventitious roots start to form on the aerial parts of the tree. At first, the adventitious roots rupture the bark and initially only a single root initial may form.But with time,a greater number of root initials develop on the affected area due to which burr knot increases in size. These roots do not lengthen to great extent, remain stubby giving a knobby appearance to the affected area. Older burr knots become hard and may develop an irregular bark covering. Although previously classified as disease, it is now classified as a disorder because it is no longer believed to be pathogenic.

Difference between burr knots and crown galls

Burr knots usually results into tumour-like outgrowths on the aerial parts of the tree. Similar outgrowths can also result from infection by the bacterium, *Agrobacterium tumefaciens*, causing crown gall in apple trees. Whilst, crown gall can occasionally develop above ground level, it tends to be found most commonly at or below the soil level, on the roots or bottom of the trunk. Crown galls tend to be more wart-like in the early stages. These galls may eventually protrude much further from the trunk than a burr knot.

Strategies to overcome burr knot development

a. Select rootstocks and varieties that are less prone to this problem.
b. Plant trees with the graft union 1 to 2 inches above the soil line.
c. During the growing season, maintain a vegetation-free area beneath the tree to increase air movement and promote rapid drying of the trunk.
d. Try to avoid creating the environmental conditions (particularly shade and high humidity) conducive to burr knot formation, particularly with rootstocks and cultivars known to be susceptible to the condition.
e. Avoid weed growth and other thick vegetation beneath the tree, thereby allowing good air circulation and rapid drying of the trunk after rain
f. When burr knots are visible, the root initials can be cut out using a knife, followed by pasting with Gallex.

Sensors based IoT- a step forward in apple disease and insect pest forewarning

Bhupesh K Gupta, Anil Handa and Ajay Brakta

Under the regime of global trade and changing climate, there is continuous exposure of pathogens to new predisposing conditions leading to a continuously changing scenario of new diseases and pests. According to Food and Agriculture Organization (FAO) of the United Nations, plant diseases are responsible for at least 40 percent crop losses due to pests and diseases annually, especially under the changing climate scenario (FAO, 2021). These losses will entail serious impact for food security of burgeoning population that requires additional food every year. While combating pests and diseases farmers should be encouraged to adopt the use of environment friendly strategies. In order to address the increased food demand, timely management of the diseases and pests is of utmost importance for nipping the evil in the bud. Forecasting plant diseases is, therefore very important in timely management, which is done by disease modeling and prediction through a complex phenomenon and has many underlying nonlinear patterns. Such datasets are difficult to be dealt with stringent assumptions of the statistical or mathematical models. Therefore, machine learning (ML) techniques provide great deal of flexibility for modeling and forecasting the plant diseases. Internet of Things (IoT) has been considered the state of the art in disease forecasting that uses wireless sensor network (WSN) technology and is accessible through the internet. IoT comprises of hardware and software modules. In hardware module, physical devices like sensors are deployed in the field. These sensors measure requisite parameters like temperature, humidity, soil temperature, leaf wetness, wind speed, solar radiation intensity, soil moisture etc. The software contains two components *viz*. Artificial Intelligence (AI) and Graphical User Interface (GUI). The data driven decision support system helps in enhancing maximum yield potential of crops and reduce input cost through timely application of critical and judicious inputs.

Horticulture is the backbone of economy of the hill state of Himachal Pradesh that requires timely and judicious use of various inputs for achieving maximum yield potential and thus elevating economy of the growers. Department of Plant Pathology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan under the World Bank funded HPHDP project has taken a lead for forecasting and forewarning of the diseases by deploying such twenty expert systems in experimental research fields, progeny cum demonstration plots, and at progressive farmers' orchards. These systems collects critical microclimatic data such as canopy temperature, canopy humidity, soil moisture on primary and secondary root zone, soil temperature, wind speed and direction, rainfall, vapour pressure deficit, leaf wetness, NDVI etc. These datasets are then transferred to the cloud and processed with the help of machine learning (ML) approaches mainly Artificial Intelligence (AI). Overall, these expert systems forecasts stagewise irrigation time and amount of water required by the crop and preventive measures for disease and pests outbreaks (e.g. Apple scab, Marssonina blotch, Alternaria leaf spot, European red mite, and Woolly apple aphid). These systems help in saving 20-30 percent water besides reduction in spray cost by 18-25 per cent. Also help in increasing yield 8-15 percent. These systems not only help farmers in managing the crop but also help in keeping a digital record of all farm expenses and revenues to get simple and useful reports and through market intelligence helps farmers abreast to nearest agriculture markets. Forewarning about disease or pest outbreak will in turn help us in pushing advisories to the farmers well in time encouraging judicious use of agrochemicals and production of safe food.

An Expert System deployed in HDP apple at Experimental farm of Fruit Science Department

A report on National symposium on "Novel strategies in plant stress diagnosis and management"

Anil Handa, Bhupesh Gupta, Ajay Brakta, Manica Tomar, Meenu Gupta, Arti Shukla, Shalini Verma, Savita Jandaik, RS Jarial and Monica Sharma

Himalayan Phytopathological society (HPS) under the aegis of Department of Plant Pathology organised a National symposium on "**Novel strategies in plant stress diagnosis and management"** on May 6-7, 2022 at main campus of the university. The symposium focussed on abiotic and biotic stresses which are taking the edge off the crop quality and productivity. Around 300 delegates from across the country participated in this symposium. The chief guest of the inaugural session was Hon'ble Vice chancellor of the university, Dr. Ravinder Sharma. He exhorted the scientific community to exchange their valuable ideas through this symposium to mitigate the effects of climate change through novel scientific approaches. The symposium began with the ceremonial inaugural session where President of the Society and Head of Plant Pathology department, Dr. HR Gautam, in his presidential address, emphasised and outlined the role of the department of Plant Pathology in agricultural economy of the state since last 56 years and the endeavours of HPS in organising symposia and seminars from time to time on relevant topics which have helped the researchers, scientists, farmers and agri based firms from across the country and globe to come under an umbrella to help in mitigating plant stresses. The secretary of the HPS, Dr. Narender K Bharat gave an overview of the Himalayan Phytopathological society and chronology of deliberations, discussions, workshops, seminars and symposia organised by the society since its inception. The organising secretary of the National Symposium, Dr. Anil Handa gave an overview of the symposium and added that the symposium would herald a new chapter in mitigating plant stress through novel scientific approaches.

Professor & Head Dr HR Gautam welcoming Hon'ble VC & Chief Guest lighting the lamp at Inaugural Ceremony

Awards of the Society

1. Life Time Achievement Award - 2022

The HPS conferred Life time achievement award to Dr. VK Baranwal, National Professor, Advanced centre for Plant Virology, ICAR-IARI for demonstrating leadership in plant virology research in the field of genomics, diagnostics and interaction of plant viruses with host and vectors. His most significant research outcome includes development of microarray chip and novel rapid detection of viruses through isothermal recombinase polymerase amplification. He has played active role in certification programme of tissue cultured plants of Department of Biotechnology, Government of India since 2010.

Dr. VK Baranwal receiving Life Time Achievement Award and Dr Gaurav Zinta receiving Young Scientist Award from Hon'ble Vice Chancellor

2. Young Scientist Award - 2022-06-22

The HPS society appreciated the efforts of Dr Gaurav Zinta by presenting him Young scientist award .He is presently working as Senior Scientist in the Biotechnology division of CSIR Institute of Himalayan Bio resource Technology, Palampur (HP). He has been doing exemplary work in the field of integrative molecular plant stress physiology, climate change biology, genome editing, epigenetics, and chemical genetics.

3. Innovative Farmer Award – 2022

This year the innovative farmer award was conferred upon Mr Nishant Gazta, a 32 year old farmer from Distt. Solan who pioneered in growing and selling a medicinal mushroom and Continental delicacy i.e *Cordyceps militariea* in his laboratory. He took his initial training on cultivation of this rare variety of mushroom from Chandigarh. Thereafter, after borrowing a loan under Mukhyamantri Swavlambi Yozna, he developed his laboratory to cultivate this mushroom. Since its inception in 2021, Mr Gazta has sold mushrooms worth Rs. one lakh. He also trains youth and entrepreneurs in the cultivation of *Cordyceps militariea*.

In the Inaugural Ceremony, the chief guest and other dignitaries also released a Book on “Novel Strategies in Plant Stress Diagnosis and Management” edited by HR Gautam, NK Bharat, A Handa & SK Sharma and also The Souvenir and Book of Abstracts edited by Bhupesh Gupta, A Brakta, M Gupta, S. Verma, M Tomar, NK Bharat, SK Sharma, A Handa & HR Gautam

Mr. Nishant Gazta receiving Innovative Farmer Award from Hon'ble Vice Chancellor

Dr HR Gautam Prof. & Head delivering Presidential Address to the delegates

Hon'ble Vice Chancellor and others releasing the book on “Novel Strategies in Plant Stress Diagnosis and Management edited by HR Gatam, NK Bharat, Anil Handa & SK Sharma

Hon'ble Vice Chancellor and others releasing the Souvenir & Book of Abstracts

Hon'ble Vice Chancellor addressing the delegates and other dignitaries

Technical Sessions

The symposium comprised of three technical sessions and the First session was on current areas of research in plant pathology, stress management and economic importance of fungi. The session was chaired by Dr. VK Baranwal and co chaired by Dr. Supradip Saha. In this session there were five speakers. Dr. Baranwal presented his lead lecture on "Novel approaches for detection and discovery of plant affecting fruit crops". He elaborated the role of Next generation sequencing (NGS) in detecting and targeting next generation viruses. He added that NGS has become a powerful tool in optimizing the major shortcoming of traditional methodologies i.e. high sequence variability present in fruit tree infecting viruses. Dr Gaurav Zinta presented his work on "Multi-omics analysis on plant responses to global climate change". He elucidated the mechanistic insights on the impact of global climate change on plants and multi-omics (spanning from genes to ecosystem levels) approaches to elucidate plastic and adaptive responses. He revealed that elevated CO_2 mitigates the impact of abiotic stresses on plants and epigenetic mechanisms are involved in stress adaptation. According to him Overall, integrative analyses comprising transcriptomics, epigenomics, metabolomics, and eco-physiology are essential for getting deeper insights into plant processes affected by climate change. Dr. Pramod Prasad delivered a lecture on "Defense mechanisms activated during plant-biotroph interactions". He elucidated the defense mechanisms and conventional management strategies of disease resistance breeding and application of pesticides. He emphasised that the plants utilise pre-existing physical as well as chemical barriers to defend microbial pathogen infection. Dr. KB Palanna spoke about Management of diseases and abiotic stresses in millets. He emphasised upon the importance of millets in food security and highlighted that the incorporation of stress tolerance traits in millets will improve productivity in marginal environments and will help in overcoming future food shortage due to climate change. Dr. Sanjeev K Sanyal gave a presentation on Economically important macrofungi: taxonomy and analysis. Dr Sanyal elaborated that some basidiomycetes collectively referred to as white rot and brown rot fungi possess the unique ability to degrade cellulose and lignin completely into CO_2 for use as carbon and energy sources. He emphasized on collection and identification of these fungi from their natural habitat and analyse for their different useful components.

Dr VK Baranwal from IARI, New Delhi delivering his lecture and Dr KB Palanna from UAS, Bangalore being felicitated by Dr HR Gautam

The second session was chaired by Dr Thangavelu Raman and co-chaired by Dr. Deepika Sood. In this session, three lead lectures and four invited lectures were delivered. Dr. Amrender Kumar delivered a talk on weather-based epidemiology and forewarning system of diseases in crops. He emphasized on the need of forecasting of various diseases and pest under the changed scenario today. There is need to generate strategic knowledge based on modelling approach in diseases and insect-pests dynamics with changing climate and accordingly crop protection strategies may be adapted which leads an Integrated Decision support system (IDSS) for crop protection services for value added agro-advisory. Recent Advances in diagnosis of bacterial diseases of crops were very well elucidated by Dr. Dinesh Singh. He elaborated in detail the basic and advanced techniques in the diagnosis of bacterial plant diseases. Dr. AK Das delivered an exhaustive talk on the diagnosis and management of important fungal and bacterial diseases of citrus. He elucidated minute differences in symptomatology of various citrus diseases which can be helpful in their diagnosis. He discussed the intensive and integrated management approaches for citrus greening disease. He also explained current diagnostic techniques and integrated management strategies for prevention and control of important fungal and bacterial disease of citrus Mr. Claus Brakemeier from Ferti Global Italy delivered online talk on Enhanced Nutrition Vitalizes technology from FertiGlobal: an innovation for plant stress management online. He explained the utility of EnNuVi a new and unique patented technology that affects high analysis formulations with plant nutrients complexed by bioactive polyphenols which can help to change the impact of agriculture on environment supporting the demand for food and higher field productivity. Dr. Manisha Thakur discussed about the development of Fusarium yellows resistance in ginger through biotechnological approaches. She explained her work on gamma irradiation to ginger clones for producing mutations. Dr. Neeraj Sharma from Corteva Agrisciences demonstrated the efficacy of Zorvec Enibel – a novel fungicide for the management of potato late blight. Dr. Narendran M Nair from Seven Star Fruits Private Limited demonstrated the quality apple planting material production using allied dwarfing rootstocks.

The Chief Guest Mr Ajay Sharma being presented with the memento by the Hon'ble VC and HOD

The Chief Guest Mr Ajay Sharma and others releasing a book written by Anil Handa, Bhupesh Gupta, Ajay Brakta, and Bunty Shylla

Third Technical Session was chaired by Dr. VK Sehgal and co chaired by Dr. Amrender Kumar. There were three lead lectures and three invited lectures in this session. First lecture was delivered by Dr. Thangavelu Raman on management of Sigatoka leaf spot of banana which is a major problem in India as well as abroad. For effective and rational management, he stressed on use of effective chemicals along with mineral oil as well as some bio control agents like *Penicillium*. Dr. Ashutosh Bhaik presented his talk on new generation chemicals. He elucidated various products and some future fungicides and natural products of Corteva for managing various plant diseases. Third lead lecture was diagnosis and management of abiotic stresses by Dr. Vinay K Sehgal. He sensitized about the novel approaches like sensors, drones, satellites and plant phenotyping for managing abiotic stresses. Invited lecture on Shiitake cultivation and its future prospects by Dr Deepika Sood recommended the use of mango and poplar saw dust for obtaining higher yield and quality of Shiitake and for good spawn production. Another lecture on sheath rot of rice by Dr. Sachin Upmanyu recommended screening of large number of germplasm against the disease to strengthen breeding program for development of resistant rice varieties. Dr. Vipasha Verma demonstrated use of CRISPR/Cas9 technology for engineering herbicide and disease resistant crops.

Poster presentations

Out of 135 submitted papers around 100 research papers were presented in the form of posters. Amongst the presented research papers the following four best research papers were selected by the Evaluation Committee chaired by Dr Bishnu Maya Bashyal, Principal Scientist, Div. of Plant Pathology, IARI, New Delhi for the Best Poster Award:

The winners receiving their Certificates from the Chief Guest of Plenary Session

Prize	Name address of the Awardee	Title and Authors of Research paper
First	**Ms. Diksha Sinha** CSK HPKV, Palampur (HP)	Profiling of Alternaria solani isolates with respect to aggressiveness on tomato – Diksha Sinha and DK Banyal
Second	**Ms. Shivani Gupta** Dr YS Parmar UHF, Nauni, Solan(HP)	DAPI staining based fluorescence microscopy and graft transmission for the detection of "*Candidatus* Phytoplasma ziziphi", the causal agent of peach yellow leaf roll phytoplasma – Shivani Gupta, Anil Handa, Ajay Brakta and Gulshan Negi
Third	**Mr. Varinder Khepar** PAU, Ludhiana (Pb)	ZnS-Sepiolitineno composites as ecofriendly, biodegradable and assimilative storage tool against seed borne fungi of rice- Varinder Khepar, Anjali Sidhu and Anju Bala
Consolation	**Dr. Ratna U Thosar** ICAR- National Research Centre for Grapes Pune (Ma)	In-vitro and field analysis of compatibility of biocontrol agents with metrafenone 50% SC in controlling the powdery mildew of grapes - Ratna U Thosar, Dimpi Das, Vijayshree Chavan and Sujoy Saha

Chairman of the Himachal Pradesh Public Service commission Mr. Ajay Sharma was the chief Guest of the plenary session of the symposium held on May 7, 2022. In his address, he applauded the scientific community for their endeavours and showed his sanguinity towards the outcome of symposium in framing strategies of the benefit of farmers. The programme concluded with the thanks to the chair.

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