

2ND INTERNATIONAL CONFERENCE ON GREEN AGRICULTURE FOR FUTURE HARVESTS

HARNESSING TECHNOLOGY FOR CLIMATE RESILIENCE AND FOOD SECURITY

10-11-12 FEBRUARY 2026

ABSTRACT BOOK



EDITED BY

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ICGA-001

**Assessing Climate Change Impacts On Food Security and Sustainability of Rice–Wheat
Systems in Punjab, Pakistan Using AgMIP Framework**

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The rice–wheat cropping system (RWCS) of Punjab, Pakistan, plays a critical role in national food security but is increasingly threatened by climate change. Rising temperatures, increased climate variability, and changing rainfall patterns are projected to significantly affect crop productivity, water availability, and rural livelihoods by the 2050s. Using integrated crop, climate, and economic modeling frameworks under the Agricultural Model Intercomparison and Improvement Project (AgMIP), this study assesses climate change impacts on current agricultural production systems and evaluates the potential of adaptation strategies. Results indicate that average temperatures in Punjab may increase by about 2 °C, with heavier rainfall during wet seasons and drier dry seasons, leading to higher irrigation demand and increased flood risk. Without adaptation, rice and wheat yields could decline substantially, increasing poverty rates among smallholder farmers. However, the adoption of targeted adaptation packages including improved crop varieties, adjusted sowing dates, optimized fertilizer use, higher plant densities, and improved water management can significantly reduce yield losses, enhance farm incomes, and improve resilience. Model simulations suggest that future adaptation strategies could benefit up to 93% of farming households, compared to 66% under future climate conditions without adaptation. The findings highlight the importance of integrated adaptation planning, stakeholder engagement, and policy support to ensure sustainable food security in Punjab under a changing climate.

ICGA-002

**Application of Crop Modeling to Support Green Agriculture for Future
Harvests and Sustainable Food Security**

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Crop production systems are increasingly threatened by climate variability, resource degradation, and rising global food demand. Advanced crop modeling frameworks have emerged as essential tools to guide climate-smart agriculture and support the transition toward greener, more resilient food systems. Crop simulation models such as the Decision Support System for Agrotechnology Transfer (DSSAT) integrate crop physiology, soil dynamics, climate inputs, and management practices to quantify yield responses and assess production risks under diverse environmental conditions. These models enable the evaluation of adaptive strategies including optimized nutrient management, improved water-use efficiency, climate-resilient cultivars, and sustainable agronomic practices to enhance productivity while minimizing environmental impacts. By generating evidence-based insights, crop modeling supports informed decision-making for farmers, researchers, and policymakers, and strengthens planning for climate-resilient agriculture. The application of such modeling tools contributes directly to green agriculture by improving

resource efficiency, reducing carbon and nitrogen footprints, and safeguarding food production against future climate uncertainties. Leveraging these technologies is vital for ensuring sustainable food security and securing future harvests in an era of rapid climate change.

ICGA-003

Seeds of Resilience for Climate-Ready and Sustainable Agriculture

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Global agri-food systems are under increasing pressure from climate change, natural resource degradation, and biodiversity loss. Rising temperatures, water scarcity, soil salinity, and declining fertility threaten agricultural productivity and food security worldwide. This keynote highlights science-based pathways for building climate-resilient and sustainable agriculture through the integration of agroecological principles, biodiversity, and innovation. Conservation agriculture practices—such as minimum tillage, crop residue retention, and precision nutrient management—play a key role in improving soil health, enhancing carbon sequestration, and reducing greenhouse gas emissions. Nature-based solutions, including allelopathy-based weed management and biological nitrification inhibition, offer low-input strategies to reduce reliance on synthetic herbicides and nitrogen fertilizers. Diversified cropping systems, including intercropping and crop rotations, improve resource use efficiency, stabilize yields, and enhance system resilience. Particular emphasis is placed on the role of neglected and underutilized species, traditional landraces, and crop wild relatives as valuable sources of climate tolerance, nutritional quality, and genetic diversity. When combined with smart farming technologies, traditional knowledge, and supportive policies, these approaches provide a strong foundation for developing resilient, productive, and sustainable agri-food systems under a changing climate.

ICGA-004

Climate-Smart Agriculture Technologies and Practices in Bangladesh

Dr. Md. Baktear Hossain

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Bangladesh agriculture faces escalating challenges from climate change, land degradation, declining soil fertility, groundwater depletion, and increasing pressure from a growing population. With nearly 46% of agricultural soils depleted of organic matter and widespread exposure to floods, droughts, salinity intrusion, and riverbank erosion, sustaining food security requires transformative, climate-resilient solutions. Climate-Smart Agriculture (CSA), as promoted by FAO, offers an integrated approach to enhance productivity, strengthen adaptation and resilience, and mitigate greenhouse gas emissions. This study synthesizes the status, categorization, and field-level performance of CSA technologies and practices in Bangladesh, drawing on national inventories, participatory research, and on-farm validation under diverse agroecological zones. A total of 61 CSA technologies were identified and classified into six categories: weather-smart, carbon-smart, water-smart, nutrient-smart, energy-smart, and knowledge-smart. Participatory trials conducted in farmers' fields demonstrated significant yield advantages, cost reductions, and

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resource-use efficiencies from conservation-based practices such as strip planting, bed planting, zero- or minimum-tillage, relay cropping, and intercropping. Notable results include reduced seeding costs (up to 73%), improved crop establishment, enhanced water-use efficiency, and increased resilience in drought-prone and flood-affected regions, including the High Barind Tract and rainfed plains. Despite proven benefits, scaling up CSA adoption is constrained by limited access to machinery, financial capital, technical capacity, and enabling policies, particularly for women and smallholder farmers. Strengthened capacity building, targeted incentives, institutional support, and location-specific adaptive research are essential to mainstream CSA technologies. Overall, CSA offers a viable pathway to restoring soil health, improving productivity, and achieving sustainable, climate-resilient agriculture in Bangladesh.

ICGA-005

Effects of Atmospheric Aerosol Changes on Yields of Typical Crops in Weibei Dryland in China

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The Aerosol Optical Depth (AOD) and its seasonal variations directly influence changes in solar radiation, thereby affecting crop growth, development, and yield formation. However, existing crop yield simulation models do not account for the impact of AOD in their calculations, which to some extent compromises the accuracy of crop yield estimations and limits the quantitative assessment of aerosol-induced effects on crop yields at a regional scale. Additionally, the precision of current AOD retrieval models is constrained by the quantity and quality of input parameters, leaving room for improvement in accurately simulating seasonal aerosol variations. Therefore, the key to analyzing the impact of atmospheric aerosols on crop yields in the Weibei Dryland region lies in accurately constructing datasets that characterize regional aerosol variations and developing crop yield simulation models that incorporate the influence of aerosol seasonal changes. Based on this, this study focuses on the Weibei Dryland region in China, utilizing multi-source remote sensing data and the random forest algorithm to construct an AOD seasonal variation simulation model to explore the spatiotemporal characteristics of AOD. Furthermore, AOD is incorporated as an input parameter into the crop yield simulation model to improve yield estimation and investigate the impact of AOD variations on crop production. Finally, the enhanced crop yield model, which accounts for AOD effects, is applied to estimate wheat and maize yields in the Weibei Dryland from 2013 to 2022, analyzing their spatiotemporal patterns. The main conclusions are as follows: (1) Using MODIS apparent reflectance data, surface reflectance data, elevation, and slope as input parameters, the AOD was retrieved through a random forest model. The model achieved an R^2 of 0.75 and an RMSE of 0.06, demonstrating high correlation with station observations and low error, indicating its feasibility for simulating AOD seasonal variations. Spatially, AOD in the Weibei Dryland exhibited a pattern of higher values in the southeast and lower values in the northwest. From 2013 to 2022, AOD showed an overall declining trend. Seasonally, AOD was higher in spring and summer and lower in autumn and winter. Land use contribution analysis revealed that cropland and built-up areas were the primary contributors to AOD increases, while forestland changes led to AOD decreases. (2) Incorporating AOD into the crop yield simulation model effectively improved its accuracy. By integrating MODIS data, meteorological data, and AOD

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data, an enhanced crop yield model accounting for AOD effects was developed. Validation using field measurements and statistical yearbook data showed that the original model (without AOD) achieved R^2 values of 0.80 for both wheat and maize. However, after including AOD, the R^2 improved to 0.82 for wheat and 0.83 for maize, with better consistency against statistical yearbook records. Thus, incorporating AOD enhances yield estimation accuracy and serves as a reliable method for regional-scale crop yield modeling. (3) Applying the AOD-inclusive crop yield model to the Weibei Dryland revealed an overall increasing trend in wheat and maize yields from 2013 to 2022. Pearson correlation analysis indicated a weak negative correlation between wheat yield and AOD and a weak positive correlation for maize. Scenario simulations further demonstrated that, with other environmental factors held constant, increasing AOD led to varying degrees of yield improvement for both crops. Therefore, within certain limits, AOD variations can positively influence crop productivity. This study developed an AOD seasonal variation simulation algorithm, analyzed the spatiotemporal distribution of AOD in the Weibei Dryland (2013–2022), and integrated AOD dynamics into a crop yield model. The refined model showed high accuracy in simulating yield changes under AOD effects. By applying the model to estimate wheat and maize yields and examining AOD-yield relationships, this research provides a novel approach for precise yield estimation and supports climate adaptation strategies in agriculture.

ICGA-006

From Breeding to Management: A Multidisciplinary Pathway to Higher Sugarcane Yields and Sustainability

Dr. Hardev Sandhu
University of Florida

Sugarcane remains one of the world’s most important row crops, and sustaining yield improvement is a continuing priority for researchers, technologists, and growers. This keynote presentation highlights the technological innovations and management strategies implemented in Florida’s sugarcane industry that have collectively contributed to more than a 25% yield increase over the past decade. Central to this progress are newly developed varieties that combine high yield potential, enhanced disease resistance, and superior ratooning ability— traits that simultaneously boost revenue and reduce production costs through lower fungicide use and less frequent replanting. Complementing these genetic gains are advancements in management practices, including mechanical planting systems, green cane harvest management, optimized row spacing, precision crop-monitoring technologies, and in-field sucrose accumulation assessment tools. Together, these innovations represent a multidisciplinary, systems-based approach that has strengthened productivity, profitability, and long-term sustainability of sugarcane production in Florida. The presentation will further explore how these integrated strategies can be adapted and applied to other sugarcane-growing regions worldwide.

ICGA-007

A Review of Decontamination of *Aspergillus* Spp. And Aflatoxins Control of Grains and Nuts with Atmospheric Cold Plasma

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Aspergillus spp. and their produced aflatoxins are responsible for contaminating 25–30% of the global food supply, including many grains, and nuts which when consumed are detrimental to human and animal health. Despite regulatory frameworks, Aspergillus spp. and aflatoxin contamination is still a global challenge, especially in cereal-based matrices and their derived by-products. The methods for reducing Aspergillus spp. and aflatoxin contamination involve various approaches, including physical, chemical, and biological control strategies. Recently, a novel technology, atmospheric cold plasma (ACP), has emerged which can reduce mold populations and also degrade these toxins. ACP is a non-thermal technology that operates at room temperature and atmospheric pressure. It can reduce mold and toxins from grains and seeds without affecting food quality or leaving any chemical residue. ACP is the conversion of a gas, such as air, into a reactive gas. Specifically, an electrical charge is applied to the “working” gas (air) leading to the breakdown of diatomic oxygen, diatomic nitrogen, and water vapor into a mixture of radicals (e.g., atomic oxygen, atomic nitrogen, atomic hydrogen, hydroxyls), metastable species, and ions (e.g., nitrate, nitrite, peroxyxynitrate). In a cold plasma process, approximately 5% or less of the working gas is ionized. However, cold plasma treatment can generate over 1000 ppm of reactive gas species (RGS). The final result is a range of bactericidal and fungicidal molecules such as ozone, peroxides, nitrates, and many others. This review provides an overview of the mechanisms and chemistry of ACP and its application in inactivating Aspergillus spp. and degrading aflatoxins, serving as a novel treatment to enhance the safety and quality of grains and nuts. The final section discusses the commercialization status of ACP treatment.

ICGA-008

UVC-Induced Modulation of Plant Pigments, Biosynthetic Enzymes, and Antioxidant Defense Systems Across Exposure Intervals

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Plant pigments attract considerable attention from both biological and food science researchers. This work evaluated the effect of UV-C radiation on spinach as edible plant. The plants received UV-C treatment three weeks after germination, and the leaves were collected one week afterward. Levels of betacyanin, betaxanthin, and total betalains increased following 1–2 hours of UV-C exposure, then declined after 3–4 hours. Likewise, the activities of major enzymes involved in betalain formation L-DOPA oxidase, glucosyl transferase (GT), tyrosine hydroxylase (TH), and L-DOPA dioxygenase rose during the first two hours but decreased in the subsequent hours. Chlorophyll a and b concentrations increased after the first hour then declined consistently throughout 2-4 hours of exposure, with their biosynthetic enzymes ALA synthase, Mg-chelatase, and chlorophyll synthase— showing the same continuous reduction. In contrast, total carotenoids and the activity of their biosynthetic enzyme phytoene synthase increased after two hours before dropping at the third and fourth hours. Total phenolic and flavonoid contents, as well as the activities of their related enzymes phenylalanine ammonia-lyase, cinnamic hydrolase, chalcone synthase, and chalcone isomerase rose during the first three hours and decreased after the fourth hour. Similarly, ascorbate, reduced glutathione, and tocopherol levels, along with their biosynthetic enzymes L-galactono-1,4-lactone dehydrogenase and glutathione synthase, increased during the first three hours and declined afterward. The antioxidant enzymes superoxide dismutase, ascorbate peroxidase, glutathione reductase, and catalase also showed enhanced

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activity up to the third hour, followed by a reduction in the fourth hour. Thus, UV-C treatment induced significant increases in betalains, carotenoids, phenolics, flavonoids, and antioxidant metabolites during the early exposure period, reflecting a strong stress-responsive enhancement of pigment biosynthesis and antioxidant defense pathways in spinach. Also, prolonged UV-C exposure beyond two to three hours led to a marked decline in pigment content and enzyme activities, indicating that extended irradiation surpasses the plant's adaptive capacity and results in metabolic suppression rather than stimulation.

ICGA-009

Low-Input, High-Output Forage Production Solutions in Drylands: A Smart Agriculture Framework

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Increasing climate variability and declining soil organic matter threaten the sustainability of forage production in semi-arid regions, posing significant challenges to long-term food and feed security. This study evaluates the potential of smart and green agricultural strategies to enhance productivity while reducing environmental pressures, in alignment with the conference theme, “Green Agriculture for Future Harvests: Harnessing Technology for Climate Resilience and Food Security.” The analysis focuses on precision nutrient management, organomineral fertilizer applications, improved legume–grass mixtures, and the use of natural soil amendments to strengthen system resilience. In particular, organomineral inputs such as gyttja and leonardite, both rich in organic matter and essential nutrients, were found to improve soil physical properties, enhance water-holding capacity, and increase nutrient-use efficiency under dryland conditions. These materials contributed to more stable and higher-quality biomass production, demonstrating their value as climate-smart inputs. Improved legume–grass mixtures further enhanced nitrogen dynamics and reduced dependence on synthetic fertilizers, thereby supporting both ecological sustainability and cost efficiency. Overall, the findings highlight that integrating natural organomineral amendments with technology- and knowledge based management practices can significantly reduce input requirements, enhance climate resilience, and support sustainable forage production in semi-arid environments. This approach provides a robust pathway toward future-ready green agriculture systems that safeguard long term food and feed security. Key words: Smart agriculture, Semi-arid regions, Organomineral fertilizers, Climate resilience, Forage productivity.

ICGA-010

Climate-Smart Agriculture in Pakistan

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The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases

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(GHGs), and require planning to address tradeoffs and synergies between these three pillars: productivity, adaptation, and mitigation. The priorities of different countries and stakeholders are reflected in achieving more efficient, effective, and equitable food systems that address challenges in environmental, social, and economic dimensions across productive landscapes. While the concept is new, and still evolving, many of the practices that make up CSA already exist worldwide and are used by farmers to cope with various production risks. Mainstreaming CSA requires critical stocktaking of ongoing and promising practices for the future, and of institutional and financial enablers for CSA adoption. This country profile provides a snapshot of a developing baseline created to initiate discussion, both within countries and globally, about entry points for investing in CSA on scale.

ICGA-011

Management of Basal Rot Disease of Onion by Exploiting Natural Resources'

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This research work was carried out to assess the potential of five *Trichoderma* spp. and *Sisymbrium irio* dry biomass for the management of basal rot of onion caused by *Fusarium oxysporum* f. sp. *cepae* (FOC). *Trichoderma harzianum* caused the highest suppression (79%) in FOC radial growth in laboratory bioassays followed by *T. viride* (73%), *T. koningii* (71%), *T. pseudokoningii* (71%), and *T. hamatum* (69%). In pot experiment, FOC inoculated soil was amended with *T. viride*, *T. harzianum* and dry biomass of *S. irio* (DBS) for control of the disease. The highest disease incidence (97%) was recorded in the positive control treatment (FOC inoculation only). Disease incidence was significantly reduced by 85–100% over positive control in different treatments of *Trichoderma* spp. and DBS. The disease was completely controlled in *T. viride*, and *T. harzianum* + DBS treatments. Application of different soil treatments enhanced fresh yield of onion from 2.93 g in positive control to 76.96–126.93 g and dry weight from 0.55 g to 7.75–16.14 g. The highest increase was due to 3% DBS followed by 3% DBS + *T. harzianum*. Soil amendments also significantly enhanced the chlorophyll, carotenoid and protein contents. The effect of soil amendments on activities of peroxidase (POX), polyphenol oxidase (PPO) and catalase (CAT) was also studied where all the treatments significantly enhanced PPO and CAT activities over positive control. Root and stem sections stained with FeCl₃ showed an increase in phenolic substances due to different soil amendments. Soil amendments enhanced the expression of POX and PAL (phenylalanin ammonia lyase) gene over positive control. On the other hand, expression of CHI (chitinase) gene was diminished due to *T. harzianum*, *T. viride* alone or together with DBS. It concludes that the highest yield of onion in FOC infected soils can be obtained either by sole application of 3% DBS or together with *T. harzianum*.

ICGA-012

Optimizing IPM for Sustainable Cotton Farming in Changing Climate in South Punjab

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Cotton cultivation in South Punjab has undergone a significant decline in both area and productivity over the past decade. In 2014–15, cotton was grown on 5,740 acres, whereas by 2025–26 the area had shrunk to 3,126 acres. Similarly, the average yield has dropped from 23.02 maunds per acre in 2014–15 to 14.30 maunds per acre in 2024–25, with total production reduced to 3,810 bales. Among the major contributing factors, insect pests—particularly the pink bollworm (PBW), *Pectinophora gossypiella**, and the whitefly, *Bemisia tabaci**—pose the greatest threat to sustainable cotton production. PBW has developed resistance to single-gene (Cry1Ac), double-gene (Cry1Ac + Cry2Ab), and even triple-gene (Cry1Ac–Cry2Ab–EPSPS) Bt cotton varieties, while whitefly populations have become increasingly resistant to available synthetic insecticides. To address these challenges, an optimized Integrated Pest Management (IPM) approach is crucial. Yellow sticky traps are effective for monitoring and suppressing whitefly populations, with four to eight traps per acre installed approximately 60 cm above the crop canopy. For PBW, mass trapping using 12–16 pheromone traps per acre throughout the season significantly reduces male moth activity, mating frequency, and subsequent egg-laying. These trapping strategies, when integrated with two timely applications of environmentally safe bio-pesticides, offer a sustainable and resistance-minimizing alternative to conventional chemical control. The application of pyrethroids during the first three months after sowing significantly reduces beneficial fauna, which may lead to a flare-up of whitefly populations. Importantly, this IPM package does not require the introduction of new pesticide molecules or transgenic traits, making it practical, cost-effective, and fully compatible with existing seed systems and pesticide regulations. Such an approach can support long-term cotton sustainability in South Punjab.

ICGA-013

Modeling the Impact of Climate Warming on Tomato Phenology

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Climate warming is a worldwide phenomenon that impacts all sectors of life from local to global levels. Agri culture has also been severely impacted by climate warming in terms of crop phenology, productivity, and produce quality. So far research on the impact of climate warming on tomato phenology has been not published either from Pakistan or elsewhere in the world. The first objective of this study was to assess the effect of thermal trends on the temporal and spatial variation on tomato phenology from 1980 through 2023. The second objective was to apply a dynamic crop growth model, CSM-CROGRPO-Tomato, for determining the influence of climate warming, variety selection, and management practices on tomato phenology. The overall goal was to devise adaptation strategies for tomato to mitigate the potential impact of climate warming in Punjab, Pakistan. The study was conducted at 18 locations in farmers' fields in Punjab, Pakistan, from 1980 to 2023 by using observed phenological data. The results showed that at all study sites the phenological stages were delayed. There was an average delay of 7.5 days per decade for planting, 7.2 days per decade for emergence, 4.7 days per decade for anthesis, and 3.1 days per decade for maturity. The duration of phenological phases was on average reduced by 3.3 days per decade for planting-anthesis, 2.1 days per decade for anthesis-maturity, and 5.4 days per decade for planting-maturity. Local weather station observations showed that the average air temperature increased by 2.0 ° C from 1980-2023. Phenology had a statistically significant but negative correlation with the increase in temperature. Using standard cultivars across sites and years, simulated phenology was advanced due to the increase in temperature as compared to observed phenology. These findings revealed that during the last four and half decades, adaptation approaches, such as a delay in planting and growing newer varieties that require more thermal time or growing degree days, have been adopted by tomato farmers to mitigate the impact of climate warming on tomato phenology.

ICGA-014

Climate Smart Agriculture: A Way to Ensure Food Security

Dr. Jafar Jaskani

Climate Smart Agriculture (CSA) is a holistic and forward-looking approach for attaining food security in the face of an increasing climatic challenge. Changes in rainfall patterns, increased temperatures, and extended droughts interspersed with increased flooding are increasingly altering agricultural productivity in many parts of the world. Such climatic changes more strongly affect those individuals whose livelihoods depend directly on farming. Climate change affects agriculture not only at the farm level but also along the entire value chain. Reduced crop and animal productivity, together with soil and water quality degradation, disrupt food markets, raise food prices, and increase population vulnerability to food insecurity. Such vulnerability can be significantly overcome through enhancing farmers' adaptive capacity and strengthening the resilience of agricultural systems with efficient use of natural resources like water, land, and energy. CSA addresses these challenges by engaging key stakeholders-farmers, researchers, the private sector, civil society organizations, and policymakers-in coordinated and inclusive action. The approach is organized around four principal action areas. First, CSA puts emphasis on the generation and use of robust scientific and local evidence in order to better understand climate risks and to develop practical, locally appropriate solutions. Second, it focuses on strengthening the local institutions for the provision of effective support to farmers via the provision of extension services, information, and community-level governance. Third, it promotes coherence between

climate policy and agricultural policy to enable national adaptation and mitigation strategies to lead towards agricultural development objectives. Finally, it seeks to link financing between climate and agriculture in ways that allow farmers and institutions to access the investments that will propel the adoption of climate-resilient practices. Climate-smart agriculture retains particular relevance for Pakistan, which is highly vulnerable to climate-induced flooding, heat waves, and water scarcity, as well as changes in the pattern of monsoon rains. Recent climatic events in Pakistan have shown just how fragile its agricultural systems are and provide a sense of urgency toward finding resilient solutions. Climate-smart agriculture provides an opportunity for Pakistan to boost farm productivity, protect rural livelihoods, and help stabilize supplies of food.

ICGA-015

Building Climate Resilience and Ensuring Food Security Through Spate Irrigation

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Floods under the climate change threat are often considered as a menace, however it does not always stand true. Rainwater from dry mountains can be a potential source for irrigating low lying fields and getting reasonable crop production. Floods in plains through rise in level of river flow and floods originating from mountainous areas (Hill torrents / Rod Kohi) differ from each other. Speed of water flow is very high as compared to riverine floods. The irrigation technique that diverts flood water from dry mountainous areas by gravity through regulatory structures for crop cultivation in low lying farmland is referred to as spate irrigation. Currently on an average 9% of the irrigated area of Pakistan is under the system of hill torrents. Though there is a potential of increasing the area under spate irrigation up to 34%. Currently, 1.4-to-2.34-million-hectare area is under spate irrigated agriculture. Nevertheless, the potential area is approximately 7 million hectares. Three aspects must be inculcated to harvest the benefits from hill torrents i.e. Building regulatory structures, Canal maintenance and repair system and management of commanded areas of the hill torrents. There is a need to build a database of spate irrigation in the country. Currently, there is little academic research regarding key aspects of spate irrigation. Wherever feasible, spate irrigation should be augmented with judicious ground water use. Improvement in indigenous vegetables, trees and fodder should be included in research program for improving the intended benefits. There is a huge potential for developing commodity specific organic markets. Like Thal and Cholsitan Development Authorities, Rod Kohi Development Authorities on at least province level should be initially established. Research should be focused on breeding crop cultivars that can extract water from more soil depths. Research should also be focused on developing drought-tolerant crops cultivars and fruit plants like Beri and Dates. There is also a potential of planting more forest trees in spate irrigated areas which will not only recharge ground water but will also reduce land degradation and negative consequences of climate change. Low-cost drinking water technologies for humans and livestock consumption should be considered on priority basis. Engineering, social sciences and agricultural faculties of universities should incorporate spate irrigation curriculum for capacity building and preparing scientific brains for meeting future challenges. Creating awareness and coordination among all the society groups is needed. It is of utmost importance to include spate irrigated areas into national development plan. An integrated

approach unveiling all these aspects will definitely promise uplift in the socio-economic lives of the poorest of the poor farmers in the country.

ICGA-016

Unlocking Drought and Heat Tolerance Through Genomic Breeding of Wheat in Pakistan

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Wheat (*Triticum aestivum* L.) is one of the largest grain-producing crops of the world that provides one-fifth of the world's calories and protein. It plays a significant role in global food security for the establishment of world agriculture. In Pakistan, it is the cornerstone of food security and rural economy, as it is the main staple crop for over 200 million people. However, frequent changes in climatic conditions result in an increase in the frequency and intensity of drought and heat stress, which is a major limitation to crop production. It is evident in major wheat-producing regions of the country, particularly in arid and semi-arid regions such as Sindh, Balochistan, and southern Punjab. Wheat yield is significantly reduced due to changes in plant morphological, physiological, biochemical, and molecular activities in response to heat and drought stress. Numerous efforts to mitigate drought through breeding resilient varieties are underway across the world. However, progress is hampered because heat and drought tolerance are complex traits that are controlled by multiple genes, and their full expression is affected by the environment. Furthermore, wheat has a structurally intricate and large genome. Consequently, breeding for drought tolerance requires the integration of various knowledge systems and methodologies from multiple disciplines in plant sciences. Recent advances in Genomics technologies were seen as a path to understand the genetic and environmental complexity of heat and drought stress. Robust and low-cost selection tools are now available in wheat for screening genetic variations for drought tolerance traits. Genomic breeding represents a transformative approach to unlocking drought and heat tolerance in wheat. Its strategic application in Pakistan's breeding programs holds the key to building a resilient agricultural future in the face of climate uncertainty.

ICGA-017

Ameliorating Cadmium Toxicity in Agroforestry Tree Species Via Soil Amendments: Effects on Growth, Physiology and Biochemical Changes

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Cadmium (Cd) is a serious threat to our ecosystem and food chain as being one of the lethal heavy metals falling in the category of nonessential elements that is of major concern due to its longevity and highly persistent nature. The objective of this study was to determine the efficacy of different soil amendments to decrease the effects of cadmium-induced stress on, multipurpose tree species. Four versatile tree species, including *Eucalyptus camaldulensis*, *Dalbergia sissoo*, *Salix*

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tetrasperma, and *Populus deltoides* were selected. These species were grown under 50 ppm cadmium (Cd) stress and four soil amendments including farmyard manure (FYM), elemental sulphur, EDTA, and citric acid were to determine the effects of these soil amendments on plant growth, physiological performance, antioxidant enzyme activity and nutrient uptake under Cd stress. The findings revealed that Cd toxicity had more significant effect on decreasing root and shoot growth, biomass, the rate of photosynthesis, and the conductance of stomata and its concentration in the plant tissues. All soil amendments enhanced the Cd stress tolerance of plants with FYM was most effective increasing the plant biomass and antioxidant activities (SOD, CAT, POD), while citric acid and EDTA were most effective in improving ionic homeostasis (Zn, Fe, Ca, Mg content), and minimized the Cd leakage into leaves. In the principal component analysis (PCA), the relationship between growth traits and physiological responses was found to be strongly on the positive side whereas Cd accumulation was negatively related. The findings of the present study concluded that *D. sissoo* and *E. camaldulensis* are suitable tree species to grow under cadmium contaminated soils.

ICGA-018

Improving River Stage Forecast Accuracy Through Wavelet Packet Decomposition and Statistical Modeling

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Accurate river stage forecasting is essential for flood risk management and water resources planning, particularly under increasing hydroclimatic variability. This study evaluates the applicability of wavelet packet decomposition (WPD) as a preprocessing technique to enhance the performance of conventional statistical models for river stage forecasting. WPD is employed to decompose non-stationary river stage time series into multiple frequency sub-bands, allowing improved representation of both high- and low-frequency hydrological signals. These decomposed components are then used as inputs to statistical forecasting models, and their performance is compared with models developed using raw time series data. Model evaluation based on standard goodness-of-fit and error metrics demonstrates that WPD-assisted statistical models consistently outperform their non-decomposed counterparts, particularly in capturing extreme fluctuations and short-term dynamics of river stage. The results highlight the potential of integrating wavelet packet decomposition with statistical approaches to improve forecasting accuracy and robustness, offering a computationally efficient and interpretable framework for operational river stage prediction.

ICGA-019

Agricultural Biodiversity; Plant Genetic Resources Conservation for Sustainable Crop Production to Ensure Food Security

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Plant genetic resources are the progenitor of diverse plant varieties. Plant diversity is the past, present and future of the food security. The food security of the nation lies within the insurance of plant genetic resources conservation. Plant genetic resources are not only the progenitors of diverse plant varieties and but their associated genetic information, serve as the foundation for future plant breeding under the genetic laws. These resources include wild and cultivated plants with valuable traits such as stress tolerance, disease resistance, enhanced yield potential and climate proofing by combating environmental hazards by the best level of adaptability. Biodiversity contain valuable accumulation of knowledge since the emergence of living beings. As a result of changing climatic conditions, biological diversity is under threat and genetic variations and information are becoming limited. Plant breeders utilize these genetic materials to develop new varieties with improved characteristics, contributing to crop improvement and agricultural sustainability in amalgamation with ecological farming and agro forestry to safeguard balanced ecosystems. Conservation and exploration of genetic resources are crucial to ensure a robust foundation for future plant breeding efforts that translate in to nature's insurance policy. In this respect, conservation is essential part for sustainable food production.

ICGA-020

Evaluation of Chickpea On Different Farmers' Fields of Tandojam Surroundings, Subdivision Hyderabad Rural

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The study was carried out at 14 farmers' fields of Tandojam surroundings, subdivision Hyderabad (Rural). to evaluate the first-time performance of chickpea (Gram) in which chickpea variety DG-92 was tested. The field study was conducted in a three replicated randomized complete block design (RCBD) with net plot size of one acre per farmer. Fields of fourteen (14) farmers' viz (T₁ = Farmer 1, T₂ = Farmer 2, T₃ = Farmer 3, T₄ = Farmer 4, T₅ = Farmer 5, T₆ = Farmer 6, T₇ = Farmer 7, T₈ = Farmer 8, T₉ = Farmer 9, T₁₀ = Farmer 10, T₁₁ = Farmer 11, T₁₂ = Farmer 12, T₁₃= Farmer 13 and T₁₄= Farmer 14) were evaluated with chickpea variety DG-92 on various agronomical characters. The results showed that highest plant population m⁻² (32.95) was recorded from the field of (Farmer 4) and the lowest plant population m⁻² (22.89) was recorded from the field of (Farmer 10). The maximum plant height (77.23 cm) was recorded from the field of (Farmer 1) and the minimum plant height (48.63 cm) was recorded from the field of (Farmer 8). The maximum branches plant⁻¹ (21.70) were recorded from the field of (Farmer 1) and the minimum branches plant⁻¹ (7.37) were recorded from the field of (Farmer 5). The maximum pods plant⁻¹ (75.28) were recorded from the field of (Farmer 3) and the lowest pods plant⁻¹ (30.30) were observed from the field of (Farmer 8). The maximum seeds plant⁻¹ (152.37) were recorded from

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the field of (Farmer 4) and the lowest seeds plant⁻¹ (37.97) were observed from the field of (Farmer 8). The maximum seed weight plant⁻¹ (25.40 g) was observed from the field of (Farmer 4) and the minimum seeds weight plant⁻¹ (6.74 g) was observed from the field of (Farmer 8). The maximum seed index (310.42 g) was recorded from the field of (Farmer 5) and the minimum seed index (216.03) was recorded from the field of (Farmer 8). The maximum seed yield (1713.7 kg ha⁻¹) was observed from the field of (Farmer 1) and the minimum seed yield (309.0 kg ha⁻¹) was observed from the field of (Farmer 7) and the maximum biological yield (5140.9 kg ha⁻¹) was recorded from the field of (Farmer 1) and the minimum biological yield (929.8 kg ha⁻¹) was recorded from the field of (Farmer 7). It could be concluded from the studies that chickpea crop has great potential for cultivation in this belt with precautions that all recommendations from seed bed preparation to threshing and bagging should be applied properly and timely. These studies has a significant adventure that we introduced a new crop in this area which has never been cultivated before.

ICGA-021

Integrated Smart Agricultural Technologies for Sustainable Crop Production Under Resource-Constrained Farming Systems

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Sustainable crop production in developing regions is increasingly challenged by labor scarcity, inefficient input use, climate variability, and limited access to modern technologies. This research presents a portfolio of indigenous, integrated agricultural innovations spanning crop establishment, mechanization, water and nutrient management, precision protection, and artificial intelligence-based decision support. The developed technologies include mechanized bud-node planting systems, precision planting and intercropping tools, sustainable irrigation and soil-moisture management solutions, smart nutrient delivery mechanisms, and energy-efficient field machinery, supported by AI-enabled monitoring for crop growth and physiological maturity assessment. Field validation demonstrated significant improvements in crop establishment, input-use efficiency, early vigor, resource conservation, and overall productivity, while substantially reducing labor dependence and production costs. Also working on AI-assisted sensing enhanced decision accuracy for irrigation scheduling, pesticide application, and harvest timing, leading to improved yield quality and environmental sustainability. These innovations collectively bridge the gap between traditional farming practices and precision agriculture by offering scalable, cost-effective, and farmer-centric solutions. The integrated approach supports climate resilience, promotes rural entrepreneurship, and provides a replicable model for sustainable intensification across diverse cropping systems, contributing to long-term food security and livelihood improvement.

ICGA-022

Regenerative Agriculture as A Harnessing Option for Climate Resilience and Food Security in Pakistan

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Regenerative agriculture presents Pakistan with a robust strategy to enhance climate resilience and secure long-term food supplies. By emphasizing soil health through techniques such as minimum

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tillage, crop diversification, organic amendments, agroforestry, and efficient water management, regenerative practices improve the land's capacity to retain moisture, prevent erosion, and withstand climate disruptions like droughts and heatwaves. These approaches also increase carbon sequestration, promote biodiversity, and reduce dependence on costly chemical inputs—making farming more sustainable and profitable, especially for small-scale farmers. In a nation severely impacted by climate change, regenerative agriculture offers a practical, locally adaptable, and economically viable solution to sustain agricultural productivity and develop a resilient, climate-smart food system for the future. We applied regenerative agricultural practices in cotton on 11000 acres at farmer's field in Bahawalpur and 5000 acres in rice under Gujranwala conditions and found that through these practices, we reduced the use of chemical fertilizer, pesticide, water use, input cost reduction and increased yield, 20, 50, 30, 50 and 20% in cotton, 20, 29, 40, 26, and 30%, in rice respectively.

ICGA-023

Optimization of Inorganic Nitrogen Source on Wheat Growth and Useful Soil Microbiome Dynamics- A Way Towards Climate Smart Agriculture

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Optimizing inorganic nitrogen (N) sources is critical for improving wheat productivity while minimizing environmental footprints under climate-smart agriculture frameworks. This study evaluated the effects of different inorganic nitrogen sources on wheat growth, yield-related traits, and associated soil microbiome dynamics. Field experiments were conducted using commonly applied N fertilizers differing in chemical form and release characteristics, arranged in a randomized complete block design with replicated treatments. Wheat growth parameters, biomass accumulation, and yield components were recorded alongside soil physicochemical properties. Soil microbial abundance, diversity, and functional groups involved in nitrogen cycling were assessed to elucidate fertilizer-induced shifts in the soil microbiome. Results demonstrated that nitrogen source significantly influenced wheat growth and soil biological activity. Balanced and efficiently available N sources improved plant vigor, biomass, and yield attributes, while also promoting beneficial microbial populations linked to nitrogen mineralization and nutrient-use efficiency. In contrast, less efficient N sources resulted in weaker crop responses and reduced microbial functional diversity. The findings highlight that strategic selection of inorganic nitrogen sources can simultaneously enhance wheat performance and sustain a beneficial soil microbiome. This integrated nutrient–microbe approach offers a practical pathway toward climate-smart wheat production by improving nitrogen-use efficiency and reducing potential environmental losses.

ICGA-024

Polymer Based Heterogeneous Catalysts for Sustainable Multicomponent Reactions

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Multicomponent reactions (MCRs) are pivotal in synthetic organic chemistry, offering efficient pathways for the construction of diverse compound libraries in a one-pot synthesis. Among these,

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the Biginelli reaction stands out, facilitating the synthesis of biologically active dihydropyrimidin(thio)ones (DHPMs) through the reaction of aldehydes, β -ketoesters, and (thio)urea. These DHPMs exhibit significant biological properties, including calcium ion channel modulation and enzyme inhibition. The search for efficient, recoverable, and environmentally friendly catalysts has positioned heterogeneous biopolymer-based catalysts as a promising solution. Biopolymers are abundant, cost-effective, biodegradable, and sustainable, making them ideal candidates for green chemistry applications. In this study, various biopolymer-supported catalysts were synthesized using hemicellulose derived from *gond katira* and *ispaghula* husk as solid supports for metal ions. Among these, a catalyst composed of sodium alginate and divalent nickel ions demonstrated exceptional performance in promoting the Biginelli reaction. Characterization techniques, including FTIR, SEM, and EDAX, revealed a highly porous surface structure conducive to catalytic activity. The synthesized catalysts exhibited excellent recoverability and reusability, highlighting their potential for sustainable multicomponent synthesis.

ICGA-025

Integrating Allelopathy into Modern Weed Management: A Pathway to Sustainable Agriculture in Pakistan

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Weeds present a major constraint to agricultural productivity and food security in Pakistan by competing with crops for essential resources such as light, water, and nutrients, and by acting as hosts for pests and diseases. Plants naturally interact with neighbouring species through biochemical mechanisms, a process known as allelopathy, in which they release compounds that influence the growth and survival of other plants. This natural phenomenon has emerged as a practical and eco-friendly approach in modern agriculture. Allelochemicals released into the rhizosphere enhance nutrient availability through solubilization, biological nitrification inhibition, chelation, and selective nutrient retention. At low concentrations these compounds promote plant growth, but at higher levels they may suppress it. Despite its ancient recognition, allelopathy has gained significant relevance in contemporary weed management due to increasing challenges such as herbicide resistance, climate change, and ineffective traditional control methods. In Pakistan, reliance on manual weeding and chemical herbicides is becoming increasingly unsustainable because of rising labour costs, environmental concerns, and the evolution of resistant weed biotypes. This highlights the urgent need for sustainable and integrated weed management strategies. Integrated Weed Management (IWM) provides a comprehensive framework that incorporates allelopathy alongside crop rotation, cover cropping, precision agriculture, and the development of herbicide-resistant varieties. These approaches focus on reducing dependency on synthetic chemicals while supporting ecological stability. Successful adoption of IWM requires farmer awareness, supportive policy measures, and greater investment in agricultural research. By integrating allelopathy-based practices within IWM, Pakistan can reduce crop losses, improve productivity, and contribute to national food security. Sustainable weed management is therefore not only critical for current agricultural performance but also essential for ensuring long-term food stability in the country.

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ICGA-026

Green Chemistry: Innovations, Trends, and Future Directions

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With the growing awareness of safety, health, and environmental risks associated with conventional chemical processes and products, green chemistry has emerged as a transformative framework for innovation in modern chemical science. It now exerts a significant influence across chemistry, chemical engineering, and related disciplines, including natural product chemistry. A major focus of contemporary green chemistry research is the replacement of hazardous volatile organic solvents with safer and more sustainable alternatives, particularly in the extraction and processing of plant-derived bioactive compounds. Increasing attention is being directed toward the use of water and other benign solvent systems for the extraction of phenolics, flavonoids, antioxidants, and other value-added natural products from plants and biological matrices, as well as for environmentally responsible organic synthesis. In parallel, the design and application of novel green solvents, such as ionic liquids (ILs) and deep eutectic solvents (DESs), have emerged as powerful tools for enhancing the extraction efficiency, selectivity, and stability of natural bioactives. Solvent-free extraction strategies and reactions represent another rapidly advancing area, offering significant reductions in solvent consumption and chemical waste. Furthermore, greener enabling technologies, including microwave- and ultrasound-assisted extraction and synthesis, along with solvent-free mechanochemical approaches, are being actively explored as sustainable alternatives to environmentally hazardous conventional techniques. Innovations in green chemistry are essential for achieving environmental sustainability while simultaneously improving efficiency, cost-effectiveness, and safety in natural product research and processing. This talk will highlight selected emerging research directions at the interface of green chemistry and natural product chemistry, with the aim of inspiring young chemists to engage with this rapidly evolving and impactful field.

ICGA-027

Deep Eutectic Solvents as Green Media for Sustainable Synthesis of Bioactive Molecules Toward Environmentally Responsible Chemical Production

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Deep Eutectic Solvents (DES) can be considered as a special class of ionic liquids (ILs). The extensive hydrogen bonded network found in the DES, formed as a result of non-covalent interactions typically between a hydrogen bond donor and an acceptor, is responsible for the formation of a eutectic mixture. The melting point of such eutectic mixtures (DES) are much lower than that of the parent compounds. DES can be easily synthesized in a variety of ways and in many ways can be considered as “designer solvents” that can be tailor-made for highly specific applications. Natural Deep Eutectic Solvents (NDES) are made from naturally occurring non-toxic, biodegradable compounds. Certain inherent properties of DES such as low vapour pressure, high thermal stability, miscibility in water, non-toxic nature make them ideal solvents to replace traditional organic solvents in a multitude of synthetic applications. Moreover, their recoverability

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and reusability render them especially attractive for advancing the United Nations' Sustainable Development Goals (SDGs) and promoting environmentally responsible synthesis. Because of their excellent solubility profile, most of the water insoluble agrochemicals can be dissolved in DES, formulated, and then sprayed where needed. Upon contact with water, the DES will dissolve, releasing the agrochemical in a finely dispersed form. The non-toxic and biodegradable DES will not harm the environment and serve as an efficient tool for safe delivery of agrochemicals.

ICGA-028

Integration of Legume-Oil Seed Crops Intercropping into Climate-Smart Agriculture for Sustainable Crop Production

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Global food security is under a significant threat due to climate change and global warming because it is characterized by an escalation of heat stress, rise in the occurrence of droughts, unpredictable rainfall cycles, and sustained soil erosion, especially in arid and semi-arid agroecosystems. The Climate-Smart Agriculture (CSA) has become a unified scheme that targets to improve the crop productivity and make the crops resistant to the climate stresses as well as to curb greenhouse gases emission. In this context, intercropping as the concomitant growth of two or more crops on a unit of land is one of the climate-smart techniques since it allows maximization of resource utilization based on spatial and temporal complements. Of major significance are the legume-oil seed inter-culture systems, which combine effective fixation of nitrogen biological processes with efficient use of nutrient and water, hence enhancing soil fertility, productivity and sustainability. Optimized planting geometry is important in order to maximize the performance of intercropping through controlling the plant population density and spatial locations, increasing the light interception, canopy microclimate, rooting relations and nutrient acquisition. Empirical observation suggests that legume-oilseed intercrops with proper planting geometry result in a higher land productivity, yield stability, and water and nutrient-use efficiency compared to sole cropping, and has been represented as being greater than unity. Moreover, these systems improve soil organic carbon, functional biodiversity, pest and disease suppression, and reliance on synthetic fertilizers and chemicals, and this helps in mitigating climate change by sequestration of carbon and reducing greenhouse gas emissions. All in all, the legume-oilseed intercropping with optimal planting geometry is a scientifically sound, low-input, and climatically resilient strategy, which in many ways aligns with CSA goals and provides a sustainable way of enhancing productivity, resource use, and agro-food system resilience to changing climatic conditions.

ICGA-029

Advances in Food and Nutrition Science: Integrating Health, Innovation, And Sustainable Food Systems

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Recent developments in food and nutrition science have uncovered complex interactions between diet, metabolism, and overall human health, with a growing emphasis on disease prevention and long-term well-being. Contemporary research highlights the health benefits of plant-based diets and whole foods rich in dietary fiber, essential vitamins, and natural antioxidants, which significantly reduce the risk of chronic diseases. Functional foods enriched with probiotics, omega-3 fatty acids, and other bioactive compounds are gaining attention for their role in enhancing gut health and immune function. Progress in food technology and biotechnology has enabled the emergence of precision nutrition, allowing dietary recommendations to be tailored according to individual genetic and metabolic profiles. In parallel, the development of sustainable food systems has become a global priority, focusing on waste minimization, soil health restoration, and eco-friendly production practices. Alternative protein sources, including plant-based, insect-derived, and cell-cultured proteins, are increasingly recognized as viable substitutes for conventional animal products. Additionally, biofortification and nutrient enhancement strategies are being explored to combat micronutrient deficiencies and hidden hunger. Public awareness initiatives and nutrition education remain critical for promoting healthier dietary behaviors. Overall, current research underscores the necessity of integrating scientific innovation, sustainability, and technology to achieve global nutrition and food security.

ICGA-030

Agro Physiological Response of Okra Genotypes Cultivated Under Water Stress and Normal Irrigation Conditions

Syed Jawad Khan and Syed Majid Rasheed

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An experiment was carried out at Bacha Khan University Agriculture Research Farm during 2023-2024. Sowing of three different okra genotypes was carried out in spring and summer season. For irrigation treatments, the experimental plot was split into three separate plots. The results of study revealed significant differences among the genotypes for all traits except for pod length and seeds per pod. Irrigation treatment revealed significant differences for days to flowering, internode length, internode per plant and pod diameter. Genotype x treatment revealed significant differences for pod length only, whereas significance among genotype x season interaction was revealed for days to flowering, pod length, pod length and pod weight. Minimum days to flowering (49) was attained by Sada Bahar, maximum fruit length and fruit diameter was evident for Swat green (9.1 cm) and Sada Bahar (1.53 cm), respectively. Sada bahar also revealed maximum fruit weight of 16.14g. Minimum internode length was observed in Sabzpari (5.04 cm), Optimum plant height

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(76cm), primary branches (2), seeds per pod (46) across all treatment and seasons was evident for Sada Bahar. The PCV and GCV values were low for days to flowering, internode length and seeds per pod, whereas the other parameters revealed high PCV and GCV values. The heritability estimates of different parameters ranged from 3.81% (days to flowering) to 78.8 % (internode length). High genetic advance was observed for internode length, pod weight and pod length revealed moderate genetic advance whereas other traits revealed low genetic advance. Thus from above study it could be concluded that the performance of SADA BAHAR is relatively better from other genotypes in its performance across the irrigation treatment and season for different parameters and could be adopted for varietal selection under limited irrigation.

ICGA-031

Low-Temperature Urea–Koh Pretreatment of Sugarcane Bagasse for Biorefinery Applications

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A simple and eco-friendly pretreatment method was developed to improve the utilization of sugarcane bagasse for biorefinery applications. In this study, sugarcane bagasse was pretreated using a combined urea and potassium hydroxide (UK) system at low temperature, optimized using response surface methodology. Unlike conventional alkaline pretreatments that require large amounts of water and washing steps, this method was carried out without washing, reducing water use and liquid waste. Under the optimal condition (–20 °C and 7.5 % UK), lignin and hemicellulose were effectively removed, while cellulose content significantly increased compared to untreated biomass. As a result, enzymatic hydrolysis efficiency improved more than three times. Structural analysis showed that urea helped open the fiber structure, reduced cellulose crystallinity, and prevented lignin from re-depositing on cellulose surfaces. Overall, the wash-free UK pretreatment is a promising and sustainable approach for lignocellulosic biomass valorization and biorefinery processes.

ICGA-032

Nutrients Uptake and Growth Efficacy of Onion Can Be Improved Through Climate Smart Technology of Rock Phosphate Enriched Vermicompost Under the Changing Climate

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The climate smart technology of vermicomposting can be adopted as a cost-effective for improving P mineralization from rock phosphate (RP) and increasing soil-plant health. The current study was conducted to convert the RP blended degradable organic wastes into phosphorus (P) rich vermicompost through earthworms and phosphate solubilizing microbes (PSMs) and assessed its role on onion growth and soil health. Three types of RP enriched vermicomposts were produced by mixing of powdered RP with biodegradable wastes in the presence of earthworms and PSMs in vermi-boxes, pits and piles. The efficiency of each vermicompost was evaluated on onion growth

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and nutrients uptake in a pot trial. Then, the most efficient vermicompost selected for pot trial was further assessed on onion growth parameters and soil health under field conditions. The results expressed that under pot trial, half fertilization of RP enriched vermicompost together with half doses of inorganic fertilizers (Urea, SSP, SOP) significantly enhanced the post-harvest shoot biomass (17.66 g pot⁻¹), bulb weight (94.65 g pot⁻¹), plants height (34.33 cm) as well as N (242.33 mg pot⁻¹) and P (20.06 mg pot⁻¹) uptake by onion as compared to control. Similarly, compared to sole RP vermicompost, the N and P uptake, shoot dry biomass, height and bulb weight of onion plants under field conditions were also significantly improved by the treatments supplemented with half doses of both inorganic fertilizers and RP enriched vermicompost. The current experiments concluded that half dose of RP enriched vermicompost in combination with half inorganic fertilizers has great potential to improve soil health, nutrients uptake, and growth parameters of onion under pot and field conditions. The RP enriched vermicompost can be used as a cost-effective and climate smart strategy to increase vegetable growth and minimize the usage of chemical fertilizers in alkaline calcareous soils.

ICGA-033

Agro Physiological Response of Okra Genotypes Cultivated Under Water Stress and Normal Irrigation Conditions

Syed Jawad Khan and Syed Majid Rasheed

This experiment titled “Agro physiological response of okra genotypes cultivated under water stress and normal irrigation conditions” was carried out at Bacha Khan University Agriculture Research Farm during 2023-2024. Sowing of three different okra genotypes was carried out in spring and summer season. For irrigation treatments, the experimental plot was split into three separate plots. The results of study revealed significant differences among the genotypes for all traits except for pod length and seeds per pod. Irrigation treatment revealed significant differences for days to flowering, internode length, internode per plant and pod diameter. Genotype x treatment revealed significant differences for pod length only, whereas significance among genotype x season interaction was revealed for days to flowering, pod length, pod length and pod weight. Minimum days to flowering (49) was attained by Sada Bahar, maximum fruit length and fruit diameter was evident for Swat green (9.1 cm) and Sada Bahar (1.53 cm), respectively. Sada bahar also revealed maximum fruit weight of 16.14g. Minimum internode length was observed in Sabzpari (5.04 cm), Optimum plant height (76cm), primary branches (2), seeds per pod (46) across all treatment and seasons was evident for Sada Bahar. The PCV and GCV values were low for days to flowering, internode length and seeds per pod, whereas the other parameters revealed high PCV and GCV values. The heritability estimates of different parameters ranged from 3.81% (days to flowering) to 78.8 % (internode length). High genetic advance was observed for internode length, pod weight and pod length revealed moderate genetic advance whereas other traits revealed low genetic advance. Thus from above study it could be concluded that the performance of SADA BAHAR is relatively better from other genotypes in its performance across the irrigation treatment and season for different parameters and could be adopted for varietal selection under limited irrigation.

ICGA-034

Yield Estimation of Wheat at Critical Stages Using Normalized Difference Vegetation Index Technique

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Spectral reflectance and remote sensing techniques offer rapid, non-destructive approaches for assessing crop growth and productivity under varying nutrient conditions. This study evaluated the potential of vegetation indices, particularly the Normalized Difference Vegetation Index (NDVI), for estimating biomass, leaf area index (LAI), and grain yield of wheat under different nitrogen regimes. The experiment was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, using a randomized complete block design with a split-plot arrangement and three replications. Ten wheat genotypes were evaluated under four nitrogen levels (0, 55, 110, and 220 kg ha⁻¹). Spectral reflectance was measured using a GreenSeeker Hand Held™ optical sensor, and NDVI, total dry matter (TDM) and grain yield were recorded at key growth stages from tillering to maturity. Results revealed significant genotypic variation in NDVI across nitrogen levels. NDVI showed strong correlations with grain yield at later growth stages, explaining 64–77% of yield variation under nitrogen stress, while 70–90% of biomass variation was accounted for by NDVI. Positive relationships were also observed between NDVI and LAI, particularly at booting and grain filling stages. Among all stages, NDVI at grain filling emerged as the most reliable predictor of yield. Overall, NDVI proved to be a more precise indicator of biomass than yield. The findings demonstrate that NDVI is an effective tool for differentiating wheat genotypes under nitrogen stress and holds significant potential for enhancing precision agriculture and nutrient stress management.

ICGA-035

Intercropping as A Strategy to Improve Land Use Efficiency, Soil Fertility, and Crop Yield

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To achieve sustainable food production, effective land utilization is critical especially in the context of a growing population of the world and global climate changes. Intercropping two or more crops planted simultaneously on a common unit of land is efficient in land use, using complementary relations between canopy structure, root architecture, and nutrient needs, and often with land equivalent ratios (LER) above unity, then in mono-cropping. These advantages are further enhanced by optimized planting geometry that helps to control plant density and row spacing layout, enhance light interception and nutrient uptake and interspecific interaction. Intercrops of legumes are also involved in biological fixation of nitrogen to the soil and diversified systems of crop rotation also prevents pests and disease outbreaks by reducing the reliance on chemical fertilizers. Intercropping together with planned spatial layouts promote resource-use

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efficiency, resource stability and agro-ecosystems resilience in support of both ecological and economic sustainability. Intercropping is a low input, climate resistant and sustainable method of land productivity maximization and the development of resilient agricultural systems in the face of variable environmental conditions through the integration of crop diversity, spatial optimization and management of soil fertilities.

ICGA-036

Optimizing Nursery Age for Transplanted Cotton to Sustain the Cotton–Wheat Cropping System Under Climate Stress

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The cotton–wheat cropping system is a major production system of southern Punjab and Sindh, Pakistan, but is increasingly constrained by climate change–induced temperature stress, erratic rainfall, and pest pressure. Early cotton sowing enhances yield but is impractical due to overlap with wheat harvest. Transplanting nursery-raised cotton seedlings was evaluated as an alternative strategy to sustain system productivity. Six cotton genotypes were assessed at three nursery ages (20, 30, and 40 days) for seedling vigor and root development traits under a completely randomized factorial design with four replications. Key parameters included germination attributes, seedling growth, biomass partitioning, root architecture, leaf traits, and chlorophyll index. Results showed that 30- and 40-day-old seedlings exhibited significantly higher vigor index, root length, biomass accumulation, and root-to-shoot ratio compared to 20-day-old seedlings. Cultivars FH-333 and Cyto-2023 consistently outperformed others across most traits. The study concludes that transplanting 30–40-day-old cotton seedlings is an effective approach to improve cotton yield and overall productivity of the cotton–wheat cropping system under changing climatic conditions.

ICGA-037

Sustainable Crop Rotations with Dry-Out Periods for Physical Suppression of Purple Nutsedge in Cotton–Wheat Systems

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Purple nutsedge (*Cyperus rotundus* L.) is among the most destructive perennial weeds in cotton-based cropping systems, severely reducing productivity and increasing reliance on herbicides. A three-year field study (2018–2020) was conducted to evaluate the effectiveness of diversified crop rotations incorporating dry-out (fallow tillage) periods as a sustainable weed management strategy under a cotton–wheat system. The experiment was laid out in a randomized complete block design with a split-plot arrangement, where cotton, maize, sunflower, and mungbean were grown as rotational crops, with herbicide application and weedy check as sub-plot treatments. Results revealed that *C. rotundus* infestation was highest in continuous cotton fields, while sunflower- and maize-based rotations significantly reduced tuber density, shoot biomass, and weed persistence. Dry-out periods played a critical role by desiccating underground tubers, resulting in lower weed pressure and improved cotton performance in the third year. The integration of crop rotation and

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dry-out tillage significantly enhanced cotton yield while reducing dependence on chemical weed control. These findings demonstrate that ecologically based crop rotations can serve as a viable green agriculture strategy for sustainable weed management and future crop productivity.

ICGA-038

Integrated Use of Crop Rotation and Reduced Herbicide Application for Improved Weed Management and Crop Productivity

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Excessive reliance on herbicides for weed control threatens environmental sustainability and crop system resilience. This study assessed the combined effects of crop rotation and selective herbicide use on purple nutsedge (*Cyperus rotundus* L.) suppression and crop productivity under a cotton–wheat cropping system. Field experiments were conducted over three consecutive years using a split-plot RCBD, where crop rotations (cotton, maize, sunflower, and mungbean) were assigned to main plots and herbicide treatments to sub-plots. Herbicide application significantly reduced weed density and biomass compared to weedy checks; however, its effectiveness was markedly enhanced when combined with sunflower- and maize-based rotations. Improved growth traits, including leaf area, chlorophyll content, and biomass accumulation, were observed in all crops under integrated management. Cotton yield increased substantially in fields previously subjected to dry-out periods and diversified rotations. The study highlights that judicious herbicide use integrated with rotational cropping can reduce chemical inputs while maintaining high productivity. This approach aligns with green agriculture principles by promoting environmentally responsible weed management and sustainable intensification.

ICGA-039

Allelopathic Effect of Wild Oat On Growth, Yield and Economic Outcome of Wheat in Controlled and Field Environment

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Weeds interfere with crops by releasing secondary metabolites into soil and aerial environments to inhibit normal growth and development of crops. Wild oat (*Avena fatua*) is considered one of the most important weeds of wheat with potent allelochemicals. This experiment was planned to evaluate the phytotoxic as well as growth promotive allelopathic effect of wild oat extract on the germination and growth of wheat in laboratory as well as in field conditions. Wheat seeds were subjected to wild oat extract under eleven different extract concentrations ranging between 0% and

10% (w/v). The results suggested that in laboratory bioassay, parameters of wheat (germination index, final germination %, energy of germination, seed vigor index, root length, and shoot length) were affected positively at a lower concentration of 0.05% of wild oat extract, whereas the negative effect was recorded by a gradual increase in wild oat aqueous extract concentration from 0.1 to 10% as compared with control treatment. In field conditions, leaf area index, crop growth rate, yield and yield components of wheat were also affected significantly by wild oat extract with growth promotive effect at lower concentration of 0.05% and phytotoxic effect at higher extract concentrations (0.1-10%). Moreover, the lower wild oat extract concentration (0.05%) produced the highest net benefits from wheat, while the minimum net return was observed at higher extract concentration (10%). In conclusion, wild oat extract improved the germination, growth and yield of wheat at lower concentration and inhibited the growth and development of wheat when the concentration was increased.

ICGA-040

Polymer Based Heterogeneous Catalysts for Sustainable Multicomponent Reactions

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Multicomponent reactions (MCRs) are pivotal in synthetic organic chemistry, offering efficient pathways for the construction of diverse compound libraries in a one-pot synthesis. Among these, the Biginelli reaction stands out, facilitating the synthesis of biologically active dihydropyrimidin(thio)ones (DHPMs) through the reaction of aldehydes, β -ketoesters, and (thio)urea. These DHPMs exhibit significant biological properties, including calcium ion channel modulation and enzyme inhibition. The search for efficient, recoverable, and environmentally friendly catalysts has positioned heterogeneous biopolymer-based catalysts as a promising solution. Biopolymers are abundant, cost-effective, biodegradable, and sustainable, making them ideal candidates for green chemistry applications. In this study, various biopolymer-supported catalysts were synthesized using hemicellulose derived from gond katira and ispaghula husk as solid supports for metal ions. Among these, a catalyst composed of sodium alginate and divalent nickel ions demonstrated exceptional performance in promoting the Biginelli reaction. Characterization techniques, including FTIR, SEM, and EDAX, revealed a highly porous surface structure conducive to catalytic activity. The synthesized catalysts exhibited excellent recoverability and reusability, highlighting their potential for sustainable multicomponent synthesis.

ICGA-041

Unraveling Cotton Performance Under Water Deficit Stress in Changing Climate: Morpho-Physiological Insights

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Climate change has become a global argument for cotton due to rising temperatures and low rainfall, resulting in water shortages and decreased yields. On the global level, climate change has become a severe and immediate concern, with far-reaching effects on agricultural productivity and on the demand for water and energy. The present pot study was conducted to evaluate the adverse effects on morphophysiological performance of cotton under water-deficit conditions. Three different stress levels, such as control (100% FC), mild water stress (80% FC), semi-moderate water stress (60% FC), moderate water stress (40% FC) and severe water stress (20% FC) conditions were applied by using one of the latest cotton variety (NIAB- 878). The randomized completed block design with three replications was used during the course of study. The stress levels were applied after the completion of germination of crop. Water deficiency is causing a serious decrease in the yield and quality of field crops worldwide. The plant was grown to maturity, and the following parameters were measured from 0 to 56 days after water stress application. The data on morphological, physiological, and yield components were recorded using a standard procedure. Plant height, number of nodes, total biomass, total retained bolls, and open bolls showed significant differences among treatments and declined with increasing stress severity. Even though stem elongation and photosynthesis rates declined linearly with increasing water deficit, the decline in vegetative growth was steeper than that in gas exchange processes. Cell membrane thermostability and chlorophyll stability indices showed significant differences ($P = 0.014$ and $P = 0.001$, respectively) among the control, moderately, and severely water-stressed treatments.

ICGA-042

Status and Distribution of Viral Pathogens Affecting Tobacco (*Nicotiana tabacum* L.) In The Dera Ghazi Khan Region, Pakistan

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Tobacco (*Nicotiana tabacum* L.) is an economically important cash crop in southern Punjab, Pakistan; however, its productivity is increasingly threatened by viral pathogens. The present study was conducted to assess the status, prevalence, and field distribution of major viral diseases affecting tobacco crops in the Dera Ghazi Khan region. Extensive field surveys were carried out during the cropping season across major tobacco-growing areas, and plants exhibiting typical viral symptoms such as mosaic patterns, leaf curling, chlorosis, vein clearing, and stunted growth were documented. Disease incidence and severity were recorded, and representative symptomatic samples were collected for laboratory confirmation using serological and molecular diagnostic approaches. The results revealed a widespread occurrence of viral infections, with Tobacco mosaic virus (TMV), Cucumber mosaic virus (CMV), and begomovirus-like symptoms being predominant across surveyed locations. Disease incidence varied among fields, likely influenced

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by agronomic practices, vector population dynamics, and environmental conditions. Viral infections were found to significantly affect plant vigor and leaf quality, ultimately posing a serious threat to tobacco yield and economic returns for farmers in the region. This study provides the first comprehensive overview of tobacco viral diseases in Dera Ghazi Khan and highlights the urgent need for integrated disease management strategies, including vector control, use of virus-free planting material, and farmer awareness programs. The findings will contribute to improved disease surveillance and sustainable tobacco production in arid and semi-arid agro-ecological zones of Pakistan.

ICGA-043

Advances in Food and Nutrition Science: Integrating Health, Innovation, And Sustainable Food Systems

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Recent developments in food and nutrition science have uncovered complex interactions between diet, metabolism, and overall human health, with a growing emphasis on disease prevention and long-term well-being. Contemporary research highlights the health benefits of plant-based diets and whole foods rich in dietary fiber, essential vitamins, and natural antioxidants, which significantly reduce the risk of chronic diseases. Functional foods enriched with probiotics, omega-3 fatty acids, and other bioactive compounds are gaining attention for their role in enhancing gut health and immune function. Progress in food technology and biotechnology has enabled the emergence of precision nutrition, allowing dietary recommendations to be tailored according to individual genetic and metabolic profiles. In parallel, the development of sustainable food systems has become a global priority, focusing on waste minimization, soil health restoration, and eco-friendly production practices. Alternative protein sources, including plant-based, insect-derived, and cell-cultured proteins, are increasingly recognized as viable substitutes for conventional animal products. Additionally, biofortification and nutrient enhancement strategies are being explored to combat micronutrient deficiencies and hidden hunger. Public awareness initiatives and nutrition education remain critical for promoting healthier dietary behaviors. Overall, current research underscores the necessity of integrating scientific innovation, sustainability, and technology to achieve global nutrition and food security.

ICGA-044

Soil Health: Management Strategies for Sustainable Agroecosystems

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Soil health is a foundational component of sustainable agroecosystems, directly influencing crop productivity, environmental quality, and ecosystem resilience. Defined as the capacity of soil to function as a living system, soil health emerges from the dynamic interactions among physical,

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chemical, and biological processes. This paper reviews key soil health management strategies that enhance these processes and promote long-term sustainability in agricultural systems. Emphasis is placed on practices such as maintaining soil cover, minimizing soil disturbance, diversifying cropping systems, sustaining continuous living roots, and integrating livestock. These strategies improve soil structure, nutrient cycling, organic matter dynamics, and biological activity, thereby increasing water infiltration, reducing erosion, and enhancing resistance to climatic stresses. Evidence from existing literature indicates that soil health-centered management not only sustains crop yields but also improves resource-use efficiency and environmental stewardship. The synthesis highlights soil health management as a practical and science-based framework for developing resilient agroecosystems capable of meeting future food security and sustainability challenges.

ICGA-045

Investigating The Behaviour of Nucleic Acid Based Nanoparticles in Plants for Next Generation Crop Protection

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The major challenges of climate change, pesticide resistance, and the urgent need for sustainable agriculture have pushed conventional crop protection strategies to their limits. Nucleic acid-based nanoparticles (NANPs), particularly those formulated with DNA or RNA nanostructures, are emerging as a transformative technology for next-generation plant protection due to their non-toxicity, biocompatibility, and ability to cross biological barriers in plants. This work introduces an innovative class of stimuli-responsive nucleic acid nanoparticles engineered to deliver double-stranded RNA (dsRNA), small interfering RNA (siRNA), or artificial microRNAs (amiRNAs) with precision in crop species. Unlike traditional naked RNA spray face rapid environmental degradation (short shelf life) and poor cellular uptake, our NANPs are protected by layered DNA origami shields functionalized with pH-sensitive linkers and leaf-surface adhesion peptides. These smart carriers remain stable during foliar application but disassemble exclusively inside phloem or mesophyll cells upon sensing the slightly alkaline plant cell environment (pH 7.2–7.8), thereby achieving triggered and protected RNA release. Study demonstrate, for the first time, systemic and transgenerational silencing of harmful insects pest and pathogen target genes, (acetyl-CoA carboxylase of aphids, β -glucuronidase of *Pseudomonas syringae*, and coat protein of potyviruses), in tomato, soybean, and maize using a single low-dose application (<5 μ g/plant). The lab and field Bioassays revealed >90% target gene knockdown prolonged up to 45 days, significantly outperforming commercial liposome or clay-based RNA formulations. Moreover, the DNA origami backbone itself acts as an immunostimulatory motif that primes salicylic acid and jasmonic acid pathways, conferring broad-spectrum resistance without genetic modification of the host genome. Toxicity profiling in non-target organisms (honeybees, ladybugs, and soil nematodes) and environmental fate studies confirmed rapid biodegradation within 72 hours and negligible off-target effects. These findings establish stimuli-responsive nucleic acid nanoparticles as a safe, potent, and fully biodegradable alternative to chemical pesticides, paving the way for RNA-based precision agriculture that is compatible with organic farming standards and global food security goals.

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ICGA-046

The Calcium-Biological Bridge: Framework for Soil Organic Carbon Stabilization

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Soil organic carbon (SOC) is the largest terrestrial carbon reservoir, yet mechanisms driving its long-term stability are incompletely represented in predictive models. This is particularly true for the calcareous soils, which cover around one third of the ice-free Earth's land and are known for high pH and abundance in calcium (Ca²⁺). Existing frameworks such as Microbial Efficiency-Matrix Stabilization (MEMS) and the Microbial Carbon Pump (MCP) have improved our SOC dynamics understanding. But they were largely developed for the non-calcareous soils and fail to fully integrate the unique chemistry of carbonate rich environments. Here, we synthesize emerging evidence to propose the "Calcium-Biological Bridge" (CBB) framework. This novel model proposes that SOC persistence in calcareous soils arises from interaction between the two bridges including Biological Bridge which represents microbial processing of the carbon into stabilizable necromass, and the Calcium Bridge represents the set of physicochemical mechanisms that protect this carbon. We evaluate how Ca²⁺ influences microbial carbon use efficiency, necromass composition and community structure, while simultaneously working on stabilization pathways via cation bridging, aggregation, and organo-carbonate co-precipitation. By integrating the biological and geochemical processes, the CBB framework fills the critical gap in our predictive understanding. It also offers new insights for managing the calcareous soils as carbon sink and suggests the future research to refine Earth system models.

ICGA-047

Non-Chemical Suppression of Purple Nutsedge Through Tuber Burial Depth and Deficit Irrigation Strategies

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Physical and water-based management practices offer promising alternatives to chemical weed control in sustainable agriculture. A controlled pot experiment was conducted to investigate the effects of tuber burial depth and deficit irrigation on the emergence and growth of purple nutsedge (*Cyperus rotundus* L.). The experiment followed a completely randomized factorial design with four burial depths (4, 8, 12, and 16 cm) and three irrigation regimes (light, medium, and frequent). Emergence traits, shoot and root biomass, tuber density, and growth indices were recorded. Results indicated that increasing burial depth significantly delayed emergence and reduced shoot and tuber development, with maximum suppression observed at 16 cm depth. Deficit (light) irrigation further constrained weed growth by limiting moisture availability for tuber sprouting. The combined effect of deep burial and reduced irrigation resulted in the lowest weed emergence and biomass production. These findings confirm that physical soil manipulation and optimized water

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management can effectively suppress *C. rotundus* without chemical inputs. Such non-chemical approaches are vital components of green agriculture, supporting sustainable weed control under water-limited environments.

ICGA-048

Integrated Smart Agricultural Technologies for Sustainable Crop Production Under Resource-Constrained Farming Systems

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Sustainable crop production in developing regions is increasingly challenged by labor scarcity, inefficient input use, climate variability, and limited access to modern technologies. This research presents a portfolio of indigenous, integrated agricultural innovations spanning crop establishment, mechanization, water and nutrient management, precision protection, and artificial intelligence–based decision support. The developed technologies include mechanized bud-node planting systems, precision planting and intercropping tools, sustainable irrigation and soil-moisture management solutions, smart nutrient delivery mechanisms, and energy-efficient field machinery, supported by AI-enabled monitoring for crop growth and physiological maturity assessment. Field validation demonstrated significant improvements in crop establishment, input-use efficiency, early vigor, resource conservation, and overall productivity, while substantially reducing labor dependence and production costs. Also working on AI-assisted sensing enhanced decision accuracy for irrigation scheduling, pesticide application, and harvest timing, leading to improved yield quality and environmental sustainability. These innovations collectively bridge the gap between traditional farming practices and precision agriculture by offering scalable, cost-effective, and farmer-centric solutions. The integrated approach supports climate resilience, promotes rural entrepreneurship, and provides a replicable model for sustainable intensification across diverse cropping systems, contributing to long-term food security and livelihood improvement.

ICGA-049

Development of A Climate-Resilient, Bacterial Leaf Blight–Resistant, Extra- Long Grain Basmati Rice Variety Through Marker-Assisted Breeding

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Rice (*Oryza sativa* L.) is a major staple food crop, providing nutrition to more than half of the world's population and contributing significantly to food security and rural livelihoods. Among rice types, Basmati holds a premium position due to its extra-long slender grains, unique aroma, and superior cooking quality, characteristics that are strongly influenced by specific agro-ecological conditions of the traditional Basmati-growing regions of Punjab, Pakistan. However, productivity of traditional Basmati cultivars is increasingly constrained by biotic stresses, particularly bacterial leaf blight (BLB), lodging susceptibility, and delayed maturity, challenges that are further intensified under changing climatic conditions. To address these limitations, a climate-resilient, early-maturing, lodging-resistant, extra-long grain Basmati rice line, PKBB15-

116 (Super Gold), was developed through marker-assisted backcross breeding by introgression the BLB resistance gene Xa21 from IRBB60 into the Super Basmati background. The candidate line was evaluated from 2014 to 2018 through observational plots, station yield trials, regional adaptability trials, hotspot testing, micro-plot trials, and National Uniform Rice Yield Trials across major rice-growing regions of Pakistan. Results demonstrated that PKBB15-116 consistently outperformed commercial checks, including Super Basmati and Basmati 515, with an average yield advantage of 10–17%, coupled with stable performance across environments. The variety exhibited strong resistance to bacterial leaf blight, moderate resistance to major insect pests, improved stem stiffness, early maturity (≈ 105 days), and superior grain quality attributes, including extra-long slender grains, high head rice recovery, and excellent cooking quality. Economic analysis indicated substantial yield gains and potential national-level savings due to reduced BLB-related losses. Overall, the development of PKBB15-116 represents a significant advancement toward green and sustainable rice production, offering a climate-smart solution that integrates disease resistance, high yield, and premium grain quality. This variety has strong potential to enhance farmer income, stabilize Basmati rice production, and contribute to food security under climate change scenarios.

ICGA-050

Screening of Rice Genotypes for Resistance Against Bacterial Leaf Blight and Sheath Blight Under Field Conditions

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Rice yield is affected by a number of diseases among which bacterial leaf blight (BLB); caused by *Xanthomonas oryzae* pv *oryzae* and sheath blight (caused by *Rhizoctonia solani*) are one of the oldest and most severe ones. The introduction and widespread cultivation of high yielding cultivars having narrow genetic base was led to increased susceptibility to the diseases such as bacterial blight. Phenotypic assessments were conducted using standard disease scoring systems. Promising genotypes exhibiting high levels of resistance were further analysed using molecular markers linked to ShB and BLB resistance genes. Selected resistant lines were then employed in back cross breeding with elite but susceptible cultivars to combine desirable agronomic traits with disease resistance. This study aimed to evaluate the resistance of rice germplasm against sheath blight and bacterial leaf blight (BLB) and to utilize these resistant lines in a back cross breeding program for developing superior rice varieties. A total of thirty (30) rice lines were screened under field conditions and the results indicated a variation in resistance levels among the tested lines. For sheath blight, two exotic lines (Tetop and TKM6) exhibited resistance, characterized by significantly lower lesion lengths and disease severity indices compared to the susceptible control. Similarly, 04 lines namely; IRBB21, IRBB23 IRBB58 and IRBB66 lines showed resistance to BLB, with minimal lesion lengths and disease progression. These resistant lines were then employed in a back cross breeding program aimed at developing new rice varieties with enhanced disease resistance. The initial crosses involved using the resistant lines as donors and a high-yielding, but disease-susceptible, variety as the recurrent parent. Subsequent back cross generations (BC1F1, BC2F1, etc.) will be screened for disease resistance and agronomic

performance, with selection for desirable traits being carried out at each generation. In conclusion, the screening experiment effectively identified rice lines resistant to sheath blight and bacterial leaf blight, which will be successfully used in a back cross breeding strategy. This approach holds potential for developing new rice varieties that combine high yield with enhanced disease resistance, contributing to sustainable rice production.

ICGA-051

The Shielded Based RNA Interference (RNAi) Sprays and Seed Treatments That Silence Insecticide Detoxifying Genes

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RNA interference (RNAi) has emerged as one of the most revolutionary tools in modern crop protection by offering species-specific pest control with minimal ecological footprint. Unlike conventional insecticides, topically applied dsRNA formulations and seed-coated double-stranded RNA (dsRNA) enable the silencing of essential genes ((PgCadl), r13PgCadl, PgABCA2, PgCadl aIIeles (r1-r20), and PgABCC2, Acetylcholine esterase (AChE), orckinin (Orc), sex lethal protein, Ecdysone receptor (ECR) genes (B. tabaci Asia-1, PgCadl, Cadherin aIIeles (r19 and r20) in target insects, leading to stop of feeding and eventual mortality while non-toxic for non-target beneficial organisms, including pollinators (Honey bee) and other natural enemies. Recent innovations have improved the stability, uptake efficiency, and cost-effectiveness of RNAi-based products, bringing them closer to widespread commercial adoption. Key breakthroughs include nanoparticle-mediated dsRNA delivery systems (chitosan, liposomes, and carbon quantum dots) that protect RNA from UV, dew drops (Rain) and nuclease degradation and enhance translocation across the insect gut epithelium. Transplastomic chloroplast expression and bacterial production platforms have reduced manufacturing costs by more than 80 % compared to early chemical synthesis methods. Field trials conducted between 2022 and 2025 on maize, soybean, potato, and citrus demonstrated that topical RNAi sprays targeting fall armyworm (*Spodoptera frugiperda*), Colorado potato beetle (*Leptinotarsa decemlineata*), and Asian citrus psyllid (*Diaphorina citri*) and other chewing and sucking harmful insects pest achieved 75–95 % mortality rates with application rates below 10 g dsRNA , comparable to or better than synthetic chemical insecticides, but without resistance development after multiple generations. Furthermore, seed-treatment formulations incorporating dsRNA-expressing symbiotic bacteria or layered double-hydroxide clay nanosheets provide prolonged protection from root-feeding pests while remaining stable under diverse soil and climatic conditions. This next generation RNAi-based insecticides and seed treatments represents a paradigm shift toward truly sustainable, and ecofriendly integrated pest management, offering farmers highly effective pest management that align with global regulatory trends favoring low-risk, biologically based plant protection products.

ICGA-052

Effect of High Temperature on Rice Grain Quality

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High temperature stress during rice cultivation has become a critical barrier to grain quality amid accelerating climate change. Elevated temperatures, especially at flowering and grain-filling stages, disrupt key physical, chemical, and cooking quality traits through impaired endosperm development. High temperatures hinder starch biosynthesis, protein accumulation, and assimilate translocation, causing chalky grains, lower weight, and poor milling yields. Altered starch-synthesizing enzyme activity shifts amylose-amylopectin ratios and loosens granule packing, degrading appearance and texture. Heat modifies protein profiles and mineral distribution, while suppressing aroma biosynthesis in fragrant varieties via disrupted metabolic pathways. These changes diminish eating quality and market value, with effects varying by stress intensity, duration, growth stage, and genotype. Genetic variation offers promise for heat-tolerant cultivars, complemented by agronomic practices like adjusted sowing and enhanced irrigation. Understanding of these mechanisms is vital for resilient rice value chains and sustained food quality in warming climates.

ICGA-053

Nano-Emulsified Synergistic Blends of Botanical Pheromone Enhancers and Entomopathogenic Fungi Propagules: A Novel Strategy for Soil-Dwelling Pests

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The management of soil-dwelling insect pests remains a major challenge in sustainable agriculture due to the limited efficacy and environmental concerns associated with conventional synthetic insecticides. This study introduces a novel biopesticide formulation combining nano-emulsified botanical extracts rich in semiochemicals with high concentrations of entomopathogenic fungal propagules (*Metarhizium brunneum* and *Beauveria bassiana*). The botanical blend, derived from neem (*Azadirachta indica*), garlic (*Allium sativum*), and citrus peel, contains natural pheromone enhancers and kairomones that significantly increase pest foraging activity and prolong contact time with fungal conidia in the rhizosphere. Nano-emulsification (droplet size 20–80 nm) was achieved using food-grade lecithin and Tween 80, ensuring excellent stability, deep soil penetration, and prolonged release of both active components. Laboratory choice assays demonstrated that the presence of the nano-emulsified botanical blend increased larval movement of black vine weevil (*Otiorhynchus sulcatus*) and *Agriotes lineatus* and *Melolontha melolontha* by 3.2–4.8 fold, resulting in 2.5–3.1 times higher conidial acquisition compared to fungal spores applied alone. Under greenhouse conditions, a single soil drench application (2×10^8 conidia mL⁻¹ + 1.5% nano-emulsion) achieved 82–91% larval mortality within 14–21 days against wireworms and white grubs, significantly outperforming commercial fungal products (58–67% mortality) and botanical oils alone (34–49%). Field trials conducted in maize and strawberry plots confirmed sustained efficacy (>75% reduction in pest population) up to 10 weeks post-application with no phytotoxic effects. The formulation showed good compatibility with soil microbial communities

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and earthworm populations. These results suggest that synergism between pheromone-enhanced attractancy and fungal virulence offers a promising, environmentally safe tool for managing harmful soil-dwelling pests while reducing reliance on chemical soil fumigants

ICGA-054

Effect of Foliar Application of Moringa Leaf Extract (MLE) On Growth, Development and Yield of Mungbean (*Vigna radiata* L.)

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An experiment to study the impact of foliar application of moringa leaf extract (MLE) on growth, development and yield of mungbean (*Vigna radiata* L. cv. AEM-96) was carried out at Students' Experimental Farm, Department of Agronomy, Faculty of Crop Production (FCPD), Sindh Agriculture University, Tandojam-Pakistan, during the "Kharif" season, 2023 and the same experiment was repeated during the "Kharif" season, 2024. The field experiment was laid out in four replicated randomized complete block design (RCBD) with a single factor arrangement and seven treatments. The net plot size was 4 m x 3 m (12 m²). The study examines the effect of different concentrations of moringa leaf extract (MLE), MLE @ 20%, 40%, 60%, 80%, and 100% were applied against a control (without MLE) and a recommended dose of fertilizer (RDF) NPK @ 25: 50: 25 (kg ha⁻¹) was applied in all plots to evaluate their effects on crop performance. The study aimed to assess, to determine MLE's influence on crop performance, identify the optimal MLE concentration, and analyze correlations and regression relationships among variables. Throughout the experiment, the study aimed to evaluate the measurements included soil physio-chemical properties, agronomic traits, physiological attributes, meteorological observations, grain nutrient status, and economic returns. Statistical analysis was performed using Statistix-8.1 software with the HSD test to compare treatment effects, while the regression and Pearson correlation analysis tested relationships among variables. The results demonstrated that MLE significantly enhanced mungbean performance ($P \leq 0.05$) across both years. The highest response occurred at MLE @ 100%, which recorded the earliest germination (4.5 days compared to 11 days in control) and the highest seed yield SY (1942.87 kg ha⁻¹), whereas the control produced the lowest seed yield SY (1386.87 kg ha⁻¹). Among, the regression analysis indicated a strong treatment yield relationship ($R^2 = 0.857$, Adjusted $R^2 = 0.807$, $F = 17.17$, $p < 0.0001$), with MLE @ 100% treatment (T₇) improving yield by (543.71 kg ha⁻¹, $p < 0.0001$), followed by MLE @ 80% treatment (T₆) with (453.71 kg ha⁻¹). Similarly, Pearson's correlation analysis revealed extremely strong positive relationships between seed yield SY (kg ha⁻¹) and traits like (seed weight pod⁻¹ SWPP g: $r = 0.9979^{***}$), (plant height PH cm: $r = 0.9971^{***}$) and (branches plant⁻¹ BPP: $r = 0.9937^{***}$). Additionally, the results of economic analysis specifically focused on benefit-cost ratio (BCR) showed MLE @ 100% had the highest benefit-cost-ratio (BCR = 3.955), indicating

superior profitability. Overall, the study recommends foliar application of MLE @ 100% (200 L ha⁻¹) at critical crop growth stages (germination, flowering and pod development), ideally combined with NPK, as an eco-friendly, high-efficiency bio-stimulant for mungbean cultivation.

ICGA-055

Molecular and Physiological Mechanisms of Heat Stress Tolerance in Rice for Green Agriculture and Food Security Under Climate Change

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Global climate change poses significant challenges to rice (*Oryza sativa* L.) production, with elevated temperatures negatively impacting both yield and grain quality. Heat stress triggers complex molecular and physiological responses in rice, including alterations in gene expression, protein stability, antioxidant defense systems, and hormonal signaling pathways. Key molecular mechanisms involve heat shock proteins (HSPs), transcription factors, and stress-responsive genes that help maintain cellular homeostasis and reproductive development under high-temperature conditions. Physiologically, heat-tolerant rice varieties exhibit improved membrane stability, efficient photosynthesis, and reproductive resilience, resulting in better grain set and quality. Understanding these mechanisms is crucial for breeding climate-resilient cultivars and implementing agronomic practices that support sustainable rice production. Integrating molecular insights with adaptive management strategies, such as precision irrigation, optimized sowing dates, and stress-tolerant cultivars, can enhance productivity while minimizing environmental impacts. This research emphasizes the role of heat-tolerant rice in green agriculture, ensuring food security under future climate scenarios.

ICGA-056

Wasted Wealth: The Impact of Food Waste On Food Security in Pakistan – A Case Study On Causes, Consequences, And Solutions

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Food waste has emerged as a critical challenge in Pakistan, where over 37% of the population faces food insecurity despite the annual wastage of approximately 36 million tons of food. This study explores the magnitude and root causes of food waste across Pakistan's food supply chain and assesses its direct and indirect impact on food security. Using a mixed-methods approach involving qualitative interviews and quantitative data analysis, the study identifies waste at production, post-harvest handling, processing, distribution, and consumption stages. The research

proposes actionable and scalable solutions to reduce food waste and enhance national food security.

ICGA-057

Impact of Heat Stress on Rice Productivity and Grain Quality: Implications for Sustainable Food Security under Climate Change

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Rice (*Oryza sativa* L.) is a staple food for over half of the global population, yet its productivity and grain quality are increasingly threatened by rising temperatures due to climate change. Heat stress, particularly during the reproductive and grain-filling stages, adversely affects yield components, including panicle fertility, grain number, and grain weight, while also altering key quality traits such as amylose content, chalkiness, and aroma. This study reviews current evidence on the physiological and molecular responses of rice to elevated temperatures, highlighting varietal differences in heat tolerance and mechanisms underlying grain quality stability. Understanding these responses is critical for breeding programs aimed at developing climate-resilient rice varieties. Furthermore, integrating agronomic interventions, such as adjusted sowing dates, irrigation management, and stress-tolerant cultivars, can mitigate yield losses and maintain grain quality. Addressing heat stress in rice is therefore essential for sustaining global food security, particularly in heat-prone regions. This research underscores the need for a combined approach of genetic improvement and adaptive agronomic practices to ensure resilient rice production under future climate scenarios.

ICGA-058

Role of Satellite-Based Precipitation Monitoring in Advancing Green Agriculture: A Strategic Review for Climate Resilience in Pakistan

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Climate-induced water scarcity is a significant bottleneck for sustainable food production in Pakistan. As the country moves toward "Green Agriculture," the integration of precision monitoring tools becomes essential for optimizing water use efficiency and ensuring future harvests. This paper provides a comprehensive review of the role of satellite-derived precipitation estimates (such as TRMM, CHIRPS, and GPM) in establishing robust drought early-warning systems. Unlike traditional gauge-based observations, which are spatially limited in regions like Balochistan and Gilgit-Baltistan, satellite remote sensing offers high-resolution, continuous data vital for "Smart Farming." The study highlights how these digital tools can identify moisture-stress

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hotspots, enabling farmers to adopt nature-based solutions and proactive irrigation scheduling. By synthesizing recent findings on the Standardized Precipitation Index (SPI) across various ecological zones of Pakistan, this review underscores the shift from reactive crisis management to proactive climate resilience. The findings suggest that incorporating satellite data into national agricultural policy can significantly mitigate the impacts of prolonged dry spells, thereby safeguarding rural livelihoods and enhancing national food security. This work serves as a strategic roadmap for policymakers and stakeholders to foster a technology-driven, sustainable agricultural ecosystem.

ICGA-059

Post-Harve Reducing Post-Harvest Losses Under Changing Climatic Conditions

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The problem of post-harvest losses is a very severe risk to the world food security, especially with the fluctuating climatic conditions that increase the rate of spoilage and degradation of agricultural products. Global warming, rising humidity, and changes in climate have heightened problems faced by post-harvest, particularly in the developing world that has low storage and handling facilities. This paper has discussed post-harvest and storage technologies that have a role in minimizing post-harvest losses in climatic conditions. The study tested climate resilient post-harvest technologies, better storage facilities, and new handling protocols that were aimed at maintaining quality of produce and prolonging shelf life. The focus was on low-cost and scalable solutions, such as hermetic storage, controlled atmosphere, and thermal and moisture control. The results proved that the implementation of such innovations caused significant decrease in the number of quantitative and qualitative losses and the increase in the efficiency of the storage. The research was able to arrive at the conclusion that novel post-harvest and storage approaches are necessary to alleviate the effects of climate on losses, enhance food system resilience, and facilitate feasible agricultural development. Enhancement of technology adoption, institutional support and policy alignment were found to be key towards long term reduction of post-harvest losses in changing climatic conditions.

ICGA-060

Genotypic Variation and Physiological Responses of Rice (*Oryza Sativa* L.) To Heavy Metal Stress: Implications for Food Safety and Sustainable Production

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Deteriorating water quality and heavy metal pollution are serious obstacles to the sustainable cultivation of rice and environmental health. This study investigated the genotypes and physiological responses of twenty rice cultivars to heavy metal-contaminated irrigation water. The study aimed to identify genotypes that were tolerant to heavy metals and low accumulators for the safe production of food. The experiment was performed in a factorial randomized complete block

design with three replications under controlled levels of Cd and Pb (Cd=1.5 mg L⁻¹; Pb=3.0 mg L⁻¹). Highly significant ($p < 0.01$) genotypic differences were noted in respect of yield, metal and antioxidant characters. The Cd concentration in the grains ranged from 0.18 to 0.72 mg kg⁻¹, while that of Pb varied from 0.22 to 0.95 mg kg⁻¹, three of the genotypes (R3, R9 and R15) being below the WHO limits for safety. These genotypes maintained a greater content of chlorophyll (78.4%), lower lipid peroxidation (-36%) and higher enzymatic activity of SOD (41%), CAT (39%) and GR (28%), showing an efficient detoxification mechanism. The average reduction in grain yield was 23.5% in contamination, but these tolerant genotypes maintained a yield of 5.2–5.9 t ha⁻¹. PCA accounted for 71.8% total variation and showed that antioxidative capacity and restricted root-to-grain translocation were important adaptive mechanisms. These results show the importance of genetic screening to reduce impacts of pollution for the benefit of environmental health, food safety and sustainability in climate–water–environment use.

ICGA-061

Enhancing Wheat Nutritional Quality Through Agronomic Biofortification

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Enhancing Wheat Nutritional Quality through Agronomic Biofortification Micronutrient malnutrition, often termed "hidden hunger," affects over two billion people globally, particularly in regions reliant on cereal-based diets. Wheat (*Triticum aestivum* L.) is a primary staple crop, yet its grains are naturally low in essential minerals like zinc (Zn) and iron (Fe). This abstract explores agronomic biofortification—the strategic application of mineral fertilizers—as a rapid and highly effective complementary strategy to genetic breeding for enhancing grain nutrient density.

ICGA-062

Optimizing Nitrogen for The Assessment of Growth and Productivity of Spring Maize Cultivars

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In semi-arid regions, improving the management of nitrogen (N) is crucial for achieving optimal growth and productivity of spring maize cultivars. This study sought to determine the effect of tailored nitrogen rates on the physiological and yield responses of maize cultivars grown under semi-arid environments. The study was designed using the randomized complete block design (RCBD) with four N levels of 0, 75, 150, and 225 kg N ha⁻¹. With the most notable growth and yield attributes arriving at 225 kg N ha⁻¹, the data at 225 kg N ha⁻¹ showed heightened plant height (229.3 cm), leaf area index (5.21), chlorophyll content (56.7), and crop growth rate (18.4 g m⁻² day⁻¹) specifically for C2. A grain yield of 10.83 t ha⁻¹ was recorded at 225 kg N ha⁻¹ with 5.21 t

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ha⁻¹ as the control (under 0 kg N ha⁻¹). This was at the expense of agronomic nitrogen use efficiency (ANUE) which was highest at 150 kg N ha⁻¹ (46.2 kg grain kg⁻¹ N) with 31.1 kg grain kg⁻¹ N at 225 kg N ha⁻¹, demonstrating N yield plateauing and ANUE decline with excessive N. Among all cultivars, Hybrid-B (C2) had the best yield and N uptake (193.6 kg ha⁻¹) and protein content (9.82%). Such results demonstrate that 150-225 kg N ha⁻¹ maximizes productivity; however, 150 kg N ha⁻¹ is preferred from an N utilization efficiency standpoint. The combination of improved N rates and cultivar selection will enhance maize production with N use efficiency in semi-arid agriculture.

ICGA-063

Pakistan Agriculture Research Council Feb 2024 to 'Hands On Soil Physio-Chemical Properties Analysis Techniques

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Internship Pakistan Agriculture Research Council Feb 2024 To 'Hands on Soil Physio-chemical Properties Analysis Techniques' Conducted detailed soil sampling and testing to determine physio-chemical properties. Operated laboratory equipment for soil texture, pH, and nutrient analysis. Maintained accurate records of soil testing data and prepared detailed reports.

ICGA-064

The Impact of Farmyard Manure and Mineral Fertilizers On Soil Fertility and Crop Growth

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Eco-agriculture is producing a lot of waste, whose experience is increasingly adversely affecting our environmental and farming systems. Scientific and environmentally friendly ways can be used to minimize this fast-developing menace, and composting has been the most effective method in controlling agricultural wastes. With increasing environmental and health issues, farm businesses are confronted with ongoing new challenges and opportunities to manage this stream of waste sustainably. This experiment was divided into two parts: Part I was on the compost enrichment, and Part II entailed the utilisation of the enriched compost in soil treatment and thereafter growing a maize crop to evaluate the effect. At Phase I, five treatments were prepared based on Farmyard Manure (FYM): T1 =FYM (control); T2=FYM + microbes; T3 FYM + bentonite; T4 FYM + zeolite; and T5 = FYM + zeolite + bentonite + microbes. The preparation was done according to a Completely Randomized Design (CRD) with three replications. Test on the processed compost revealed that the combination method (T5: FYM + Bentonite + Zeolite + Microbes) always gave the best results in nutrition and chemical characteristics improvement. In particular, this treatment had the lowest pH (approximately 7.28) and the lowest Electrical Conductivity (EC) (approximately 2.2 dS/m), highlighting a synergistic response in terms of reducing the alkaline condition and salinity of the compost. This complex treatment was also proven to greatly increase nutrient content and displayed the highest mean values as follows: Total Nitrogen (N) (1.90%),

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Total Phosphorus (P) (exactly 1.40%), and Total Potassium (K) (exactly 2.2%). The greatest Organic Matter (OM) (about 1.48%) was also shown in this enriched compost, which clearly shows the effectiveness of combining amendments. In the second phase, a maize crop got to be utilized, and the soil was treated with the prepared composts (T1 = soil/ control, T2-T6 = Compost 1-5 + soil). The soil and plant samples were subjected to the determination of dry matter, pH, EC, N, P, and K, and the analysis was done using standard statistical methods. T6 treatment was the mixture of all amended parameters, and the highest nutrient content was obtained in this treatment. And this trial also showed an effect on plant growth. The lowest PH and EC in the compost shows that the mixture of bentonite, zeolite, and microbes is a highly efficient blending therapy toward the production of high-quality, nutrient-rich rich and environmentally safer composts, unlike agricultural wastes. This finished compost can offer a significant opportunity to upgrade soil health and crop production in pursuit of sustainable farming processes.

ICGA-065

Effect of Diluted Oil Mill Wastewater on Growth, Physiological, and Biochemical Attributes of Garlic (*Allium sativum* L.)

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Oil mill effluents are considered hazardous due to improper disposal and the associated risks to human and environmental health. However, when properly diluted, these effluents can serve as a valuable source of organic matter and essential plant nutrients. This study evaluated the effect of diluted oil mill wastewater on the growth, physiological, and biochemical attributes of garlic (*Allium sativum* L.). The experiment was conducted in the Department of Botany, Ghazi University, Dera Ghazi Khan, using a randomized complete block design (RCBD). Growth, morphological, physiological, and physicochemical parameters were recorded, and the data were statistically analyzed using SPSS software. Results indicated that the application of diluted oil mill wastewater significantly enhanced garlic growth, as evidenced by increased shoot length, root length, and fresh weight of shoots and roots. Physiological and biochemical traits, including chlorophyll content, relative water content, membrane stability index, total soluble sugars, and proline content, were also significantly improved under treated conditions. In contrast, catalase activity was reduced, suggesting an altered antioxidant response. Overall, the findings demonstrated that the controlled application of diluted oil mill wastewater positively influenced garlic growth and nutrient uptake. However, appropriate management practices, regular monitoring, and site-specific evaluations were recommended to optimize application rates and ensure environmental safety and sustainable crop production.

ICGA-066

Impact of Pomegranate Peel Powder Supplementation On Growth, Yield and Biological Efficiency of White and Blue Oyster Mushrooms

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Oyster mushroom (*Pleurotus ostreatus*) is an economically important edible fungus widely cultivated worldwide due to its rapid growth, excellent nutritional profile including high levels of protein, dietary fiber, vitamins, and minerals. Its cultivation supports sustainable waste valorization within circular economy systems, enhances rural livelihoods through low-input, high-value production, and contributes to food security and environmental sustainability. This study was conducted to evaluate the effect of pomegranate peel powder supplementation on growth performance, yield attributes and biological efficiency of two oyster mushroom cultivars, White and Blue. Four levels of pomegranate peel powder were applied, including T₀ (control), T₁ (1%), T₂ (2.5%) and T₃ (5%). Growth and yield-related parameters such as time required for mycelial colonization, duration for completion of spawn run (25%, 50%, 75% and 100%), number of pinheads per bag, time to pinhead formation, No of days for completion of first, second and third flush, weight of individual flushes, total yield per bag and biological efficiency were recorded. The experiment was laid out in a completely randomized design under a two-factor factorial arrangement. Results revealed a clear treatment-dependent response in both cultivars. The highest concentration of pomegranate peel powder (T₃, 5%) significantly improved most growth and yield parameters. Mushrooms grown under T₃ showed earlier pinhead initiation, increased number of pinheads per bag, heavier flush weights and superior total yield and biological efficiency compared to other treatments. T₂ (2.5%) ranked second in performance, while T₁ (1%) showed moderate improvement over the control. The control treatment (T₀) consistently recorded the poorest growth and yield attributes. Varietal comparison indicated that the White oyster mushroom (V₁) outperformed the Blue oyster mushroom (V₂) across most growth and yield traits, demonstrating better adaptability and utilization of supplemented substrate. This study revealed that supplementation with 5% pomegranate peel powder proved most effective in enhancing oyster mushroom productivity, particularly in the White oyster. We conclude that the incorporation of pomegranate powder favorably influenced the overall production of oyster mushroom.

ICGA-067

Effect of Chickpea Powder Supplementation On Physical Growth and Yield Performance of White and Grey Oyster Mushroom (*Pleurotus Ostreatus*)

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Oyster mushroom (*Pleurotus ostreatus*) cultivation relies heavily on substrate quality to achieve higher yield and improved growth performance. The present investigation was conducted to determine the optimum concentration of chickpea powder supplementation in cotton waste for enhancing physical growth and yield attributes of White and Grey oyster mushrooms. Cotton waste without chickpea powder served as the control (T₀: 100% cotton waste), while supplemented treatments included T₁ (99% cotton waste + 1% chickpea powder), T₂ (97.5% cotton waste + 2.5% chickpea powder) and T₃ (95% cotton waste + 5% chickpea powder). The experiment was laid out in a completely randomized design under a factorial arrangement. Growth and yield-related parameters such as time required for initiation of mycelial growth, completion of mycelial

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colonization (25%, 50%, 75% and 100%), days to pinhead initiation, number of pinheads, days to completion of first, second and third flushes, weight of individual flushes and total yield were recorded. Results indicated that increasing levels of chickpea powder significantly improved growth performance and yield compared to the control. The shortest duration for mycelial growth, earlier pinhead initiation, higher number of pinheads and greater flush weights were observed under T₂ and T₃ treatments. Total yield increased progressively with supplementation level, with T₃ producing the highest yield. Varietal comparison revealed that the White oyster mushroom consistently outperformed the Grey oyster mushroom in most physical growth and yield parameters. Thus, the addition of chickpea powder to cotton waste, particularly at 2.5% and 5%, resulted in improved growth and yield and the White oyster mushroom demonstrated greater adaptability than the Grey oyster.

ICGA-068

Effect of Pomegranate Peel Powder On Biochemical Quality, Sugar Profile and Antioxidant Activity of Oyster Mushrooms (*Pleurotus ostreatus*)

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The biochemical composition and antioxidant potential of oyster mushrooms play a crucial role in determining their nutritional and functional value. This study investigated the influence of different concentrations of pomegranate peel powder on biochemical quality, sugar profile and antioxidant-related parameters in White and Blue oyster mushrooms (*Pleurotus ostreatus*). The experiment was conducted using a completely randomized design with a two-factor factorial arrangement. Four supplementation levels were tested: T₀ (control), T₁ (1%), T₂ (2.5%) and T₃ (5%). Biochemical parameters including reducing sugars, non-reducing sugars, total sugars, vitamin C content and peroxidase (POD) activity, were analyzed to assess quality changes induced by supplementation. The results demonstrated that biochemical responses varied with treatment concentration. The control treatment (T₀) showed comparatively higher levels of reducing sugars, non-reducing sugars, total sugars and POD activity. In contrast, vitamin C content responded positively to pomegranate peel powder application and was significantly enhanced under T₂ (2.5%) supplementation. Higher supplementation (T₃, 5%) did not further increase biochemical quality parameters to the same extent, indicating that excessive supplementation may favor growth rather than biochemical enrichment. Varietal differences were also evident, with the White oyster mushroom (V₁) consistently exhibiting superior biochemical quality compared to the Blue oyster mushroom (V₂). Among all the studied treatments, T₂ emerged as the most effective treatment for improving biochemical attributes and antioxidant potential, while T₃ was more effective for yield-related traits. The study highlights that optimal pomegranate peel powder concentration can differentially influence yield and quality parameters. These findings support the use of pomegranate peel powder as a sustainable supplement to enhance the nutritional and functional quality of oyster mushrooms, with treatment and varietal selection playing a key role in maximizing benefits.

ICGA-069

Influence of Salicylic Acid On Physiological and Biochemical Responses of *Capsicum frutescens* L. Under Combined Salinity and Drought Stress

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Salinity and drought are among the most critical abiotic stresses that severely limit agricultural productivity, particularly in arid and semi-arid regions. *Capsicum frutescens* L., an economically important vegetable crop, is highly sensitive to these environmental constraints. The present study was conducted to evaluate the role of salicylic acid (SA) in mitigating the combined effects of salinity and drought stress on the physiological and biochemical performance of *C. frutescens*. A factorial experiment was carried out under a completely randomized design (CRD) using three salinity levels (0, 50 and 100 mM NaCl) and three drought regimes (100%, 75% and 50% field capacity). Salicylic acid was applied foliarly at three concentrations (0.0, 0.5 and 1.0 mM) at vegetative, flowering and fruiting stages. Physiological parameters, including relative water content (RWC), membrane stability index (MSI), stomatal conductance and chlorophyll content, along with biochemical attributes such as proline accumulation and antioxidant enzyme activities (catalase and peroxidase), were analyzed. Data were subjected to analysis of variance (ANOVA), and treatment means were compared using the least significant difference (LSD) test. The results revealed that combined salinity and drought stress significantly reduced physiological performance and disrupted biochemical balance, with the most severe effects observed at the flowering stage. However, foliar application of salicylic acid, particularly at 1.0 mM, markedly improved plant water status, membrane stability and antioxidant capacity under stress conditions. Enhanced proline accumulation and increased activities of catalase and peroxidase indicated improved osmotic adjustment and oxidative stress tolerance. Among the growth stages, the flowering stage exhibited the highest responsiveness to salicylic acid application. It is concluded that foliar-applied salicylic acid at 1.0 mM effectively alleviates the adverse effects of combined salinity and drought stress in *C. frutescens*, especially when applied at sensitive developmental stages. These findings highlight the potential of salicylic acid as a cost-effective and environmentally sustainable approach for improving stress tolerance in chili cultivation. However, further investigations under field conditions, across multiple genotypes and at the molecular level, are recommended to validate and extend these findings.

ICGA-070

Green Harvest: Smart Agriculture Through Yield Prediction and Environmentally Conscious Fertilizer Strategies

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Climate change has emerged as a major threat to global food security, particularly affecting agriculture production. Food security looks to be a major concern due to the loss of natural

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resources, particularly land and water, and the growing global population is driving up food demand. Food security is a result of agriculture, a significant economic sector. Agriculture is considered a prominent source of income. The most common issue in agriculture is farmers choosing the wrong crop and not utilizing the right fertilizer for their soil. This will result in a major decrease in their production. Green harvest helps farmers to grow an ideal crop using data like soil attributes, soil kinds, and crop yield statistics. Fertilizer suggestions are also made based on site-specific characteristics. This makes crop selection errors less frequent, and productivity rises. This issue is resolved by creating a recommendation system using machine learning models with a majority voting method that uses Random Forest, K nearest neighbor (KNN), and Support Vector Machine (SVM) as learners to accurately and effectively recommend a crop for the site-specific parameters. It is identified that Random Forest gives better accuracy than KNN and Support Vector in providing accurate results as essential instruments in precision agriculture, crop yield prediction, and fertilizer advice to help farmers increase crop output while reducing wasteful use of resources and environmental impact. Organic farming is one such approach. It involves using organic materials like compost and natural ways to protect crops instead of relying on synthetic fertilizers and pesticides. Organic farmers use techniques like crop rotation, animal manure, and natural pest control to keep their soil healthy and their crops strong. It also helps future researchers to use Random Forest as an accurate machine learning algorithm in this field.

ICGA-071

Quinoa as a Superfood: Combating Stunting and Malnutrition in Pakistan

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Malnutrition and childhood stunting remain critical public health challenges in Pakistan, driven by inadequate dietary diversity and micronutrient deficiencies. Quinoa (*Chenopodium quinoa* Willd.), a nutrient-rich pseudocereal, holds immense potential as a superfood to address Pakistan's pervasive stunting and malnutrition crises amid climate-vulnerable agriculture. Quinoa grains are rich in high-quality protein with a balanced essential amino acid composition, dietary fiber, healthy lipids, and key micronutrients such as iron, zinc, magnesium, and vitamins, which are commonly deficient in Pakistani diets. Additionally, quinoa is gluten-free and exhibits a low glycemic index, making it suitable for vulnerable populations, including children, pregnant women, and individuals with metabolic disorders. The crop's adaptability to marginal soils, salinity, and drought further enhances its relevance under Pakistan's climate variability and resource constraints. Integrating quinoa into local cropping systems and food-based nutrition programs can improve household nutrition while supporting agricultural diversification and resilience. The abstract highlights quinoa's dual role as a climate-resilient crop and a strategic dietary intervention for improving nutritional security and reducing stunting in Pakistan.

ICGA-072

Improvement in Drought Tolerance in *Luffa aegyptiaca* (L.) By Nano-Biochar is Associated with Photosystem Ii and Atp-Synthase Activities

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Drought stress impairs plant physiology including water and nutrient uptake through roots & transport to leaves thereby affecting plant photosynthetic capacity. This study investigated whether addition of nano-biochar in soil modulates soil-plant relations that results in changes in photosynthetic capacity of plants of *Luffa aegyptiaca*. Nano-biochar is a carbon-rich compound that can improve soil water retention, plant water status, and photosynthesis. The results demonstrated that drought stress reduced the growth of sponge gourd. Application of 0.5% nano-biochar to the growth medium caused an increase in growth of sponge gourd. This increase in plant biomass of sponge gourd due to nano-biochar under drought stress was positively correlated with nano-biochar-induced increase in plant water status, photosynthetic performance & quantum yield of PSII. Drought stress minimized structural stability of photosystem II (PSII) at the donor and acceptor end. Drought stress caused a reduction in active reaction center density, and energy fluxes for electron flow. Nano-biochar application enhanced the structural stability of PSII, active reaction center density and electron transport. Drought stress minimized the functional efficiency of PSII (PSII), linear electron flow and increased the non-photochemical quenching (NPQ). Nano-biochar improved PSII, linear electron transport by dissipating excessive heat energy through photoprotective pathways (NPQ, NPQt), and reduced photoinhibition of PSII NO in *Luffa aegyptiaca* plants. Application of nano-biochar also improved the ATP-synthase activity in sponge gourd plants indicated plants had better ability to process absorbed light energy through photosynthesis. Thus, the application of biochar is a promising tool to mitigate the harmful effects of drought on *Luffa* plants.

ICGA-073

Transforming Agriculture: Tech-Driven Pathways to Future Harvests and Climate Security

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Climate change poses unprecedented challenges to agricultural productivity, resource sustainability and global food security. Modern technologies for climate resilience and food security explores how emerging innovations are transforming traditional farming into a climate-smart, resource-efficient, and environmentally restorative system. This study highlights the integration of advanced tools particularly crop simulation models and decision support systems (DSS) to optimize crop management under variable climatic conditions. By simulating crop growth, yield responses and stress interactions, these models enable farmers and policymakers to predict future scenarios, refine adaptation strategies and minimize climate-induced risks. DSS platforms further translate complex datasets into actionable, site-specific recommendations, supporting precision irrigation, nutrient management, and climate-resilient varietal selection.

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Together, these technologies enhance productivity, reduce greenhouse gas emissions, and strengthen the resilience of food systems. This underscores how green agriculture, empowered by digital innovations can secure sustainable harvests for future generations while aligning with global climate and food security policies.

ICGA-074

Phytoremediation of Industrial Effluents in Mung Bean (*Vigna radiata* L.) Assisted by Plant Growth Promoting Bacteria

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This research explored the effect of plant growth-promoting rhizobacteria (PGPR) on three varieties of Mung bean (Azhari Mung, Chakwal Mung and Nayab Mung) under four levels of industrial wastewater stress. For two hours before planting, seeds were soaked in a mixture made from PGPR. The effluent from Pak Arab Fertilizer, Multan, was used at 0%, 25%, 50% and 100% following 20 days. Growth parameters, chlorophyll a and b, carotenoids, relative water content (RWC), total protein, free amino acids and antioxidant enzymes such as peroxidase (POD) and catalase (CAT) were all evaluated in the experiment. Increasing wastewater concentrations led to significant declines in plant growth, photosynthetic pigments, water retention, and protein content, indicating the onset of oxidative and osmotic stress. A decrease in antioxidant enzyme activity was observed which stands for a reduction in the plant's defenses. PGPR inoculation significantly alleviated the adverse effects by enhancing nitrogen metabolism, increasing chlorophyll and carotenoid content, maintaining cellular turgor, and elevating antioxidant levels. Although all cultivars were adversely affected by wastewater stress, Azhari Mung showed the highest recovery and responded most effectively to PGPR treatment. The study confirms that using PGPR helps Mung bean (*Vigna radiata* L.) become less sensitive to industrial wastewater and improves their growth. Using wastewater from industry together with PGPR, it becomes safe for farming, helping in save water. This system aids in saving freshwater and promotes ways to farm sustainably. Generally, applying PGPR can greatly increase how productive crops grow and how well they withstand conditions in wastewater-affected soil.

ICGA-075

Gene Discovery and Utilization of Iron and Zinc Biofortification in Cereals

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Iron (Fe) and zinc (Zn) are globally recognized as micronutrients of critical clinical significance for human health and wellbeing. Major staple crops, specifically wheat, rice, and maize, often contain insufficient levels of these essential micronutrients. Baseline concentrations in wheat and maize grains are recorded at 30 mg/g for Fe and 25 mg/g for Zn; in rice grains, these values are approximately 20 mg/g for Fe and 16 mg/g for Zn. However, for grains to meet 30-40% of the average adult dietary requirement, they should ideally contain 59 mg/g and 38 mg/g. Scientists are currently addressing widespread malnutrition by attempting to enhance Fe and Zn

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accumulation in grains through both conventional and next-generation molecular techniques. This article evaluates the applicability and efficiency of novel genome editing tools compared with traditional breeding for Fe and Zn biofortification, aiming to improve the bioavailability of cereal grains. While some wheat varieties with significant increases in Zn concentration have been developed through conventional breeding (e.g., BHU-1, BHU-6, and Zincol-2016, ranging from 35-42 mg Zn/g), there has been limited success regarding Fe concentration. Similarly, no rice variety has yet been developed through traditional breeding that reaches the required Fe concentration of 14.5 mg/g. Transgenic approaches have played a vital role in Fe and Zn improvement in cereal crops but are often hindered by low public acceptance and strict regulatory frameworks. Precise genome editing via CRISPR-Cas9 offers a promising solution to enhance Fe and Zn content in cereals without linkage drag or biosafety concerns. We conclude that there is an urgent necessity to biofortify cereal crops with Fe and Zn using efficient next-generation approaches like CRISPR/Cas9 to mitigate malnutrition problems, particularly in developing nations. Keywords: biofortification, CRISPR/Cas9, cereals, Fe, Zn, micronutrients, next-generation technologies, developing countries.

ICGA-076

Changes in Morphological Physiological and Reproductive Attributes of Sesame (*Sesamum indicum* L.) After Aerial Application of 5-Sulfosalicylic Acid Under Drought Stress Condition

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Drought stress significantly affect the plants and decrease the crop yield and productivity all over the world. Hence a pot study was planned in the Botanical Garden of Bahauddin Zakariya University Multan to observe the effects of 5-Sulfosalicylic acid at various concentrations i.e., 0, 1.5, 2.5, 5mM on sesame (*Sesamum indicum* L.) varieties namely black and white sesame, under both control and drought stress condition. The experiment was completely randomized design CRD). Results showed that drought stress caused a significant reduction in growth, coloured pigments of leaves, total protein, amino acids and enzymatic antioxidants (CAT, POD) of both varieties and enhance production of reactive oxygen species (MDA). However, aerial application of various regimes of 5-SSA enhance the all morphophysiological and biochemical attributes of both varieties. Moreover, among various aerial application of 5SSA the dose @ 5Mm significantly improve biomass production in terms of shoot and root weight, photosynthetic pigments, enzymatic antioxidants (CAT, POD), proteins and amino acids content under both control and drought stress condition. But on the other hand, oxidants (MDA) also decrease under control and as well as drought stress condition. This study suggests that aerial application of 5-SSA under drought stress is compliant in the enhancement of growth and productivity of sesame plants.

ICGA-077

Alleviation of Adverse Effect of Drought Stress On *Vigna mungo* L. By Exogenous Application of Hydrogen Peroxide

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Plant growth and development are severely hampered by drought stress because it interferes with vital metabolic functions. The exogenous administration of chemicals such as vitamins, ascorbic acid, osmolytes, and hydrogen peroxide (H₂O₂) has been investigated as a means of mitigating these negative effects. Two *Vigna mungo* varieties, Barani and Chakwal, were the focus of this investigation. They were exposed to four different foliar H₂O₂ treatments (0, 0.5, 1, and 2 mM) under controlled drought circumstances. A completely randomized design (CRD) was used for the experiment, which was carried out in pots filled with soil. Numerous morphological characteristics, including shoot length and root biomass, as well as physiological and biochemical parameters, such as chlorophyll content and the ionic balance of Na⁺ and K⁺ in roots and leaves, were adversely impacted by drought stress. To reduce the buildup of (ROS), especially excessive ROS generated during drought stress, foliar injection of H₂O₂ was utilized. Increased antioxidant enzyme activity indicates that this application strengthened the plant's antioxidant defense mechanism. The result showed that H₂O₂ foliar spraying prevented drought-induced declines in growth, photosynthetic pigments, and yield components. The most successful concentration for enhancing physiological, biochemical, and yield-related characteristics was (1 mM) H₂O₂. According to the study's overall results, exogenous application of hydrogen peroxide can greatly enhance plant performance under drought stress; *Vigna mungo* L. in particular benefits most from a concentration of 1 mM.

ICGA-078

Assessing Climate Change Impacts on Wheat in Pakistan Using DSSAT Integrated with CMIP6 Climate Projections and Python-Based Modeling Framework

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Climate change poses a significant threat to wheat production in Pakistan, a staple crop that contributes more than 60% of the population's daily caloric intake. Rising temperatures, shifting rainfall patterns, and increased climate variability are expected to adversely affect wheat growth, yield stability, and food security. This research aims to assess the impacts of climate change on wheat production in Pakistan using the Decision Support System for Agrotechnology Transfer (DSSAT) integrated with Coupled Model Intercomparison Project Phase 6 (CMIP6) climate projections within a Python-based modeling framework. The DSSAT-CERES-Wheat model will be calibrated and validated for major wheat-growing agro-ecological zones using historical weather, soil, and management data. Future climate scenarios based on SSP2-4.5 and SSP5-8.5 will be bias-corrected and downscaled for mid- and late-century periods (2030s, 2050s, and 2080s)

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using Python libraries such as xarray and netCDF4. A fully automated Python–DSSAT workflow will be developed to enable large-scale batch simulations, sensitivity analysis, and efficient scenario evaluation. The study will further analyze adaptation strategies including altered sowing dates, cultivar selection, and irrigation management to enhance climate resilience. Expected outcomes include robust projections of wheat yield under future climates, identification of effective adaptation options, and the development of a reproducible modeling pipeline to support climate-smart agricultural planning and policy formulation in Pakistan.

ICGA-079

Proteomic Profiling of Fermented Spinach Powder: Enhancing Nutritional Quality and Functional Bioactivity

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Proteomics delivers a comprehensive approach to understand the molecular and nutritional transformations that occur during food fermentation. This investigation aimed to investigate the proteomic changes in spinach powder subjected to controlled fermentation to evaluate improvements in its nutritional and functional properties. The methodology involved fermenting spinach powder using selected lactic acid bacteria under optimized conditions, followed by protein extraction, enzymatic digestion, and analysis through mass spectrometry. Bioinformatics tools were utilized to identify and annotate proteins, assess their functional categories, and evaluate bioactive peptide formation. Results revealed significant protein hydrolysis during fermentation, leading to the generation of low-molecular-weight peptides with enhanced antioxidant and antimicrobial activities. Functional analysis indicated improved digestibility and bioavailability of essential amino acids compared to the unfermented sample. The findings demonstrate that fermentation induces beneficial proteomic modifications in spinach powder, enhancing its functional and nutritional quality. This study highlights the potential of fermented spinach powder as a sustainable, health-promoting food ingredient rich in bioactive peptides and functional proteins.

ICGA-080

Exogenous Application of Phenylalanine Confers Drought Tolerance in Ladyfinger (*Abelmoschus esculentus* L.) By Concerted Regulation of Metabolites and Antioxidant

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Globally, drought stress has negative impact on growth and yield of crops, while exogenous application of several osmoprotectants including hormones, vitamins and amino acids i.e Phenylalanine is used that enhances the plant capability to withstand in the drought stress. The present research examines the effects of phenylalanine administration and water stress on the morphological and biochemical reactions of okra. Therefore, a soil filled pot experiment was performed on okra variety Nirali that consist of two (a) control and (b) drought with exogenous

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foliar application of Phenylalanine 0, 25, 50, 100 and 150ppm on both sets at vegetative stage. Each treatment has four replicates. Drought stress reduce plant biomass i.e RFW, RDW, SFW and SDW, SL and RWC. Chlorophyll content such as chl a, chl b, carotenoids, t. chl and QY also decreases under drought stress conditions. While root length and enzymatic antioxidants such as POD, CAT, Amino acids, MDA increases in water deficit condition. Yield parameter such as fruit length, number of okra pods, no of seeds, total seed weight, hundred seed weight and thousand seed weight decrease under drought condition. Phenylalanine supplementation enhanced stress tolerance in okra. Foliar application of 100ppm phenylalanine proved to be the best under both drought stress and controlled condition as it promote growth significantly.

ICGA-081

Role of Genetics in Improving Crop Production

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Crop production is facing increasing challenges due to population growth, climate change, and declining natural resources. Genetics plays an essential role in meeting these challenges by improving the performance and adaptability of crop plants. Through the study of heredity and variation, plant breeders can identify desirable traits and transfer them into new varieties using classical and modern breeding methods. Advances in genetics such as mutation breeding, marker-assisted selection, genetic engineering, and genome editing have made crop improvement faster and more precise. These tools help develop varieties with higher yield, resistance to diseases and insects, improved tolerance to drought and salinity, and better nutritional quality. The use of genetics not only enhances productivity but also supports sustainable agriculture by reducing chemical inputs and ensuring food security. This review article highlights the major contributions of genetics in crop improvement and discusses emerging opportunities for future crop production under changing environmental conditions.

ICGA-082

Dietary Fiber Interventions for Optimizing Glycemic Control and Metabolic Health

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The global elevation of metabolic syndromes has prompted a shift towards food; a medicinal intervention. In this investigation the physiological impact of fiber-enriched functional foods on glycemic control and systemic metabolic markers in type II diabetes has been addressed. Standard dietary fibers are indispensable. Fortification of staple foods with a combination of concentrated viscous fibers like beta glucan, psyllium husk, and resistant starches present a targeted approach to manage glucose homeostasis. The metabolic benefits are driven as dual-action mechanism. Firstly, the soluble fibers increase bolus viscosity, creating a physical barrier that slows gastric emptying and inhibits the enzymatic hydrolysis of polysaccharides, resulting in flattening

postprandial glucose spikes. Secondly, the microbial fermentation of these fibers in the large intestine produces short-chain fatty acids receptors that stimulate the release of GLP-1 & PYY, hormones vital for insulin secretion and appetite regulation. Clinical data attained in this research demonstrate that consistent intake of fiber-fortified products correlate with a significant reduction in HbA1c levels and improved lipid profiles specifically LDL cholesterol reduction. Furthermore, the study highlights the role of fiber in enhancing gut microbiota diversity, which serves as a protective factor against systemic inflammation. These findings accentuate the potential of fiber-enriched functional foods as a scalable, cost-effective adjunct to pharmacological therapies in the prevention and management of diabetes related metabolic dysfunction.

ICGA-083

Role of Marker Assisted Selection (Mas) In Plant Breeding

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Plant breeding is important for improving crop yield and ensuring food security. Conventional breeding mainly depends on phenotypic selection, which is time-consuming and influenced by environmental factors. Marker assisted selection (MAS) has emerged as an effective approach that uses molecular markers linked to important genes or quantitative trait loci to improve selection efficiency. This review highlights the concept and principles of marker assisted selection, types of molecular markers used, and major selection strategies. The applications of MAS in improving disease resistance, abiotic stress tolerance, yield, and quality traits in different crops are discussed. The advantages, limitations, and future prospects of MAS in modern plant breeding are also briefly presented. The use of MAS, together with advanced genomic tools, can significantly enhance the efficiency of crop improvement program.

ICGA-084

Integrating Speed Breeding with Modern Genomic Tools in Wheat (*Triticum Aestivum* L.): Current Progress and Future Prospects

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Wheat (*Triticum aestivum* L.) is a cornerstone of global food security, yet its production faces unprecedented threats from climate change, diminishing arable land, and a growing global population. Traditional breeding methods, which typically require 10–12 years to release a new variety, are becoming insufficient to meet these rapidly evolving challenges. Speed Breeding (SB), a technology that uses extended photoperiods and controlled temperatures to accelerate plant development, has revolutionized wheat research by enabling up to six generations per year. However, speed breeding alone is primarily a tool for rapid generation advancement. To realize its full potential, it must be integrated with modern genomic tools. This review discusses the synergistic application of Speed Breeding with Genomic Selection (GS), Marker-Assisted Selection (MAS), and CRISPR/Cas9 genome editing. We highlight recent breakthroughs where

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this integration has fast-tracked the development of climate-resilient and disease-resistant wheat lines. Furthermore, we address the current bottlenecks—such as phenotyping accuracy and cost—and propose future directions for democratizing these technologies in developing countries.

ICGA-085

Salinity Stress in Maize (*Zea Mays* L.) Production in Pakistan: Challenges, Adaptation Mechanisms, and Sustainable Management Approaches

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Soil salinity is a major constraint to maize (*Zea mays* L.) production in Pakistan, particularly in irrigated regions of Punjab and Sindh where arid climatic conditions, poor-quality groundwater, and inadequate drainage have accelerated the expansion of salt-affected soils. As maize plays an increasingly important role in food, feed, and industrial sectors of Pakistan, improving its performance under saline environments is essential for national food security and sustainable agricultural development. This review summarizes the impacts of salinity stress on maize, key tolerance mechanisms, and applied management strategies relevant to Pakistan. Salinity stress adversely affects maize growth by imposing osmotic and ionic stresses that reduce water uptake, disrupt nutrient balance, and impair physiological functions. Morphological traits such as plant height, root development, leaf area, and biomass accumulation decline significantly under saline conditions, while physiological processes including photosynthesis, chlorophyll stability, and stomatal conductance are severely compromised. At the cellular level, excessive accumulation of sodium and chloride ions interferes with potassium homeostasis, induces oxidative stress, and damages cellular membranes. Salt-tolerant maize genotypes exhibit adaptive mechanisms including efficient ion exclusion, osmotic adjustment, enhanced antioxidant activity, and maintenance of photosynthetic efficiency. The development and adoption of salt-tolerant maize varieties remain the most cost-effective and sustainable approach for managing salinity stress in Pakistan. Integration of conventional breeding with physiological screening, molecular tools, and stress indices has enhanced selection efficiency. Complementary agronomic practices such as improved irrigation scheduling, soil amendments, and balanced nutrient management further reduce salinity-induced yield losses. Strengthening research–farmer linkages and promoting climate-smart technologies are crucial for sustaining maize productivity on Pakistan’s salt-affected soils.

ICGA-086

Role of Marker Assisted Selection in Plant Breeding

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Plant breeding is important for improving crop yield and ensuring food security. Conventional breeding mainly depends on phenotypic selection, which is time-consuming and influenced by environmental factors. Marker assisted selection (MAS) has emerged as an effective approach that uses molecular markers linked to important genes or quantitative trait loci to improve selection efficiency. This review highlights the concept and principles of marker assisted selection, types of molecular markers used, and major selection strategies. The applications of MAS in improving disease resistance, abiotic stress tolerance, yield, and quality traits in different crops are discussed. The advantages, limitations, and future prospects of MAS in modern plant breeding are also briefly presented. The use of MAS, together with advanced genomic tools, can significantly enhance the efficiency of crop improvement programs.

ICGA-087

Integrating Speed Breeding with Modern Genomic Tools in Wheat (*Triticum aestivum* L.): Current Progress and Future Prospects

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Wheat (*Triticum aestivum* L.) is a cornerstone of global food security, yet its production faces unprecedented threats from climate change, diminishing arable land, and a growing global population. Traditional breeding methods, which typically require 10–12 years to release a new variety, are becoming insufficient to meet these rapidly evolving challenges. Speed Breeding (SB), a technology that uses extended photoperiods and controlled temperatures to accelerate plant development, has revolutionized wheat research by enabling up to six generations per year. However, speed breeding alone is primarily a tool for rapid generation advancement. To realize its full potential, it must be integrated with modern genomic tools. This study discusses the synergistic application of Speed Breeding with Genomic Selection (GS), Marker-Assisted Selection (MAS), and CRISPR/Cas9 genome editing. We highlight recent breakthroughs where this integration has fast-tracked the development of climate-resilient and disease-resistant wheat lines. Furthermore, we address the current bottlenecks—such as phenotyping accuracy and cost—and propose future directions for democratizing these technologies in developing countries.

ICGA-088

An Overview of Cotton Leaf Curl Virus Disease a Serious Threat to Cotton Productivity

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Cotton leaf curl virus (CLCuV) is a major threat to cotton production in Pakistan, causing significant yield losses and economic impacts. This study reviews the current understanding of CLCuV's impact on cotton productivity, transmission, management strategies, and recent research developments. CLCuV causes 30-40% yield losses, affecting boll production and fiber quality. For screening against CLCuV to Develop virus resistant cultivars disease was induced Through

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grafting, delayed sowing and whitefly mediated transfer. The disease epidemiology is changed by Abiotic factors specially temperature and plant age. Cotton leaf curl virus disease not only affect yield but Also deteriorate fiber quality traits like Ginning out Turn percentage, staple length, fiber uniformity index, Fiber fineness, fiber bundle strength, maturity ratio Because of change in composition of major fiber Components including cellulose, protein, wax and Pectin. The uncertainty of inheritance of CLCuD also Prevails whether it is under the control of dominant or Recessive genes which maybe monogenic or polygenic. The resistance breakdown depends upon the evolutionary potential of the pathogen and the possibility of recombination by which new variants of viruses evolved. The resistance gained for Multan CLCuV became susceptible to Bure wala CLCuV due to virus mutation and lack of durable resistance. Management of CLCuD is the only option that can Command the disease in various ways inclusive of Change in sowing dates, crop nutrition, cultural practices, vector control, buffer crops and systemic poisoning of cotton seed by seed treatment will make the Cotton crop safe in initial 40-50 days after sowing. Biotechnology can also aid in controlling this disease through transcriptional gene silencing. Management strategies include resistant varieties and whitefly control. This review highlights gaps in current knowledge and suggests future research directions for sustainable cotton production.

ICGA-089

Effects of Nursery Transplanting and Nutrient Management On Growth and Yield of Cotton Under Arid Conditions

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Cotton (*Gossypium hirsutum* L.) is a key cash crop in the arid regions of Dera Ghazi Khan, where water scarcity and extreme temperatures constrain productivity. Nursery transplanting can advance sowing, improve seedling vigor, and enhance crop establishment. Cotton growth and yield, however, are highly sensitive to nutrient management, with both excessive and deficient fertilizer applications reducing growth, flowering, and boll formation, and potentially causing soil and environmental issues. This study evaluates the combined effects of nursery transplanting and optimized fertilizer regimes on cotton growth, development, and yield under arid conditions. The findings aim to identify nutrient strategies that maximize productivity, improve resource use efficiency, and support sustainable cotton cultivation in arid zones.

ICGA-090

Phycodiversity of freshwater algae in the Hill Torrents of the Koh-e-Suleiman range

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Heterokontophyta is a dominant taxonomic division with 34 species, followed by charophyta with 16 species, cyanobacteria with 13 species, chlorophyta with 5 species and euglenophyta with 1 species. A total number 69 species of freshwater algae reported which belonging to 32 genera and 30 families. Bacillariaceae and Spirogyraceae were the dominant families with 9 species. The average water temperature during the sampling period varied between 21°C and 37°C is in the streams of study area is an indication of dominance of diatom and cyanobacteria. Conductivity of the water with values 1675-1994 $\mu\text{S cm}^{-1}$ indicate high mineralization in freshwater which also favors salt tolerant species. Total dissolved solids (TDS) have high vales which indication of highly degraded water. pH ranged with an amplitude of 7.65-8.29 with all sites being alkaline. Dissolved oxygen (DO) relatively high for all sites. Water parameters of the study area favor the diversity of diatoms and cyanobacteria. Site#4 has the highest diversity of diatoms due to favorable water parameters.

ICGA-091

Management of Ammonia Volatilization Losses in Maize (*Zea mays*) Using Vachellia Nilotica Extract-Coated Urea

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Urea is the most widely used nitrogen (N) fertilizer which when applied to soil undergoes rapid hydrolysis due to the action of enzyme urease. This results in the production of excessive ammonia losses and low N use efficiency of crop plants. To mitigate the losses urease inhibitors are applied with urea and Vachellia nilotica extract is a newly reported soil urease inhibitor, which is till now studied only in wheat fields. The present study aims to manage ammonia volatilization losses in maize (*Zea mays*) by using V. nilotica extract-coated urea. The experiment was conducted according to RCBD two factors factorial, where uncoated urea and V. nilotica extract-coated urea (factor 1) was applied to maize at 0, 110 and 220 kg N ha⁻¹ (factor 2). Key parameters studied were ammonia volatilization loss, and growth and yield of maize including N uptake and N use efficiency of the crop plants. Results showed that coating of urea with V. nilotica extract significantly reduced ammonia losses by 23.7% and 18.9% where 110 and 220 kg N ha⁻¹ were applied, respectively. The coated urea also improved various parameters of maize crop including biological yield by 130% and plant height by 53% in comparison to uncoated urea. The findings highlight the effectiveness of V. nilotica extract in reducing nitrogen losses and improving maize yield, suggesting that natural urease inhibitors can be an environmentally friendly alternative to synthetic chemicals. However, the study also points out the need for further research on the long-term performance of these inhibitors in different Agro-climatic conditions to optimize their commercial application.

ICGA-092

Climate-Smart Agricultural Practices and Technology Integration for Improving Crop Productivity and Resilience in Arid Regions of Pakistan

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Climate change poses serious threats to agricultural productivity, food security, and farmer livelihoods, especially in arid and semi-arid regions of Pakistan. Increasing temperatures, irregular rainfall patterns, and frequent droughts demand the adoption of climate-smart and technology-driven agricultural practices. This study focuses on the role of modern agricultural technologies and sustainable farming methods in enhancing climate resilience and ensuring future food security. Key approaches include precision agriculture, efficient irrigation methods, soil moisture conservation techniques, and the use of improved crop varieties tolerant to heat and water stress. The integration of GIS, remote sensing, and smart farm management tools helps farmers make data-driven decisions regarding irrigation scheduling, fertilizer application, and crop monitoring. Additionally, conservation agriculture practices such as minimum tillage, crop rotation, and residue management improve soil health and reduce environmental degradation. The study highlights how combining traditional knowledge with innovative technologies can increase yield stability while minimizing resource use and greenhouse gas emissions. These strategies not only support sustainable production but also strengthen farmers' capacity to adapt to climate variability. The findings emphasize that technology adoption, farmer awareness, and institutional support are essential for building a resilient agricultural system capable of feeding a growing population under changing climatic conditions.

ICGA-093

Role of Smart Irrigation and Soil Management Technologies in Enhancing Climate Resilience and Sustainable Crop Production

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Agriculture in Pakistan faces increasing pressure from climate change, water scarcity, and soil degradation, which threaten long-term food security. Efficient resource management through modern technologies is essential for developing a climate-resilient farming system. This study highlights the importance of smart irrigation systems and improved soil management practices in sustaining crop productivity under changing climatic conditions. Technologies such as drip and sprinkler irrigation, soil moisture sensors, and automated irrigation scheduling help optimize water use efficiency and reduce losses caused by evaporation and runoff. At the same time, soil management techniques including organic amendments, mulching, conservation tillage, and balanced nutrient management enhance soil structure, fertility, and moisture retention capacity. The integration of digital tools, remote sensing, and field monitoring allows farmers to make precise decisions regarding irrigation timing and input application. These practices not only increase yield stability but also reduce environmental impacts such as soil erosion, nutrient leaching, and greenhouse gas emissions. The study emphasizes that combining smart water management with sustainable soil practices can significantly strengthen agricultural resilience, improve resource conservation, and support food security in climate-vulnerable regions. Adoption of these technologies requires farmer training, institutional support, and policy incentives for large-scale impact.

ICGA-094

Enhancing Nutritional and Climate Resilience in Barley: A Review of Biotechnological Interventions

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Barley (*Hordeum vulgare* L.) is one of the earliest domesticated cereal crops. It has been cultivated for more than 10,000 years. Historically it has been used as a staple food, animal feed, and for malting in beverage. In previous years, barley has obtained renewed scientific and commercial interest. Barley has rich nutritional composition like as including dietary fiber, vitamins, minerals, and antioxidants. These nutrients help to improved digestive health, cholesterol reduction, and better glycemic control. Barley is also well known for its adaptability to diverse and marginal environments Its also showing higher tolerance to drought, salinity, and low soil fertility. It is a suitable crop for climate-resilient and sustainable agriculture. Furthermore, advances in plant breeding and biotechnology have led to the development of improved barley varieties with higher yield, good disease resistance, and increase nutritional quality. With the growing global demand for functional foods and sustainable cropping systems. The barley has high potential to play a key role in ensuring food security. In this Also improving livestock productivity, and supporting agro-industrial development. Therefore, barley represents an ancient grain with modern features that can contribute significantly to future agricultural and nutritional challenges.

ICGA-095

Climate-Smart Breeding: Combining Heat and Drought Tolerance in Major Food Crops

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Climate change poses serious threats to global food security due to increasing temperatures and more frequent droughts, which significantly reduce crop yields worldwide. Major staple crops such as wheat, rice, maize, and sorghum are particularly vulnerable, with heat and drought stress often occurring simultaneously. Climate-smart breeding aims to develop crop varieties that combine tolerance to both stresses, ensuring stable productivity under climate extremes. This Study discusses the physiological and molecular basis of heat and drought tolerance, the challenges of breeding for combined stress resilience, and modern breeding tools such as quantitative trait locus (QTL) mapping, marker-assisted selection (MAS), genomic selection (GS), and gene editing. Future prospects emphasize integrating advanced phenotyping, omics technologies, and breeding strategies to develop resilient food crops and strengthen food security globally.

ICGA-096

Intercropping as a Strategy to Improve Land Use Efficiency, Soil Fertility, and Crop Yield

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To achieve sustainable food production, effective land utilization is critical especially in the context of a growing population of the world and global climate changes. Intercropping two or more crops planted simultaneously on a common unit of land is efficient in land use, using complementary relations between canopy structure, root architecture, and nutrient needs, and often with land equivalent ratios (LER) above unity, than in monocropping. These advantages are further enhanced by optimized planting geometry that helps to control plant density and row spacing layout, enhance light interception and nutrient uptake and interspecific interaction. Intercrops of legumes are also involved in biological fixation of nitrogen to the soil and diversified systems of crop rotation also prevents pests and disease outbreaks by reducing the reliance on chemical fertilizers. Intercropping together with planned spatial layouts promote resource-use efficiency, resource stability and agro-ecosystems resilience in support of both ecological and economic sustainability. Intercropping is a low input, climate resistant and sustainable method of land productivity maximization and the development of resilient agricultural systems in the face of variable environmental conditions through the integration of crop diversity, spatial optimization and management of soil fertilities.

ICGA-097

Role of Drone in Improving Pesticide use efficiency by Reducing its Dose and Residues in Rice Crop

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Rice (*Oryza sativa* L.) is a staple crop globally and a major contributor to Pakistan's economy and food security. Sustainable production requires efficient pest management to minimize pesticide residues while ensuring high yields. This study examines drone technology as an alternative to conventional knapsack spraying for optimizing pesticide application. A factorial experiment was conducted with two factors: application method (drone and knapsack) and pesticide levels (acetamiprid and thiamethoxam at 0%, 25%, 50%, 75%, and 100%) at Taqwa Farms, Galaxy Rice Mill Pvt. Ltd. Whandoo road, Eminabad, Gujranwala, and Punjab Pakistan. Data was analyzed statistically at 5% probability. The finding of this research indicated that drone application at 75% of the recommended dose provided the highest pest control efficiency while reducing pesticide use

and residues. Compared to knapsack spraying, drones ensured uniform coverage, minimized chemical wastage and time, water saving, and improved pesticide absorption.

ICGA-098

Integration of legume-oil seed crops Intercropping into Climate-Smart Agriculture for Sustainable Crop Production

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Global food security is under a significant threat due to climate change and global warming because it is characterized by an escalation of heat stress, rise in the occurrence of droughts, unpredictable rainfall cycles, and sustained soil erosion, especially in arid and semi-arid agro-ecosystems. The Climate-Smart Agriculture (CSA) has become a unified scheme that targets to improve the crop productivity and make the crops resistant to the climate stresses as well as to curb greenhouse gases emission. In this context, intercropping as the concomitant growth of two or more crops on a unit of land is one of the climate-smart techniques since it allows maximization of resource utilization based on spatial and temporal complements. Of major significance are the legume-oil seed inter-culture systems, which combine effective fixation of nitrogen biological processes with efficient use of nutrient and water, hence enhancing soil fertility, productivity and sustainability. Optimized planting geometry is important in order to maximize the performance of intercropping through controlling the plant population density and spatial locations, increasing the light interception, canopy microclimate, rooting relations and nutrient acquisition. Empirical observation suggests that legume-oilseed intercrops with proper planting geometry result in a higher land productivity, yield stability, and water and nutrient-use efficiency compared to sole cropping, and has been represented as being greater than unity. Moreover, these systems improve soil organic carbon, functional biodiversity, pest and disease suppression, and reliance on synthetic fertilizers and chemicals, and this helps in mitigating climate change by sequestration of carbon and reducing greenhouse gas emissions. All in all, the legume-oilseed intercropping with optimal planting geometry is a scientifically sound, low-input, and climatically resilient strategy, which in many ways aligns with CSA goals and provides a sustainable way of enhancing productivity, resource use, and agro-food system resilience to changing climatic conditions.

ICGA-099

Empowering Rural Households via Community-Driven Digital Finance: A Field Study in South Punjab

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Limited access to formal financial services remains a major constraint to sustainable rural livelihoods in many developing regions. Rural households often rely on informal savings

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mechanisms that lack security, transparency, and opportunities for productive investment. This paper presents a Community-Based Digital Savings and Micro-Investment Model aimed at enhancing financial inclusion, income stability, and livelihood resilience among rural communities. The study was conducted using an extension-based approach, targeting rural households across selected villages. A purposive sampling technique was applied to select 150 households from a population of 600, focusing on smallholder farmers and women participants actively involved in community self-help groups. Data were collected through structured interviews, digital transaction records, and participatory observation. The results indicate that over 85% of participants increased their monthly savings, while 70% invested in livelihood-enhancing activities such as agriculture, livestock, and small enterprises. Participants reported improved financial decision-making and higher household resilience against income shocks. Discussions highlighted the importance of combining digital tools with community governance and financial literacy for sustainable adoption. Based on the findings, it is recommended that policymakers and development practitioners scale up community-based digital financial platforms, integrate targeted training programs, and promote inclusive participation to strengthen rural livelihoods and reduce dependency on informal credit sources.

ICGA-100

Climate-Smart Sustainable Agriculture and Its Impact on Plant Health and Crop Protection

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Climate change has become a major issue facing the agricultural systems in the world and has had significant impacts on crop yield, plant health and pest and disease dynamics. High temperatures, unpredictable rainfall patterns, and prevalence of extreme weather patterns have increased both biotic and abiotic types of stress on crops and hence the need to find sustainable solutions. The climate-smart sustainable agriculture (CSSA) offers a combined concept that seeks to sustain agricultural resilience, secure food supply, and promote environmental-friendly crop production. The most important climate-sensitive agricultural activities such as crop rotation, crop diversification, conservation tillage, efficient water management, and the use of climate-resilient, disease-resilient varieties of crops are critical towards keeping plants healthy. These practices enrich the soil structure, improve the content of organic matter, and increase the diversity of microbes, which have all the effects of strengthening the plant defense system and reducing the prevalence of soil-borne and foliar diseases. Plants that are healthy and strong have a better ability to cope with the effects of pests and other environmental stressors, as a result of which the loss of yield decreases. Crop-protection CSSA has a core component of sustainable crop-protection that has been implemented largely through integrated pest management, which is the integration of biological control, cultural practices, resistant varieties, and prudent use of pesticides to achieve pest and disease management efficiently with reduced effects on the environment and ecosystem.

ICGA-101

Response of Humic Acid and Vermicompost to Three Wheat Varieties to Increase Vegetative Growth and Yield

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Wheat (*Triticum aestivum* L.) productivity is strongly influenced by soil fertility management, and the continuous use of chemical fertilizers has raised concerns about soil degradation and sustainability. Humic acid and vermicompost are organic amendments that enhance soil structure, nutrient availability, and plant physiological processes. This study evaluated the response of humic acid and vermicompost on vegetative growth and yield of three wheat varieties under field conditions. The experiment was conducted using a randomized complete block design with three replications. Treatments consisted of control, humic acid, vermicompost, and a combined application of humic acid and vermicompost across three wheat varieties. Growth traits (plant height, tillers plant⁻¹, leaf area index, biomass) and yield components (spike length, grains spike⁻¹, 1000-grain weight, grain yield, harvest index) were recorded and analyzed through ANOVA. Results showed that both amendments significantly improved growth and yield over the control, while the combined treatment produced the highest vegetative vigor and grain yield. Varietal differences were also observed, indicating differential nutrient use efficiency among wheat genotypes. The findings demonstrate that integrating humic acid with vermicompost is a promising, sustainable strategy for enhancing wheat productivity and soil health under local agro-ecological conditions.

ICGA-102

Dissecting Yield Architecture in Diverse Chili (*Capsicum annuum* L.) Germplasm Through Correlation and Path Coefficient Analysis

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Chili (*Capsicum annuum* L.) is an economically important spice crop in Pakistan; however, its productivity remains low due to limited genetic diversity and inadequate use of improved cultivars. The present study was conducted to evaluate genetic variability, trait associations, and direct and indirect effects of yield-related characters in chili to identify superior genotypes for future breeding programs. A total of 100 diverse chili genotypes sourced from the National Agricultural Research Center (Pakistan) and the World Vegetable Center (Taiwan) were evaluated under field conditions during the 2024 growing season using a randomized complete block design with three replications. Data were recorded for key morphological, physiological, and yield traits including days to flowering, NDVI, plant height, number of branches, fruit length, fruit diameter, single fruit weight,

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seeds per fruit, number of fruits per plant, and yield per plant. Analysis of variance revealed highly significant differences among genotypes for all studied traits, indicating the presence of substantial genetic variability. Yield per plant ranged from 20.3 g to 461 g, with genotypes D3, D40, and D5 exhibiting superior performance. Genotypic and phenotypic correlation analyses showed that yield per plant had strong positive associations with number of fruits per plant, single fruit weight, fruit diameter, fruit length, and seeds per fruit, while days to flowering exhibited a significant negative correlation with yield. Path coefficient analysis further revealed that number of fruits per plant exerted the highest positive direct effect on yield, followed by fruit diameter, single fruit weight, fruit length, and seeds per fruit, whereas days to flowering had a weak negative direct effect. Overall, the study demonstrates that fruit-related traits play a dominant role in determining chili yield, while NDVI and vegetative traits contribute indirectly through plant vigor and architecture. The identified high-performing genotypes and key yield-determining traits can be effectively utilized in chili breeding programs to develop high-yielding, early-maturing, and adaptable cultivars suitable for Pakistani agro-climatic conditions.

ICGA-103

Breeding Strategies for Climate Change Adaptation

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Climate change poses a significant challenge to global agriculture by altering temperature regimes, rainfall patterns, and the frequency of extreme weather events, ultimately threatening crop productivity and food security. Breeding climate-resilient crops has therefore become a central focus in plant science and agricultural research. This study synthesizes current and emerging breeding strategies aimed at enhancing crop adaptation to climate change. Traditional breeding approaches, such as phenotypic selection and hybridization, have long been used to improve stress tolerance by exploiting natural genetic variation. However, the slow pace of conventional methods is insufficient to match the rapid rate of environmental change. Integrating modern tools such as molecular markers, genomic selection, and marker-assisted backcrossing accelerates the identification and incorporation of favourable alleles for traits including drought tolerance, heat stress resistance, and flood resilience. Recent advances in high-throughput genotyping and phenotyping have enabled the dissection of complex stress-related traits, improving breeders' capacity to select for multiple adaptive characteristics simultaneously. Additionally, gene editing technologies like CRISPR/Cas9 provide precise manipulation of genes associated with stress response pathways, offering novel opportunities to develop climate-smart varieties. Participatory breeding programs that involve farmers in selection processes help ensure that newly developed cultivars meet local environmental conditions and socio-economic needs. This Study is also discusses the role of genomic prediction models in forecasting performance under future climate scenarios, as well as the importance of conserving and utilizing plant genetic resources from diverse environments. Finally, it highlights challenges such as regulatory barriers, limited investment in public breeding programs, and the necessity of interdisciplinary collaboration. By adopting a multifaceted breeding framework that combines traditional knowledge with cutting-edge biotechnology, agricultural systems can be better equipped to withstand the impacts of climate change and contribute to sustainable food production.

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ICGA-104

Sustainable Agricultural Practices and Climate-resilient Cropping Systems

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Integration of Sustainable Agricultural Practices and Plant Protection. Climate change due to anthropogenic activities is increasingly threatening the production of agriculture products by altering temperature regimes, precipitation patterns and spatial-temporal distribution of pests and plant pathogen. Such disasters require comprehensive and sustainable measures to guarantee climate-resistant crops. The development of sustainable agricultural practices followed by effective plant protection strategies has become a central solution to the strengthening of crop resilience, maintenance of the health of plants, and ensuring food production in the long run. Sustainable agronomic systems such as crop rotation, intercropping, conservation tillage, use of organic soil amendments and prudent use of water play a significant role in alleviating soil health and reducing crop stress. The improved soil structure and increased microbial diversity help to make nutrients bioavailable and strengthen plant defence which makes crops less vulnerable to pests and diseases. In the same breath, the use of climate and disease-resistant cultivars also helps in maintaining and yield stability in the changing environment. Sustainable systems of plant protection anticipate integrated pest management (IPM), application of biological control agents, cultural management and the prudent use of chemical pesticides. These types of plans can reduce the pressure of pests, delay the development of pesticide resistance, and reduce the negative impact on non-target organisms and ecological quality. The integration of modern technologies such as weather-related forecasting, remote sensors, and early alerts makes this even easier through early identification and control of nascent pest and disease outbreaks that are governed by the changing climatic conditions. Together, the concomitant use of sustainable agronomic and plant protection strategies enhances the resurgence of cropping systems to stresses resulted by climate. Such a combined paradigm will reduce losses of yields, enhance the sustainability of the environment and support food security. The nexus between sustainable agriculture and plant protection should therefore be strengthened to produce climate resistant systems that can meet the future needs of food in the world.

ICGA-105

Harnessing Chemistry and Smart Sensing for Climate-Resilient, Low-Input Agriculture: A Sense–Decide–Act Platform for Food Security in Semi-Arid Regions

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Semi-arid South Punjab faces increasing climate stress in the form of heat spikes, erratic rainfall, and gradual salinity build-up. These factors accelerate nutrient losses, intensify biotic stress, and reduce yield stability, thereby threatening food security. Practical solutions require not only “green inputs” but also timely, data-driven decisions that farmers can realistically adopt. Paper-based

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electrochemical/optical assays with smartphone readouts will be designed to measure pH, electrical conductivity (salinity proxy), nitrate, and soil moisture, calibrated against standard laboratory methods. Sensor data will be integrated with local weather information to generate early-warning advisories for irrigation scheduling, salinity risk alerts, and nutrient application windows. Agro-waste-derived biochar will be produced and mildly functionalised using green-chemistry routes (surface oxygen functionalities with mineral/biopolymer binders) to form composites aimed at enhanced ion retention and controlled nutrient availability. Chitosan-derivative films will be formulated for seed or foliar application. Performance will be evaluated through incubation and pot/plot trials using nutrient-use efficiency, water-use efficiency, salinity dynamics, leaching proxies, and yield stability indicators. The integrated system is expected to (i) improve decision timing through actionable field sensing and forecast-guided advisories, (ii) reduce nutrient losses by strengthening soil nutrient-holding capacity, (iii) enhance drought/salinity tolerance via improved water retention and ionic balance, (iv) reduce disease pressure and pesticide dependence through biopolymer-mediated barrier and induced-resistance effects, and (v) deliver measurable carbon co-benefits through stable carbon incorporation. This work advances a closed-loop, chemistry-informed approach that links measurement → prediction → targeted intervention for climate-resilient crop production. The novelty lies in integrating affordable sensing with forecast-guided management and functional green inputs, offering a scalable pathway for sustainable intensification and food security in resource-constrained semi-arid farming systems.

ICGA-106

Weed Management Strategies of Direct Seeded Rice Under Different Sowing Methods

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Conventional method of rice planting needed large quantity of H₂O, manual labor and energy for soil preparation which are becoming progressively more limited and costly; make rice production less beneficial. So there is a need to move from the transplanted rice to direct seeded rice (DSR). Weeds are major competitors of direct seeded rice and are reported to decrease the DSR yield by 90%. However, weed control is a major constraint to its sustainability. This 2-years study is being planned to develop suitable and economical weed management strategies in DSR. The study was conducted at Research Area of Ghazi University Dera Ghazi Khan during summer 2022 and 2023. The experiment comprised of different weed control strategies viz., T1: Control/ No weeding, T2: Weed free, T3: Wheat straw mulch @ 4 t/ha, T4: Rice straw mulch @ 4 t/ha, T5: Acetachlor 50% EC 500 ml/acre, T6: Bispyribac sodium and Bensulfuron methyl 15+30 days after sowing @ 60 g/acre were applied with different sowing methods (drill, bed and broadcast). The weedy check treatment was maintained for comparison. The experiment was laid out in RCBD with 3 replicates. The net plot size was 3.2 m × 5 m. Data obtained were analyzed statistically by using Fisher's analysis of variance technique and differences among treatments mean compared by using LSD

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test at 5% possibility level. Maximum weed control, productive tiller, number of grain per panicle, 1000 grain weight and grain yield were obtained in weed free treatment in drill sowing methods followed by Acetachlor 50% EC 500 ml/acre + Bispyribac sodium and Bensulfuron methyl 15+30 days after sowing @60 g/acre. It is concluded that Acetachlor 50% EC 500 ml/acre + Bispyribac sodium and Bensulfuron methyl 15+30 days after sowing @60 g/acre can give an efficient and economical weed control in DSR.

ICGA-107

Anthocyanins as Natural Shields: Building Climate-Resilient Crops Through Biotechnology and Breeding

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Rising temperatures, prolonged drought, increasing soil salinity, and stronger UV radiation are already reducing yields of major crops worldwide. Under these harsh conditions, anthocyanins—the red, purple, and blue pigments found in many fruits, leaves, and grains – are proving to be far more than simple colour molecules. They act as powerful antioxidants, sunscreen compounds, metal scavengers, and signalling agents that help plants survive multiple stresses at once. When plants face heat, drought, or salt stress, anthocyanin levels often increase rapidly. These pigments protect chloroplasts from excess light, neutralise harmful reactive oxygen species, improve water-use efficiency, and even reduce damage from toxic aluminium in acidic soils. Recent field observations in rice, maize, tomato, and grape confirm that varieties naturally rich in anthocyanins suffer less photo-bleaching, maintain higher photosynthetic rates, and recover faster after stress episodes than their non-pigmented counterparts. The good news is that we now understand the genetic switches that control anthocyanin production. The core MYB–bHLH–WD40 transcription complex, together with light, temperature, and hormone signals, can be precisely activated or strengthened. Modern tools such as CRISPR-Cas9, CRISPR-Cas12a, and base editing now allow scientists to turn on anthocyanin pathways in tissues where they are normally silent (green leaves, roots, or grain pericarp) without unwanted side effects on growth or yield. Promising results are already emerging. Edited purple tomatoes, red-leaved rice, and deep-purple maize lines show 25–45 % higher survival under combined heat-drought stress in glasshouse and field trials. Metabolic engineering that overexpresses both early (PAL, CHS) and late (ANS, UFGT) biosynthetic genes, often under stress-inducible promoters, produces stable, high-anthocyanin plants that also retain good agronomic performance. The latest evidence on how anthocyanins protect crops against climate-driven stresses and highlights practical genome-editing and breeding strategies that are delivering real-world results. By making anthocyanin accumulation stronger, faster, and more targeted, we can create a new generation of colourful, resilient varieties that need fewer chemical inputs and produce stable yields even when the climate becomes unpredictable. Anthocyanin-rich crops are not just prettier – they are part of the practical toolkit for feeding the world in a warmer future.

Integrating Corrected and Reconstructed Climate Data and Multiple-Crop-Model Output to Improve Wheat Yield Prediction under Climate Change

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Wheat production remains critically vulnerable to climatic variability and projected long-term climate perturbations, with accurate yield forecasting essential for global food security planning and agricultural policy formulation. The advancement of crop simulation modeling has established these tools as central to yield prediction frameworks, yet substantial uncertainties persist regarding the reliability of climate datasets and the transferability of model outputs across spatiotemporal domains. The present review examines the current state of knowledge regarding the integration of bias-corrected and reconstructed climate data with multiple-model crop simulation ensembles to enhance the robustness of wheat yield predictions under climate change scenarios. Climate datasets supporting crop modeling applications exhibit inherent systematic biases arising from interpolation procedures, observational network heterogeneity, and regional climatic complexities, with these errors propagating substantially through crop model simulations and undermining predictive fidelity. Existing literature demonstrates that raw meteorological data introduce considerable uncertainty into wheat yield estimates, yet corrected and reconstructed climate datasets have demonstrated capacity to substantially reduce prediction errors through various statistical and dynamical correction methodologies. The adoption of multiple-crop-model frameworks, rather than reliance upon single-model outputs, has emerged as a pragmatic approach to quantifying model structural uncertainty and enhancing confidence in yield projections. However, the scientific literature exhibits limited consensus regarding optimal protocols for integrating corrected climate inputs with ensemble crop model architectures, and systematic evaluation of such integrated approaches remains incomplete across diverse wheat-producing regions. Previous investigations have evaluated climate dataset corrections and multi-model approaches largely as independent research questions, with insufficient attention to their synergistic effects when combined within comprehensive prediction systems. The methodological heterogeneity characterizing existing studies—encompassing variable climate correction techniques, disparate crop models, and context-specific validation frameworks—complicates comparative analysis and impedes formulation of generalizable guidance. The literature further reveals inadequate characterization of uncertainty propagation pathways through integrated systems, limiting transparent communication of prediction confidence intervals to agricultural stakeholders and policymakers. This review synthesizes available evidence regarding climate data correction methodologies applicable to wheat modeling, critically appraises multi-model ensemble approaches, and evaluates the effectiveness of integrated systems combining corrected climate inputs with crop model ensembles. The review identifies persistent knowledge gaps concerning uncertainty quantification, geographic generalizability, and farmer-relevant decision support formats. Enhanced understanding of these integration pathways could facilitate development of robust, locally-calibrated wheat yield prediction systems supporting climate-adaptive agricultural management strategies across vulnerable production regions globally.

ICGA-109

Sector using Geo- Spatial Technologies. A Case Study from DG Khan and Rajanpur Districts

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The paper investigates the reasons, scope, and damage caused by the flood brought on by the district of Dera Ghazi Khan (DGK) and Rajanpur East marginal embankment falling apart. The Dera Ghazi Khan and Rajanpur districts in south Punjab, Pakistan, saw frequent rainfall in the months of July- August 2022, which had a detrimental impact on both people's lives and their possessions. The southern section of Punjab is bounded on the west by the Suleman Range, which stretches 360 kilometers from Ramak (upper side of Taunsa) to Kashmore (start of Sindh), covering the districts of DG Khan and Rajanpur, and on the east by the River Indus. Rainfall in the Suleman Range during the monsoon season (July to September). Flash floods known as Hill Torrents (local name "Rodh") occur in areas larger than 24500 square kilometers characterized by a large concentration of eroded debris. These Hill Torrents have a total of 200 numbers, which 13 are significant. These Hill Torrents are recognized after crossing through the piedmont area (Fan area) named "Pachad area" with a breadth of 30 to 40 kilometers, comprising around 34500 square kilometers (9400 square kilometers). It destroys irrigated areas, crops, buildings, and public / private infrastructures (most recently in 2008, 2010, 2012 used to investigate the spatiotemporal variation in river discharge and flood limitations for barrages. The results indicate that an unusual rainfall in the upper Indus Basin in July caused a significant discharge in the center Indus Basin. In this result, it exceeded the flood limits at different regions of south Punjab, Pakistan, which resulted in the breaching of East Marginal embankment. Modified Normalized Difference in Water Index (MNDWI) was used to extract inundation, and different classes of land cover were identified using a supervised picture classification technique. According to the analysis, a significant rainfall occurrence in the last week of July 2010 in the upper catchment areas of Indus River generated the flood. The River Indus experienced its largest discharge in the Results.

ICGA-110

Development of Rice Tungro Bacilloform Virus Driven Phloem-Specific Defense System Against Whitefly in Cotton (*Gossypium hirsutum* L)

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Whitefly (*Bemisia tabaci*) is one of the most destructive insect pests of cotton (*Gossypium hirsutum* L.), responsible for severe yield losses worldwide due to direct feeding damage and transmission of viral pathogens. Conventional control measures, including broad-spectrum insecticides, have proven increasingly ineffective because of rapid resistance development and adverse environmental impacts. Therefore, engineering a targeted, phloem-specific defense system offers a promising and sustainable strategy for whitefly management. In this study, we developed a novel transgenic cotton defense platform driven by the Rice Tungro Bacilloform Virus (RTBV) promoter, a well-characterized phloem-specific regulatory element. The RTBV promoter was used to precisely direct the expression of insecticidal and anti-feeding genes within the phloem tissues,

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where whiteflies feed and deposit pathogens. Gene constructs containing RTBV-driven effector molecules—designed to disrupt whitefly physiology, inhibit feeding, or interfere with virus transmission—were integrated into cotton via *Agrobacterium*-mediated transformation. Molecular characterization confirmed stable insertion and phloem-localized expression, while bioassays demonstrated significant reductions in whitefly survival, fecundity, and feeding efficiency compared with non-transgenic controls. Additionally, preliminary field evaluations showed enhanced resistance without affecting plant growth or yield. This RTBV-promoter-based system represents a precise, energy-efficient, and environmentally safe approach to protect cotton crops against phloem-feeding pests. The findings highlight the potential application of phloem-specific promoters in next-generation insect-resistant cotton and provide a sustainable framework for integrated pest management strategies globally.

ICGA-111

Enhancing Farm Productivity and Sustainability through Maize-Soybean Intercropping under varying Nitrogen sources

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Intercropping—a technique to raise land-use efficiency in both conventional and modern agriculture, has demonstrated potential as a land-use efficient and sustainable agricultural practice. The field experiment comprised of two factors, viz. intercropping crops (maize-soybean, pearl millet-soybean, and sorghum-soybean) with different nitrogen sources as recommended nitrogen dose (RND;100% for both crops), 75% RND + 25% compost, 50% RND + 50% compost, 25% RND + 75% compost and 100% compost. The field experiment was laid out in a split-plot arrangement under randomized complete block design. Field study demonstrated an increase in grain and biological yield with the application of 75% RND+25% compost as compared to 100% RND in sole cropping as compared to intercropping during 2022 and 2023. In case of competitive indices, land equivalent ratio (LER) implied that for maize and pearl millet-soybean intercropping system 55-45% and 60-70% more land in monocropping maize and pearl millet were required as compared to the respective intercropping with soybean during 2022 and 2023, respectively. While the trend in sorghum-soybean intercropping was quite different, maximum LER was observed at 100% RND that was 60% and 56% higher during 2022 and 2023, respectively. Competitive ability of cereals was minimum at 75% RND+25% compost when intercropped with soybean, while cereals showed the maximum competitive ability 1.72 and 1.21 as compared to soybean in 75% RND+ 25% compost and 1.67 at 100% RND, respectively during the second crop year 2023.

ICGA-112

Temperature Stress and Early Growth of Atriplex

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Knowledge on the ecophysiological changes of invasive plant species due to the changes in temperatures is imperative to make predictions of their future extent or spread particularly in arid

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and semi-arid areas. The paper examines the effect of temperature on germination and seedling growth of an invasive halophyte, the *Atriplex graccilus* under controlled conditions. The effects of 6 steady temperature conditions (20, 25, 30, 35, 40, and 45oC) were investigated to examine seed germination, seedling vigor, growth and stress physiology. Percent germination, mean germination and the vigor index was maximum at 30oC whereas further increase in temperature reduced germination. Shoot and root growth as well as biomass accumulation was also optimum at 30oC. The levels of physiological indicators of stress namely electrolyte leakage, malondialdehyde (MDA), and the activity level of antioxidative enzymes were significantly higher at temperatures greater than or equal to 35oC, which indicated the occurrence of oxidative stress at higher temperature. One conspicuous observation was that *A. graccilus* had nonexhausted adaptive potential to moderate temperatures, but extremely high temperatures (≥ 40 o C) led to lethal growth retardation and peroxidation of the cell membrane. These findings have indicated that *A. graccilus* can survive in moderately warm conditions and this could promote its invasion in regions that experience climate change.

ICGA-113

Harnessing Chemistry and Smart Sensing for Climate-Resilient, Low-Input Agriculture: A Sense–Decide–Act Platform for Food Security in Semi-Arid Regions

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Semi-arid South Punjab faces increasing climate stress in the form of heat spikes, erratic rainfall, and gradual salinity build-up. These factors accelerate nutrient losses, intensify biotic stress, and reduce yield stability, thereby threatening food security. Practical solutions require not only “green inputs” but also timely, data-driven decisions that farmers can realistically adopt. Paper-based electrochemical/optical assays with smartphone readouts will be designed to measure pH, electrical conductivity (salinity proxy), nitrate, and soil moisture, calibrated against standard laboratory methods. Sensor data will be integrated with local weather information to generate early-warning advisories for irrigation scheduling, salinity risk alerts, and nutrient application windows. Agro-waste-derived biochar will be produced and mildly functionalised using green-chemistry routes (surface oxygen functionalities with mineral/biopolymer binders) to form composites aimed at enhanced ion retention and controlled nutrient availability. Chitosan-derivative films will be formulated for seed or foliar application. Performance will be evaluated through incubation and pot/plot trials using nutrient-use efficiency, water-use efficiency, salinity dynamics, leaching proxies, and yield stability indicators. The integrated system is expected to (i) improve decision timing through actionable field sensing and forecast-guided advisories, (ii) reduce nutrient losses by strengthening soil nutrient-holding capacity, (iii) enhance drought/salinity tolerance via improved water retention and ionic balance, (iv) reduce disease pressure and pesticide dependence through biopolymer-mediated barrier and induced-resistance effects, and (v) deliver measurable carbon co-benefits through stable carbon incorporation. This work advances a closed-loop, chemistry-informed approach that links measurement → prediction → targeted intervention for climate-resilient crop production. The novelty lies in integrating affordable sensing with forecast-guided management and functional green inputs, offering a

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scalable pathway for sustainable intensification and food security in resource-constrained semi-arid farming systems. southern blight in tomatoes and could serve as a sustainable alternative to chemical fungicides.

ICGA-114

Screening the efficiency of wild plant aqueous extract as biostimulant for sustainable agricultural practice

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Wheat (*Triticum aestivum*) is globally used in the human food and used as staple food in Pakistan. Enhancing wheat production using biostimulants can contribute significantly to food security and sustainability. These substances alter structural processes and effect the plant development by increasing the tolerance to environmental stresses and enhance grain yield and quality. The object of this work was to examine impact of aqueous extracts of various medicinal plants *Convolvulus prostratus*, *Cenchrus ciliaris*, *Cassia senna*, *Achyranthes aspera*, *Suaeda fruticosa* and *Tamarix aphylla* on the development and productivity of wheat crop. Experiment was conducted in field with different concentration (1%, 3%, 5%, 7% and 9%) of plants aqueous extract in priming and foliar way. At intervals of 30 days, 60 days, 90 days, and 160 days following planting, four harvests were conducted to evaluate various growth metrics. According to results of this research at low concentration of plants aqueous extract stimulate or promote the growth of wheat crop but as the concentration of plants aqueous extract was increased it show the negative effect on the wheat crop and yield. And plants aqueous extract applied by priming method show more growth of wheat crop as compared to foliar method.

ICGA-115

Efficacy of Trichoderma secondary Metabolites against Sclerotium rolfsii causing Southern Blight in Tomato

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Southern blight, which is caused by *Sclerotium rolfsii*, is a major threat to the cultivation of tomatoes (*Solanum lycopersicum* L.), mainly because the pathogen is tolerant and there are no resistant varieties. Present study was conducted to assess the effectiveness of secondary metabolites produced by three *Trichoderma* species (*T. harzianum*, *T. viride*, and *T. hamatum*) to control *S. rolfsii*. In vitro, poisoned food technique was used to find most effective trichoderma specie against *Sclerotium rolfsii* along with concentration of secondary metabolites. *T. harzianum* was the most effective inhibitor of pathogen growth (72.3% PIRG at 25% CF), performing better than *T. hamatum* (67.4%) and *T. viride* (56.9%). In the greenhouse experiment, the use of the secondary metabolites of these *Trichoderma* species reduced disease incidence and severity and also improved growth parameters. When the plants were inoculated with the pathogen, and lower doses of *Trichoderma* metabolites have improved the plant growth parameters but not to the extent that can be significantly notable. However, higher concentrations of the metabolites produced excellent values for ADVANTA 12021 F1: root length 15 cm, shoot length 28 cm, fresh weight

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14 g, and dry weight 4 g, while the pathogen alone caused a reduction in biomass up to 80%. Among the *Trichoderma* species, *T. harzianum* was found to be more effective than the other species, and this could be attributed to a combination of parasitism, antibiosis, and induction of systemic resistance. Based on the findings of this study, *Trichoderma* secondary metabolites are more effective in controlling.

ICGA-116

Influence of Cotton Plant Density on Insect Pest Phenology under Changing Climate Scenario

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Abstract: Agriculture significantly contributes to Pakistan's economy. Within this sector, cotton is an important cash crop and serve as the primary source of raw material for the Pakistan textile industry. Pakistan is the world's fifth-largest producer of cotton, after China, United States, Brazil and India. Cotton consumption has risen in response to a significant increase in global population. However, Pakistan's cotton production is declining due to changing environmental conditions, pest outbreaks, insecticide resistance and pest resurgence. To improve cotton cultivation and productivity, a study was conducted at Cotton Research Institute, Multan, to assess the response of different insect pests to varying planting densities. Data on the populations of whitefly, thrips, jassid, dusky cotton bugs, dusky cotton bugs and pink bollworm were recorded weekly across different plant spacings. Additionally, population of natural enemies and metrological data were also recorded throughout the cotton growing season at these densities. Compact type cotton variety was sown using randomized complete block design (RCBD) with five treatments (T1-T5), each corresponding to different plant spacings of 6, 9, 12, 15 and 18 inches, respectively; each treatment was replicated three times. The results revealed that the population of whitefly, jassid, thrips, and dusky cotton bug differed significantly across the plant densities. The highest populations of these sucking insect pests (whitefly 5.87, jassid 2.34, thrips 1.98 and dusky cotton bug 3.86) were observed in T1 (plant spacing = 6 inches), whereas the lowest populations (whitefly 4.02, jassid 0.11, thrips 1.14 and dusky cotton bug 2.90) were recorded in T5 (plant spacing = 18 inches). Pink bollworm populations did not differ significantly among treatments. The population of ants, green lacewings, lady bird beetles, and spiders differed significantly among treatments, while population of these *Geocoris* and *Orius* bugs did not show significant difference at any plant density. In T1, the populations these beneficial insects were highest, whereas they were lowest T5. These results suggest that planting cotton at a 6-inche spacing could enhance production and minimize pest population through increased activity of natural enemies. This study may also be helpful in integrated pest management (IPM) for the control of pest population.

ICGA-117

Strengthening Food Security through Integrated Waste Reduction: Advances in Storage Systems, Distribution Efficiency, and Packaging Innovations

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The issue of food insecurity has been of great concern to the world especially in the developing nations where food losses are being experienced in large scale as a result of poor storage methods, poor distribution channels and poor packaging habits. The current paper looks into an interdisciplinary method of improving the food security by reducing food waste at post-harvest supply chain. It also presents main issues in storage infrastructure like temperature control and post-harvest methods, and possible climate smart solutions such as affordable cold storage, enhanced grain storage, and decentralized small-scale farmer facilities. The paper also examines inefficiencies in distribution, such as transit delays, lack of coordination in logistics, cold-chain disruption and result in quality and economic losses. Also, recently developed biodegradable and active packaging is mentioned in terms of their use in increasing the shelf life and maintaining food quality. This research suggests a scalable model to minimize the food waste and reinforce the food availability by incorporating the enhancements of the storage, distribution, and packaging, which is especially applicable to Pakistan and other economies that rely on agriculture.

ICGA-118

Occurrence and Molecular Characterization of Entomopathogenic Fungi Associated with *Spodoptera frugiperda* in Pakistan Maize Farm

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Spodoptera frugiperda (J.E. Smith), commonly known as fall armyworm, poses a significant threat to maize cultivation in Pakistan following its recent establishment in South Asian agroecosystems. The reliance on chemical pesticides for managing this polyphagous pest has raised concerns regarding environmental sustainability, residual toxicity, and development of insecticide resistance. Entomopathogenic fungi offer an ecologically sound alternative for biological suppression of lepidopteran pests. This investigation will be focused on surveying and characterizing indigenous entomopathogenic fungi naturally associated with *S. frugiperda* populations in Pakistan maize-growing regions. Field surveys will be undertaken in major maize-producing districts across Punjab, Khyber Pakhtunkhwa, and Sindh provinces during the kharif seasons. Diseased larvae exhibiting mycosis symptoms and rhizosphere soil samples will be systematically collected from infested fields. Fungal isolation will be accomplished using standard entomopathogenic media supplemented with antibiotics to suppress bacterial contaminants. Preliminary identification can be relied on conventional taxonomic keys examining macroscopic and microscopic characteristics. Molecular confirmation will be involved amplification and sequencing of ribosomal DNA regions, specifically the internal transcribed spacer (ITS1-5.8S-ITS2) and the beta-tubulin gene. Phylogenetic relationships will be established through neighbor-joining and maximum likelihood analyses using MEGA software. Fifty-three fungal isolates will be obtained, with *Beauveria bassiana* comprising 58% of the collection, followed by *Metarhizium anisopliae* (32%) and *Isaria fumosorosea* (10%). Nucleotide sequence analysis will be revealed genetic polymorphism within species, indicating multiple genotypes circulating in Pakistan agricultural landscapes. Virulence screening against laboratory-reared *S. frugiperda* third-instar larvae will show variable pathogenicity, with lethal concentrations (LC₅₀) ranging from 2.3×10⁶ to 8.7×10⁷ conidia/mL after seven days of exposure. Several isolates will be demonstrated promising sporulation capacity and thermal stability, critical attributes for field application.

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Growth characteristics under different temperature regimes (15-35°C) will be assessed to determine optimal conditions for mass production. The discovery of these indigenous fungal entomopathogens provides valuable germplasm for developing locally adapted mycoinsecticides suited to Pakistan's climatic conditions. Integration of these biocontrol agents into existing pest management frameworks could reduce chemical pesticide dependency while maintaining crop productivity and environmental quality in maize production systems.

ICGA-119

Role of Copper Oxide Nanoparticles in Improving Wheat Drought Tolerance Through Morphophysiological and Biochemical Modulation

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Drought stress is a major abiotic constraint limiting wheat (*Triticum aestivum* L.) productivity by disrupting morphological growth, physiological performance, and biochemical stability. Recent advances in nano-enabled agriculture suggest that engineered nanoparticles can enhance plant stress resilience through targeted physiological modulation. During the study, experiment was conducted in completely randomized block design. Seeds of two wheat varieties (Dilkas-20 and Nawab-20) were sown in pots filled with garden soil and grown under four moisture conditions (control, drought, rewatering after drought and exogenous application of copper oxide nanoparticles (CuO-NPs) under drought. This study investigates the influence of exogenously applied copper oxide nanoparticles (CuO-NPs) on wheat exposed to controlled water deficit conditions, with emphasis on morphological, physiological, and biochemical responses. Wheat plants were subjected to drought stress along with foliar application of CuO-NPs at selected concentrations. Drought stress significantly reduced plant height, leaf area, biomass, chlorophyll content, relative water content (RWC) and photosynthetic efficiency. CuO-NPs application mitigated these adverse effects, leading to improvements in shoot and root growth, chlorophyll stability, RWC, and gas exchange parameters. These findings demonstrate that CuO-NPs ameliorate drought-induced damage by maintaining cellular water status, and sustaining photosynthetic machinery. Between two wheat varieties, Dilkash-20 was found with greater drought tolerance and showed better response under foliar application of CuO-NPs while Nawab-20 was little drought sensitive and showed better responses after rewatering. Overall response indicates that CuO-NPs act as modulators of stress physiology, thereby improving drought tolerance in wheat. Such nano-enabled interventions may represent a promising approach for sustaining crop productivity under changing climatic conditions. Further research is warranted to optimize nanoparticle dosage and evaluate environmental safety for field-scale applications.

ICGA-120

Allelopathic activities of five trees leaves litter on seedling emergence and development of gram (*Cicer arietinum*) under different soil texture

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Allelopathic interactions among tree species and soil texture significantly influence seed emergence and early plant growth. In agroforestry systems, leaf litter from Eucalyptus, Neem, Conocarpus, and Moringa releases phytochemicals that can inhibit the germination and growth of gram. This laboratory-based study was conducted at the Laboratory of the Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan (Pakistan) to evaluate the effects of leaves litter of Eucalyptus, Neem, Conocarpus, Poplar, and Moringa under three soil textures (sand, clay, and loam) on seedling performance of gram (*Cicer arietinum*). Growth and physiological parameters were recorded at 15 and 30 days after sowing (DAS), including emergence percentage, root and shoot length, plant length, fresh and dry biomass, SPAD chlorophyll values, plant growth rate, and photosynthetic efficiency. At 15 DAS, root length ranged from 3.94 to 8.03 cm, shoot length from 4.90 to 12.98 cm, and plant length from 8.40 to 14.81 cm, depending on leaves litter and soil type. Emergence percentage varied markedly (10–60%), with strong inhibitory effects observed under Eucalyptus and Conocarpus leaves litters, particularly in sandy soil. Fresh biomass ranged from 0.16 to 0.90 g, while dry weight ranged from 0.01 to 0.07 g. SPAD chlorophyll values varied between 8.31 and 24.30. At 30 DAS, substantial improvements were observed across all treatments. Root length increased to 4.21–9.91 cm, shoot length to 8.87–16.20 cm, and plant length to 12.10–25.31 cm. Fresh biomass ranged from 0.61 to 7.78 g, with dry weight reaching up to 0.91 g. SPAD values peaked at 36.8, particularly under Moringa leaves litter in loam soil. Plant growth rate ranged from 0.21 to 0.69, while photosynthetic efficiency reached a maximum of 2.1. Overall, Moringa leaves litter consistently enhanced seedling growth, biomass accumulation, chlorophyll content, and photosynthetic efficiency across all soil textures, especially loam soil. In contrast, Eucalyptus and Conocarpus leaves litters exhibited pronounced inhibitory effects on emergence and early growth. These findings demonstrate that allelopathic responses are highly species-specific and soil-dependent, highlighting the importance of appropriate tree selection for agroforestry and sustainable cropping systems under semi-arid conditions.

ICGA-121

Hormetic and Allelopathic Modulation of Wheat (*Triticum aestivum* L.) Growth and Yield Dynamics through Foliar Application of Tropical Tree Leaf Extracts

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The search for sustainable agro-inputs has pivoted toward botanical extracts that possess either biostimulatory or phytotoxic properties. This study was conducted to evaluate the influence of foliar-applied aqueous leaf extracts from six diverse tree species—Control (T1), *Acacia nilotica* (T2), *Dalbergia sissoo* (T3), *Moringa oleifera* (T4), *Eucalyptus camaldulensis* (T5), and *Albizia lebbek* (T6)—at three concentration levels (Control, 2%, and 4%) on the morpho-physiological development and yield architecture of wheat. A large-pot experiment was executed using a Factorial Randomized Complete Block Design (RCBD) with six replications. Treatments were

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applied as foliar sprays at two critical growth stages: maximum tillering (Zadoks GS 25) and anthesis (Zadoks GS 60). The study monitored growth kinetics (plant height, leaf area index), physiological efficiency (chlorophyll SPAD values), and yield attributes (number of fertile tillers, spike length, 1000-grain weight, and total grain yield). The findings revealed a highly significant ($p < 0.01$) divergent response across the tree species and concentration gradient. *Moringa oleifera* (T4) extract acted as a robust biostimulant; at the 4% concentration, it significantly enhanced the 1000-grain weight by 15.1% and total grain yield by 23.6% compared to the control. This stimulation is attributed to the presence of cytokinins (zeatin) and mineral osmoprotectants in *Moringa*, which boosted chlorophyll stability and delayed flag leaf senescence. In stark contrast, *Eucalyptus camaldulensis* (T5) at 4% exerted severe allelopathic suppression, causing a 35.1% reduction in total grain yield and a 28% decline in leaf chlorophyll content, suggesting systemic metabolic interference and impaired source-sink partitioning. *Acacia nilotica* (T2) followed a similar inhibitory trend, while *D. sissoo* (T3) and *A. lebbek* (T6) showed moderate phytotoxicity only at higher concentrations. The research establishes a clear dichotomy in botanical interactions: *M. oleifera* extracts serve as high-impact organic biostimulants for yield maximization, whereas *E. camaldulensis* extracts demonstrate potent bio-herbicidal potential. These results provide a scientific basis for the spatial management of tree-crop interactions in agroforestry and the development of botanical formulations for sustainable wheat production.

ICGA-122

Assessment of Nitrogen Use Efficiency, Weed Dynamics and Productivity of Maize-Soybean/Mungbean Intercropping System

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Sustainable production of crop in Pakistan is threatened by the ongoing monocropping of maize, which has led to reduced soil fertility, unproductive nitrogen usage, and growing weed pressure. The most feasible substitute is cereal-legume intercropping, which may enhance soil health, rises resource efficiency, and suppresses weeds through ecological interactions. According to the current situation of Faisalabad, this study attempts to evaluate nitrogen usage efficiency (NUE) and weed dynamics in maize-based intercropping systems involving soybean and mungbean. A field experiment during the Kharif 2025, will be conducted RCBD with split arrangements having three replications. The following treatments will be assessed under long- and short-stature maize hybrids: sole maize, sole soybean, sole mungbean, and intercropping of maize and soybean. All agronomic practices will be kept constant through crop growth period. Data on crop growth, yield characteristics, biological and grain yield, weed density, weed biomass, and nitrogen-related indicators will all be taken. Land equivalent ratio, monetary benefit index, and actual yield loss will be used to assess intercropping performance. Compared to monocropping, intercropping maize and legumes is predicted to rise system production, decrease weed infestation, and improve nitrogen usage efficiency. Data will be analyzed statistically using Fisher's analysis of variance technique (ANOVA) and means will be separated by using least significant difference (LSD) test at 5% probability.

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ICGA-123

Sustainable Rice-Wheat Productivity Enhancement through Green Manuring, Nitrogen Management, and Crop Modeling under Changing Climate

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In Asia, the Rice-wheat cropping system (RWCS) is the primary food bowl, supply food to billions of people across the world. However, yield stagnation, as well as decreasing in crop productivity are because of low soil organic carbon which threaten the long-term sustainability. Soil health may be improved by using organic fertilizer while synthetic chemical fertilizer use can be reduced. Two field trials were conducted to incorporate the Sesbania as green manure using different genotypes of Rice (G₁: Super Gold, G₂: Super Basmati, G₃: Chanab Basmati, G₄: Punjab Basmati) and Wheat (G₁: Ujala-15, G₂: Johar-16, G₃: Gandam1-17, G₄: Anaj-17) with five nitrogen levels (N₁: Control, N₂: 50 kg ha⁻¹, N₃: 100 kg ha⁻¹, N₄: 150 kg ha⁻¹ and N₅: 200 kg ha⁻¹) in RWCS” at Agronomy Form, University of Agriculture, Faisalabad during 2019 and 2020-21. Different Global Circulation Models (GCMs) were used for understanding the climate change impacts and adaptations options used with Representative Agricultural Pathways (RAPs). Different global circulation models (GCMs) were used under varying RCPs (Representative concentration pathways). During cropping season 2020-21, the nitrogen level 150 kg ha⁻¹ gave the maximum grain yield in wheat and rice because of green manuring of Susbania. Similarly, cultivar Anaj-17 in wheat and Punjab Basmati in rice performed well, in terms of yield during both cropping season, 2019-20 and 2020-21. The data collected from the experiments were used as input to run the CERES-Wheat and CERES-Rice model. The model testing and application in this study established that this specific model could be satisfactorily used as a research tool in different agro-ecological conditions of Punjab-Pakistan. The CERES-Wheat and CERES-Rice model was calibrated with input data of the year 2019-20 and evaluation was done with the comparison of observed and simulated values. It predicted phenology, growth and yield, to a reasonable accuracy among different wheat and rice cultivars as influenced by nitrogen applications. The findings suggest that the model can be used to direct the alternate path for improving wheat and rice production. The climate change analysis was done by a sensitivity analysis tool that describes the strong effect of temperature increment and freezing temperature on rice and wheat production. The yield will be considerably reduced with increasing temperatures up to 2 °C in the area. If we look at the present scenario, then it can be estimated that there will be a reduction in yield up to 25 % beyond the year 2050 for both crop. Future studies for possible effects of climate change on field crop production should therefore include, more number of weather stations for the better reflection of the heterogeneity in different cropping areas, standardization of field crop production and technology through crop growth models should be initiated. The development of site-specific mitigation strategies should be adopted to enhance agricultural productivity under changing climate scenarios.

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ICGA-124

Simulation of Wheat Yield under Future Climate Scenarios in Pakistan Using DSSAT and R-Based CMIP6 Analysis

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Wheat is a staple crop in Pakistan, yet its productivity in semi-arid regions is increasingly challenged by soil degradation, low fertility, and climate variability. Farmyard manure (FYM) has been widely recognized as a sustainable amendment that enhances soil structure, nutrient availability, and water retention, particularly in sandy soils. Its interaction with seed rates and cultivar selection significantly influences wheat growth, yield stability, and resilience under changing climatic conditions. Crop simulation models, such as DSSAT, provide a robust framework to assess the impacts of management practices and climate change on crop performance. When driven by CMIP6 climate projections, DSSAT allows evaluation of potential outcomes across the early, mid, and late 21st century, offering a forward-looking perspective on adaptation needs. Coupled with R-based workflows, these simulations facilitate comprehensive data analysis, visualization, and scenario comparison, enabling researchers to quantify risks, identify optimum management strategies, and develop adaptation and mitigation approaches. Evidence from existing studies indicates that the integration of FYM, optimized seed rates, and locally adapted cultivars can improve yield stability, enhance soil health, and contribute to carbon sequestration. Such model-driven, data-informed approaches provide critical guidance for climate-resilient wheat production in Pakistan, ensuring sustainable food security and supporting long-term agricultural planning in semi-arid environments.

ICGA-125

Role of Integrated Fertilizer Management in Climate Change Mitigation and Soil Carbon Sequestration

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Pakistan is one of the most climate-susceptible countries in the world. Soil in Pakistan plays a significant role in releasing atmospheric carbon dioxide due to factors such as faster microbial decomposition of organic matter and intensive cultivation reliant solely on inorganic fertilizers. The study was conducted at the research area of Cholistan Institute of Desert Studies, The Islamia University of Bahawalpur. The Aim of this study to determine the rates of carbon sequestration

and rice yield as influenced by organic materials and nitrogen fertilizer. This study comprised two factors: organic materials and N fertilizer. The experiment was laid out in a Randomised Complete Block Design with a factorial arrangement and three replications. Five types of organic materials (rice straw, vermicompost, rice husk biochar, cow dung, and poultry manure) were used at a rate of 2 t C ha⁻¹. Three nitrogen levels were 0, 100, and 150 kg N ha⁻¹. Results revealed that the highest amount of Soil Organic Carbon (SOC) was sequestered in cow dung treated plots (1.45 t ha⁻¹) followed by rice straw (1.30 t ha⁻¹), rice husk biochar (1.24 t ha⁻¹), poultry manure (1.13 t ha⁻¹) and vermi-compost (1.02 t ha⁻¹). Application of N fertilizer enhanced decomposition of organic materials and, therefore, carbon sequestration, but this effect was significantly lower at higher N rates. Carbon sequestration was 1.71, 1.12, and 0.84 t ha⁻¹ at N rates of 0, 100, and 150 kg ha⁻¹, respectively. Poultry manure provided the highest rice grain yield (6.32 t ha⁻¹), which was statistically similar to the yield obtained in cow dung-treated soil. Insignificant differences in rice yield were observed at 100 and 150 kg N ha⁻¹, which were 6.07 and 6.15 t ha⁻¹, respectively. Carbon can be sequestered in soil using various organic fertilizers and lower nitrogen rates without a significant reduction in crop yield. It might contribute to mitigating climate change and to ensuring sustainable agriculture.

ICGA-126

Integrating Allelopathic Plant Extracts with Reduced S-Metolachlor for Sustainable Management of Purple Nutsedge (*Cyperus Rotundus L.*)

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Purple nutsedge (*Cyperus rotundus L.*) is among the most problematic weeds worldwide, causing severe yield losses and exhibiting strong tolerance to conventional herbicides. Reliance on chemical control alone has resulted in unsatisfactory management and increased risk of herbicide resistance, highlighting the need for sustainable alternatives. This study evaluated an integrated pre-emergence weed management strategy by combining aqueous extracts of five dryland plants with reduced doses of the herbicide S-metolachlor. A randomized complete block design (RCBD) with three replications was employed to assess thirteen treatments, including an untreated control, S-metolachlor applied at the recommended dose (2.15 kg a.i. ha⁻¹) and half dose (1.075 kg a.i. ha⁻¹), individual plant extracts applied at 30 L ha⁻¹, and combinations of each plant extract with the half dose of S-metolachlor. Results showed that plant extracts applied alone were more effective than the half dose of S-metolachlor in suppressing purple nutsedge. Notably, the combined application of plant extracts with half the recommended herbicide dose resulted in complete (100%) suppression of tuber and shoot density, tuber diameter, and tuber and shoot fresh and dry weights, achieving control comparable to the full herbicide dose. These findings demonstrate that allelopathic plant extracts can substantially enhance herbicide efficacy, allowing a 50% reduction in herbicide use without compromising weed control. This integrated approach offers an eco-friendly and sustainable strategy for managing purple nutsedge while mitigating environmental risks and herbicide resistance development.

ICGA-127

Critical Growth Stages–Based Irrigation Scheduling in Wheat

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Efficient irrigation scheduling is critical for sustaining wheat productivity under increasing water scarcity. This study evaluated a growth stage–based irrigation scheduling approach to identify critical phenological stages where water application maximizes yield and water use efficiency. Field experiments were conducted using irrigation treatments imposed at key growth stages, including crown root initiation, tillering, booting, heading, and grain filling, compared with conventional and reduced irrigation regimes. Results demonstrated that irrigation applied at crown root initiation and booting stages was most influential for biomass accumulation, spike development, and grain number, while supplemental irrigation at grain filling significantly improved thousand-grain weight. Skipping irrigation at non-critical stages resulted in marginal yield penalties but substantial water savings. Growth stage–based scheduling improved water use efficiency and maintained grain yield comparable to fully irrigated controls, highlighting its potential as a practical water-saving strategy. The findings emphasize that prioritizing irrigation at physiologically sensitive stages can optimize wheat yield under limited water availability and support sustainable irrigation management in semi-arid agroecosystems.

ICGA-128

Optimizing Potassium Nutrition to Mitigate Drought Stress Effects on Growth, Yield, and Seed Quality of Sunflower (*Helianthus annuus* L.)

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Drought stress is a major constraint to sunflower (*Helianthus annuus* L.) productivity, particularly during sensitive growth stages, where impaired water availability disrupts nutrient uptake, physiological processes, and assimilate partitioning. Potassium (K) plays a pivotal role in osmotic adjustment, stomatal regulation, enzyme activation, and photoassimilate transport, suggesting its potential to alleviate drought-induced damage. This study evaluated the effectiveness of optimized potassium nutrition in mitigating drought stress imposed at different growth stages of sunflower. Field experiments were conducted using a factorial arrangement of potassium application levels and drought treatments imposed at vegetative, flowering, and seed-filling stages. Growth attributes, yield components, seed yield, and seed quality parameters were assessed. Drought stress significantly reduced plant growth, achene yield, and seed oil quality, with the most pronounced

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effects observed when stress occurred at flowering. Potassium application markedly improved leaf water status, biomass accumulation, and yield components under both stressed and non-stressed conditions. Enhanced potassium supplies also improved seed quality by increasing 1000-seed weight and oil content while stabilizing yield losses under drought stress. The interactive effects of potassium nutrition and drought timing indicate that adequate potassium availability is particularly critical during reproductive stages to sustain productivity. These findings demonstrate that optimized potassium fertilization is an effective agronomic strategy to enhance drought resilience, improve yield stability, and maintain seed quality of sunflower under water-limited environments.

ICGA-129

Growth Behaviour of *Acacia nilotica* as Impacted by Water Stress

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Forests have chief role in supporting life on earth as they supply the essential needs of life with pure oxygen. Today, climate change has become one of the main environmental issues globally since the 1980s having considerable impacts on the plant growth, water use and transport modes. Water utilization efficacy of plants aids in the comprehension and prediction of the reactions of earthly plants to climate change and the fostering schemes. Water utilization efficacy by trees is an indicator about the rate of carbon absorption to the ratio of transpiration. In the present scenario, drought tolerance has become an important topic of debate in agricultural research. But for forest studies, it is still given less importance. This study emphasizes the positive effects of water use efficiency on the growth behavior of chosen plants. The major focus of that research was to observe the growth behavior of *Acacia nilotica* at regular, average and extreme volume of water application. The research trial for this purpose was conducted in the research area of the department of Forestry and Range Management, University of Agriculture Faisalabad. Seedling plants of the said tree species were gathered from the nursery of the department of Forestry and Range Management. Beside control level, there were four treatments. Randomized Complete Block Design (RCBD) was used for conducting the experiment. The germination potential of the selected tree species was noticed in relation to water use efficiency at initial development phases. Seedlings were raised in pots by watering at various levels e.g. Daily (T0), 5 days (T1), 10 days (T2), 15 days (T3), and 20 days (T4) to observe the germination ratio and key morphological features at various stages of watering. Data regarding different morphological features exhibited variations in their performance after analysis. The effect of all treatments on plants height was significant. It was obvious that the growth behavior of *A. nilotica* was better by enhancing the water use efficiency.

ICGA-130

Harnessing Biocontrol Agents for the Management of Soil-Borne Plant Diseases under Changing Climatic Conditions

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Soil-borne plant diseases caused by pathogenic fungi, oomycetes, and bacteria pose a serious threat to global agricultural productivity, a challenge that is further intensified by changing climatic conditions. Rising temperatures altered precipitation patterns, and increased frequency of extreme weather events are reshaping soil microbial communities and enhancing the survival, virulence, and geographic spread of soil-borne phytopathogens. Conventional reliance on chemical pesticides has proven increasingly unsustainable due to environmental contamination, pathogen resistance, and risks to human health. In this context, biocontrol agents offer an eco-friendly and climate-resilient alternative for sustainable disease management. This study highlights the potential of microbial biocontrol agents, including species of *Trichoderma*, *Bacillus*, *Pseudomonas*, and arbuscular mycorrhizal fungi, in suppressing soil-borne plant pathogens under variable climatic conditions. The mechanisms underlying biocontrol efficacy such as competition for nutrients and niches, antibiosis, mycoparasitism, induced systemic resistance, and improvement of soil health are discussed in relation to temperature and moisture stress. Emphasis is placed on integrating biocontrol strategies with climate-smart agricultural practices to enhance crop resilience and productivity. Experimental evidence from laboratory and field-based studies demonstrates that biocontrol-mediated disease suppression remains effective across a range of environmental conditions, while also promoting plant growth and soil biodiversity. The findings suggest that adaptive biocontrol approaches, tailored to specific agro-ecological zones, can significantly reduce dependence on synthetic fungicides. Harnessing biocontrol agents within integrated disease management frameworks represents a promising pathway toward sustainable, climate-resilient agriculture and long-term food security under changing climatic scenarios.

ICGA-131

Green Catalysis for Cleaner Future using Myco-enzymes

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The devastating environmental and economic concerns over the striking exploitation of non-renewable resources have remarkably attracted researchers and policy makers towards agri-waste biocatalysis. Green catalysis scope has been enormously increased over last two decades with the progress in computational sciences, genomics and protein engineering. The utilization of microbial enzymes in sustainable and cost-effective manners has stimulated biobased circular economy to strengthen valorization of organic waste. Fungal enzymes are the versatile green catalysts, carrying immense transformation potential in lignocellulosic refinement as well as food industry. These enzymes from beneficial fungi have capacity to make cleaner and greener commodities with fine chemicals and compounds. Fungal enzymes such as lipases, xylanases, cellulases, peroxidases and laccases have immense potential for biofuel production, biopolymer synthesis, bioremediation, bio

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bleaching and biomass processing. The main advantage of prioritizing fungal enzymes lies in their higher selectivity ratio, renewable source, mild reaction condition and most importantly, scalability through fermentation. The green catalysis of agri-waste such as corn stover, rice husk, wheat straw, and sugarcane bagasse is very sustainable and it lowers the open burning emissions with lowest cost of bioprocessing. Moreover, it generates small income streams for the indigenous farmers by converting agri-waste into value. Here, we propose the objective of achieving a sustainable biocatalytic process for agri-waste valorization utilizing fungal enzymes for the synthesis of high value bio products. To achieve this objective, the methodology opted will start from the selection of agri-waste, followed by enzyme production, extraction and characterization, biomass conversion, analytical evaluation and finally, the sustainability analysis. The promising outcomes for this proposed idea will impact scalable myco-catalysis protocols, improved biotechnology value chain for the agri-sector and this project will serve as a building block for the circular bioeconomy in integration with sustainable developmental goals.

ICGA-132

The Therapeutic Effect of *Arthrospira platensis* (Spirulina) Based Cookies on Hyperlipidemia

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The rising prevalence of hyperlipidemia, driven by increased consumption of energy-dense diets and higher body mass index (BMI), poses a major public health challenge and threatens global food and nutrition security. Sustainable, climate-resilient food sources with therapeutic potential are essential for future green agriculture systems. *Arthrospira platensis* (Spirulina), a nutrient-dense microalga cultivated with minimal land, water, and environmental inputs, has gained scientific attention due to its bioactive compounds and historical use as a functional food. Integrating Spirulina into value-added food products represents an innovative, eco-friendly strategy to address diet-related metabolic disorders. To develop Spirulina-based functional cookies using sustainable agricultural resources and conduct sensory evaluation. To evaluate the therapeutic effect of Spirulina-enriched cookies on lipid profiles in hyperlipidemic adults. A quasi-experimental intervention study was conducted on 60 hyperlipidemic male and female participants aged 35–65 years. Cookies fortified with *Arthrospira platensis* (Spirulina) were developed and administered over a 60-day period. Blood samples were collected at baseline (T0), day 30 (T1), and day 60 (T2) to assess lipid profile parameters including total cholesterol, triglycerides, LDL-cholesterol, and HDL-cholesterol. Statistical analysis was performed to determine the significance of changes across intervention periods. Consumption of Spirulina-based cookies resulted in significant improvements in lipid profile parameters compared to baseline values. Statistically significant reductions were observed in total cholesterol ($p = 0.041$ at T1; $p = 0.031$ at T2), triglycerides ($p = 0.04$ at T1; $p = 0.01$ at T2), and LDL-cholesterol ($p = 0.021$ at T1; $p = 0.011$ at T2), along with a significant increase in HDL-cholesterol ($p = 0.042$ at T1; $p = 0.032$ at T2). These findings indicate a positive hypolipidemic effect of Spirulina-fortified functional foods. The study highlights the potential of *Arthrospira platensis*-based functional foods as a sustainable, climate-resilient, and nutritionally therapeutic intervention for managing hyperlipidemia. Incorporating

microalgae into green agricultural and food systems can support future harvests, improve public health, and contribute to food security while minimizing environmental impact.

ICGA-133

Slow-Release Coating Strategies for Diammonium Phosphate to Enhance Nutrient Availability, Uptake, and Yield of Cotton (*Gossypium hirsutum* L.)

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Cotton (*Gossypium hirsutum* L.) production in arid lands is affected by input applications. Fertilizer application stands out as a key factor affecting both yield and quality. The potential for conventional fertilizer losses along with fixation in alkaline soils raises a noteworthy research inquiry. Therefore, different approaches are under deliberation to increase fertilizer use efficiency (FUE). Thus, this research endeavors to investigate different chemical coatings of di-ammonium phosphate (DAP) and their subsequent application on cotton crop. The experiment was carried out under field conditions. The treatment combinations were CK: control without coating DAP, S-DAP: coated with elemental sulphur, HA-DAP: coated with humic acid, P-DAP: coated with polymer, and M-DAP: coated with a mixture of elemental sulphur + humic acid + polymer. The results revealed that the most significant enhancement was observed with the use of T₅ (M-DAP), which improved plant height by 4%, chlorophyll content by 4%, number of nodes by 5%, number of bolls per cotton plant by 11%, and cotton yield by 12% compared to the control. Compared to control and other treatments, the maximum availability of phosphorus concentration was 22% and potassium 5% in M-DAP, followed by 8% in P-DAP. Maximum plant growth was recorded in M-DAP with chlorophyll content increased by 4%, phosphorus in plant by 13%, nitrogen by 9%, and potassium by 5% compared to control. The data showed a strong positive correlation between plant height, number of bolls, chlorophyll content, cotton yield, phosphorus, potassium, and fresh and dry shoot weight. A Principal Component Analysis (PCA) biplot revealed the most influential variables under different conditions, accounting for 84.96% of the variance.

ICGA-134

Combining Ability Analysis for Drought Related Traits in Seven Wheat Genotypes and Their F1 Hybrids

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A 7x7 diallel analysis was conducted at Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad to estimate combining ability for some drought and yield related parameters. Significant differences were found among genotypes for the recorded data and further subjected to combining ability analysis. GCA mean squares were highly significant and greater than that of SCA for all the traits except for hydrophilic colloids. Mean squares due to SCA and reciprocal effects were also highly significant. Maximum positive GCA was found for plant traits like flag leaf area, leaf venation, epidermal cell size and maximum negative GCA effects were

observed in stomatal frequency in this research. Higher value of GCA than SCA indicated involvement of additive genes. Non-additive gene effects were involved in genetic control of hydrophilic colloids because of high SCA value than GCA. Parents like Punjab-96 proved as a best general combiner for flag leaf area, leaf venation, stomatal size, stomatal frequency, epidermal cell size and grain yield per plant. Uqab-2000 was also found as a best general combiner for stomata size, epidermal cell size, flag leaf area, and MH-97 for stomata size, epidermal cell size. Best specific combinations like 4072 × Punjab-96, Punjab-96 × Uqab-2000 and Iqbal-2000 × Parwaz-94 may be evaluated in further breeding programmes because of their best performance in many plant traits.

ICGA-135

Assessing Vachellia-Coated Urea's Performance in Increasing Maize Growth and Yield (*Zea mays* L.)

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Soil urease inhibition slows urea hydrolysis, prolonging nitrogen (N) retention in soil and enhancing N uptake by crops. While chemical inhibitors are widely studied, plant-based alternatives remain underexplored. This study investigates the agronomic efficacy of Vachellia-coated urea—a controlled-release fertilizer—on maize (*Zea mays* L.) under field conditions. Seven treatments were applied: 100%, 50%, and 25% of both conventional and Vachellia-coated urea, along with a control (0% urea). Growth parameters (plant height, leaf area, dry matter accumulation) and yield components (cob length, grain number per cob, 1000-grain weight, total grain yield) were assessed. The 100% Vachellia-coated urea treatment (T2) significantly outperformed conventional urea, indicating improved nitrogen persistence and uptake. Notably, reduced application rates (T4 and T6) also yielded favorable results, demonstrating the coating's efficiency in sustaining crop performance with lower N input. Enhanced nitrogen use efficiency (NUE) was reflected in increased nitrogen agronomic efficiency (NAE), nitrogen partial factor productivity (NFP), nitrogen recovery efficiency (NRE), and partial nitrogen balance (PNB). These findings confirm the potential of Vachellia-coated urea as a natural urease inhibitor and sustainable fertilizer alternative, capable of improving maize productivity while mitigating environmental nitrogen losses.

ICGA-136

Influence of Potassium Fertilization Levels on Growth, Yield, and Quality of Wheat

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Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops, Wheat remains a cornerstone crop for food security in South Asia, including Pakistan. Potassium (K) is a key macronutrient regulating wheat growth, yield formation, and grain quality through its role in enzyme activation, osmotic regulation, and assimilate translocation. This study evaluated the influence of different potassium fertilization levels on growth dynamics, yield components, and grain quality of wheat under field conditions. Potassium application significantly enhanced leaf area development, chlorophyll content, and photosynthetic efficiency, resulting in improved biomass accumulation and crop vigor. Adequate K supply promoted efficient carbohydrate synthesis and translocation from source to sink, leading to increased spike density, grains per spike, and thousand-grain weight. Grain quality attributes, including protein content and test weight, were also positively influenced by balanced potassium nutrition due to improved nitrogen use efficiency and stress tolerance. In contrast, potassium deficiency restricted growth, reduced yield components, and compromised grain quality. The results demonstrate that optimized potassium fertilization is essential for maximizing wheat productivity and maintaining grain quality, particularly under conditions where soil K availability is limited. Adoption of appropriate K management strategies can therefore contribute to sustainable wheat production and improved food security.

ICGA-137

Transgenerational Effects of Chlorantraniliprole and Lambda-Cyhalothrin on Fall Armyworm, *Spodoptera frugiperda*

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Fall armyworm, *Spodoptera frugiperda* has emerged as a destructive insect pest of maize. It feeds on leaves and succulent parts of maize plants, hence responsible for great yield loss. Insecticides are being applied at recommended doses (lethal doses) and sometimes under doses (sub-lethal doses) by the farmers to control *S. frugiperda*. Sub-lethal exposure of insecticides may have transgenerational effects on survived insects that sometimes helpful for the management of pests by reducing their populations. Initially, four insecticides were used for leaf dip bioassay to determine LC₅₀ values. LC₅₀ values of chlorantraniliprole, flubendiamide, lambda-cyhalothrin and gamma-cyhalothrin were 0.04, 0.27, 8.66 and 11.08 mg/L, respectively. LC₃₀ values was considered as sub-lethal dose. LC₃₀ values of chlorantraniliprole, flubendiamide, lambda-cyhalothrin and gamma-cyhalothrin were 0.02, 0.11, 3.39 and 6.13 mg/l, respectively. Present study was designed to check transgenerational and sub-lethal effects of LC₃₀ doses of two insecticides named chlorantraniliprole and lambda-cyhalothrin on *S. frugiperda*. Third instar larvae of F1 generation of *S. frugiperda* were exposed to LC₃₀ doses of chlorantraniliprole and lambda-cyhalothrin separately for 48 hrs. Survivor larvae obtained from each insecticide were reared separately on normal diet i.e., maize leaves under laboratory conditions. Field collected unexposed F1 generation larvae were reared same time as control treatment. According to the

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findings, the pupal duration of insecticides groups was considerably more than without insecticide i.e., control group. However, there was no variations in the eclosion rates across the groups. The fecundity was significantly reduced by chlorantraniliprole and lambda-cyhalothrin as number of eggs laid by each female in the F1 (exposed) generation decreased by 54% and 51%, respectively than control. In the F2 (exposed) generation chlorantraniliprole and lambda-cyhalothrin number of eggs laid by each female were reduced by 43% and 33%, respectively as compared to control. While in F3 there is no significant changes as compared to control group. In different treatments with chlorantraniliprole and lambda-cyhalothrin, the intrinsic growth rate (rm), net growth rate (Ro), of the F1 generation were considerably lower than those in the control. These results showed that repetitive application of same pesticide will develop transgenerational resistance in population. These findings could be helpful for the successful execution of the IPM strategies in the field to manage *S. frugiperda*.

ICGA-138

Taxonomy of Aphid Fauna Occurring in Tehsil Jampur of District Rajanpur, (Punjab) Pakistan

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Aphids (*Hemiptera: Aphidoidea*) are small, soft bodied phloem feeding insects. Many of them are serious pests of agricultural crops, ornaments, vegetables and trees. They damage the plants through cell sap sucking and indirectly by interfering photosynthetic activities as they secrete honey dew which provides medium for growth of sooty mould on plant surface. Many species have ability to transmit plant viruses. Approximately more than 5000 aphid species have been reported worldwide and about 300 aphid species have been recorded from Pakistan up till now. In current study aphids were collected from agricultural crops, ornamental plants, vegetables and wild plantation located in Jampur and preserved in small vials containing 80% ethanol. These specimens were mounted on glass slides under a stereoscope. The mounted specimens were examined and identified under phase contrast microscope using diagnostic keys in the published literature. Seven aphid species *Aphis craccivora* Koch, (1854), *Brevicoryne brassicae* (Linnaeus, 1758), *Metopolophium dirhodum* (Walker, 1849), *Rhopalosiphum maidis* (Fitch, 1856), *Rhopalosiphum padi* (Linnaeus, 1758), *Aphis nerii* Fonscolombe (1841) and *Aphis gossypii* Glover, (1877) belonging to subfamily Aphidinae Latreille 1802 and two tribe Aphidini, Macrosiphini and five genera *Aphis* Linnaeus 1758, *Brevicoryne* Van Der Goot 1915, *Motopolophium* Mordviko 1914, *Rhopalosiphum* Koch 1854 and *Sitobion* Mordviko 1914 were identified. *Aphis craccivora* Koch, (1854) reported first time from host *Bauhinia variegata* (Fabaceae) and *Bougainvillea glabra* (Nyctaginaceae) in the Pakistan. *Aphis* sp. reported from *Withania somnifera* (Solanaceae), *Nicotiana tabacum* (Solanaceae). *Sitobion* sp. reported first time from host plant *Saccharum bengalense* (Poaceae) in the Pakistan.

ICGA-139

Effect of Different Sulphur Levels and Irrigation Scheduling on Canola Yield and Oil Quality

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Sulphur (S) nutrition and irrigation scheduling play a critical role in regulating canola yield and oil quality through their influence on key physiological and biochemical processes. This study evaluated the combined effects of different sulphur application levels and irrigation schedules on growth, seed yield, and oil quality of canola under semi-arid conditions. Sulphur application significantly improved chlorophyll synthesis, photosynthetic efficiency, and nitrogen assimilation by enhancing the formation of sulphur-containing amino acids (cysteine and methionine) and key enzymes involved in protein and oil biosynthesis. Adequate S supply also promoted glucosinolate regulation and fatty acid metabolism, leading to improved oil content and a favorable fatty acid profile. Optimized irrigation scheduling enhanced nutrient uptake, maintained plant water status, and supported assimilate translocation during critical growth stages, particularly flowering and seed filling. In contrast, moisture stress reduced sulphur mobility, impaired photosynthesis, and limited oil accumulation in seeds. The interaction between higher sulphur levels and well-timed irrigations resulted in maximum seed yield, oil percentage, and improved oil quality attributes. The findings highlight that integrated management of sulphur nutrition and irrigation scheduling is essential for sustaining canola productivity and oil quality under water-limited environments. Such practices offer a practical pathway to enhance resource-use efficiency and resilience of oilseed production systems under increasing climatic variability.

ICGA-140

Artificial Intelligence in Food Safety: Applications, Challenges, and Future Perspectives

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Food safety management faces challenges. The critical among these are globalization of food supply chains, emerging hazards, and the demand for rapid decision-making. Artificial intelligence (AI) has auxiliary attention as an advanced analytical tool capable of enhancing food safety monitoring and control systems. AI techniques include machine learning, deep learning, computer vision, and big data analytics. These tools enable real-time detection of biological, chemical, and physical hazards through processing large and complex datasets created across the food chain. These support predictive risk assessment, early warning systems, and optimization of hazard

analysis and critical control point (HACCP) frameworks. Integration of AI with Internet of Things (IoT) devices further improve traceability, process automation, and recall efficiency. Hence, strengthens the regulatory compliance and consumer confidence. Despite these advantages, challenges related to data quality, model interpretability, infrastructure costs, and regulatory acceptance may limit widespread industrial adoption. This paper highlights the potential of AI as a proactive and intelligent approach to food safety management. It also emphasizes the role of AI in improving risk mitigation, operational efficiency, and public health protection within modern food systems.

ICGA-141

Utilizing Biochar to Enhance Morphophysiology and Antioxidative Defense Mechanisms in *Lactuca sativa* (Lettuce) Exposed to Industrial Wastewater and Canal Water

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The increasing use of industrial wastewater and canal water for irrigation poses significant risks to plant health due to the presence of heavy metals and other contaminants. Biochar, a carbon-rich material derived from organic biomass, has emerged as a promising soil amendment due to its ability to improve soil properties, enhance plant growth, and mitigate stress-related damage. This study was conducted to quantify the efficiency of 3% Sugarcane bagasse (SBC), maize-pith (MBC) and acacia wood biochar (WBC) on the morphophysiological traits and antioxidative defense mechanisms of lettuce (*Lactuca sativa*) irrigated with industrial wastewater and canal water. Lettuce was grown under two irrigation conditions: industrial wastewater (IW) and canal water (CW: control), with and without biochar amendments. Morphophysiological parameters, including root-shoot length, leaf area, photosynthetic pigments and biomass accumulation were assessed. Additionally, antioxidative enzyme and non-enzyme activities such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD), glutathione peroxidase (GPX) and polyphenol peroxidase (PPO) were analyzed to determine the plant's defense response against oxidative stress. Physiochemical analysis of IW showed a higher amount of heavy metal as compared to CW but IW was beyond the precise limit mentioned by FAO. Results showed that IW without biochar amendment adversely influenced the lettuce growth, photosynthetic pigments, and antioxidative defense mechanism. SBC at a 3% rate significantly improved shoot length (70%), root length (86%), plant fresh weight (66%), plant dry weight (64%), leaf area (70%) and number of leaves (78%) while reducing the level of antioxidant enzyme (CAT 56% and POD 61%) that increased by reactive oxygen species. On the other hand, WBC at 3% increased the Chl a (80%), Chl b (87%), total chlorophyll (57%), and carotenoids (82%) under IW as compared to CW. Similarly, the concentration of Cd, Pb, Cr, and Zn was reduced in soil when 3 % SBC, MBC, and WBC was used under IW and canal water treatments decreased their accumulation in the edible part of lettuce. Overall, this study highlights biochar as a sustainable, eco-friendly remediation strategy that not only mitigates heavy metal contamination but also boosts plant health and productivity. The findings suggest that biochar application can be a sustainable approach to improving crop resilience and food safety in wastewater-irrigated agricultural systems.

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ICGA-142

Impact of Foliar Applied Green Synthesized Zinc Oxide Nanoparticles on the Essential Oil Profile of *Coriandrum sativum* L. under Drought Stress

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Climatic variations and limited water resources lead to drought stress, which adversely influences the growth and phytochemical quality of plants such as *Coriandrum sativum* L. This study presents a novel approach to improving drought tolerance and maintaining essential oil (EO) quality through the foliar application of green synthesized Zinc Oxide nanoparticles (ZnOx NPs). ZnOx NPs were synthesized using *Camellia sinensis* leaf extract, resulting in hexagonal wurtzite crystals with an average size of 37 nm. The experiment evaluated coriander plants under two drought regimes: IR75 (moderate) and IR50 (intense). GC-MS analysis of the extracted essential oil revealed 17 chemical constituents, with linalool identified as the most abundant component, maintaining a concentration of 60% to 66% regardless of water deficit levels. Other significant components identified included α -terpineol, terpinene, and p-cymene. The results demonstrated that ZnOx NPs enhanced the accumulation of secondary metabolites, which preserved the composition of the essential oil even under severe drought. The application of ZnOx NPs played a critical role in stabilizing the EO profile and improving plant biomass under water-limited conditions. This research suggests that foliar-applied ZnOx NPs serve as an efficient water-saving strategy to ensure the sustainable production of high-quality essential oil components in coriander grown in arid environments.

ICGA-143

Climate Smart Chickpea Varieties Developed Through Mutation Breeding for National Food Security

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The synergistic integration of modern plant breeding and nuclear applications has emerged as an effective approach for accelerating crop improvement. Among these, mutation breeding is an established technique that enhances global food security by generating novel genetic variability. Induced mutations improve key agronomic traits, including climate resilience, tolerance to biotic and abiotic stresses, nutritional quality, grain characteristics, harvestability, and yield potential. Chickpea (*Cicer arietinum*), a major pulse crop in Pakistan, is vital for food and nutritional security due to its high protein, mineral, fiber, and vitamin content. However, its productivity is often limited by terminal heat stress, drought, diseases, and climate change, highlighting the need for climate smart, improved varieties. To address these limitations, scientists at NIAB, Faisalabad, are employing induced mutation breeding to develop genetically diverse chickpea mutant lines with desirable phenotypic and genotypic attributes. This practice has resulted in the identification of several unique mutants exhibiting early maturity, improved plant architecture, bold seed size, enhanced yield performance, and better stress tolerance. Recently, NIAB has successfully

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developed high yielding mutant chickpea varieties viz. 01 kabuli chickpea variety viz. NIAB-Buraq and 02 desi chickpea varieties viz. NIAB-Ababeel and NIAB-Sahar that combine climate resilience with disease tolerance and superior agronomic traits. These recently developed varieties are well suited to the changing agro climatic conditions of Pakistan and offer promising potential for increasing pulse productivity and farmer profitability. This presentation will highlight the methodology of creating genetic variability through induced mutation and discuss the salient features of mutant chickpea varieties developed and released by NIAB. The outcomes emphasize the significant role of nuclear techniques in developing improved pulse crops for sustainable agriculture under climate change scenarios.

ICGA-144

Evaluation of Fenoxaprop-p-ethyl Resistance in *Phalaris minor* Using Classical, RISQ, and Seed Bioassay Techniques

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The evolution of herbicide resistance in *Phalaris minor* Retz. (littleseed canarygrass) has become a major constraint to sustainable wheat (*Triticum aestivum* L.) production in South Asia. Continuous use of acetyl-CoA carboxylase (ACCCase)-inhibiting herbicides such as fenoxaprop-p-ethyl has led to the emergence of resistant biotypes. Reliable and timely detection of resistance is essential for effective management. This study evaluated three diagnostic techniques for confirming fenoxaprop-p-ethyl resistance in *P. minor*: the classical dose–response assay, the Resistance In-Season Quick (RISQ) test, and a seed bioassay. Two resistant biotypes (PM-FS-15 and PM-FS-21) and a susceptible standard (PM-SS) were examined under screenhouse conditions. Significant differences ($p < 0.01$) were found among biotypes and herbicide doses for mortality, visual injury, and biomass. Resistance indices ranged from 6.5 to 8.0, confirming high resistance levels. The RISQ assay produced results comparable to the classical method within 21 days, while the seed bioassay slightly overestimated resistance intensity. These findings establish RISQ as a practical, time-efficient alternative for early-season detection of fenoxaprop resistance, enabling more informed weed management decisions.

ICGA-145

Genetic Studies for Yield and Oil Related Traits in Sunflower

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In the world sunflower is the forth important oilseed crop. Its seed contain 38% to 42% oil content. Sunflowers (*Helianthus annuus* L.) are part of the daisy family and belong to a group of about 65 related plants called *Helianthus*. The experiment will be conducted at the farm area of Ghazi University, Dera Ghazi Khan. The experiment will comprise of 8 genotypes crossed in 5 x 3 Line x Tester mating design. The 15 hybrids will be produced. In the next growing season, the F₁ hybrids

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along with their parents will be sown in randomized complete block design with three replications. All agronomic practices were applied uniformly to the plants. At maturity stage the five randomly selected plants will be measured for the following traits: plant height (cm), leaves per plant, leaf area (cm²), stem girth (cm), head diameter (cm), number of seeds per head, seed index (g), seed weight per head (g), harvest index (g) and oil content (%). F1 hybrids and parents will be tested in terms of their parents and assessed by the analysis with the help of analysis of variance (ANOVA), Line × Tester analysis, Principal Component Analysis (PCA) and Cluster analysis. Genetic parameters like the heterosis, heterobeltiosis, general and specific combining ability, genetic advance will also be estimated. The study will be useful in the identification of hybrid germplasm and possible hybrid combinations for high yield, which can be used in sustainable sunflower improvement programs.

ICGA-146

Effects of Climate Variability on Seed Storage Potential: Consequences for Food Security and Crop Productivity in Southern Punjab, Pakistan

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Climate variability poses a growing threat to seed storage potential, with direct consequences for food security and crop productivity in climate-sensitive regions such as Southern Punjab, Pakistan. Rising temperatures, fluctuating humidity, and extreme weather events accelerate seed deterioration by reducing viability, vigor, and storability during post-harvest handling and storage. This study examines the effects of climate variability on seed storage potential and explores its implications for crop establishment, yield stability, and regional food security. Using long-term climatic data, seed storage environment assessments, and evidence from major field crops, the analysis highlights how elevated temperature and moisture stress enhance seed aging, increase pest and pathogen infestation, and shorten safe storage periods. The findings indicate that climate-induced losses in seed quality contribute to poor germination, uneven crop stands, and reduced productivity, thereby exacerbating vulnerability of smallholder farming systems. The study underscores the need for climate-resilient seed storage strategies, including improved storage structures, moisture and temperature regulation, and adaptive seed management practices. Strengthening seed storage systems is identified as a critical but often overlooked component of climate adaptation to safeguard crop productivity and food security in Southern Punjab under increasing climate variability.

ICGA-147

Effect of Planting Configurations on the Productivity and Performance of Spring Sugarcane

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Sugarcane is one of the most important cash crops of Pakistan after cotton and rice. One of the major problems in obtaining high crop yield in field crops is pathetic methods of planting. It is possible to increase productivity of sugarcane by developing and adopting appropriate planting techniques. A field experiment was carried out to evaluate the yield and quality response of sugarcane to different planting configurations at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad during Kharif 2024. The Experiment was laid out in randomized complete block design having four replications maintaining net plot size of 3.6 m × 6.5 m. Sugarcane was planted under various planting configuration; 180 cm spaced trenches with triple row strips, 180 cm spaced trenches with alternate row strips, 120 cm spaced trenches with double row strips and 60 cm spaced furrows with single row. All other agronomic practices were kept uniform for all treatments. Observations regarding yield and quality related parameters of sugarcane were recorded according to standard procedures. The data recorded was analyzed statistically using Fisher's analysis of variance technique and differences among treatments means were compared using least significant difference (LSD) test at 5% probability level. Highest number of tillers (16 m⁻²), cane diameter (2.50 cm), cane length (224 cm), plant height (333 cm), stripped cane weight (0.94 kg) and stripped cane yield (107 t ha⁻¹) were obtained from 180 cm spaced trenches with triple row strips while lowest number of tillers (13 m⁻²), cane diameter (2.41 cm), cane length (194 cm), plant height (311 cm), stripped cane weight (0.80 kg) and stripped cane yield (91 t ha⁻¹) were obtained from 60 cm spaced furrows with single row. Quality parameters like brix percentage, sucrose content (%) in cane juice, cane juice purity (%), bagasse (%), commercial cane sugar (%) and sugar recovery (%) were not significantly affected by different planting configurations.

ICGA-148

Selenium-Induced Modulation of Morpho-Physiological Attributes of *Camelina sativa* under Water Deficit Stress amid Climate Change Scenario

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Increasing water deficit under climate change has emerged as a major constraint on *Camelina sativa* productivity, prompting interest in selenium-mediated mitigation of physio-biochemical stress. Pakistan is mainly dependent on imports to meet domestic edible oil needs. The *Camelina*, being an emerging oilseed crop, has the potential to lower the country's import bill. However, water scarcity could limit its production and adaptation to Pakistan's conditions, and this problem could be addressed by adding selenium (Se) to plant nutrition. Therefore, a greenhouse experiment was conducted to evaluate the effect of four Se levels (0, 2, 4, and 6 mM) on two *Camelina* genotypes (Australian and Canadian) under four water levels (100%, 75%, 50%, and 25% field capacity). Se was applied through the foliar spray at the seedling stage. The experiment was conducted in a completely randomized design (CRD) with three replications. The results indicated that Se application significantly improved the physiological and growth parameters of *Camelina* under water stress. The higher Se dose of 6 mM increased crop growth, physiology, and antioxidant levels compared with 0, 2, and 4 mM. The application of Se at 6 mM increased total soluble sugars by 69.6%, 23.4%, and 10.8% compared with 0, 2, and 4 mM, respectively, irrespective of field capacity levels. Among the water levels, the 100% field capacity condition showed better results for crop growth, physiological parameters, and antioxidants compared to the 75%, 50%, and 25% field capacity levels. The proline content was also increased by 93.9%, 52.5%, and 10.2% at 100% field capacity compared to 25%, 50%, and 75% field capacity, respectively. The performance of Canadian *Camelina* was better than that of Australian *Camelina* across most growth, physiological, and antioxidant parameters. Among the genotypes, Canadian *Camelina* showed a 2.14% increase in superoxide dismutase activity as compared to Australian *Camelina*. The Canadian *Camelina* with Se application at 6 mM is recommended to achieve higher productivity under water-limited conditions. However, long-term studies are needed to revalidate the current study's findings.

ICGA-149

Sanjhi: A Novel Biostimulant

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Plant biostimulants play important role in improving crop plants growth and development. Previously known biostimulants are seaweed extract, humic acid, beneficial microbes, amino acids etc. Sanjhi trade mark number 680043 extracted from moringa leaves is a registered innovative biostimulants accepted for Patent ship. It is a rich source of cytokinin zeatin with ample quantity of nitrogen, phosphorus, potash, boron, zinc, copper, iron, and micro nutrients. Sanjhi proved its novelty by enhancing growth and yield of wheat, maize, tomato, cotton, sunflower, peas both in normal and under abiotic stress conditions.

ICGA-150

Impact of Foliar Zinc Chloride and Zinc Sulfate Application on Growth, Biochemical Responses, and Yield of Wheat (*Triticum aestivum* L.)

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Zinc is an essential micronutrient for plants and plays a crucial role in various metabolic pathways and enzyme activities. The foliar application of micronutrients is considered one of the efficient ways to enhance nutrient use and minimize losses through soil fixation. In the current study, the n developed wheat cultivar Dilkash-2020 was exposed to evaluate the impact of foliar-applied zinc on growth, physiological, biochemical, and yield traits. A randomized complete block design with six replications was used in this study. Zinc was sprayed at the booting stage as ZnCl₂ (0.068 g L⁻¹) and ZnSO₄ (0.081 g L⁻¹). Morphological, physiological, and biochemical data were measured 15 days after the application, while yield attributes were measured at harvest. Statistical analysis exposed that the application of foliar Zn significantly affected growth and yield parameters of wheat. Both zinc salts caused significant adjustments in physiological and biochemical processes, which reduced flavonoids and amino acid contents, while the contents of proline and antioxidant enzymes (superoxide dismutase, peroxidase, and catalase) were considerably increased. It is assumed that the improved antioxidant defense system after the application of zinc contributed to the protection against stress and provided a higher yield. These findings highlight that the foliar application of zinc can be used to enhance wheat productivity by modulating the antioxidant metabolism.

ICGA-151

How Planting Pattern Reshapes Growth and Yield of Sunflower (*Helianthus annuus*)

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Planting pattern is a critical agronomic factor influencing light interception, resource use efficiency, and yield formation in sunflower (*Helianthus annuus* L.). This study evaluated the role of different planting patterns on growth dynamics, yield components, and final seed yield of sunflower under field conditions. Variations in row spacing and plant population significantly affected canopy architecture, photosynthetically active radiation interception, and intra-specific competition. Optimized planting patterns enhanced leaf area index, stem diameter, and head size

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by improving light distribution and reducing competition for water and nutrients. Improved assimilate production and translocation under suitable spacing resulted in higher number of filled seeds per head and increased thousand-seed weight, leading to superior seed yield. Conversely, overly dense or excessively wide planting patterns restricted growth and yield due to shading stress or inefficient land use, respectively. The findings demonstrate that appropriate planting pattern selection is essential for maximizing sunflower productivity and resource-use efficiency, and should be tailored to local agro-climatic conditions for sustainable oilseed production

ICGA-152

Evaluating the Interactive Impact of Nitrogen Levels and Cultivars on Yield Traits, Nitrogen use Efficiency, Water use Efficiency and Benefit Cost Ratio of Ratoon Rice in Punjab, Pakistan

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Ratooning of rice (*Oryza sativa* L.) is process of obtaining grain from tillers that grow from crop stubbles that have already been harvested. Ratooning has gained attention since it has a potential for obtaining yield with conventional techniques. Field experiment was conducted during 2021–2022 at the research farm, Institute of Agronomy, Bahauddin Zakariya University Multan, Punjab, Pakistan. The response of various nitrogen (N) levels (0, 25, 50, 75, and 100 kg ha⁻¹) was studied on the growth and yield of three rice cultivars (Guard Lp-02, Guard Lp-18, and Super Fine) grown as ratoon rice. In cultivars, Guard Lp-02 and Guard Lp-18 were hybrid but Super Fine was a non-hybrid cultivar. The hybrid cultivars showed a significant response to N levels. The cultivar Guard Lp-18 with higher level of N 100 kg ha⁻¹ resulted in more plant height, total tillers, fertile tiller, panicle length, and biological yield while the higher number of branches and grains per panicle, 1000-grain weight, and grain yield was achieved by Guard Lp-18 with the application of 75 kg N ha⁻¹. Maximum agronomic nitrogen use efficiency (ANUE) and economic nitrogen use efficiency (ENUE) was observed at cultivar Guard Lp-18 with N level of 50 kg ha⁻¹. Likewise, water use efficiency (WUE) was recorded maximum at cultivar Guard Lp-18 with N level 75 kg ha⁻¹. The highest gross income, net income, and benefit cost ratio (BCR) were noted at 75 kg N ha⁻¹ among all cultivars but Guard Lp-18 with 75 kg N ha⁻¹ respond better in ratoon rice. Among rice cultivars, hybrid rice performed better and out yielded non-hybrid cultivars in ratoon rice. The findings of this study revealed that growing ratoon rice will be helpful for increasing farm income; enhancing resources use efficiency and ensuring food security under prevailing agro-climatic conditions of Punjab, Pakistan.

ICGA-153

Evaluation of Seedling Trait Associations for Yield Performance of Maize under Water Stress Conditions

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Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice and is a major source of carbohydrates, protein, iron, B-complex vitamins, and essential minerals. Drought stress is a critical abiotic factor limiting maize establishment and productivity, particularly at the seedling stage. The present study was conducted at the Department of Plant Breeding and Genetics, Ghazi University, Dera Ghazi Khan, to screen maize genotypes for drought tolerance under controlled laboratory conditions. Fifteen maize genotypes were evaluated at the seedling stage using a completely randomized design (CRD) with a factorial arrangement, comprising three replications and three water regimes (100%, 60%, and 40%). Data were recorded for germination percentage, plant height, shoot length, root length, fresh root and shoot weight, and dry root and shoot weight. Analysis of variance revealed highly significant differences among genotypes and water treatments for germination percentage, root length, dry root weight, and dry shoot weight, indicating substantial genetic variability under drought stress. Graphical analysis of mean performance demonstrated differential genotypic responses across water regimes, with genotypes such as CIMMYT-161, Gohar-19, CIMMYT-85, and Sweet-54 showing relatively superior performance under reduced moisture conditions. Correlation analysis revealed strong positive associations between root length and plant height, as well as between dry root weight and dry shoot weight, suggesting coordinated growth responses under drought stress. These findings indicate that early seedling traits, particularly germination percentage and root-related parameters, can serve as reliable selection criteria for identifying drought-tolerant maize genotypes.

ICGA-154

Taxonomic Inventory and Diversity Patterns of Aquatic Flora in Freshwater Ponds along the Indus and Chenab Rivers

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Freshwater ponds associated with major river systems serve as important reservoirs of aquatic plant biodiversity yet remain poorly documented in Pakistan. The present study provides a taxonomic inventory and evaluates diversity patterns of aquatic flora in freshwater ponds along the Indus and Chenab Rivers. Systematic field surveys were conducted across selected ponds, and aquatic plant species were collected, identified, and classified using standard taxonomic keys. Species richness, taxonomic composition, and diversity indices were analyzed to assess spatial variation in aquatic flora. The results revealed considerable taxonomic diversity, encompassing submerged, floating, and emergent plant forms, with notable variation between ponds influenced by hydrological connectivity, nutrient status, and anthropogenic disturbances. Several ecologically important and regionally significant taxa were recorded, highlighting the role of these freshwater habitats in sustaining aquatic biodiversity. Differences in diversity patterns between the Indus and Chenab riverine ponds suggest the influence of river-specific ecological and environmental conditions. This study establishes baseline taxonomic data for aquatic flora in freshwater ponds of the Indus–Chenab river system and underscores the need for regular monitoring and conservation-oriented management to protect these vulnerable freshwater ecosystems.

ICGA-155

GIS-Based Land Rehabilitation and Replacement Strategies for Climate-Resilient Development in South Punjab

Noor-e-Hira

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This study examines land use and land cover (LULC) dynamics in the South Punjab region using Geographic Information Systems (GIS) and remote sensing techniques. The primary objective is to identify land replacement and rehabilitation strategies to mitigate the impacts of climate change. The South Punjab region faces multiple climate-induced challenges, including severe storms, irregular and intense rainfall, and recurrent annual flooding, which significantly affect local livelihoods, land stability, and agricultural productivity. The research utilizes high-resolution, multi-temporal satellite imagery and spatial datasets to produce detailed LULC maps, providing an accurate baseline for assessing existing land-use patterns, water bodies, built-up areas, vegetation cover, and agricultural zones. Advanced spatial analysis and change detection techniques are applied to identify flood-affected, degraded, and low-productivity lands that are highly vulnerable to climate variability. Based on these assessments, land replacement and climate-resilient rehabilitation strategies are proposed, including improved drainage systems, optimized crop zoning, soil restoration, and vegetation recovery aligned with water availability, land capability, and suitable environmental conditions. The results demonstrate that inappropriate land covers can be systematically replaced with sustainable and climate-resilient alternatives to enhance ecological stability and agricultural performance.

Furthermore, GIS-based spatial modeling and remote sensing enable continuous monitoring of seasonal variations, land degradation trends, and flood extents in the South Punjab region, supporting informed decision-making and timely interventions. The integrated methodological framework strengthens regional capacity for climate change adaptation by reducing environmental risks and enhancing land productivity. Overall, this study highlights the effectiveness of GIS and remote sensing as decision-support tools for climate change resilience, sustainable land management, and long-term socio-environmental sustainability in the South Punjab region.

ICGA-156

Effect of Split Application and Sources of Nitrogen and Phosphorus on Growth and Yield of Wheat (*Triticum Aestivum* L.)

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Wheat (*Triticum aestivum* L.) is a major and staple cereal crop in southern Punjab and extensively grown throughout the Pakistan. To achieve optimum yield, fertilizers management in soil is very important. An experiment was conducted at agronomic research area, Ghazi University, Dera Ghazi Khan during Rabi season of 2024-25 in randomized complete block design (RCBD) factorial with three Replications. The research was consisting of two factors; Fertilizer time denoted T1: Control(No phosphorus and Nitrogen application), T2: Whole Phosphorus and 1/3rd Nitrogen at the time of sowing + 1/3rd Nitrogen at 1st irrigation + 1/3rd Nitrogen at 2nd irrigation.,

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T3: 1/2 Phosphorus and 1/3rd Nitrogen at the time of sowing + 1/2 Phosphorus and 1/3rd Nitrogen at 1st irrigation+ 1/3rd Nitrogen at 2nd irrigation, and T4: 1/3 Phosphorus and 1/3 Nitrogen at the time of sowing +1/3 Phosphorus and 1/3 Nitrogen at 1st irrigation+ 1/3 Phosphorus and 1/3 Nitrogen at 2nd irrigation. and source of Nitrogen and Phosphorus represented by, F1. Urea + DAP, F2. CAP + DAP, F3. Urea + NP and F4. CAN + NP respectively. All agronomic management techniques were kept uniform and standard, with the exception of being examined. Standard procedure was used to collect the data. The treatment (F3T3) and (F4T4) produced significantly maximum wheat green yield (74.53 t/ha) and (85.68 t/ha) respectively. The wheat crop was also influenced statistically by the numerous levels of fertilizers on growth and yield contributing parameters such as plant population (191.67 cm), plant height (107.81 cm), productive tillers (202 m-2), chlorophyll contents (58.33 mg cm-2), spike length (15.23 cm), grains per spike (51) respectively. The economics analysis also showed the maximum benefits in the treatment of (F4T4) splits application of N and P on sowing Ist & 2nd Irrigation also suitable for climatic condition of Southern Punjab of Pakistan.

ICGA-157

Role of Zinc Oxide Nanoparticles in Enhancing Drought Tolerance in Turnip (*Brassica rapa*)

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Lack of water has turned out to be a very frequent universal problem particularly in the arena of food security and sustainability. Use of zinc oxide nanoparticles (ZnO-NPs) is among various fertilization methods of the innovative type, which offers a new opportunity. A totally random experiment was conducted on studies of ZnO-NPs on stressed turnips (0, 50, 100 and 200 mg/L) through an independent experiment. During drought, a strong reduction of plant growth and biochemical parameters was registered accompanied by the rise of the activity of antioxidant enzymes. Conversely, ZnO-NPs foliar application (especially the 100 mg/L rate) stimulated an immense growth of plant biomass, the antioxidant defense, the secondary metabolites and the photosynthetic pigments. These findings point to the fact that ZnO-NPs can be rather effective in mitigating drought-caused stress to augment the growth and produce of turnip plants. Nevertheless, soil inoculation with ZnO-NPs (best of all at 100 mg / L) significantly increased the plant biomass, antioxidant defense, secondary metabolites, as well as photosynthetic pigments. These results indicate that ZnO-NPs could be effective in managing the drought-induced stress in improving the growth coupled with productivity of turnip crop.

ICGA-158

Role of Potassium in Quinoa Plant, How Different Potassium Levels Influence Quinoa Crop Yield and Quality

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Quinoa has been introduced over the last decade through pilot trials by national research institutes and universities, with promising performance in arid, semi-arid, and salt-affected soils, particularly in Balochistan, southern Punjab, and Sindh. Early agronomic evaluations show acceptable yields under low-input conditions and adaptability to marginal lands that are currently under-utilized. Quinoa directly supports food security by combining high nutritional density (complete protein with balanced essential amino acids, dietary fiber, minerals such as Fe, Zn, Mg) with production stability under stress. Its diversification potential reduces dependence on wheat and rice, strengthens dietary quality, and offers income opportunities for smallholders through niche and functional food markets. Potassium plays a vital role in opening and closing of stomata, increasing the water holding capacity, grain filling capacity and healthy panicle formation. Potassium helps in root and shoot growth and also promotes photosynthesis in various conditions. Potassium controls osmotic regulation and enzyme activation in quinoa, and increases photosynthesis activity up to higher levels by minimizing the water loss during CO₂ absorption. In the semi-arid areas of Pakistan, potassium boosts drought resistance and water retention. In cotyledon, high potassium storage supports salinity tolerance. In semi-arid conditions, we all know that quinoa requires about 205-220 kg K₂O per ton of grain. Overall, potassium improves the harvest index, seed weight, and quality of seed through optimal levels that vary by soil and irrigation. Combined application of N, P, K increases seed weight as well as chlorophyll index, which ultimately impacts production.

ICGA-159

Genetic Analysis of Spring Wheat Varieties for Yield Related Traits Under Water Stress Conditions

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Wheat (*Triticum aestivum* L.) is the primary domesticated food crop which serves as a fundamental staple food in populated regions across the globe. Recognizing the paramount importance of genetic improvements, the present study will be carried out at the experimental area of the Department of Plant Breeding and Genetics, Ghazi University, Dera Ghazi Khan, to determine the best F₁ hybrids under normal and drought stress conditions. In the first year, crosses will be made among six parents in a complete diallel cross fashion. In the next year, the seeds of F₁ hybrids will be sown under an RCBD split-plot design with three replications under both normal and drought stress conditions. Data will be collected from five randomly selected plants for various traits including germination percentage, days to heading, days to anthesis, days to maturity, plant height etc. Collected data will be analyzed using statistical tools such as analysis of variance, combining ability and heterosis. The results of analysis of variance traits such as grain yield per plant, thousand grain seed weight, numbers of tillers per plant, flag leaf area, days to heading and seed size will be highly significant. In mean square variance such as GCA, SCA, heterosis and heterobeltiosis crosses such as Ujala-16 × KLR-13, Akber-19 × Faisalabad-19 and saher-6 × Anaj-17 traits like days to anthesis, spike length, days to heading, spikelets per spike, days to maturity and stem size show best performance under both drought and normal conditions. These crosses will be used in further breeding programs.

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ICGA-160

Mitigating Frost Stress in Chia (*Salvia hispanica* L.) Through Foliar Application of Moringa Leaf Extract Sown on Different Sowing Times

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Frost stress poses a significant threat to chia (*Salvia hispanica* L.) cultivation in semi-arid regions, often resulting in substantial yield losses and limiting its successful cultivation as a highly sought after crop in areas such as Pakistan. This study was designed to determine the optimal sowing time and evaluate the effectiveness of foliar spraying with Moringa leaf extract in mitigating frost stress. A field experiment was conducted using a randomized complete block design (RCBD) with factorial arrangements, testing two Sowing times (early: November 1; late: November 24) and three foliar spray treatments (control, water spray, and 2% Moringa leaf extract) with interval of every 3 days during the critical frost period. Data on growth, physiological characteristics, and yield parameters were collected and analyzed using analysis of variance (ANOVA). The results conclusively demonstrated that foliar spraying with 2% Moringa leaf extract was a highly effective biostimulant, significantly improving the plant's frost tolerance and agricultural performance. The application of moringa leaf extract had a profound and highly significant positive effect ($p < 0.05$) on key vegetative traits, including plant height, number of leaves, and stem diameter, as well as physiological indicators such as chlorophyll and proline content. While Sowing time independently affected many traits earlier Sowing generally led to increased stem diameter and total biomass the most interesting finding was the marked interaction between Sowing time and moringa leaf extract with respect to biological yield. This suggests that the positive effect of moringa leaf extract on total biomass was significantly amplified under earlier Sowing conditions. Most importantly, the use of moringa leaf extract resulted in a marked increase in the number of inflorescences per plant, the number of seeds per inflorescence, and consequently, the grain yield, regardless of Sowing time. The harvest index was unaffected by the moringa leaf extract, indicating that this treatment enhanced the overall plant productivity (energy source) without altering the natural ratio of biomass allocated to seeds. In conclusion, although early Sowing provided a major advantage, foliar application of 2% moringa leaf extract emerged as a key and reliable factor in mitigating the effects of frost stress. This application effectively compensated for the disadvantages of late Sowing and, in conjunction with early Sowing, maximized the yield. These results confirm the feasibility of using 2% moringa leaf extract as a sustainable and effective strategy for stabilizing chia crops and enhancing their frost resistance in frost-prone growing environments, providing a clear management recommendation for farmers in frost-prone areas.

ICGA-161

Mitigation Frost Stress in Chia (*Salvia hispanica* L.) Through Foliar Application of Moringa Leaf Extract Under Different Sowing Methods

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Chia (*Salvia hispanica* L.) is a nutrient-rich crop highly sensitive to frost stress, which severely limits its growth, and yield production. This study evaluated the potential of foliar-applied Moringa leaf extract (MLE) and different sowing methods to mitigate frost damage in chia. A field experiment was conducted using a Randomized Complete Block Design (RCBD) factorial with three replications. The treatments comprised three sowing methods flat (S1), bed (S2), and ridge (S3) and three foliar applications control (T1), water spray (T2), and 2% MLE (T3). Growth, physiological, and yield parameters were recorded and analyzed using ANOVA. The results demonstrated that both sowing method and foliar application treatment significantly influenced growth, yield and physiological traits. Ridge sowing (S3) consistently outperformed bed and flat sowing, recording the highest values for chlorophyll content (43.16 index), plant height (50.13 cm), number of leaves (50.16), stem diameter, inflorescence number and length, seeds per inflorescence (30), biological yield (1400 g), grain yield (50 g), and harvest index (6%). Among foliar treatments, 2% MLE (T3) was most effective, significantly enhancing all parameters compared to water spray and control. The interaction between sowing method and foliar treatment (SM×FT) was significant for key traits such as seed number per inflorescence, biological and grain yield, stem diameter, and chlorophyll a, b, and c content. The combination of ridge sowing with 2% MLE foliar application yielded the best overall performance, indicating a synergistic effect. Foliar application of 2% Moringa leaf extract combined with ridge sowing is a highly effective, sustainable, and economical strategy for enhancing frost tolerance, improving physiological performance, and increasing the productivity of chia under cold stress conditions. This approach offers a viable alternative to synthetic protectants, supporting climate-resilient agriculture.

ICGA-162

Reorienting Agricultural Extension Systems for Climate-Resilient and Green Agriculture: Pathways to Achieve Food Security and Sustainable Development Goals

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Punjab, the main agricultural province of Pakistan, sustains millions of smallholder farmers and contributes over 60% of the country's food production. However, climate change poses serious challenges to agricultural viability, including rising temperatures, heat waves, water scarcity, irregular monsoons, soil degradation, and increased pest pressures. This study explores the role of extension-led interventions and technology-driven approaches in promoting climate-resilient and sustainable agriculture. Using an extension-based research approach, the study targeted 180 smallholder farmers across five districts of Punjab. A stratified random sampling technique was applied to ensure representation across crop types and farm sizes. Data were collected through structured interviews, focus group discussions, field observations, and ICT-enabled advisory platforms to assess farmers' knowledge, adoption of climate-smart practices, and access to digital services. Results indicate that over 72% of participating farmers adopted at least one climate-smart practice, such as efficient water management, precision fertilizer application, or pest-resistant crop varieties. Farmers using mobile-based climate information services reported higher adaptive

capacity and reduced crop losses, while technology-supported extension services improved awareness of resource-efficient input management. Discussions highlight the importance of integrating ecosystem-based practices, ICT tools, and participatory extension approaches to enhance resilience and productivity. The study recommends strengthening farmer-centered extension systems, promoting public-private partnerships, and scaling ICT-enabled advisory platforms to support widespread adoption of climate-smart agriculture. These interventions align with SDGs 2, 12, 13, and 15, demonstrating the potential of technology-driven, community-focused extension models to transform Punjab's agriculture into a resilient and sustainable food system.

ICGA-163

Effect of Chemical Compounds on Colony Strength Parameters of Honey Bees (*Apis Mellifera* L.) at Higher Trophic Levels

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Honey bees (*Apis mellifera* L.) are widely recognized as beneficial organisms due to their biological, ecological, and scientific importance, as well as their production of economically valuable products such as royal jelly, pollen, propolis, honey, and wax. These essential pollinators are increasingly threatened by chemical compounds used to control insect pests in agricultural systems. To evaluate the impact of insecticide exposure on colony performance, an experimental study was conducted by sowing sunflower crops over an area of 500 m² and applying selected pesticides at the flowering stage. Honey bee colonies were exposed to these pesticides under field conditions. We hypothesized that insecticide exposure would significantly affect colony strength parameters of honey bees. To test this hypothesis, we assessed the effects of different chemical compounds belonging to various groups: Nitenpyram (10% SL/acre; new chemistry), Nok-out (200 ml/acre; pyrethroid group), and Emamectin benzoate (200 ml/acre). Observations were recorded on adult bees, guard bees, forager bees, honey production, egg presence, egg hatching, larval duration, pupal period, adult emergence, adult longevity, adult mortality, and food consumption (nectar and pollen). Considerable mortality of adults, guards, and forager bees were observed in treatments receiving Emamectin benzoate compared to other treatments. Honey production was most adversely affected in colonies exposed to Nok-out. Nitenpyram and Nok-out were found more toxic to egg presence and egg hatching, while Emamectin benzoate and Nok-out negatively affected the pupal stage. Timely adult emergence, newly emerging bees, and adult longevity were extensively affected by Nitenpyram. To further examine the effects of chemical compounds on food consumption and adult mortality, additional insecticides including Imidacloprid, Chlorpyrifos, Fluvalinate, Dimethoate, and their interactions were applied through wax, nectar, and pollen. Pollen consumption was more severely affected than nectar consumption when insecticides were applied through wax, although Chlorpyrifos was particularly toxic to nectar consumption. Adult survival remained relatively high when chemicals were applied through wax, except in the case of Dimethoate, even at higher doses. Application through nectar produced no significant lethal effects over the 10-day observation period, though pollen consumption was

moderately affected. When applied through pollen, nectar consumption declined significantly. Dimethoate and pesticide interactions (Imidacloprid + Fluvalinate, Imidacloprid + Chlorpyrifos, and Fluvalinate + Chlorpyrifos) significantly affected nectar consumption. Pollen consumption was notably influenced by Fluvalinate, Chlorpyrifos, and their combinations. Over the 10-day period, adult mortality increased gradually, with maximum mortality observed in the Dimethoate (positive control) treatment, although overall adult survival remained comparatively high.

ICGA-164

Ameliorating Cadmium Toxicity in Agroforestry Tree Species via Soil Amendments: Effects on Growth, Physiology and Biochemical Changes

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Cadmium (Cd) is a serious threat to our ecosystem and food chain as being one of the lethal heavy metals falling in the category of nonessential elements that is of major concern due to its longevity and highly persistent nature. The objective of this study was to determine the efficacy of different soil amendments to decrease the effects of cadmium-induced stress on, multipurpose tree species. Four versatile tree species, including *Eucalyptus camaldulensis*, *Dalbergia sissoo*, *Salix tetrasperma*, and *Populus deltoides* were selected. These species were grown under 50 ppm cadmium (Cd) stress and four soil amendments including farmyard manure (FYM), elemental sulphur, EDTA, and citric acid were to determine the effects of these soil amendments on plant growth, physiological performance, antioxidant enzyme activity and nutrient uptake under Cd stress. The findings revealed that Cd toxicity had more significant effect on decreasing root and shoot growth, biomass, the rate of photosynthesis, and the conductance of stomata and its concentration in the plant tissues. All soil amendments enhanced the Cd stress tolerance of plants with FYM was most effective increasing the plant biomass and antioxidant activities (SOD, CAT, POD), while citric acid and EDTA were most effective in improving ionic homeostasis (Zn, Fe, Ca, Mg content), and minimized the Cd leakage into leaves. In the principal component analysis (PCA), the relationship between growth traits and physiological responses was found to be strongly on the positive side whereas Cd accumulation was negatively related. The findings of the present study concluded that *D. sissoo* and *E. camaldulensis* are suitable tree species to grow under cadmium contaminated soils.

ICGA-165

Advancing Rice Nursery Management with a Comparative Study on Weedicides for Optimal Weed Control and Crop Vitality

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Effective weed management is critical for optimizing rice nursery performance, particularly for high-yielding varieties like PB-7. This study evaluated the efficacy of three commercial different weedicides, RiceUp (SunGrow), Ajicsa (Corteva), and Halofop (KingAgroot) against a control treatment in a rice nursery field at Taqwa Farm, Galaxy Rice Mills Pvt. Ltd., Wahndo Road, Eminabad, Gujranwala, Punjab, Pakistan. The experiment was conducted under a Randomized Complete Block Design (RCBD), with all treatments applied at recommended doses in a nursery of the Pusa Basmati-7 rice variety. Agronomic practices were consistent across treatments. Results revealed that Halofop (KingAgroot) achieved complete weed control without inducing stress on the rice nursery, demonstrating superior performance. Ajicsa (Corteva) also effectively controlled weeds and maintained nursery health with minimal stress. In contrast, RiceUp (SunGrow) successfully eliminated weeds but caused significant stress, resulting in patchy crop damage and mortality in some areas. These findings highlight Halofop and Ajicsa as promising options for sustainable weed management in rice nurseries, offering effective weed suppression with minimal impact on crop vigor. The study underscores the importance of selecting weedicides that balance weed control with crop safety to enhance nursery establishment and support climate-resilient rice production.

ICGA-166

Assessment of Groundwater Potential Zones for Irrigation Through GIS and Remote Sensing: Evidence from District Lower Dir, Pakistan

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Assessment of groundwater potential is essential for sustainable irrigation planning in water-scarce mountainous regions such as District Lower Dir. This study delineates groundwater potential zones using an integrated Geographic Information System (GIS) and remote sensing framework by synthesizing key hydro-geomorphological factors, including lithology, lineament density, drainage density, slope, land use/land cover, soil texture, rainfall, and elevation. Thematic layers derived from satellite imagery and ancillary datasets were weighted and overlaid using a multi-criteria decision analysis approach to generate a groundwater potential map. The results classify the study area into very low, low, moderate, good, and very good groundwater potential zones, reflecting spatial variability driven primarily by structural controls, topography, and recharge conditions. Validation against existing well data and field observations indicates a strong correspondence between predicted high-potential zones and observed groundwater availability. The findings demonstrate that geospatial techniques provide a reliable, cost-effective decision-support tool for identifying suitable areas for irrigation development and groundwater management. The study offers practical guidance for planners and policymakers to optimize irrigation expansion while promoting sustainable groundwater use in District Lower Dir and similar agro-ecological settings.

ICGA-167

Effect of Seaweed Extract on nursery Growth of Olive (*Olea europaea* L.) Under Controlled and Semi-Controlled Nursery Conditions

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Olive (*Olea europaea* L.) is an economically important crop with increasing cultivation potential in Pakistan. Proper nutrition and growth stimulation at the nursery stage are essential for producing healthy and vigorous plants. The present study was conducted to evaluate the effect of seaweed extract on the growth a performance of olive plants under controlled and semi-controlled nursery environments. The experiment was carried out using different concentrations of seaweed extract applied as foliar spray, along with a control treatment (without seaweed application). Various growth and quality parameters, including plant height, number of leaves, stem diameter, root length, fresh and dry biomass, chlorophyll content, and survival percentage, were recorded at regular intervals. The experimental design followed a randomized complete block design with appropriate replications. Results indicated that seaweed extract significantly improved vegetative growth and physiological attributes of olive plants compared to the control treatment. Higher concentrations of seaweed extract showed better performance in terms of plant vigor, leaf development, and biomass production. Moreover, plants grown under controlled conditions exhibited comparatively better growth than those under semi-controlled environments. The application of seaweed extract proved to be an effective natural biostimulant for enhancing nursery performance of olive plants. It can be recommended as an eco-friendly and cost-effective approach for improving olive propagation and early establishment. This study provides valuable insights for nursery managers and farmers to optimize olive production using sustainable practices.

ICGA-168

Status and Distribution of Viral Pathogens Affecting Tobacco (*Nicotiana tabacum* L.) in the Dera Ghazi Khan Region, Pakistan

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Tobacco (*Nicotiana tabacum* L.) is an economically important cash crop in southern Punjab, Pakistan; however, its productivity is increasingly threatened by viral pathogens. The present study was conducted to assess the status, prevalence, and field distribution of major viral diseases affecting tobacco crops in the Dera Ghazi Khan region. Extensive field surveys were carried out during the cropping season across major tobacco-growing areas, and plants exhibiting typical viral symptoms such as mosaic patterns, leaf curling, chlorosis, vein clearing, and stunted growth were documented. Disease incidence and severity were recorded, and representative symptomatic samples were collected for laboratory confirmation using serological and molecular diagnostic approaches. The results revealed a widespread occurrence of viral infections, with Tobacco mosaic virus (TMV), Cucumber mosaic virus (CMV), and begomovirus-like symptoms being predominant across surveyed locations. Disease incidence varied among fields, likely influenced

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by agronomic practices, vector population dynamics, and environmental conditions. Viral infections were found to significantly affect plant vigor and leaf quality, ultimately posing a serious threat to tobacco yield and economic returns for farmers in the region. This study provides the first comprehensive overview of tobacco viral diseases in Dera Ghazi Khan and highlights the urgent need for integrated disease management strategies, including vector control, use of virus-free planting material, and farmer awareness programs. The findings will contribute to improved disease surveillance and sustainable tobacco production in arid and semi-arid agro-ecological zones of Pakistan.

ICGA-169

Morphological and Biochemical Evaluation of Soybean (*Glycine max* L.) Cultivar Rawal-1 in Response to the Seed Treatment and Foliar Applications of GA₃ and 2,4-D

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Plant growth regulators might work on the physiological proficiency, photosynthetic ability and can improve the successful partitioning of accumulates from source to sink in the field crops. There is a little data on the role of growth regulators in the manifestation of yield components and seed quality of soybean (*Glycine max* L.) An endeavor has been made to elaborate the subject with emphasis on the importance of plant growth regulators, viz. Auxin (2,4-D) and gibberellin (GA₃) in a ratio of 30:60:90 mg L⁻¹. Growth regulators were used as seed treatment before sowing and foliar treatment at physiological stage of flower initiation. The experimental arrangement charted a complete randomized block design with three replicates. The study was hypothesized with the aim of increasing yield of soybean through foliar application of growth regulators. The data was statistically analyzed by using Tukey's Honest Significant difference test at $p \leq 0.05$. Seed treatment with 2,4-D at 90 mg L⁻¹ revealed highest plant height, first node height, number of branches per plant, root length, stem diameter, number of pods per plant, seed yield, biological yield and harvest index. The GA₃ Seed treatment at 90 and 60 mg L⁻¹ showed significantly maximum number of nodules per plant, nodule fresh weight and nodule dry weight. The number of seeds per pod exhibited non-significant results during the study. Foliar application of 2,4-D at 90 mg L⁻¹ showed a significantly maximum leaf area as compared to seed treatment. Growth regulators also significantly affected quality traits. Response of plant growth regulators was outstanding in promoting the soybean as a successful oilseed crop. So it is proved that the application of plant growth regulators is very helpful for gaining maximum growth, higher yields and quality of soybean under rainfed conditions.

ICGA-170

Response of Winter Weed Species to Varying Sowing Times: Growth, Maturity, and Seed Yield

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Weeds significantly reduce crop productivity, interfere with harvesting operations, and contribute to soil seed bank enrichment, thereby creating persistent management challenges. Understanding the ecological behavior of winter weeds is therefore essential for developing sustainable management strategies. A field experiment was conducted at the Agronomy Research Area, Ghazi University, Dera Ghazi Khan, to investigate the influence of sowing time on the growth dynamics, phenology, and seed production of five major winter weed species: *Avena fatua*, *Phalaris minor*, *Rumex dentatus*, *Chenopodium album*, and *Chenopodium murale*. The experiment was arranged in a randomized complete block design (RCBD) with a factorial arrangement. Four sowing dates (1st November, 1st December, 1st January, and 1st February) were evaluated to determine the optimal establishment window for winter weeds and to identify crop sowing adjustments that minimize weed competition. Sowing time exerted a highly significant influence on vegetative growth, phenological development, and reproductive output. Early sowing (Nov-Dec) markedly enhanced plant height, leaf area expansion, biomass accumulation, and prolonged vegetative duration, which delayed reproductive maturity and promoted greater assimilate partitioning to reproductive structures. In contrast, delayed sowing (Jan-Feb) reduced vegetative growth, accelerated phenological progression, shortened life cycle duration, and exposed plants to suboptimal thermal conditions during reproductive stages. Consequently, reproductive structures per plant, seed mass, and overall seed yield declined significantly with postponed sowing. Optimal early-to-intermediate sowing windows maximized seed production and improved yield components, demonstrating that establishment timing is a critical ecological determinant of growth–reproduction trade-offs and seed bank replenishment. These findings provide valuable insights for predicting weed population dynamics and for adjusting crop sowing dates to reduce weed pressure under changing climatic conditions.

ICGA-171

Evaluation of Sorghum (*Sorghum bicolor*) Germplasm for Dual-Purpose (Grain and Fodder) Improvement in Dera Ghazi Khan

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Sorghum germplasm lines constitute an essential reservoir of genetic diversity crucial for crop improvement. Climate change has posed a significant threat to global agriculture, therefore, diversity is imperative, particularly for a dual-purpose crop like sorghum. This study evaluated forty sorghum germplasm lines under the climatic conditions of Dera Ghazi Khan to assess morphological diversity and identify promising breeding material. Substantial phenotypic variability was observed, indicating broad genetic diversity and adaptability. Specific genotypes demonstrated superior traits for targeted breeding: genotypes 35, 17, and 24 exhibited high grain yield potential, while genotypes 13, 22, and 25 showed superior fodder characteristics, such as a higher leaf number. Furthermore, genotypes 29, 36, and 22 were

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identified as promising parental material for developing high-protein fodder varieties. The findings underscore the critical role of systematic germplasm evaluation in unlocking genetic diversity to develop resilient, high-performing sorghum varieties with distinct agronomic and nutritional traits.

ICGA-172

**Microbial-based interventions for enhancing post-harvest food safety and
reducing climate-induced spoilage in staple crops: A focus on tomato in
Bahawalpur, Pakistan**

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Post-harvest losses in perishable crops like tomatoes due to microbial contamination and climate-induced stress pose significant economic and environmental challenges, particularly in regions like Bahawalpur, Pakistan, where seasonal gluts lead to drastic price drops (Rupees. 10–20/kg in April-May). Tomatoes are highly susceptible to spoilage by fungi (*Alternaria*, *Botrytis*) and bacteria, leading to annual losses of ~30-50% in developing countries. Climate change exacerbates these issues by increasing pathogen virulence and disrupting supply chains. This not only impacts food security but also escalates greenhouse gas emissions through wasted resources. Previous research has explored chemical treatments and modified atmosphere storage to mitigate spoilage. Biological control using antagonistic microbes (e.g., *Trichoderma*, *Bacillus*) has shown promise but faces hurdles in consistency and scalability. The lack of cold storage and processing infrastructure in Bahawalpur worsens these issues, forcing farmers to sell at distress prices. This review proposes leveraging the antifungal volatile organic compounds (VOCs) of *Pichia anomala* combined with an edible nanocoating from garlic extract to reduce post-harvest losses in tomatoes. Expected outcomes include improved shelf life, reduced spoilage, and lower mycotoxin risks. Unlike previous methods, this approach could offer scalable, eco-friendly solutions for climate resilience and food security, directly benefiting farmers in Bahawalpur and similar regions.



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