NIFA

Annual Report 2018-19

NIFA Mung-2019

NIFA Awaz-2019

Nuclear Institute for Food and Agriculture (NIFA), Peshawar

NIFA

Annual Report

2018-19

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C O N T E N T S

NIFA ANNUAL REPORT 2018-19

PROLOG

With climate change, agricultural production and food security is likely to face one of the biggest challenges in the years to come. The country has already been witnessing some impacts of climate change, such as crop loss due to unusual outbreaks of diseases and pests, erratic rainfalls, windstorms, hail storms, droughts, flash floods and landslides annually. Nuclear Institute for Food and Agriculture (NIFA) is striving for innovative research and development (R&D) technologies in agriculture, specially focusing on the development of climate resilient technologies. NIFA aims at promoting sustainable food production systems to meet rather to exceed the expectations of end-users through human resource development and use of nuclear and other contemporary advanced technologies. The achievements of four research divisions during the period under report are summarized as below:

PLANT BREEDING AND GENETICS DIVISION

Development and release of new high yielding, disease resistant and well adapted wheat varieties are imperative to increase wheat production in the province. To achieve this objective, continuous efforts are being made by the breeders. Awaz-2019 is genetically different having Milan and Berkut in its pedigree responsible for abiotic stress tolerance, and has potential yield of 4917 kg ha^{-1}. The variety is semi dwarf with dark green waxy leaves, yellowish white spike with amber colour grains and good chapatti making quality. The Khyber Pakhtunkhwa seed council in its 38th meeting held on 3rd January, 2019 approved "Awaz-2019" as a new improved wheat variety for general cultivation in the province.

Rapeseed candidate line RR-8-1 ranked 2nd in National Uniform Rapeseed Yield Trial with 13% increase over Super Canola (check). Out of 14 advanced rapeseed mutant/recombinant lines evaluated for adaptability studies in Khyber Pakhtunkhwa and Punjab; RR-8-1 and RR-8-2 significantly out yielded the check and exhibited seed yields of 2523 and 2538 kg ha^{-1} respectively. In replicated seed yield trials at NIFA, 08 rapeseed genotypes produced seed yields in the range of 3040 - 3482 kg ha^{-1} and out yielded the check Faisal Canola (2366 kg

ha^{-1}). Pre-basic seed of NIFA-Gold (786 kg) and Durr-e-NIFA (359 kg) was produced at NIFA Experimental Farm.

An advanced high yielding and disease resistant mungbean line "NFM-5-36-27" was approved as commercial variety under the name "NIFA Mung-2019" by the KP Seed Council in 2019. NIFA Mung-2019 is the first mungbean variety in the country with green hypocotyl/green stem, which is the main requirement of mungbean sprout production industry. In advanced yield trials 14 genotypes produced statistically significant ($P \leq 0.05$) higher seed yield (608-834 kg ha^{-1}) as compared to the check varieties Ramzan and NIFA Mung-2017.

In chickpea, 28 recombinants produced statistically significant ($P \leq 0.05$) higher seed yield (1803-2500 kg ha^{-1}) as compared to the check varieties NIFA-2005 (1160 kg ha^{-1}) and Bittal-16 (903 kg ha^{-1}) out of 55 advanced chickpea recombinant lines evaluated in 05 sets of replicated yield trials.

Exotic and local germplasm of peach were studied for better quality and higher yield. Creation of genetic variability through budwood irradiation was carried out in peach and plum. Budwood, irradiated with 20 and 30 Gy, budded on peach rootstock in the nursery showed delay in sprouting. Marianna plum cuttings were subjected to different concentrations of IAA and IBA for promoting root formation. It was found that Marianna cuttings treated with 1000 ppm IAA gave the highest (70%) cuttings sprouted. Early budding (10^{th} June) in peach gave better response as compared to other treatments.

FOOD AND NUTRITION DIVISION

Scientists in the Food and Nutrition Division are working on value addition and shelf life extension of food/agricultural commodities through gamma irradiation and other modern techniques to enhance food safety and to achieve food security. Production of already developed products like squashes, jams and syrups was enhanced by improving processing efficiency. An overall 35% increase in different squashes production was achieved. A net sale of Rs. 10,08,640/- of different food products (squashes, jams and syrups) yielded profit of Rs. 5,40,138/-. Work was initiated on zero energy cooling chamber as part of an ALP funded project. A cooling chamber with inner size: 5.5 ft length, 3.5 ft width, 2.5 ft height was constructed at NIFA. Experiment on storage stability of okra revealed weight loss of 5-6% inside the chamber compared with 70-75% outside the chamber during 12-days storage period. The effect of EB and gamma irradiation was studied on MRE by considering the dose rate and throughput of both the technologies. Among the treatments, the highest irradiation dose (12.0 kGy) showed best results in terms of overall acceptability, microbial control and shelf life

extension of MRE at room temperature for three months. Furthermore, 0.9 kGy was found effective for the removal of astringency in persimmon. In another study, MRE was fortified with milk thistle (10%) and irradiated at different doses to evaluate the nutrients stability and microbial safety. Results showed that at least 10 kGy dose is needed for the preservation of fortified meals.

Indigenously produced mushroom spawn at NIFA was sold on subsidized rate to the interested farmers. A total of about Rs. 1,71,000/- was earned from the sale of mushroom spawn and mushrooms at NIFA Mushroom Farm. Polyethylene bags with vacuum sealing showed great potential for removing astringency from persimmon fruit.

A study was carried out to produce bio-preservatives from lactic acid bacteria. Out of 16 isolates of lactic acid bacteria obtained from yoghurt (dahi), three strains of lactic acid bacteria i.e. NIFA-1, NIFA-2 and NIFA-3 showed the capability to produce bio-preservatives known as bacteriocin. These strains were also used to prepare probiotic yoghurt as a value-added dairy product. The maximum zone of inhibition was observed for NIFA-3 against *Staphylococcus aureus* (38 mm). These three isolates were primarily identified by classical methods and then by API 50 CHL kits. Isolates were identified as *Pidococcus resemblences* (NIFA-1), *Lactococcus lactis* subsp lactis-1 (NIFA-2) and *Lactococcus lactis* sub-sp. lactis-2 (NIFA-3). FTIR spectra of these strains were also carried out to determine their clustering with locally isolated strains. Their identification was further re-confirmed by 16S rRNA amplification.

SOIL AND ENVIRONMENTAL SCIENCES DIVISION

Agriculture sector has become highly vulnerable under the twin menace of changing climate and inherent poor fertility of soils in Pakistan. This coupled with highly input intensive farming to feed the ever-increasing population are posing grave threats to the sustainability of farming. Research endeavors at Soil and Environmental Sciences Division address the above stated issues using conventional and nuclear techniques. Our team has devised environment friendly packages of production technology for various field and horticultural crops, perfected tunnel farming technology for off-season vegetables production, bio-geyser technology for warming water through the use of agro-wastes and developed organic fertilizer products (compost and compost tea) for particular use by vegetable growers. Technology packages developed are disseminated to various stakeholders through awareness seminars, training workshops and field demonstrations.

Off-season vegetables farming in high tunnel has wide scope and creates economic opportunities particularly for small landholders. The critical timings, methods and economical levels of fertilizer and irrigation for tomato and cucumber were identified for growing off-season vegetables in high tunnels with furrow and drip irrigation systems. It was found that off-season tomatoes and cucumbers produced in high tunnels presented fifteen times higher income than conventional ones. The technology of tunnel farming was effectively demonstrated to over 100 stakeholders as part of project activities being sponsored by the University of Agriculture, Peshawar Endowment Fund on March 27, 2019 through a training/demonstration workshop organized at NIFA.

Biofortification of staple food crops with micronutrients is a cost-effective and sustainable approach to address the problem of micronutrient malnutrition. Extensive screening of genotypes was carried out under hydroponics and field conditions. Zinc efficiency of ten wheat genotypes under hydroponics ranged from 29 to 79%. Field application of Zn @ 5 kg ha^{-1} increased yield of six genotypes tested, of which Tatara and NIFA-Aman produced the highest grain yield of 4386 and 4335 kg ha^{-1}, respectively.

Development of fertilizer recommendations for upcoming varieties is compulsory information desired by Provincial Seed Council in a proposal document for varietal approval. Findings revealed that wheat line CTES 16122 performed better at 140-90-60 NPK kg ha^{-1}. The maximum brassica grain yield (3367.8 kg/ha) was recorded where NPK were applied @ 90-60-60 kg/ha.

Findings from a study to improve yield of plum revealed that maximum plum fruit yield of 50 kg $tree^{-1}$ was observed in the treatment which received NPK @ 270-187-270 g $tree^{-1}$ as fertigation + foliar N (0.5%) + humic acid (0.05%).

The ongoing variability in weather pattern necessitates to slightly modify wheat sowing times and fertilizer application rates. Field studies showed that early sowing with higher fertilizer application rates may help to obtain better grain yield under current scenario of changing climate.

Innovative modeling approaches were used to identify measures for enhancing wheat yield under water limited conditions. It was found that yield can be enhanced by modifying leaf area index and maximum rooting depth. The study demonstrated the potential of CropSyst to predict grain yield successfully under existing conditions.

The protocol for formulation of compost tea was standardized through a series of laboratory experiments and analytical work. Compost tea being fermented over a period of seven days by using compost and water in 1:5 ratio showed relatively better N content and microbial load.

PLANT PROTECTION DIVISION

The Plant Protection Division is working on the integrated pest and vector management techniques useful in minimizing the pest losses to fruits & vegetables and vectors of deadly diseases in human beings. The IPM in Agriculture Entomology involves environment friendly chemical and biological control techniques targeted to fruit flies, chick pea pod borer, wheat rust and subterranean termites. The integrated vector management in the Medical Entomology has focus on vector surveillance, identification and control of disease carrying vectors. The research based products and technologies are transferred to the end users especially researchers, agriculture extension specialists, progressive farmers and community leaders through training workshops, seminars and print materials.

PLANT BREEDING AND GENETICS DIVISION

Wheat Irrigated

Field evaluation of exotic wheat germplasm

Global exchange of wheat germplasm, in particular CIMMYT / ICARDA through provision of observation nurseries and trials to cooperating institutions plays a pivotal role for having desirable idiotypes to wheat breeders.

51st IBWSN (International Bread Wheat Screening Nursery) consisting of 300 genotypes received from CIMMYT, Mexico, was evaluated with local check NIFA-Aman. Based on plant type, yield performance and disease reaction (YR, LR, LS and BYD), a total of 88 genotypes were selected. The selected genotypes out yielded the check cultivar NIFA-Aman (2444 - 4129 kg ha^{-1}) by producing grain yield in the range of 5039 - 7333 kg ha^{-1}.

20th FHBSN (Fusarium Head Blight Screening Nursery) consisting of 52 genotypes including two checks was evaluated for yield and yield related traits along its response to prevailing diseases (YR, LR, LS and BYD). A total of 11 genotypes were selected for further evaluation and confirmation of desired traits. The selected genotypes out yielded the checks (2000-4000 kg ha^{-1}) by producing grain yield in the range of 4666-6666 kg ha^{-1}.

29th HRWSN (High Rainfall Wheat Screening Nursery) consisting of 139 genotypes including local check NIFA-Aman was evaluated for yield performance and disease reaction against YR, LR and LS. Out of the test genotypes, 33 were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety (3066-5000 kg ha^{-1}) by producing grain yield in the range of 5066 - 7333 kg ha^{-1}.

13th STEM RRSN (Stem Rust Resistance Screening Nursery) consisting of 168 genotypes was evaluated for yield and yield related traits and response to prevailing diseases (YR, LR, LS and BYD) using NIFA-Aman as local check. Out of 168 genotypes, 30 high yielding and disease resistant genotypes were selected for further evaluation in PYTs (2019-20). The selected genotypes out yielded the check variety Aman (3546 kg ha^{-1}) by producing grain yield in the range of 5199 - 7333 kg ha^{-1}.

39th ESWYT (Elite Selection Wheat Yield Trial**)** consisting of 50 genotypes was evaluated for yield performance and

reaction against diseases (YR, LR and LS) with local check NIFA-Aman. Out of 48 test genotypes, 13 were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety NIFA-Aman (2983 kg ha^{-1}) by producing grain yield in the range of 3199 to 4748 kg ha^{-1}.

1st CWYT (Coordinative Wheat Yield Trial) consisting of 50 genotypes was evaluated for yield performance and resistance against diseases (YR, LR, LS and BYD) with local check NIFA-Aman (2400 kg ha^{-1}). Out of 48 test genotypes, seven genotypes with yield performance in the rage of 3767-4833 kg $ha^{-1}$and desirable disease response were selected for further evaluation and confirmation of its desired traits.

NIFA Disease Screening Nursery (NDSN) 2018-19 consisting of 138 genotypes from advanced and preliminary yield trials (2018-19) was evaluated with standard check Morocco for disease reaction against yellow rust (YR), leaf rust (LR) and barley yellow dwarf (BYD).

Performance of advanced wheat lines in various yield trials

Sixty-six genotypes were evaluated in three (3) sets of preliminary yield trials under both normal and late planting conditions. In PYT-I, two lines *viz*. CT-18033 and CT-18062 out yielded the high yielding check Khaista-2017 (7910 kg ha^{-1}) by producing grain yield of 8310 and 8009 kg ha^{-1}, respectively. The remaining five lines *i.e.* CT-18145, CT-18048, CT-18034, CT-18063 and CT-18087 out yielded the low yielding check NIFA-Aman (4844 kg ha^{-1}) by producing grain yield in the range of 7233-7766 kg ha^{-1}. In PYT-II, two lines *viz.* CT-18236 and CT-18191 produced higher grain yield of 7255 and 6833 kg ha^{-1} respectively, in comparison to check NIFA-Aman (5155 kg ha^{-1}). In PYT-III, three lines *i.e.* CTFHB-1843, CTFHB-1824 and CTFHB-1831 out yielded the high yielding check cultivar (6910 kg ha^{-1}) by producing grain yield in the range of 6933 - 7222 kg ha^{-1}. Six (6) lines of the same trial out yielded the low yielding checks NIFA-Bathoor (5444 kg ha^{-1}), Fakhr-e- Sarhad (4622 kg ha^{-1}) and NIFA Aman (4444 kg ha^{-1}) by producing grain yield in the range of 6377 to 6722 kg ha^{-1}.

Based on yield performance, evaluation of desirable genotypes in preliminary trials is a prerequisite for further evaluation in advanced yield trials. The selected genotypes are being tested in yield trials conducted at NIFA. Forty four genotypes were evaluated in two advanced selection yield trials (AYTs) under both normal and late planting conditions. In ASYT-I, eight (08) genotypes out yielded both the check cultivars. Genotype CTES-1803 produced the highest grain yield (7053 kg ha^{-1})

followed by CT-171115 (6875 kg ha^{-1}) and CTES-1849 (6675 kg ha^{-1}) in comparison to check cultivars (5087 - 6459 kg ha^{-1}). While in ASYT-II, eight (8) genotypes out yielded all the check cultivars (NIFA-Aman, Fakhr-e-Sarhad, NIFA-Bathoor-08 and Khaista-17) by producing grain yield in the range of 6586 -7142 kg ha^{-1} compared to that of the check cultivars (4387- 6492 kg ha^{-1}).

Multi location testing of elite material is a pre-requisite for genotypes to be considered as candidate variety. For assessment of performance, 12 genotypes were evaluated at 03 locations in the central irrigated zone of Khyber Pakhtunkhwa. Three high yielding and disease resistant genotypes (CTHN-162009, CTHN-162056 and CTES-17133) were selected out of twelve (12) genotypes in multi-locational yield trial. The selected genotypes out yielded the local check cultivars by producing grain yield in the range of 6005 to 6350 kg ha^{-1} in comparison to the checks (3433 to 5726 kg ha^{-1}). These genotypes will be evaluated in KPWYT 2019-20.

Zonal trials of advanced wheat lines are pre-requisites for development of new genotypes with wider adaptability and selection of suitable candidate varieties for evaluation in NUYT. Four promising genotypes (CT-161072, CT-161130, CTHN-162076 and NON-16053) were evaluated for grain yield stability and disease response at seven locations of KP. As per results of the trials received from the concerned quarters, genotype CT-161130 secured 2nd position by producing mean grain yield of 5522 kg ha^{-1} under normal irrigated conditions. These genotypes will further be evaluated in NUWYT-2019-20.

Country-wide field evaluation of candidate wheat varieties is a vital link between genetic improvement and the production environment. Two candidate lines CTG-154013 and CTG-154028 based on higher grain yield, yield components and disease resistance in 1st year National Uniform Yield Trials (NUYT) were subjected to the 2nd year mandatory evaluation in the national trials during 2018-19. Agronomic data of the trial recorded at NIFA were submitted to the National Wheat Coordinator for necessary compilation at country level. NUYT pooled analysis showed that CTG-154013 secured 1st position and produced higher mean grain yield (5095 kg ha^{-1}) over all the candidate lines in KP. However, this line could not qualify against the prevailing rust diseases as reported by Crop Disease Research Institute (CDRI Report 2018-19).

Creation of desired genetic variability and evaluation of segregating populations

F_3 population resulted from 17 cross combinations was raised in the field in space planting. The material was thoroughly evaluated during the growth

period for disease/lodging resistant, high tillering capacity and early maturity. Altogether, 31 desirable recombinants were selected for further evaluation regarding the desired traits.

F_2 segregating population resulted from 38 cross combinations was raised in the field in space planting. The material was thoroughly evaluated during the growth period for disease/lodging resistant, high tillering capacity and early maturity. In all, 23 desirable recombinants were selected for further evaluation regarding the desired traits.

F_1 generation resulted from 5 cross combinations (E-238 / Yr-10, Tatara / Yr-10, Daman / Yr-5, CT-161057 / Yr-10 and Dera / Yr-5) was raised (space plantation) in the field at NIFA and seeds from each cross combination were separately harvested on maturity.

A crossing block consisting of 84 genetically diverse genotypes was planted on two different dates for acquiring floral synchrony among early and late flowering parents. Based on transfer of genes for disease resistance and other economically important traits to otherwise well adapted cultivars/genotypes, seventeen (17) fresh cross combinations among desirable wheat genotypes were attempted. F_0 seeds were separately and successfully harvested from the cross combinations.

M_2 segregating generation resulted from the seed treatment of two well adapted varieties (Fakhr-e-Sarhad and NIFA Bathoor-08) each with 100, 150 and 250 Gy doses of gamma rays was space planted in the field along with their respective control for comparison. Based on disease resistance, high tillering capacity and better ideotype, 03 desirable mutants were recovered from M_2 population.

Two varieties (Fakhr-e- Sarhad and NIFA Bathoor-08) each treated with 150, 200 and 250 Gy gamma rays doses were raised as M_1 generation and seeds were separately harvested on dose wise basis at maturity.

Maintenance of purity in varieties and production of quality seed

More than 300 progeny rows / blocks of wheat varieties for irrigated areas *i.e.* Bakhtawar-92, Fakhr-e-Sarhad, NIFA Bathoor-08 and NIFA Aman-2017 were planted at Experimental Farm of NIFA. Progeny rows / blocks having off-type plants were discarded. A total of 3648 kg quality seed of Fakhr-e-Sarhad, NIFA Bathoor and NIFA Aman, was produced and after processing and certification by FSC & RD, the seed was distributed to Department of Agriculture Extension, seed companies and farming communities of KP.

Wheat Rainfed

NIFA Awaz-2019: New Rainfed Wheat Variety

NIFA Awaz-2019, a new improved wheat variety, is the most recent addition with potential yield of 4917 kg ha^{-1}. The variety underwent extensive field testing with the code NRL-1123 in moisture stressed environments during 2010-2017. Khyber Pakhtunkhwa provincial seed council in its 38th meeting approved and recommended it for general cultivation in the province. In national yield trials new candidate line NRL-1448 showed excellent performance in 1st year mandatory testing by producing mean grain yield of 4534 kg ha^{-1} on country basis. In Khyber Pakhtunkhwa wheat yield trials 2018-19, NIFA elite line NRL-1664 ranked 1st among the tested genotypes by giving the highest mean grain yield. From station trials and nurseries a total of 332 desirable genotypes were selected for further evaluation.

Performance of exotic germplasm

During the previous growing season (2018-19) two international wheat screening nurseries *i.e.* 36th Semi-Arid Wheat Screening Nursery (36th SAWSN) and 19th Dryland Spring Bread Wheat Observation Nursery (19th DSBWON) comprising of 300 and 200 exotic genotypes respectively, were evaluated in a non-replicated field trial under moisture stress conditions at the Institute. Data regarding yield, yield components and disease resistance were recorded for each genotype at different growth stages. Based on field performance 26 best genotypes were identified and selected on the basis of yield and disease resistance.

Thirty three (33) exotic wheat genotypes received in 8th Stress Adaptive Trait Yield Nursery (SATYN) were evaluated for yield performance and disease (Yellow and Leaf rust) resistance at NIFA Experimental Farm under moisture stress conditions. Statistical design of the trial was alpha lattice with 02 replications. Based on field performance one genotype (#9421) was selected.

Performance of wheat genotypes in various yield trials

Twelve (12) promising wheat genotypes including Lalma as standard check were assessed for grain yield, yield components and disease resistance in Advanced Barani Trial (ABT) at the institute. Based on grain yield and disease resistance 05 promising genotypes i.e. NRL-1707, NRL-1720, NRL-1725, NRL-1734 and NRL-1756 were selected. The average grain yield in advanced barani trials was in the range of 2322 kg ha^{-1} to 4589 kg ha^{-1}. NRL-1725 ranked 1st by producing grain yield of 4589 kg ha^{-1} showing an increase of 17% over the check cultivar Lalma. The lowest grain yield of 2322 kg ha^{-1} was produced by NRL-1721.

Thirty six (36) newly selected genotypes were tested for grain yield, disease resistance and other agronomic traits in 03 Preliminary Barani Trials (PBT-I, PBT-II and PBT-III) under moisture stress conditions at the institute. Wheat variety Lalma was included as a standard check in each trial. On the basis of high yield and disease resistance 04 genotypes (NRL-1801, NRL-1803, NRL-1804 and NRL-1809) were selected from PBT-I, 04 genotypes (NRL-1812, NRL-1816, NRL-1821 and NRL-1822) from PBT-II and 05 genotypes (NRL-1825, NRL-1827, NRL-1828, NRL-1830 and NRL-1832) from PBT-III. The grain yield of different genotypes in these 03 preliminary yield trials ranged from 1644 kg ha^{-1} to 4756 kg ha^{-1}. These selected lines will be further tested in advanced barani trial during the coming growing season.

The relative effects of environment, genotypes and their interaction on grain yield and agronomic attributes were assayed using 20 promising bread wheat genotypes grown in replicated trials in the plains, southern parts and northern part of Khyber Pakhtunkhwa. NIFA rainfed wheat variety "Lalma" was used as a grand check. The trails were conducted with standard cultural practices with no irrigation. Two elite wheat lines of NIFA (NRL-1664 and NRL-1685) were among the contested genotypes. NIFA elite line NRL-1664 secured 1st position among the tested genotypes by producing grain yield of 4004 kg ha^{-1}. Along with high yield NRL-1664 is highly resistant to yellow rust (RRI = 8.73). This line will be further evaluated in national trials during 2019-20.

NIFA candidate variety "NRL-1448" was subjected to 1st year mandatory evaluation in National Uniform Wheat Yield Trials (NUWYT- Rainfed) at different sites in the country. The candidate variety showed excellent results by producing mean grain yield of 4534 kg ha^{-1} on country basis (09 sites). It out yielded Pakistan-13 by 02%, local check by 07% and Faisalabad-08 by 11%.

Evaluation of segregation material and creation of genetic variability for desired traits

Extending the genetic diversity for combating stripe rust, introgression lines were developed by back-crossing i.e., Yr5/ 2*Barsat, Yr5/2*Tatara, Yr5/2*LalTara. Single and Complex crosses were also made that include Yr15/Lalma, Yr5// Yr10/Tatara, RIL1736/Yr5//Lalma, Yr15/ MarSat//Barsat, Insaf /Yr5 //Lalma/3/ Lalma, LalTara/Yr10//Yr10/ LalTara. F_1 generation of 12 cross combinations was space planted (50-100 seeds / combination) *i.e.* Yr5/Barsat, Yr10/LalTara, Yr10/ Tatara, Yr15/Lalma, RIL1736/Yr5, LalTara/Yr10, Yr15/MarSat, Insaf/Yr5// Lalma, Shahkar/SM2//Yr10, Barsat/

Sarang//Shahkar/3/PR105/Yr5, Shahkar/ PR105//Yr10/3/Lalma/Yr5, Insaf/Sarang// Shahkar/3/PR105/Yr5. Selfed plants were eliminated and the remnant plants of each entry were bulk harvested. F_2 generation of 16 cross combinations was space planted (2000 seeds/ combination) *i.e.* Insaf/Yr5, Shahkar / Sarang // Yr5, Shahkar/PR-105//Yr10, TDM / Tatara // Yr5, Lalma/ Yr5, Tatara/MarTara, Insaf/Aman//Yr5, Barsat/RIL1609, Lalma/Lalma//Marvi/Wx, Insaf/Sarang//Shahkar/PR105,Barsat/ PR 105//Yr5, Shahkar/Aman//Yr10, Lalma/ Awaz // Yr5, Lalma / PR105//Shahkar, Shahkar/ NRL1123//Yr5, Barsat/ Sarang// Yr5. Within the better F_2 populations, the best plants were selected during 3-5 rounds of selection, based on good agronomic type, "durable" disease resistance, synchronous tillering, desired spike type, good fertility, and appropriate height and maturity. F_3 progeny rows of simple crosses *i.e.* Insaf/PR105, Insaf/Sarang, Lalma/Aman, Lalma/PR105, Shahkar/PR105, Barsat/ PR105, Barsat/ Aman, Shahkar/Sarang, Shahkar/Aman were planted and suitable plants were selected in best progenies. F_4 progeny rows of crosses i.e., Barsat/SAWSN3077//Yr5, Barsat/SAWSN 3077//Yr5, Barsat/ NRL-114//Shahkar, Barsat/SAWSN3077// Barsat/ Shahkar were space planted and best plants were selected in best progenies. Progenies of M_3 generation (i.e., 25Krad, 30Krad, 35Krad) of NR-1511 and Tatara were space planted and suitable plants were selected.

Maintenance and seed production of NIFA rainfed varieties

A total of 5830 kg quality seed of NIFA rainfed wheat varieties NIFA Awaz-2019, NIFA-Lalma, NIFA-Insaf and Tatara was produced at the institute and certified by Federal Seed Certification and Registration Department (FSC & RD). The seed was distributed to Department of Agriculture Extension, seed companies and farming communities of KP. 300 progeny blocks and 400 progeny rows of these varieties were grown. With the help of FSC & RD official 245 progeny blocks and 310 progeny rows were selected and the rest were discarded. The Pre-Basic seed will be distributed among the provincial agricultural departments, seed companies and farming community in Khyber Pakhtunkhwa while the Breeder Nucleus Seed will be planted at the Institute to produce Pre-basic seed.

Oilseed

Evaluation of oilseed brassica mutants/recombinants in various yield trials

Two rapeseed candidate lines *viz.* RR-41-4 (recombinant) and RM-193-1 (mutant) were evaluated for the 2nd and RR-8-1 (recombinant) for the 1st year mandatory adaptability testing in National Uniform

Rapeseed Yield Trial (NURYT) 2018-19. Genotype RR-8-1 produced high genotypic mean (1881 kg ha^{-1}) and produced 13% higher seed yield against check Super Canola (1626 kg ha^{-1}). It ranked 2nd among 24 tested candidate lines including hybrids while RR-41-4 and RM-193-1 remained at par with the check. In National Uniform Mustard Yield Trial (NUMYT) 2018-19, second year evaluation of mustard candidate lines/mutants (MM-31-3 and MM-31-5) was performed where mutants could not replicate the achieved seed yield like that in the previous years and remained average to check Super Raya (1805 kg ha^{-1}).

Based on high seed and oil yields and other agronomic traits; performance of 14 rapeseed recombinant/mutants advanced lines (RM M2/014-1-2; RM M2-1-5; RR F2-2-6; RM M2-1-9; RRM F1M4106-1; RR F2-1-4; RM M2-2-2; RM M2-3-5; RR-40-1; RR-3-1; RR 8-1; RR 8-2; RM 193-1 and RM 276-1) were assessed in multi-location adaptation trials at selected sites in Khyber Pakhtunkhwa and Punjab (NIFA-Peshawar, AZRC-DI Khan, BARI-Chakwal and RARI-Bahawalpur). The recombinants, RR-8-1 and RR-8-2 significantly out yielded the check by exhibiting seed yields of 2523 and 2538 kg ha^{-1} respectively, while five other rapeseed recombinants/ mutants achieved numerically high seed yield (2260-2497 kg ha^{-1}) as compared with check Faisal Canola (2174 kg ha^{-1}). The GGE bi-plot (average tester coordination graph) revealed that rapeseed mutant RM 276-1 was most stable being nearest to axis of the vector and fit for D.I. Khan and Chakwal. Rapeseed recombinants RR 8-1, RR-8-2 and a mutant RM M2/014-1-2 found slightly less stable over the environment but presented high seed yield. Based on seed yield for locations, NIFA, Peshawar and AZRC, DI Khan were most productive environments.

At station trials, *brassica* genotypes developed at NIFA consisted of nineteen rapeseed recombinants and one mutant were evaluated for their agronomic performance against commercial check Faisal Canola in two separate preliminary seed yield trials at NIFA during 2018-19. Rapeseed recombinants RRF3/016-49 and RRF3/016-101 achieved statistically higher seed yields of 3138 and 3040 kg ha^{-1} respectively, while other five gave numerically higher seed yield (2416 - 2707 kg ha^{-1}) over check (2166 kg ha^{-1}) in PYT-I. In PYT-II, RRF3/016-34, RRF3/016-99, RRF3/016-82, RRF3/016-16, RRF3/016-31 and RRF3/016-20 were remarkable with seed yields of 3482, 3290, 3276, 3207, 3193 and 3182 kg ha^{-1} while three rapeseed recombinants/ mutants numerically expressed higher seed yield (2957-3165 kg ha^{-1}) compared to check (2566 kg ha^{-1}).

Under Cooperative Frame Work Agreement on Rapeseed Mutation Breeding between SIAE-China and NIFA-Peshawar, a set of ten rapeseed genotypes namely SIAE-1 to SIAE-10 were received from the counter part for evaluation at NIFA, Peshawar. None of the genotypes could statistically outdone the check Hyola-401, however genotypes SIAE-1, SIAE-2, SIAE-5 and SIAE-6 performed well and produced seed yields (3085; 2852; 2815 and 2537 kg ha^{-1}) higher than check Hyola-401 (2333 kg ha^{-1}).

Field assessment/selection of mutants/ recombinants at early breeding generations

Forty two rapeseed and mustard recombinant/mutants (F_4 /M_4) developed from two mustard cross combinations *viz*. EMH-274 x M-5121 and Coral-432 x M-5121 and tri-dosed irradiated rapeseed material were tested against five rapeseed and three mustard checks planted in augmented design. Three mustard recombinants exhibited seed yield 3167-3889 kg ha^{-1} higher by 3-27% while seven rapeseed mutants expressed seed yield 3472-3750 kg ha^{-1} higher by 2-20% than their respective controls/parents.

Under field assessment of newly developed genotypes at early stage of selection, forty eight (48) single plant progenies of M_3 of rapeseed and fifty one (51) of mustard developed from tri-dosed irradiated material were evaluated against their parents. Thirteen (13) rapeseed and five (05) mustard mutants M_3 single plant progenies produced better seed yields 3404-4810 kg ha^{-1} and 3238-4440 kg ha^{-1} exceeding corresponding parents by 2-31% and by 1-28%, respectively.

Thirty eight (38) and twenty three (23) single plants developed from three (03) rapeseed and one mustard cross combination were selected from corresponding F_2 segregating populations. Few selections exhibited heterotic and heterobeltiotic response. In M_2, thirty four (34) and twenty (20) rapeseed and mustard single plants were isolated and selected from relevant mutant population developed by irradiating one variety each of rapeseed and mustard at single gamma radiation dose on the basis of their phenotypic worth over parent.

Four (04) F_0s of rapeseed (Hyola-401 x 011-k-16-3, HBO-555 x AZRI Rapeseed, Kingola x KN-256 and RBN-13018 x Westar) and five (05) of mustard (HMU-322B x JS-13, KJ-221 x BRJ-1004, AUP-061616 x 45S46, Coral-432 x JS-13ys, Coral-432 x JS-13bs) were planted to develop F_1 generation. M_1 generation was also developed by irradiating a single rapeseed variety at 1.2 and 1.4 kGy. The materials were cross, species and dose wise bulk harvested for the continuity in oilseed breeding to develop early maturing, short

stature, high seed and oil yields varieties characterized with better oil quality.

A crossing block consisting of eleven (11) rapeseed and eight (08) mustard local and exotic germplasm was raised including the parental material of different breeding populations and advanced rapeseed & mustard genotypes. Eight diversified rapeseed (Hyola-401; 011 k-16-3; HBO-555; AZRI Rapeseed; Kingola; KN-256; RBN-1308 and Westar) and seven mustard lines (HMU-322B; JS-13; KJ-221; BRJ-1004; AUP-061616; 45S46 and Coral-432) were utilized in cross combinations to improve different traits in diversified genetic back ground with special emphasis on seed yield. A total of 1210 crosses were attempted. An effort was also made to visually identify the self-sterile plants and crossed in twenty six (26) cross combinations with same fertile and other stable varieties for fertility restoration viewpoint. Eighteen (18) self-fertile and two self-sterile were selfed at pre-anthesis to study the segregation pattern in the following generation and confirmation of sterility.

Oilseed Analysis

Near Infrared Reflectance Spectroscopy (NIRS) is a non-destructive, cost, time and labour effective technique for quality analysis of oilseeds. For on-going project at NIFA, about 900 samples of oilseed germplasm and breeding materials were analysed for fatty acid profile and glucosinolates contents. Regards to Quality Analysis Service of brassicas; approx-imately 2600 samples of brassica spp. were analyzed at nominal cost for academician, researchers of different universities and R & D organizations both at provincial and federal levels.

Oilseed Brassica- varietal maintenance programme

A total of 830 kg and 400 kg Pre Basic Seed (PBS) of oilseed brassica varieties NIFA-Gold and Durr-e-NIFA respectively, was produced at NIFA and certified by FSC&RD. NIFA has signed a Seed Agreement with Gala Seed Corporation (Pvt.) for procurement, production and sale of seeds of oilseed brassica varieties of NIFA to create opportunities for income generation and popularization of products.

Pulses

Mungbean

Release of new Mungbean variety "NIFA Mung-2019"

The variety proposal of an advanced recombinant line NFM-5-36-27 was submitted in March 2018 to the technical expert committee meeting for the 38th Provincial Seed Council for recomm-endation as a new mungbean variety in Khyber Pakhtunkhwa. The recombinant line NFM-5-36-27 was recommended as commercial variety in Technical Expert Committee meeting which was held on 12th

September 2018 at Agriculture Research Institute, Tarnab Peshawar. Finally the high yielding mungbean recombinant "NFM-5-36-27" was approved as commercial mungbean variety under the name "NIFA Mung-2019" for general cultivation in Khyber Pakhtunkhwa (KP) by the KP Provincial Seed Council in its 38th meeting held on 3rd January, 2019 at Agricultural Research Institute (ARI), Peshawar. NIFA Mung-2019 has green stem (without anthocyanin pigmentation). So this is the first mungbean variety in the country with green hypocotyl (green stem), which is the main requirement of mungbean sprout production industry.

Evaluation of mungbean advanced lines in various yield trials

An advanced mungbean recombinant line 'NFM-8-22' with name NIFA Mung-6 was contributed in National Uniform Yield Trial (NUYT) for first year adaptability evaluation during kharif 2018 but it did not perform well.

Adaptation trials consisted of 4 genotypes and two checks (NFM-8-22, NFM-92-2-31, NFM-5-36-27, NFM-5-63-30,NIFA Mung-2017-check and Ramzan-check) were planted at ARS, Karak and AZRC, D. I. Khan. NFM 92-2-31 was the high yielding genotype with average yield of 1090 kg ha^{-1}.

A total of 08 recombinants from 04 different cross-combinations (NM 93 x NM 92, VC 1482C x NM 92, VC1560D x NM 92 and NM 98 x VC 3902A) and 28 mutants derived from parent NFM-5-91-21 along with three check varieties i.e. Ramzan, NIFA Mung-17 and Sona-Mung were evaluated in 02 sets of Advanced Lines Yield Trials (ALYTs) during kharif 2018. Fourteen genotypes, namely 5-63-30, 16-4-20, 16-4-23, 16-4-24, 16-4-25, 16-4-27, 16-4-30, 16-4-61, 16-4-62, 16-4-64, 16-4-1, 16-4-10, 16-4-35, and 16-4-41 showed statistically significant ($P \leq 0.05$) higher seed yield (608-834 kg ha^{-1}) as compared to the check varieties' average yield (Ramzan; 476 kg ha^{-1}, NFM-2017; 552 kg ha^{-1}, and Sona-Mung; 379 kg ha^{-1}).

In case of replicated preliminary yield trials, 92 recombinants from 06 different cross-combinations (6601 x Ramzan, NFM-5-36-24 x NFM-5-63-18, NM98 x NFM-5-36-24, V2802 x Ramzan, V2802 x NM92, and V2709 x NM92 were evaluated in 05 sets of Preliminary Yield Trials (PYTs) along with two check varieties *i.e.* Ramzan and NIFA Mung-17 during kharif 2019. Twenty two recombinants, namely 96-11, 96-22, 98-20, 98-29, 98-30, 98-34, 98-42, 98-65, 98-85, 98-119, 98-130, 99-1, 99-4, 99-7, 99-9, 99-17, 99-29, 99-34, 99-38, 103-57, 111-1 and 111-4 showed statistically significant ($P \leq 0.05$) higher seed yield (426-847 kg ha^{-1}) as compared to the check varieties' average yield (Ramzan; 392 kg ha^{-1}, NFM-2017; 466 kg ha^{-1}).

Evaluation of mungbean segregating material

In the breeding of green seeded mungbean genotypes, 07 true breeding lines derived from a cross-combination "Ramzan x Kuram Green Mung" were planted in non-replicated fashion in kharif 2018 for evaluation for yield and yield components. Three (03) lines were selected based on desired criteria for further evaluation in non-replicated fashion as line-progeny-rows in F_5 generation. F_4 populations of 03 different cross combinations i.e., Kuram Green Mung x NM-2006, ML-5 x Sona Mung and Sona Mung x NM-2011 were planted during Kharif 2018 to evaluate for yield and yield components, and MYMV resistance. Entire population from Kuram Green Mung x NM-2006 was rejected for not fulfilling the desired criteria, while a total of 24 single lines were selected from two cross-combinations *i.e.* ML-5 x Sona Mung and Sona Mung x NM-2011. These lines will be further evaluated in F_5 generation as line-progeny-rows for selection for best line(s) based on desired criteria in kharif 2019.

In case of induced mutation for high grain yield and MYMV resistance, 04 mutant lines selected previously from V2802 irradiated at 400 Gy of γ rays were planted as M_5 population in kharif 2018. No selections were made as none of the lines fulfilled the desired criteria. Similarly, M_4 population derived from Kuram Green Mung (400 Gy of γ rays) was planted as plant-progeny-rows in kharif 2018 comprising of 40 mutants to select single row(s) for yield and yield components and disease resistance. Only two mutants were selected, whereas the remaining progenies were rejected for not fulfilling the criteria. These progenies will be evaluated as M_5 population in kharif 2019.

In case of breeding black seeded mungbean genotypes, 404 single plant recombinants derived from a cross-combination "NIFA black mung x Kuram black mung" previously selected on the basis of MYMV resistance, seed coat color and more pods per plant were planted as plant progeny-rows in F_4 generation for confirmation of breeding behavior in kharif 2018. Fifty seven (57) single plant recombinants were selected from this population based on pre-set criteria. These recombinants will be further evaluated in non-replicated fashion as line-progeny-rows in F_5 generation in kharif 2019. F_3 populations derived from four different cross-combinations i.e. NIFA black mung x Kuram black mung, NM-2006 x Kuram black mung, Ramzan x Kuram black mung and Kuram black mung x Ramzan comprising of 161 single plant recombinants were planted as plant-progeny-rows in kharif-2018 for further single plant selections. Based on desired criteria, 01 and 05 single plant

recombinants were selected from NIFA black mung x Kuram black mung and Ramzan x Kuram black mung, respectively, while rest of the populations from other two cross-combinations (NM-2006 x Kuram black mung and Kuram black mung x Ramzan) were entirely rejected for not fulfilling the desired criteria for seed coat color (shiny black). These recombinants will be further evaluated as F_4 generation in kharif 2019 for single row selection.

F_2 generation comprising of 78 recombinant plants derived from eight (08) cross-combinations *i.e.* Kuram black mung x Ramzan, Kuram black mung x NM 2011, Kuram black mung x NM-19, Kuram black mung x NFM 5-36-27, Ramzan x Kuram black mung, NM 2011 x Kuram black mung, NM-19 x Kuram black mung, and NFM 5-36-27 x Kuram black was raised in kharif 2018 to select single plant for more pods, MYMV resistance and black seed coat color. Based on pre-set criteria, 08 single plants (02 from NM-2011 x Kuram black mung and 06 from Kuram black mung x NFM-5-36-27) were selected, while rest of the populations were discarded due to poor seed coat color.

In order to create genetic variability for black seed coat color, yield and yield components, seven new cross-combinations (NFM-5-91-26 x Kuram black mung, NFM-5-63-3 x Kuram black mung, V2817 x Kuram black mung, NIFA Mung-2017 x Kuram black mung, Azri Mung-06 x Kuram black mung, Ramzan x Kuram black mung and NM-2016 x Kuram black mung) were attempted during summer 2018. All crossed pods were collected and F_1 was planted in summer 2019. A total of 67 recombinant plants were picked from 07 cross-combinations which will be planted as F_2 generation in kharif 2020 for single plant recombinant selections based on more pods, MYMV resistance and shiny black seed coat color.

Fresh genetic variability was created through induced mutations by subjecting uniform seed of Kuram black mung to gamma rays at 500 and 600 Gy using ^{60}Co gamma source for MYMV tolerance, black seed coat color and more pods per plant. M_1 generation comprising of 26 rows (14 from Kuram black mung irradiated at 500 Gy of γ rays and 12 from Kuram black mung irradiated at 600 Gy of γ rays) was raised in summer 2018. Dose wise bulked seed was harvested and planted as M_2 generation in kharif 2018 for selecting mutants on the basis of MYMV tolerance, black seed coat colour and more pods per plant in late segregating generation. No selections were carried out due to absence of pods in one population and poor seed coat color in the other population.

Due to early heavy rains and subsequent weeds problem, the material was substantially damaged, and no proper

evaluation could therefore be possible during the season. The material will therefore, be re-evaluated during kharif 2019.

Chickpea

Evaluation of chickpea advanced lines in various yield trials

Fifty five (55) recombinant lines from 05 different cross-combinations (NIFA-2005 x NDC-6-I-7, NIFA-2005 x NDC-6-I-6, NIFA-88 x NIFA-2005, Thal-2006 x NIFA-2005 and Dasht x NIFA-2005) along with two check varieties i.e. NIFA-2005 and Bittal-6 were evaluated in 05 different sets of replicated Preliminary Yield Trials (PYTs) during 2018-2019. Of these, a total of 28 recombinant lines produced significantly ($P \leq 0.05$) higher seed yield (1803-2500 kg ha^{-1}) as compared with check varieties, NIFA-2005 (Average yield of 1160 kg ha^{-1}) and Bittal-16 (Average seed yield of 903 kg ha^{-1}). These recombinants exhibited 23 - 25g/100 seed weight and better plant type.

A total of 63 true breeding mutants derived from two parents i.e. CM541/05 and Pb-2008 irradiated at 300 Gy of γ rays were planted in 02 sets of non-replicated yield trials for evaluation of yield, yield components and subsequent seed increase. The mutants produced seed yield ranging from 367 to 1136 kg ha^{-1} against averaged seed yield of 957 kg ha^{-1} produced by NIFA-2005. All of the mutants will again be evaluated for seed yield and yield components during 2019-20 due to improper evaluation because of erratic rains during 2018-19 crop season.

Evaluation of chickpea segregating material

F_1 generations were raised from a total of 263 crossed pods derived from 13 different cross combinations i.e. NIFA-2005 x DCD-1, CH40/09 x Punjab-2008, NIFA-2005 x NDC-20-5, DCD-1 x Bittal-16, NDC-20-5 x Bittal-16, NDC-20-5 x Punjab-2008, DCD-1 x NDC-20-5, CH40/09 x Bittal-16, NIFA-2005 x Bittal-16, DCD-1 x Punjab-2008, DCD-1 x CH40/09, NIFA-2005 x CH40/09 and CH40/09 x NDC-20-5. All recombinant plants from respective cross-combination were harvested, threshed and bagged individually.

F_2 generations comprising of 98 single plant recombinants from 10 different cross-combinations i.e. NIFA-2005 x D-08-025, D-075-09 x CH24/07, NIFA-2005 x BRC390, D-09-013 x D-08-025, D-10008 x NDC-6-15-6, D-09-027 x D-08-025, D-09-075 x NDC-6-15-6, D-08-025 x NDC-6-15-6, CH24/07 x D-09-013 and BRC390 x D-09-075 were planted during 2018-19. Due to unusual weather conditions, only 166 single plant recombinants were selected based on more number of pods per plant and better plant type. These selections will be planted as F_3 populations during 2019-

20 for further single plant selections on the basis of desired criteria.

F_3 populations comprising of 94 single plant recombinants derived from 08 cross-combinations i.e. CM156/05 x BRC390, D-075-09 x NIFA-2005, Pb-2008 x CM156/05, CH16/06 x NIFA-2005, CM541/05 x BRC390, D-08-025 x NIFA-2005, BRC390 x NIFA-2005 and NDC-6-15-6 x BRC390 were planted during 2018-19. From these populations, a total of 199 single plant recombinants were harvested, while rests of the plants were damaged by terminal rains. These plants will be planted as plant-progeny-rows in F_4 generations during 2019-20 for single row selection based on yield and yield components.

In order to create genetic variability for seed yield and yield components through hybridization, 07 new cross-combinations *viz.* CH18-D-130 x Bittal-16, CH18-D-116 x Bittal-16, CH18-D-127 x Bittal-16, NDC-6-15-9 x Bittal-16, NDC-4-25-10 x Bittal-16, NIFA-88 x Bittal-16 and NIFA-2005 x Bittal-16 were attempted during 2018-19 and all crossed pods were collected cross-combination wise.

In case of induced mutation, M_2 population derived from parent CH40/09 irradiated at 400 Gy of γ rays comprising of 104 single plant mutants were raised during 2018-19. Of these, 43 single plants were selected on the basis of desired criteria i.e. more pods per plant and better plant type. These mutant plants will be planted as plant-progeny-rows in M_4 generation during 2019-20 for single mutant row selection based on desired criteria. M_4 populations derived from two parents i.e. CM541/05 and Pb-2008 (irradiated at 300 Gy of γ rays) comprising of 83 and 09 single-plant-progeny-rows, respectively were raised during 2018-19. Based on yield and related components, 31 and 05 single mutant rows were selected from CM541/05 and Pb-2008. These will be multiplied in three rows each in non-replicated yield trials during 2019-20 for evaluation for yield and yield components and subsequent seed increase.

Most of the breeding material was substantially affected by erratic rains during the season particularly at crop maturity, and proper evaluation of the material could not be done. The material will therefore be re-evaluated for yield and yield components during 2019-20.

Horticulture

Plum

Creation of desired genetic variability through induced mutations

Budwood of plum *cv*. Fazli Manani were subjected to different doses of gamma rays (20 and 30 Gy) and preliminary dose response experiments for budwood and shoot tips were conducted. Budwood that were irradiated with 20 and 30 Gy and budded on peach rootstock in the nursery

showed delay in sprouting. Seven plants in 20 Gy treatment and 5 plants in 30 Gy treatments have been produced. All the MV_1 generation will be shifted to a Semi permanent orchard in December, 2019 and will further be budded on the rootstock to get MV_2 generation to resolve chimera.

Raising of Marianna plum rootstock

Marianna plum as root stock was budded with Fazli Manani plum and 529 plants were raised in the nursery. All the budded plants were carefully observed for successful budding. The budded plants are still wrapped in the transparent polythene. A black plum cultivar was also budded on to Marianna root stocks for evaluation. After removal of upper portion from the budded plants, the removed wood was further used as cutting for rootstock development in raised beds.

Effect of hormones on Marianna Plum cuttings

Some efficient/cost effective vegetative propagation protocols for Mariana plum rootstock using different PGRs were carried out. Marianna plum cuttings were subjected to different concentrations of IAA and IBA for promoting root formation and successful survival was studied. The cuttings were sown on December 12, 2018 on the ridges already treated with 1000, 2000 and 3000 ppm IBA and IAA solutions for 24 hours. The experiment was arranged according to RCBD and there were 18 cuttings per treatment replicated three times. It was found that Marianna cuttings treated with 1000 ppm IAA gave the highest (70 %) cuttings sprouted. The lowest number of days (95) was taken to sprouting in control treatment while the highest plant height of 130 cm was also recorded in the control treatment. The experiment reveals that sprouting is merely controlled by the stored carbohydrates in the cuttings and is not affected by the hormones treatment.

Peach

Effect of sowing dates on germination of peach stone (Swat Local)

An experiment was conducted to investigate the effect of different sowing dates on the germination, days to germination and seedling height in peach stone rootstock (Swat local). The experiment was arranged in RCBD with 5 different sowing dates, replicated three times with 200 seeds in each treatment. It was found that the peach stone sown on Nov. 10, 2018 gave the highest percent (94%) germination. Highest bud success (82%) was recorded in peach stone that were sown on December 10, 2018. The lowest days to bud sprout (11) was recorded in November 30, 2018 sowing.

Exotic/local germplasm collection and evaluation

Two exotic peach varieties were planted at NIFA Research Farm. Fifty (50) budwood

of each variety were taken and budded on local peach rootstock for adaptability in agro-climatic conditions of KP. Visits were conducted to farmer's field for selection of desirable characters in local peach germplasm. Budwood were taken from the selected plants on the basis of fruit size/quality at farmer's field in Charsadda and 20 budwood were budded on peach rootstock at NIFA Research Farm.

Creation of desired genetic variability through induced mutation

Genetic variability for desired traits was created through induced mutations. Fifty (50) budwood from Early Grand and Florida King (20 Gy irradiation) were budded on peach rootstocks. Various parameters i.e., plant height (cm), number of branches, internode length (cm) and plant diameter (mm) were studied.

Effect of different budding times on Peach rootstock

The experiment was carried out at NIFA Farm to investigate the effect of budding time on the performance of peach varieties i.e., Early Grand & Florida King as a scion cultivar on peach rootstock. Peach seedlings were budded at 5 days interval (10^{th} June, 15^{th} June & 20^{th} June). Forty plants were budded in each treatment and replicated four times. The data showed that minimum days to sprouting (Early Grand 12 days & Florida King 09 days) were recorded for plants budded on 10^{th} June. Bud sprouting in Early Grand and Florida King was recorded as 75.18 % & 76.58 % respectively, which were maximum for the plants budded on 10^{th} June. Different time of budding had also effect on budding growth, number of branches and number of leaves per plant. Maximum budding growth (98.85, 97.71 cm), number of branches per plant (4.62, 6.24) and number of leaves per plant (105.85, 115.14) were observed in Early Grand and Florida King respectively budded on 15^{th} June.

Stevia

Influence of polyamines & different growth regulators on the regeneration of Stevia

Various concentrations and combinations of BAP, 2,4-D, Kinetin, GA3, IBA, NAA & Putrescine were incorporated in MS medium for callus formation, shoot regeneration and root induction. Leaf were used as explant for callus formation. Excellent callus growth was recorded when leaf explants were placed on MS medium supplemented with 2,4-D + Putrescine + BAP (2.0, 1.0, 2.0 mgL^{-1}), while no callus was observed on MS medium without any PGRs. Data on shoot organogenesis was recorded after 30 days sub-culture of callus and maximum mean shoot length (6.23 cm) was observed on a medium containing GA3 + Putrescine (2.0, 1.0 mgL^{-1}) and number of shoots per explant (4.66) was recorded in medium containing GA3 + Putrescine (1.0,

1.0 mgL^{-1}). However, the maximum number of leaves (33) was noted in medium supplemented with BAP + Putrescine (2.0, 1.0 mgL^{-1}). The addition of polyamines (Putrescine) in combination with different plant growth regulators promoted morphogenetic potential. Root formation is in progress.

Field view of NIFA MUNG-2019

Field view of NIFA AWAZ-2019

FOOD AND NUTRITION DIVISION

Enhancement of commercial aspects of R&D activities in food product development and drying

Production of food products like squashes, jams and syrups was enhanced by improving processing efficiency. An overall 35% increase in different squashes production was achieved. A net sale of Rs. 10,08,640/- of different food products (squashes, jams and syrups), with Rs. 5,40,138/- as profit was generated for the institute.

Drying of persimmon for shelf-life extension was carried out. Initial moisture content and phenol content were 35% and 0.79%, respectively. Persimmon fruits were sliced and placed in solar dryer for about 5 days for drying. After drying, the final moisture content was 17% and phenol content was 0.43%. The dried persimmons were good in taste and texture. The drying technology has a potential of value addition of persimmon fruit. Similarly, leather drying of persimmon paste was also carried out. The initial moisture content of persimmon paste was very high (78%). Initially, the paste was solar dried. However, it did not lower the moisture content as desired. Later on, the process of solar drying was complemented with forced air drying. The moisture content dropped appreciably to 17%. However, in sensory evaluation, it was found that the paste develop astringency and the color and texture of the final product were also not good.

Development of low cost zero-energy, cooling chambers for field heat removal and storage of fruits and vegetables; and its transfer to small farmers

Postharvest losses of horticultural crops range from 30 to 40%. Most of the technologies and the commercial postharvest processing methods are expensive and beyond the means of small farmers. In order to overcome this problem, low cost zero energy (LCZE), environment-friendly cool chamber can be adopted. Work on LCZE was initiated using a model chamber (inner size: 5.5 ft length, 3.5 ft width, 2.5 ft height) constructed at NIFA. Relative humidity and temperature inside and outside the chamber were monitored. A decrease of 9-10^{o}C in temperature and an increase of 30-40 % in relative humidity inside the chamber was observed as compared to the atmospheric temperature and humidity. Experiment on storage stability of okra was conducted. Results revealed a weight loss of 5-6% inside the chamber and 70-75% outside the chamber during 12 days of storage period in okra.

Samples inside the chamber also retained their texture, while, the control samples lost it, significantly. The results obtained from this experiment showed that okra can be stored up to 12 days in zero energy cooling chamber without losing its nutritional quality and freshness.

Zero Energy Cooling Chamber

Comparative Study of Gamma and Electron Beam (EB)/X-rays on Meal Ready to Eat (MREs)

Meal Ready to Eat (MRE) samples were prepared according to the weight composition of 37.7 g meat, 9.8 g oil, 9.8 g onion, 17.9 g tomato, 0.9 g spices, 0.8 g garlic and 0.3 g ginger, per pouch. The vacuum packed MRE samples were then irradiated with high doses of 11, 12, 13 kGy by gamma and Electron Beam. The effect of EB and gamma irradiation was studied on MRE by considering the dose rate and throughput of both the technologies. Among the treatments, the highest irradiation dose (12.0 kGy) showed best results in terms of overall acceptability, microbial control and shelf life extension of MRE at room temperature for three months. Astringency was successfully removed from the persimmon fruit at dose of 0.9 kGy with significant changes in its physico-chemical and texture values during a storage period of two weeks at room temperature.

EB and gamma irradiation of MRE samples at Industrial Zone Port Qasim, Karachi and NIFA, Peshawar

Technology Transfer of Oyster, Milky and Button Mushroom to the landless community of KP, Upper Punjab and Baluchistan

Mushroom is a protein-rich, low fat and low sugar organic food with potential health benefits for heart and diabetic patients. Due to the expertise in tissue culture, spawn preparation and mushroom cultivation at NIFA, a funded project of Rs. 4.166 million was awarded by Pakistan Science Foundation (PSF) with the objective to popularize mushroom cultivation in different districts of three provinces by arranging awareness sessions and training workshops.

NIFA has successfully developed cultivation technologies for oyster, milky, King oyster and button mushroom. NIFA has standardized compost making of the three mentioned mushroom types.

Under this project, workshops were organized in different areas and districts of Baluchistan (Quetta, Mastung, Pishin,

Nushki). More than 15 workshops were organized in KP and three in Punjab (Hazro, Rawalpindi & Chakwal) in addition to three annual workshops at NIFA from 2017 to 2019. More than 1000 participants from farming community, different R & D organizations and students have been trained in these workshops. Similarly, popularization of mushroom cultivation has also been carried out through print and electronic media. Different events were covered by newspapers like Daily Shamal, Daily Chand, Daily Akhbar, Daily Aaj and Dawn News. Moreover, five radio talks were delivered for Karkeela program.

Mushroom spawn was indigenously produced at NIFA and sold out on subsidized rate to the interested farmers. An income of about Rs 171,000/- was generated from the sale of mushroom spawn and mushrooms at NIFA Experimental Farm.

Many farmers have started mushroom cultivation and sell them to different vegetable vendors for earnings on small scale. The awareness sessions have motivated the small land holding communities to adopt mushroom farming as cottage industry to alleviate poverty. Increase in cultivation of mushrooms helped self-employment opportunities as well as improved general health status of masses, as an alternate source of nutrition.

Workshops at District Agriculture Extension Department Chakwal, Punjab and NIFA, Peshawar

Assessment of Fortified Food consumption and its impact on human population in Peshawar and Nowshera Districts

The present study was carried out to assess the fortified food consumption and its impact on selected human population living in Peshawar and Nowshera Districts. For this purpose, 50 volunteers were randomly selected. Significant increase in body fat composition (assessed by skinfold clipper method) was observed with increase in age (years). Two percent population showed a decrease in body mass index (BMI) as compared to standard value (25 BMI),

while, 45% population indicated the normal BMI value. 54% sample population was categorized as overweight and obese.

Data regarding the consumption of wheat flour showed that 45% population utilized chaki atta (whole wheat flour) and 51% used the refined wheat flour from flour mills (iron fortified wheat flour). However, 4% individuals used both kinds of wheat flour. Purchasing power taken as the income earned per month showed that 15% individuals earned Rs. 15000/month and had limited access to the nourished foods for their family. While, the remaining population (85%) had sufficient resources to buy the nourished foods. Food nutrient composition data were collected by using a 24 hours food questionnaire. The data showed the respondents consumed the micro & macro nutrients according to the recommended requirements. However, intake of the foods enriched with iron and vitamin A was limited. Conclusively, dietary pattern should be changed according to the requirement of the individuals regarding micro & macro nutrients.

Production of indigenous food bio-preservatives from the micro flora isolated from the fermented dairy products

Classical approaches of food production are sufficient to meet the growing demand of food and to fight spoilage agents. However, there are concerns about the hazardous nature of these approaches. This necessitates the exploration of indigenous bio-preservatives. In this regard, food based micro-flora like lactic acid bacteria has shown the ability to retard the growth of harmful bacteria by production of anti-microbial compounds called bacteriocin. Bacteriocin are complex proteins that show anti-bacterial activities against closely resembling bacteria or food spoilers/pathogens. In the present investigation, 60 samples of dahi were collected from different local milk retailers and brought to lab in chilled condition. Each sample was incubated in MRS broth and M-17 media at 37°C for 24 hrs. The isolates were sub-cultured and purified colonies were collected and stored at 4°C. Each isolate was cultured on the respective media along with 6 indicator strains. The isolates were screened for their anti-bacterial activities by Direct Plate Method. Out of 26 lactic acid bacterial isolates, only 3 showed high antibacterial activity against pathogenic strains viz. *Staphylococcus aureus, Listeria monocytogenes, Klebsiella pneumonia* (KP), *E. coli*, *Salmonella and E. coli* ATTC. Anti-bacterial activity of these three strains was re-confirmed by paper disk method. The strains were named as NIFA-1, NIFA-2 and NIFA-3. The maximum zone of inhibition was observed for NIFA-3 against *Staphylococcus aureus*

(38mm). These three isolates were primarily identified by classical methods and then by API 50 CHL kits. They were identified as *Pidococcus resemblences* (NIFA-1), *Lactococus lactis* subsp lactis-1 (NIFA-2) and *Lactococus lactis* subsp lactis-2 (NIFA-3). FTIR spectra of these strains were also carried out to determine their clustering with locally isolated strains. Their identification was further reconfirmed by 16S rRNA amplification.

Development & Stability Assessment of Nutritionally rich Therapeutic Meal Ready to Eat (MRE) diet for Hepatic Patients

MRE diet for liver patients was developed by fortifying with milk thistle (*Silybum marianum*) extract (rich source of minerals and vitamins). The samples were prepared and treated with irradiation and autoclaving. Samples were stored for three months to study their nutrients and shelf stability. In the first part of the study, milk thistle seeds were selected, powdered by grinding and passed through 30 mesh screen. Later, the defatted powder was subjected to extraction of silymarin. In the second part, the extracted silymarin was fortified in the food system in various combinations, details are as followed: T0 = Meal (Control), T1 = Meal (Autoclaved), T2 = Meal (Radiated), T3 = Meal + Silymarin (1%) (Autoclaved), T4 = Meal + Silymarin (1%) (Radiated), T5 = Meal + Silymarin (2%) (Autoclaved), T6 = Meal + Silymarin (2%) (Radiated). The samples were stored for 90 days. Results showed better retention of vitamin C at 10 kGy irradiated sample up to 90 days storage in T6 (Irradiation + 2% Silymarin). Protein showed stability in T5 & T6 with passage of time. Moisture and fats showed non-significant difference during storage after autoclaving and irradiation. No bacteria were found in autoclave/irradiated MRE products and were, therefore, categorized as safe for consumption within 90 days.

Income Generation Activities/ Analytical Services

1.	RTKs	5,111,110/-
2	Gemstone Irradiation	996,600/-
3	Food Products	800,360/-
4	Analytical Services	491,000/-
5	Mushroom and Mushroom Spawn	171,890/-
	Total	**7,571,260/-**

SOIL AND ENVIRONMENTAL SCIENCES DIVISION

Biofortification of zinc in wheat for balanced human nutrition

Biofortification of staple food crops with micronutrients through the use of agricultural tools is a cost-effective and sustainable approach to address the problem of micronutrient malnutrition. However, plant breeding, the most powerful agricultural approach, may not effectively work in regions where soils have very low plant-available pools of micronutrients due to very adverse soil chemical and physical conditions. Besides, finding sufficient and promising genotypic variation and maintaining the stability of targeted micronutrient traits across diverse types of environments may also be difficult. Under such circumstances, agronomic biofortification, including the use of micronutrient fertilizers, is an important complementary solution to overcome the problem of micronutrient malnutrition on sustainable basis. In view of these considerations, a study was undertaken to determine the relative Zn-efficiency of wheat cultivars.

A: Screening of wheat genotypes for Zn efficiency in chelate-buffered nutrient solution

The seeds of ten wheat genotypes were surface sterilized with sodium hypochlorite and germinated on moist filter papers in petri dishes in an incubator at 20±1 ^{o}C until ready for transplanting. Three days after germination, 2 seedlings of each cultivar were transplanted into white thermopore sheet placed in stainless steel container of 50L capacity filled with 40L of the chelate-buffered nutrient solution and were placed in net house. Zn^{2+} activities of 2, 10 and 40 pM were employed to the plant. The plants were initially grown in nutrient solutions containing half strengths of all macro and micronutrients, except for Zn and K_3HEDTA (which were at full strength) till day 10 after which the full-strength solutions were used. The nutrient solutions were replaced with fresh mixtures on days 10, 15, 19, 24, 28 and 32 following transplantation. The pH values of the solutions were adjusted to 6.0±0.01 with 0.1 M HCl or 0.1 M KOH as required. Harvesting of the plants was carried out on day 35 after transplantation. The tissue samples were then air dried on paper towels and later dried in a forced drought oven at 70±1 °C for 48 hours (until constant weight) and were analyzed for micronutrients and P by standard procedures of analysis. Zinc deficiency symptoms were obvious on the plants

grown in Zn deficient medium. The whitish-brown necrotic spots appeared on Zn deficient plants along with stunted growth. The increase in the levels of Zn^{2+} activity improved the growth of plants and resulted in vigorous dry matter production. The genotype *cv*. NRL 1539 produced maximum dry matter yield at 40 pM Zn^{2+} which was 11.63 g/pot. At zinc activity level of 2 pM Zn^{2+}, the shoot dry matter production was distinctly lower and the genotype No. 16053 produced the lowest DM of 2.30 g/pot. The response of genotypes under study was variable to the applied Zn activities thus giving huge variation in DM production and this variation was exploited to determine Zn efficiency that varied from 29 to 79%. The genotypes ranked as Zn-efficient (*cv*. CT 151103 and *cv*. Zincol) produced significantly higher dry matter yields than the Zn-inefficient cultivars CT 151299 and CT 161072 when grown in Zn-deficient solution.

B: Evaluation of Zn efficiency under field conditions

The solution culture technique used in this study to grow the plants provides the similar conditions (Zn activity) as in zinc deficient soil for evaluation of Zn efficiency, however, there are many other factors which suppress or affect plant growth. On the basis of above hypothesis an experiment was executed under field conditions with 6 genotypes (2 Zn-efficient, 1 medium, 2 Zn-inefficient and a reference genotype) and two levels of Zn (0 & 5 kg ha^{-1}) to assess any change in their Zn efficiency. The experiment was laid out according to split plot design with wheat genotypes in the main plot and Zn treatments in subplots. Prior to initiation of experiment, soil samples were collected from different fields and analyzed for available Zn so as to select Zn deficient site. The available Zn in experimental site was 0.29 µg g^{-1}. The soil also contained 0.69% O.M., 7.5 µg g^{-1} Olsen P having pH 7.3 and ECe 3.1 dSm^{-1}. The basal dose of P (90 kg ha^{-1}) and K (60 kg ha^{-1}) was applied to the entire experimental site at the time of sowing whereas N (120 kg ha^{-1}) was split into two portions. One half was applied at the time of sowing and the remaining portion was applied with first irrigation. The variable response of each genotype to Zn was observed with the increasing level of applied Zn, however, grain yield of all genotypes increased with Zn application. The wheat genotypes *cv*. Tatara and *cv*. NIFA-Aman produced the highest grain yield of 4386 and 4335 kg ha^{-1}, respectively with application of 5 kg Zn ha^{-1} which was significantly higher than rest of the genotypes. Under Zn stress conditions *cv*. Zincol depicted highest grain yield of 3836 kg ha^{-1} which was significantly higher than

rest of the genotypes. It was also observed that *cv*. Zincol accumulated the maximum Zn from soil (24.3 µg g^{-1}) under Zn deficit conditions. The data depicted that Zn-efficient genotypes were less responsive to Zn application, however, all the genotypes maintained the efficiency ranking assigned to them in hydroponic studies.

Improving off-season vegetables production under high and walk-in tunnels through integrated management of nutrients, water and diseases

Off-season vegetables farming in high tunnel has wide scope and generates economic opportunities particularly for small landholders. It is possible to grow tomatoes, cucumbers and other vegetables 6-8 weeks earlier in high tunnel farming than normal production season. The tunnel technology has paved the way for bringing revolutionary changes in agriculture sector, not only enabling the growers to produce off-season vegetables but also for improving their economic conditions. However, plant growth and produce of tunnel farming is correlated with environmental factors such as light, relative humidity, temperature, carbon dioxide, water and nutrients. Fluctuations in any of the environmental factor whether in low level or in excess results in reduction in plant vigor status and poor quality produce. The major constraints in off-season vegetable production are pests and diseases and these limit farmers in obtaining better crop yield and ensuring food security. Fertilizer, water and fungicide are the costly inputs in tunnel farming system. The farmers in Khyber Pakhtunkhwa have small land holdings and normally grow traditional crops through traditional methods of irrigation. The food production from traditional farming is always very low. Under this situation tunnel farming is the best option to get maximum production from such scarce sources. The University of Agriculture, Peshawar has granted a funded project on tunnel farming under University Endowment Fund with the objective to disseminate and demonstrate the techniques of off-season vegetables cultivation to the growers and to provide training on water, nutrients and disease management. The critical timings, methods and economical levels of fertilizer and irrigation for tomato and cucumber were identified for growing off-season vegetables in high tunnels with furrow and drip irrigation systems. Time of fertilizer application proved very crucial for achieving higher yield of tomato and cucumber.

The maximum fruit yield (2.21 t/10 Marla tunnel) in furrow irrigated tunnel was recorded in the treatment receiving NPK @ 75-75-90 kg ha^{-1} as soil application after 30 days intervals, each starting after establishment of crop (20 days after transplanting) till mid of June. In drip

irrigated tunnel maximum tomato fruit yield (2.26 t/10 Marla tunnel) was obtained with 10-10-15 NPK kg ha^{-1} as fertigation at 7 days interval. The maximum cucumber yield (0.75 t /10 Marla tunnel) was recorded in treatment that received NPK (10-10-15 kg ha^{-1}) at 14-days intervals starting after establishment of crop till mid of June. Maximum Grade-A tomatoes i.e. > 100 g (60%), density (1.30 g/cm^3), total acidity (0.56%), protein content (12.0%), total soluble solids (5.0°Brix), total phenolics (2.34 mg/100 g), vitamin C (30 mg $100g^{-1}$), nitrogen (2.45%), phosphorus (0.41%) and potash (3.4%) in fruit and improved shelf-life (~ 10 days) were recorded with the NPK application at 7 days intervals with value-cost ratio of 8.5. It was calculated that off-season tomatoes and cucumbers grown in high tunnel gave fifteen times higher income compared to conventional ones. The technology of tunnel farming was demonstrated to the vegetable growers under the University of Agriculture, Peshawar Endowment Fund on March 27, 2019 in which more than 100 growers, students, researchers and academicians participated.

Differential growth and phosphorus uptake by wheat cultivars at different P levels

Phosphorus (P) is an essential macronutrient. It is vital for plant growth and is found in every living plant cell. It is involved in several key plant functions including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics over the generations. Low P availability is one of the major factors limiting crop production in alkaline soils. The concentrations of inorganic P in soil solution are, however, typically very low due its propensity to bind strongly to soil surfaces or form insoluble complexes with cations. This means that inorganic P is often a limiting factor in plant growth and development. Phosphorus is taken up from the soil solution by plant roots as orthophosphate ions, principally as monovalent orthophosphate, $H_2PO_4^-$ ions and to a lesser extent divalent orthophosphate, HPO_4^{2-} ions. Several factors can influence both the rate and amount of P taken up by the plant and, therefore, elevated P can affect the recovery of a single application of P fertilizer. The same factors can also affect the recovery of P reserves accumulated in the soil from the past additions of P as fertilizer or manure. Keeping in view these limitations, sreening programme for P efficient genotypess was initiated to find out P stress tolerant wheat genotypes. The cultivation of new improved wheat varieties tolerant to P stress may greatly reduce the cost of production and thus farmers' income may be increased.

The seeds of ten wheat genotypes were surface sterilized with sodium hypochlorite and germinated on moist filter papers in petri dishes in an incubator at 20±1°C until ready for transplanting. Five days old seedlings were transplanted in foam plugged holes of thermopore sheet floating on a continuously aerated modified Johnson nutrient solution contained in two stainless steel tubs of 50 L capacity. Two phosphorus levels were established by using ammonium phosphate ($NH_4H_2PO_4$) salt; adequate (250 µ M) and deficient (25 µ M) P levels. The pH of the solution was maintained at 5.5±0.5 with HCl or NaOH. Treatments replicated thrice were arranged according to completely randomized factorial design. Two seedlings were transplanted in one hole of a thermopore sheet and each hole was considered as one repeat. Experiment was harvested 30 days after transplanting and the data were recorded for dry biomass. Significant ($P \leq 0.05$) differences in the growth parameters and yield of various wheat genotypes were observed in response to P deficient and adequate levels. Total dry matter ranged from 0.55 to 1.98 and 1.16 to 2.21 g/plant at deficient and adequate P levels, respectively. Wheat genotype CT 151299 produced almost three times higher yield at deficient P level as compared to CTG 154028. Phosphorus Stress Factor (PSF) was higher than 50% in only one genotype (CTG 154028) and the rest of the nine genotypes had PSF less than 50% and even two genotypes i.e. CTI 161130 and CTG 154013 had PSF < 10%. Differences among genotypes were found significant ($P \leq 0.05$) for P uptake, absorption rate and utilization rate. The maximum root shoot ratio was exhibited by CTHN 162076 and minimum by CT 161072 at deficient P level, however, root shoot ratio was higher at P deficient level than that at adequate level. Wheat cultivars CT 151299, CTG 154013 and CT 151299 were found P-efficient while CTG 154028, NON 16053 and CTHN 162076 were found P inefficient genotypes.

The results from hydroponic experiments are only reliable when they have been tested under field conditions. So, a field study was executed to confirm the results of previous year hydroponic experiment with the objective to identify phosphorus efficient wheat genotypes that can be grown more efficiently on P deficient soils. Wheat genotypes selected from solution culture in 2017-18 were tested under field conditions and Aman-2017 was found P-efficient while Bathoor and Wadaan were found P inefficient genotypes in hydroponic experiment. The field study confirmed the findings of hydroponic experiment.

The effect of integrated P-management on wheat yield and P uptake

Phosphorus (P) is needed in virtually all metabolic processes such as energy transfer, signal transduction, macro-molecular biosynthesis, photosynthesis and respiration. Its efficiency from inorganic fertilizers is very low and major cause of lower crop productivity, thus proper remedy is required for maintaining optimum P supply from soil to ensure higher wheat productivity. Soils of Pakistan are generally alkaline and calcareous in nature and deficient in available phosphorus where wheat crop mostly suffers from P deficiency. Application of inorganic P fertilizer in combination with organic fertilizer, farmyard manure (FYM) was found effective in enhancing the effectiveness of inorganic P fertilizers. In soils with high P-fixing capacities, organic compounds released during decomposition processes can increase P availability. Repeated incorporation of FYM can decrease soil bulk density, increase soil aggregation and moisture retention. The present study was conducted in pot conditions to evaluate the mixing of commercially available inorganic P fertilizer (i.e. DAP, SSP) and rock phosphate with farmyard manure and to explore their effectiveness on phosphorus recovery and agronomic efficiency for higher wheat productivity. In general, the purpose of present study was to develop a feasible and simple technique for sustaining better utilization of phosphate fertilizer and higher productivity of wheat through efficient fertilizer technique.

The surface soil (0–20 cm) collected from the Experimental Farm of Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan was used for pot experiment. The soil was air-dried, sieved (<2 mm) and analyzed for physico-chemical properties: pH, electrical conductivity of saturated soil-paste extract (ECe), calcium carbonate, soil texture, potassium (K), Olsen P and organic matter, following the standard procedures. Five kilogram soil was weighed and filled into glazed pots. The treatments included control, FYM (5 and 2.5 tons ha^{-1}), TSP @ 60 kg P_2O_5 ha^{-1}, SSP @ 60 P_2O_5 ha^{-1}, RP @ 60 kg P_2O_5 ha^{-1}, TSP + 5 tons FYM ha^{-1}, SSP + 5 tons FYM ha^{-1}, RP + 5 tons FYM ha^{-1}, TSP + 2.5 tons FYM ha^{-1}, SSP + 2.5 tons FYM ha^{-1} and RP + 2.5 tons FYM ha^{-1}. Soil in the pots was irrigated up to their respective saturation percentage. After a week, when soil reached to field capacity, pots were emptied and soil was remixed and refilled in the pots. This process was repeated thrice and various treatments were imposed in triplicate. Wheat genotype (Barsat 2010) was sown and five uniform plants per pot were allowed to grow after germination.

Moisture contents in pots were maintained with distilled water at about 60% of the water-holding capacity during the growth period of plants. The experiment was harvested at maturity and the yield data were recorded.

The results indicated that maximum grain yield (145 g pot^{-1}) was recorded in treatment where TSP + 5 tons FYM ha^{-1} was applied followed by the treatment SSP + 5 tons FYM ha^{-1}. Wheat grain yield from the pots treated with RP + 5 tons FYM ha^{-1} was significantly ($P \leq 0.05$) higher than where only TSP and SSP were applied. The minimum yield was observed in control treatment.

Assessment of nutrients and water use in rapeseed mutant line by isotopic techniques

In Pakistan, rapeseed (*Brassica campestris, Brassica napus*) is the second most important source of oil. It is cultivated over an area of 307,000 hectares with annual production of 233,000 tonnes and contributes about 17% to the domestic production of edible oil. Rapeseed and mustard seeds are a rich source of oil and protein. Because of low oil extraction efficiencies of the by-product seed cake contains 10-15 percent residual oil which can be directly converted to bio-diesel using our thermo-chemical technologies. The product of this crop as whole can be used as an alternative source of energy. Pakistan is facing a serious energy deficit and its energy demand is likely to increase annually by about 19%. The currently used resources such as natural gas and oil will further decline and will not meet its future energy needs. The resulting oil-less cake can be sold back to animal market with higher nutritional value because the proteins are broken down to highly digestible amino acid. Keeping in view the problems of energy shortage there is intensive need of adoption of different scientific technologies to enhance alternate sources of energy. The objective of this research is to improve/enhance production of rapeseed.

The experiment was conducted at NIFA Experimental Farm under natural conditions. Full dose of phosphorus @ 25 kg ha^{-1} as single super phosphate and K as sulphate of potash @ 25 kg ha^{-1} and $1/3^{rd}$ of nitrogen as ordinary urea were applied at sowing time. The remaining nitrogen as ordinary urea was applied at vegetative growth stage and flowering stage. For utilization of N by crop from applied labeled urea three micro plots ^{15}N ($1m^2$) were established in each macro-plot. According to plan of work ^{15}N labeled urea was applied to one micro plot at sowing time to respective N levels i.e. 25, 50 & 75 kg ha^{-1} in equal three splits. Similar to the 2^{nd} micro plot ^{15}N was applied at vegetative

stage at the end of January and to 3rd at flowering stage in first week of April in the same way.

The results indicated that the maximum average grain yield (2.2 t/ha), water use efficiency (7.9 kg/ha/mm) and N uptake (57.54 kg ha^{-1}) were recorded for rapeseed line RM-112-2 at 50 kg N ha^{-1}. Regarding N level effect, no significant increase in yield and N uptake was recorded after increasing N level beyond 50 kg ha^{-1}. These results showed that 50 kg N ha^{-1} may be the economical and optimum level of N for rapeseed.

Effect of various levels of NPK on yield of advance wheat lines evolved at NIFA

Wheat is the most significant cereal food crop in the world. It is effectively cultivated in Pakistan on more than 9 million hectares with a production of 24 million tons. The average yield of wheat (*Triticum aestivum* L.) in Pakistan (2200 kg ha^{-1}) is very low as compared to world average, even to its adjoining countries like India and China. The wheat requirement is gradually increasing every year due to population pressure but its yield per hectare is low. There are various reasons for low yield in Pakistan. The yield gap in the country needs to be filled by increasing yield per unit area. To overcome the gap between actual and potential yield, collective use of suitable types of fertilizers is of key importance as proper combination of fertilizer can increase the yield up to 50%. The combined use of NPK fertilizers plays an important role in wheat production. Application of NPK in balanced proportion at proper time has great impact on wheat yield. Various varieties of wheat vary in their behavior to obtain and utilize NPK for grain production. Two advance wheat lines of NIFA (CTES 16107 and CTES 16122) were treated with 13 levels of NPK fertilizers (0-0-0, 70-60-0, 70-60-30, 70-60-60, 70-90-0, 70-90-30, 70-90-60, 140-60-0, 140-60-30, 140-60-60, 140-90-0, 140-90-30 and 140-90-60 kg NPK ha^{-1}). Split plot design was used where wheat lines were kept in main plots while fertilizer treatments in sub plots. The net plot size was 2.5m × 2m. Experiment was sown on November 6, 2018 and harvested at physiological maturity on May 8, 2019. The soil analysis showed that experimental field was silty loam in texture with pH of 7.4, organic matter 0.87%, 0.04% N and 6 ppm available phosphorus. Phosphorus and potash were applied at the time of sowing along with 1/3rd of the recommended N fertilizer. The remaining nitrogen was applied in two equal splits i.e. with first irrigation and at booting stage. Fertilizer application significantly ($P \leq 0.05$) enhanced yield and other traits of wheat lines over control. Results showed that maximum grain yield of 5407 kg ha^{-1} was recorded for

the wheat line CTES 16122 in treatment 13 where NPK was applied at the rate of 140-90-60 kg ha^{-1}. Similarly, wheat line CTES 16107 gave maximum grain yield of 5047 kg ha^{-1} in the treatment where NPK was applied at the rate of 140-90-30 kg ha^{-1}. The lowest yield was obtained in the control treatment. Maximum P concentration of 5000 ppm in wheat grain was found in wheat line CTES 16122 in the treatment where NPK was applied at the rate of 140-60-30 kg ha^{-1}. Similarly, maximum K concentration of 0.52% in wheat grain was found in wheat line CTES 16122 in the treatment where NPK was applied at the rate of 140-90-60 kg ha^{-1}. It is concluded from the study that wheat line CTES 16122 performed better at 140-90-60 kg ha^{-1} NPK levels when applied in splits and at proper time.

Enhancing Plum orchard sustainability and fruit quality through fertigation

Fertigation refers to the application of solid or liquid mineral fertilizers in solution form through irrigation systems, thus forming irrigation water containing nutrients. It is precisely a method of slow application of water and fertilizer. It is reported by many scientists that fertilizer applied through irrigation system is more efficient than hand broadcasting on soil surface. Fertigation is one of the quickest ways to replenish the existing nutrient deficiency, particularly for macronutrients i.e. nitrogen, phosphorus and potassium, resulting in higher yields with improved quality of the crop produce. A field experiment at NIFA Experimental Farm is in progress. Plum bearing orchards of uniform size and age have been selected. There are total eight treatments with three replications in RCB design and two trees per treatment. Treatments are as follows: T1 Control, T2 NPK (360-250-360 g $tree^{-1}$) as broadcast, T3 NPK (360-250-360 g $tree^{-1}$) as fertigation, T4 NPK (270-187-270 g $tree^{-1}$) as fertigation, T5 NPK (180-125-180 g $tree^{-1}$) as fertigation, T6 NPK (360-250-360 g $tree^{-1}$) as fertigation + foliar N (0.5%) + humic acid (0.05%), T7 NPK (270-187-270 g $tree^{-1}$) as fertigation + foliar N (0.5%) + humic acid (0.05%) and T8 NPK (180-125-180 g $tree^{-1}$) as fertigation + foliar N (0.5%) + humic acid (0.05%). All fertilizer was applied to the periphery of tree canopy. Leaves samples from the orchard were collected in mid of August for NPK analysis. Treatments in which nutrients were applied as fertigation significantly ($P \leq 0.05$) improved plum fruit yield and NPK contents in leaves and fruit pulp than broadcasted fertilizer treatment. Leaves analysis showed that maximum NPK contents (2.47% N, 0.24% P and 2.3% K) were recorded in the treatments of T6, T3 and T7, respectively where NPK were applied as fertigation. Maximum plum fruit

yield of 50 kg tree^{-1} was obtained in the treatment T7 where NPK @ 270-187-270 g tree^{-1} as fertigation + foliar N (0.5%) + humic acid (0.05%) were applied. Increase in yield was 29% over treatment 2 where NPK were broadcasted @ 360-250-360 g tree^{-1}. Maximum concentrations of nitrogen (0.68%), phosphorus (2300 ppm) and K (1.50 %) in plum fruit pulp were found in the treatments 6, 8 and 5, respectively.

Innovation in crop production technology to minimize/ mitigate the effect of climate change

Wheat (*Triticum aestivum* L.) is a main source of food for a majority of population in the world. In Pakistan it ranks first among the cereal crops. Realizing the importance of wheat crop, efforts for improving productivity are always under consideration throughout the country. Wheat yield can be increased by the adoption of appropriate production technologies. An experiment was conducted for 2nd year at NIFA Experimental Farm. Two advance lines CTG-154013, CTG-154028 and a variety Aman (SRN-0911) developed at NIFA were tested for three different sowing dates i.e. 3rd week of October (Oct. 19th, 1st sowing), 2nd week of November (Nov.13th, 2nd sowing) and 1st week of December (Dec. 5th, 3rd sowing) at the interval of 20-25 days (early, on time and late). Three fertilizer treatments/doses @ T1 (80-40-20), T2 (120-80-40) and T3 (160-120-60) (N- P- K) kg ha^{-1} were applied to all three dates of sowing making the treatments as subplots. Three replicates of the experiment were made in each date of sowing. Phosphorus and K were applied as a basal dose at the time of sowing while urea was applied in split doses; half at the time of sowing and half with first irrigation. Each plot was of 1.5m x 3m. Uniform seed rate of 100 kg ha^{-1} was used. Recommended row to row distance for sowing and other cultural practices was followed. Plant height (in cm) was recorded at early maturity stage before harvesting. The trial was harvested at physical maturity in the 1st week of May and after drying in the field gross yield (biological yield) (kg/plot), grain yield (kg/plot after threshing), spike length (cm) and 100-grain weight (g) for each plot were recorded. The overall performance of the experiment was good. The results of this year showed that average biological yield was recorded as 18477, 16305 and 14461 kg/ha and average grain yield was recorded as 5807, 5195 and 3967 kg/ha on 1st, 2nd and 3rd sowing dates, respectively. It showed that biological as well as grain yield decreased with delaying in sowing from early October to late December in all the three lines/varieties (CTG-154013, CTG-154028 & Aman). The maximum grain yield of 5807 kg/ha

was obtained when crop was sown in October. Delaying in sowing of wheat crop from October to December reduced grain yield of wheat by 32% from 5807 (Early) to 3967 (Late) kg/ha. Fertilizer has positive effect on yield as grain yield increases with the increase in fertilizer. All the varieties/lines have the potential to produce higher yield at early sowing but CTG-154028 produced 3622 kg/ha even at low NPK level under late sowing and it may perform better if sowing is delayed due to heavy rainfall or shortage of moisture for early sowing and with low level of NPK fertilizer. To confirm these results, the study will be continued.

Fertilizer requirement for newly developed candidate lines of oilseed brassica

Edible oil is one of the important commodities of everyday use. Pakistan is producing 30% edible oil of its requirement and about 70% is being imported at the cost of huge foreign exchange. Increasing domestic oilseed production can reduce this huge oil import bill. Brassica oilseed crop in Pakistan has 44-46% of good quality oil. Big gap exists between potential yield 3500 kg/ha and national average yield 922 kg/ha. Brassica oilseeds have the potential to reduce the edible oil import bill if, brassica oilseed crops are properly managed. There are many factors responsible for its low yield; one of them is the improper/imbalance use of plant nutrients/ fertilizers. Keeping in view all these, an experiment was conducted to identify suitable NPK levels for oilseed brassica new varieties/lines developed at NIFA. Two advance candidate lines V1 (011-K-16-3) and V2 (RR-41-4) of *Brassica napus* developed at NIFA were tested for high yield and best level of NPK fertilizer. The experiment was laid out in split-plot design with three replicates, keeping lines in main plots and NPK levels in sub plots. Recommended row to row distance for sowing and other cultural practices was followed. The fertilizer (NPK) treatments/levels applied in split doses included Control (T_0) (0-0-0), T_1 (30-20-20), T_2 (60-40-40), T_3 (90-60-60) and T_4 (120-80-80) kg NPK ha^{-1}. Half N and full PK were applied at the time of sowing and the remaining half N in the form of urea was applied before flowering at vegetative growth stage. Plant height was recorded at the time of maturity before harvesting. The trial was harvested in mid of April and after drying in the field gross yield (biological yield) and grain yields of each plot were recorded. The overall performance of the experiment was good. The results showed that increase in NPK levels increases plant height over control but not significantly. Fertilizer application significantly ($P \leq 0.05$) enhanced yield of brassica lines over

control. The maximum grain yield (3367.8 kg/ha) was recorded where NPK were applied @ 90-60-60 kg/ha followed by 3230 kg/ha when NPK @ 30-20-20 kg/ha were applied. The lower level of fertilizer may be suitable for economic yield of brassica grain in current situation because the increase in grain yield is less than extra fertilizer used. To confirm these results the experiment will be repeated.

Wheat productivity enhancement for rain-fed areas using innovative modeling techniques

Wheat finds a central position among major crops in Pakistan on account of its significance in national food security. Over the last few decades, dedicated research efforts have been made to improve its productivity through a multitude of interventions. The pace of improvement in productivity needs to be enhanced by applying innovative techniques in the context of changing climate and rapidly increasing population to ensure national food security. One of such innovative option lies in the application of simulation models that had emerged as strong analytical tools to provide guideline to scientists and policy makers for enhancing productivity of a given crop under specified set of conditions.

Wheat yield has traditionally been low under rain-dependent farming systems across the country. Wheat yield can be increased through systematic evaluation of model based approaches. To address the issue of wheat productivity enhancement, a planned study was conducted at the NIFA farm over a period of three years (2016-2019). The study used three wheat varieties viz. Lalma, Aman and Insaf, being planted under irrigated and rain-fed field conditions. The trials received usual agronomic management during the entire duration of study. Data on grain yield and moisture content were recorded for use with simulation studies.

A soil-plant-atmosphere continuum model, CropSyst, was used to identify plant traits to be targeted for bringing an improvement in wheat productivity under the climatic conditions of Peshawar, Khyber Pakhtunkhwa. The data from irrigated (non-water stressed) conditions was used to calibrate the model. The data from rain-fed (water stressed) conditions was used to validate the model. The modeled grain yield and measured yield (data from field experiments) were compared using IRENE (Integrated resources for the evaluation of numerical estimates) software. Findings revealed that values of all the indices (modeling efficiency index, coefficient of determination, coefficient of residual mass and root mean square error) being used for comparison were in acceptable range for calibration. The modeling efficiency index and coefficient of determination were close

to the optimal value of 1 for all three varieties during calibration of model for reproducing grain yield. The values of same indices were slightly deviant from the acceptable ranges under validation for grain yield of all the three varieties being studied. Following successful calibration of CropSyst for wheat grain yield, scenario analysis was extended to identify plant traits to be targeted for bringing an improvement in wheat yield under rain-fed conditions of Peshawar. It was found that yield can be enhanced by modifying leaf area index and maximum rooting depth. The study demonstrated the potential of CropSyst to reproduce grain yield successfully under local conditions of Peshawar and exhibited the novelty of use of simulation tools in providing guidelines for enhancing productivity of wheat.

Feasibility of enrichment of compost for nitrogen content

Wide spread use of nitrogenous chemical fertilizers is apparently increasing crop yield but is simultaneously reducing productivity potential of most of the arable lands. Under the current era of sustainable farming, we need to blend organic sources of fertilizers in conjunction with chemical fertilizer to sustain farming activities. Organic fertilizers like composts particularly prepared from agro-wastes available at farm level offer suitable alternative to partly reduce use of nitrogenous fertilizers at small scale by nursery and vegetable growers. Nitrogen content is usually low in compost despite the fact that compost improves soil conditions for plant growth on account of its ability to slowly release nitrogen and other nutrients over longer period of time with added advantages of improving fertility of soils.

A study was conducted to compare nitrogen enrichment potential of various farm based residues at the composting site of institute. Urea, poultry manure, blood meal, rhizobium and humic acid with maize stalks were used to prepare enriched composts during usual process of composting. Finished composts were evaluated for their N content. It was found that compost obtained from the combined use of Rhizobium and humic acid had the highest N content of 1.68%. The nitrogen enrichment of compost through use of additional enrichment materials and substrates needs to be exploited to develop enriched compost for use by farmers.

Pilot scale production and popularization of compost tea as organic fertilizer nutrient source

Intensive use of chemical fertilizers for increasing crop yield has led to the environmental pollution. Situation demands to identify and popularize technologies that help the farmers to

improve yield with minimal deterioration of land and water resources. Compost and compost tea offer great prospects in this regard. Compost tea has the potential to improve crop yield. It is economical to use and easier to handle than compost and chemical fertilizers. Compost needs to be applied as much bulky as about 30 tons per hectare which is very hard for the farmers to take to their fields without any proper transportation. On the other hand, compost tea can be easily taken to the fields and a farmer can easily manage and apply it to the fields through foliar application. So, it reduces the negative impacts of chemical-based fertilizers, pesticides & herbicides and adds beneficial microorganisms in the soil ecosystems.

The present project attempts to standardize the protocol for large scale production of compost tea and includes efficacy studies at field level along with training of farmers related to compost tea production and use of technology. Pilot scale production of compost tea and efficacy trials were conducted at NIFA, Peshawar.

An experiment was conducted at NIFA experimental field during 2018-19 to study the effect of different rates of inorganic fertilizer and compost tea on the yield and quality of potato. The response of potato (*Solanum tuberosum* L.) to chemical fertilizers, compost and compost tea alone as well as their various combinations was studied. The experiment was laid out in randomized complete block design with eight treatments and three replicates. Treatments included control, NPK @ 250-150-150 kg ha^{-1}, compost @ 15 t/ha, compost @ 30 t/ha, half NPK (125-75-75 kg ha^{-1}) + compost tea (CT) @ 1:5, compost tea @ 1:5 alone, NPK @ 250-150-150 kg ha^{-1} + compost tea (CT) @ 1:5 and half NPK (125-75-75 kg ha^{-1}) + compost @ 15 t/ha + compost tea @ 1:5. The results revealed that maximum tubers yield (13 t ha^{-1}), chlorophyll content (52%), plant height (51.8 cm) and grading (61 No. size) was recorded in treatment receiving half NPK (125-75-75 kg ha^{-1}) + compost @ 15 t/ha + compost tea @ 1:5. This yield was 19% more than that of NPK fertilizer treatment (250-150-150 kg ha^{-1}), and it was followed by treatment receiving half NPK (125-75-75 kg ha^{-1}) + compost tea @ 1:5, which is 11.2 t ha^{-1} and is 3% higher than control. However, maximum N (1.24%), P (0.6%) and K (3.8%) in potato tubers were recorded in treatments NPK (250-150-150 kg ha^{-1}) + compost tea, compost @ 15 t/ha and NPK (250-150-150 kg ha^{-1}), respectively. It may be due to higher nutrients uptake of potato tubers owing to compost and compost tea. In terms of economics, the compost tea with NPK (250-150-150 kg ha^{-1}) showed best results. Results indicated that compost tea may be a

good substitute for chemical fertilizers in future to get higher yield. Further comprehensive long term studies are required to develop recommendations for end-users in Khyber Pakhtunkhwa.

Preliminary studies at the institute indicated the potential to develop compost tea from compost under both aerobic and anaerobic conditions. During 2018-2019, 2000 litres of compost tea (aerobic) was prepared by different concentrations of water & compost and it is being used in various experiments.

The aerobic compost tea was prepared using various concentrations of compost and water (1:5, 1:10, 1:20, 1:50 and 1:100). After one week, compost tea was collected from each concentration and analyzed for N, P, K, Zn and Fe so that optimum ratio of compost and water for obtaining good quality compost tea may be found out. The results showed that maximum nitrogen (224 ppm), zinc (0.2383 ppm) and microbial load (7×10^7 cfu/ml) were found in compost tea having concentrations of compost and water in 1:5 ratio, whereas K (200 ppm) and iron (0.9309 ppm) were maximum in 1:10 ratio. The concentration of nutrients was recorded lowest in the 1:100 ratio of compost and water.

Changes in nitrogen content of compost tea stored in plastic bottles were evaluated to determine optimum storage duration and temperature. Compost tea was stored at different temperatures (20, 30 and 40^{o}C) for a period of 15, 30, 45 and 60 days. The results showed that there was no decline in nitrogen content (0.08%) in different storage intervals. However, it showed a little decline at 40^{o}C. This may be due to deterioration changes occurred in compost tea owing to high temperature.

Some other salient activities related to the project are given as under:

- R**e**garding the ECe of different concentrations of compost tea, the most appropriate one (ECe 2.5) was recorded in 1:20 ratio of compost and water. This suggests that 1:20 treatment may have better ECe value in terms of foliar application.
- Two tons of compost have been prepared this year and this compost has been utilized in different experiments of compost tea preparation and used in Experimental Farms/ lawns of NIFA.
- A compost sieving machine along with electric generator has been installed at composting site of NIFA as a requirement of PSF funded project. It has sieving capacity of 500 kg material per hour.

Collection and Evaluation of Agro-wastes

Agro-wastes available at local farms in the vicinity of Peshawar including sugarcane

trash, wheat straw, poultry manure, plum dried leaves and berseem fodder were collected and analyzed for their total carbon and nitrogen. Carbon content in agro-wastes ranged from 60-86% and nitrogen content ranged from 0.28-2.8%. Information will be used in suggesting optimal combination of agro-wastes based on their C:N for the preparation of compost. Preparation of nitrogen enriched compost from available agro-wastes is in progress at composting site of the institute for further use in project related activities.

Agro-wastes available at local farms in the vicinity of Swabi including samples of fodder, maize green material, wheat straws, sorghum waste and tobacco waste were collected and analyzed. The data showed that higher concentrations of phosphorus (0.15%) and potassium (2.4%) were recorded in sorghum waste as compared to other samples.

Use of biological techniques to enhance NP uptake and improve mungbean yield

Higher costs of chemical fertilizers, environmental pollution risks associated with fertilizer applications, fixation of phosphatic fertilizers and farmer's reluctance to apply costly chemical fertilizers to a minor crop like mungbean necessitate to identify innovative biological ways of improving mungbean yield. One sustainable option is to solubilize the fixed P as it may considerably improve supply of P to plants from soils. Several researchers have reported that bacterial strains (*Bacillus* sp.) can improve crop yield by improving P availability to plants by solubilizing insoluble inorganic P compounds. P solubilizers, besides solubilizing P, also improve nitrogen fixation rates, improve nutrient uptake particularly micro nutrients and produce plant hormones. Nodule forming *Rhizobium* sp. is also known to contribute towards P solubilization. Microbial inoculants are environment friendly options to improve plant growth and yield. Positive impacts of such inoculants on productivity enhancement become significant when used in conjunction with chemical fertilizers. Combined use of N-fixing and P-solubilizing bacteria may be helpful in improving mungbean yield through improved nutrient absorption. The main objective of the current study was to identify appropriate combination of bacteria and chemical fertilizers for increasing yield of mungbean.

A: Isolation and identification of N fixing and P solubilizing bacterial strains

N fixing bacteria

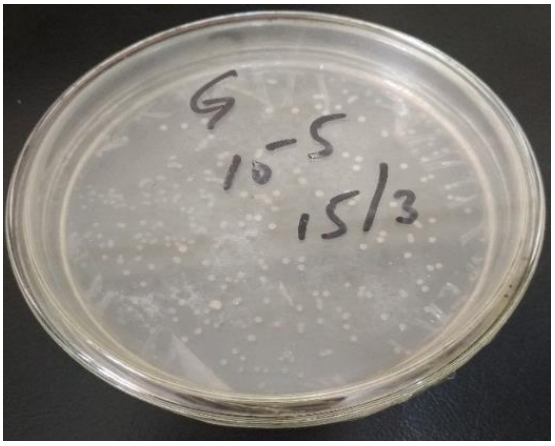
For the isolation of N fixing bacteria (*Rhizobium*), leguminous plants were carefully uprooted and the root system was washed under running water to remove the adhesive soil particles. The healthy unbroken pink nodules were surface

sterilized by dipping them for 4-5 minutes in $HgCl_2$ (0.1%). Later the nodules were washed with distilled water to remove any traces of sterilizing agent stuck to them followed by the washing with 70% ethyl alcohol and distilled water.

YEMA plates were prepared and sterilized in autoclave. 10 fold serial dilution of nodular extract was prepared by taking 1 g of nodular extract into 9 ml of sterile distilled water and mixing well to get nodular extract suspension. 1 ml of nodular extract suspension was diluted with 9 ml of sterile distilled water making the dilution to 10^{-2}, similarly making the dilutions up to 10^{-8}. 0.1 ml of nodular extract suspension from each of 10^{-3} to 10^{-8} dilutions was inoculated into sterile YEMA plates. The sample was spread throughout the YEMA plates and inoculated petri plates were incubated for 4-7 days in an incubator at 37°C. After the incubation period, *Rhizobium* colonies were observed as large mucoid elevated colonies. These bacteria were stored and later on used for inoculation of mungbean seeds in the pot experiment.

P solubilizing bacteria

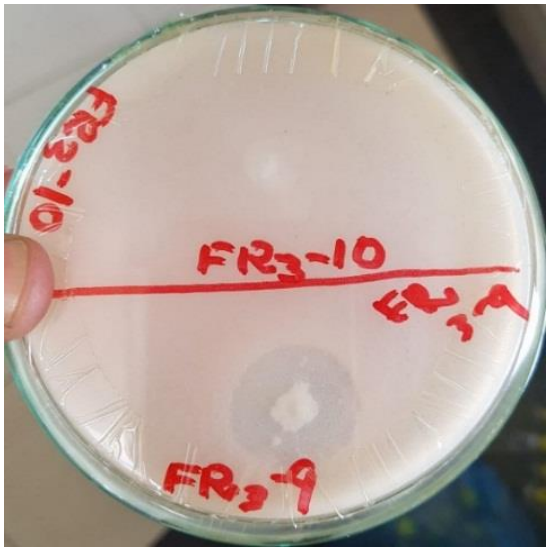
About 1 kg soil sample was collected from the rhizosphere soil of cultivated area of NIFA. This soil was put inside a plastic bag and brought to the laboratory for isolation



of bacteria from it. The sample was air-dried, powdered and mixed well to represent a composite sample. 1 g of the composite soil was taken from the plastic bag and the soil was diluted with 9 ml of water in a test-tube thus giving 10^{-1} dilution. Other 8 test tubes were filled with 9 ml of distilled water. 1 ml of the above solution was again transferred to 9 ml of sterile distilled water to form 10^{-2} dilution. Similarly 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7} and 10^{-8} serials of dilutions were made for the soil sample.

0.1 ml of each dilution was spread on Pikovskaya's agar medium (PVK) and was incubated at 28±2°C for 7 days. After incubation, the colonies showing clear

zones of phosphate solubilization were counted and expressed as colony forming unit (cfu) per gram of soil. Single, well-separated colonies, from each sample, which grew on plates showing clear zones were picked and were re-streaked onto fresh Pikovskaya's solid medium using quadrant streak method. This procedure was repeated until pure culture with high P solubilization or mineralization was obtained. The strain showing clear zones were inoculated into nutrient broth and were incubated at 28°±2C for 72 hrs. These bacteria were stored and later on used for inoculation of mungbean seeds in the pot experiment.



B: Response of mungbean to co-inoculation at various fertilizer levels

A pot experiment was conducted to study co-inoculation potential of N-fixing and P-solubilizing bacteria on mungbean yield at various levels of fertilizers. Experiment was laid out in completely randomized design with three replicates and one mungbean variety was tested. Treatments included: Control, NP @ 10-20 kg ha^{-1}, NP @ 20-40 kg ha^{-1}, Rhizobial (R) inoculation, Bacillus (B) inoculation, Co-inoculation (R+B), NP @ 10-20 kg ha^{-1} + Rhizobial (R) inoculation, NP @ 10-20 kg ha^{-1} + Bacillus (B) inoculation, NP @ 10-20 kg ha^{-1} + Co-inoculation (R+B), NP @ 20-40 kg ha^{-1} + Rhizobial (R) inoculation, NP @ 20-40 kg ha^{-1} + Bacillus (B) inoculation and NP @ 20-40 kg ha^{-1} + Co-inoculation (R+B).

The findings of this pot study revealed that the treatment 20-40 kg NP ha^{-1} + Co-inoculation performed better in terms of plant height (46 cm), plant dry weight (8.1 g), shoot biomass (6.07 g) and 100-grain weight (23.8 g) as compared with other treatments. Whereas, root depth (22 cm) and root biomass (2.17 g) were found maximum in the treatments of 10-20 kg NP ha^{-1} + Bacillus inoculation and NP @ 10-20 kg ha^{-1} + Co-inoculation (R+B), respectively. Further comprehensive long term studies under field conditions are required to develop reliable recommendations for end-users in Khyber Pakhtunkhwa.

Improving water and nutrient use efficiency of wheat based cropping systems in Khyber Pakhtunkhwa

Wheat is a key component of both rain-fed and irrigated cropping systems in Pakistan.

Farmers always look for higher wheat yield and apply excessive inputs to get higher net returns. The intensive use of costly inputs particularly chemical fertilizers has introduced the problem of environmental pollution. Water scarcity issue is becoming a limiting factor for sustaining irrigated agriculture. It is need of hour to identify cropping system that can make efficient use of available water. There exists knowledge gap on fate of applied inputs (fertilizer and water) that leads to wastage of resources. This particularly holds true for wheat based rotations. The dominant rotations particularly in Khyber Pakhtunkhwa include wheat-fallow-wheat, wheat-maize-wheat and wheat-mungbean-wheat.

The current era focussing on sustainable use of natural resources compels us to improve productivity while ensuring their minimal wastage. Improvement in productivity can be achieved through evidence based decision making for adopting a cropping system in a given region. Unfortunately, farmers in our system make decision on choice of crops without taking into consideration negative impacts of a given rotation on long term sustainability of the system. This situation arises because they do not have scientific information on pros and cons of a given rotation. This information gap can be bridged through systematic cropping system research while incorporating long term monitoring of water and nutrient dynamics under a given cropping system. Nutrient dynamics studies assume greater importance under legume based rotations as legumes are known to improve soil conditions and fertility for succeeding crop. But, this area remained under researched particularly in Khyber Pakhtunkhwa. Therefore, it is critical to study water and nutrient dynamics under dominant wheat based rotations to provide technical evidence based guideline to farmers for making rational decisions on choice of crops over a year for both sustainable use of scarce resources as well as for improving long term farm productivity.

To investigate the impact of cropping systems on water and nutrient dynamics, a wheat field experiment was executed at NIFA Research Farm in randomized complete block design with three replicates. During Rabi (2018-2019), there were three wheat blocks one each for comparison with fallow, maize and mungbean with a permanent layout. After stand establishment, probes were installed up to 1 m depth for recording data on soil moisture. Soil samples were collected up to 90 cm with every 30 cm increment before sowing and after harvesting of crop, and analyzed for C, N, P & K. The experiment received usual agronomic management for the crop during the season. The wheat yield in wheat-maize-wheat, wheat-fallow-wheat

and wheat-mungbean-wheat blocks was recorded 2.83, 3.23 and 3.03 t ha^{-1} respectively. During Kharif (2019), maize and mungbean were planted in 2 blocks while leaving the 3rd one fallow, to compare their performance in rotation with wheat. Data on soil moisture were recorded in both the seasons at fortnightly intervals using neutron scattering moisture probes. Biological and pod yields of mungbean were recorded 3667 kg ha^{-1} & 948 kg ha^{-1}, respectively. Similarly, biological and grain yields of maize were recorded 20000 kg/ha and 3111 kg ha^{-1}, respectively.

The experiment, with the same cropping scheme, will be repeated on the same experimental area for next two years to identify the most profitable rotation for the farmers in terms of water and nutrients dynamics and ultimately net profits.

PLANT PROTECTION DIVISION

A. AGRICULTURE ENTOMOLOGY

i. Fruit flies

Fruit flies cause tremendous losses and damages to fruits and vegetables at farm level, as well as to traders, retailers and exporters. In order to combat the problem, farmers usually use pesticides which are not only ineffective but also result in environmental pollution, pest resistance, pesticide residues and economic problems. Therefore, our control methods should be directed towards an effective and eco-friendly management of fruit fly including components of IPM.

Rearing Peach Fruit Fly Culture with Artificial Larval Diet

Some preliminary work has been done in our latest experiments which provided the ground to develop some basic elements for the artificial rearing of fruit fly regarding egg-laying device, egg-laying stimulant, and semisolid artificial larval diet of fruit fly, *Bactrocera zonata* at NIFA, Peshawar. The previous results indicated that Baker's yeast enhanced the efficacy of protein hydrolysate and resulted in highest egg hatchability (58%), development of larvae to pupal stage (50.53%) and fecundity (211.9) of female *B. zonata*.

Monitoring fruit fly population fluctuations and development of a degree day model

This study is being conducted in guava orchard at the Experimental Farm of NIFA. Ten methyl eugenol lure baited traps were randomly installed in the orchard for trapping and counting the adults. The results indicated that the pest was active in December (10.71, 4, 3.71 flies/trap) and January (4.28 flies/trap). Thereafter, the population declined from 25th January (0.14 flies/trap), 22nd February (0.85 flies/trap) and 8th March (0.71 flies/trap). From April onwards, the population started to build up and reached to 87.42 flies/trap/week on 26th July. The experiment is still in progress for degree day model.

Ovipositional preference of peach fruit fly on different host fruits

Three host fruits were collectively offered as free choice for oviposition. The fruits were exposed to the flies for 24 h. The sexually mature female *B. zonata* successfully laid eggs on these fruits and then each fruit was kept separately in plastic jars containing sand at the bottom (for pupation). The results indicated that Banana and Mango fruits were efficiently infested by *B. zonata* and hence they can be

used in the laboratory for rearing of peach fruit fly.

ii. Chickpea Pod Borer

Chickpea pod borer, *Helicoverpa armigera* is a major pest of chickpea, tomato, tobacco, cotton and vegetables causing economic losses to the tune of 70 to 95% in chickpea crop. Pod borer, being ubiquitous & polyphagous in nature is commonly known as chickpea pod borer, American bollworm of cotton, tomato fruit worm, corn earworm and tobacco budworm. The extent of damage inflicted by pod borer to chickpea depends not only on the number of larvae but also on its developmental stages.

Due to wider host range, multiple generations, migratory behavior and high fecundity, no single method is effective for its control. Efforts are streamlined to adopt integrated approach such as varietal screening, bio-control, use of pheromone traps and botanicals/chemical control wherein all compatible control methods are being employed to contain the pest population and reduce crop losses.

Chickpea Varietal Screening

A field trial was conducted at the Experimental Farm of NIFA, Peshawar. Six advanced NIFA chickpea genotypes (desi) *viz.* NDC-30-16, NIFA-2005, NDC-4-30-4, NDC-4-25-12, NDC-4-30-3 and NDC-4-25-7 were sown during November 2018 in a RCB design with four replications. A distance of 40 cm and 10 cm between rows and plants was maintained respectively. Each experimental plot consisted of six rows, each of 5 meter length.

Weekly observations on pod borer larvae counts were recorded on randomly selected 7 plants/plot. Total numbers of pods versus damaged pods per 7 plants by the pest was recorded weekly. Damage caused by chickpea pod borer was calculated and converted into percent damage by using the following formula:

$$Percent\ pod\ damage = \frac{Number\ of\ damaged\ pods}{Total\ numer\ of\ pods} x100$$

Data recorded on relevant parameters showed that mean larval population ranged from 5- 6 larvae per plant during the whole cropping season. Percent pods damaged were recorded as 76.98-83.80%. It was observed that during pod formation stages, pest larval population was quite high and kept on increasing which destroyed the crop. None of tested genotypes showed tolerance to pod borer infestation. Minimum grain yield of 64.16 kg/ha was recorded in chickpea genotype NDC-4-30-4 while maximum yield of 768. 33 kg/ha was recorded in NDC-30-16.

iii. Biocontrol using Trichogramma

The Hymenopterous wasp, *Trichogramma chilonis* (Ishii) is a polyphagous egg parasitoid that is wide spread throughout the world because of its ability to breed in

any environment and reproduce rapidly inside the host eggs of numerous insect pests related with Lepidoptera, Coleoptera and Neuroptera. Laboratory rearing of the agent involves use of Angoumois grain moth, *Sitotroga cerealella* (Oliv.) as fictitious host for rearing *Trichogramma* spp. An essential aspect in improving the economics of the mass production is to extend the shelf-life of host eggs and the parasitoid to ensure their continuous supply. A variety of options may be used for egg preservation including gamma radiation and cold storage. Effective storage can provide round the year availability of stocks in mass rearing insectaries for research and field releases.

Field Release of Trichogramma

Research studies on field efficiency using Trichogramma against pod borer were carried out. Chickpea variety NIFA-2005 was planted during November 2018 at NIFA. The trial comprised of 4 treatments such as T1 = 15 cards/acre, T2 = 20 cards/acre, T3 = 25 cards/acre and T4 = control (without cards) having four replications in RCB design.

For field releases, the above mentioned doses of trichocards (egg parasitoid) were installed at the onset of eggs deposited by pest female moth in chickpea crop. Periodic releases of each treatment were carried out at 7 days interval. Relevant data on larval population, total pods vs. damaged pods were recorded per plant from 7 randomly selected plants in each treatment. Results on pod borer infestation indicated very low efficacy due to continuous rainfall which possibly maximized pest population and prevailed non-conducive climate for trichogramma development under such conditions.

Oviposition preference of female egg parasitoid, *T. chilonis* on different eggs ages of *S. cerealella*

Sitotroga eggs of 12, 24, 48 & 72 hours of ages were exposed to *T. chilonis* for parasitization at 20±2°C, 32±2% R.H. & 11L:13D until the colour of parasitized eggs turned black in a no-choice experiment. The results showed significant differences among different eggs ages. Maximum parasitism (71.50%) of *Sitotroga* eggs was recorded in 12 hrs. age followed by 24 hrs. (65.50%), 48 hrs. (47.50%) and minimum was recorded in 72 hrs. (34.25%). The developmental period of *T. chilonis* inside the host eggs remained almost the same i.e. 14.0 days. The fresh *Sitotroga* eggs (from 12-24 hrs. ages) are most suitable for maximum parasitism by *T. chilonis* for 24 hrs. exposure time.

Age effect of female *Trichogramma* on oviposition preference of *Sitotroga* eggs

The age effect of *T. chilonis* on the extent of parasitization of the host eggs of *Sitotroga* was investigated. Four different

age groups, 12, 24, 48 & 72 hours after emergence were used. The results indicated that the maximum parasitization of *Trichogramma* on host eggs was recorded up to (73.50%) during 12 hrs. of its age followed by 24 hrs. (62%) and 48 hrs. (43.50%). Later on, the parasitization decreased up to 22% after 72 hrs. The developmental period of *T. chilonis* inside the host eggs remained almost the same i.e., 14.0 days. It is important to use younger parasites of (12-24 hrs. age) to achieve maximum parasitism of *Sitotroga* eggs.

Oviposition preference of the female egg parasitoid, *Trichogramma* on *Sitotroga* eggs on different colour cards

Sitotroga eggs (500) were sprinkled on six different colour cards i.e., white, red, yellow, green, blue & black and exposed to adult *Trichogramma* (50 pairs) for parasitization at 20±2°C, 32±2% R.H. & 11L:13D. Maximum parasitism of host eggs by *Trichogramma* was recorded on green colour card (45%) followed by yellow (36.25%), red (31.25%), white (30%), blue (27.50%) and minimum was noted on black colour card (15%). It is evident from the results that the egg parasitoid, *T. chilonis* preferred green colour for parasitism as compared to other colours.

Irradiation effect on parasitism of *S. cerealella* eggs by *T. chilonis*

Fresh *Sitotroga* eggs (500) were irradiated at different doses of 10, 20, 30, 40 & 50 Gy of gamma radiation. Irradiated eggs were then exposed to 10 pairs (♂ : ♀) of *T. chilonis* in glass jars and observed the radiation effect on host eggs for 24 hours maintained at 20+2^{0}C, 32+2% R.H. & 11L:13D. Percent parasitism of *Sitotroga* eggs was affected by radiation. The lowest radiation dose (10 Gy) yielded significantly higher parasitism of *T. chilonis* (71%) followed by 20 Gy (67.33%), 30 Gy (56.33%) and 40 Gy (39.33%). The highest radiation dose (50 Gy) resulted in lowest parasitism of *Sitotroga* eggs (21%) after 8th day which were significantly different at 5% level of probability. In control, parasitism of *S. cerealella* eggs by *T. chilonis* was significantly higher than all other treatments (83%). It is concluded from the data that different radiation doses also effect the parasitizing period from eggs to pupae. Lowest radiation dose (10-20 Gy) showed significantly prolonged parasitizing period (egg to pupa) i.e., 8.03 - 8.07 days followed by 30 Gy (7.47 d), 40 Gy (7.17 d), 50 Gy (7.03 d) and minimum was recorded in control (4.00 d). The findings of the study will be helpful during transportation and storage.

iv. Termites

The subterranean termites are notorious insect pest to agricultural crops and buildings in Pakistan as well as all over the world and causing billion dollars losses.

Due to cryptic in nature, it is very difficult to manage these pests. Huge amount of conventional insecticides are being used against termites, which are quite costly and environmentally hazardous. Therefore, in our research program we tried to develop some alternative environment friendly termite control methods which are cheaper and more effective.

Less hazardous management of Termites

The activity of biological control agent entomopathogenic nematodes (EPN), *Stenernema carpocapsae* (Sc) was tested against the subterranean termites, *Heterotermes indicola* in four media i.e. Sand 100%, Silt Loam 100%, Silt Loam 75% + Sand 25% and Silt Loam 50% + Sand 50%. One hundred grams of each of media was placed in petri dishes. Double layer of filter papers (Whatmann) at bottom of a petri dish was considered as control. Fifty termites (45 workers and 5 soldiers) were released in each petri dish of each medium treated with 3 concentrations of nematodes i.e. 25, 50 and 100 Infective Juveniles per termite (IJ/termite). All three concentrations of EPN performed well in pure sand medium followed by control, d. (Silt Loam 50% + Sand 50%), c. (Silt Loam 75% + Sand 25%) and b. (Silt Loam 100%) respectively. In Sand (100%) medium, 100% mortality was observed @ 100 IJ/termite after third day of treatments application, followed by @ 50 IJ/termite at 8th day of application. While in all other media, termites' mortality for all EPN concentrations and time intervals was lesser than their mortality in control medium.

To check the EPN isolation or reproduction potential from termites, firstly four concentrations of wax moth isolated EPN @ 30, 40, 50 and 60 IJ/termite were used against 50 termites workers. After the workers mortality confirmation from EPN 40, 50 and 60 IJ/termite, at least 20 carcasses of workers (0.02 g of weight) were shifted to three different white traps labelled as W40, W50 and W60 according to respective concentration for next generation EPN isolation. Similar weight of EPN inoculated wax moth was shifted to white trap labelled as WC and considered it as control. After forty days white trap WC (wax moth) maximum average EPN numbers (13550) were isolated followed by very low number isolated from carcasses of termites' white trap W50 (1650), W60 (1550) and W40 (1520).

The efficacy of next generation of (termites isolated) EPN was checked against the termites. Four different concentrations of (termites isolated) EPN @ 50, 100, 200 and 400 IJ/termite were applied. EPN @ 0/termite and (wax moth isolated) EPN @ 50/termite were considered as two control treatments. There was no significant mortality observed up to one month in all

(termites isolated) EPN concentrations. Only 12% termites' mortality (maximum) was observed in 4 weeks after the (termites isolated) EPN @ 400 IJ/termite.

B. MEDICAL ENTOMOLOGY

Dengue has become endemic disease in Pakistan and globally. No effective vaccines are available for the disease. Therefore, vector control is the only option. Reliance mainly on insecticides for vector control causes serious health hazards, entomological problems and environmental constraints. Thus development of an environment friendly vector control, such as Sterile Insect Technique (SIT) has become indispensable for integration with other available conventional control methods. Medical Entomology Group of NIFA is continuously involved in carrying out environment friendly SIT related activities as component of integrated vector management (IVM) program in collaboration with IAEA and other stakeholders.

Development of Larval Diet for rearing of Anopheles, Culex and Aedes species

Three diets; NIFA larval diet, IAEA diet and NIFA modified larval diet were tested for growth and development of three types of mosquitoes belonging to Anopheles, Culex and Aedes. Each food was replicated five times and 640 µl of each diet was supplied daily. Larval developmental from 1st instar to pupa and to adult, and their survival was recorded. Results indicated shortest larval duration, survival rate from 1st instar to pupa for NIFA modified diet followed by NIFA diet.

Blood Feeding

Three sources of blood feeding was compared; Animal feeding (mice), Artificial blood feeding through Parafilm Membrane and Artificial blood feeding using animal peritoneal membrane. 100 male and 100 females *Aedes aegypti* in cages were provided with each blood source. Blood feeding was recorded for various time intervals (20, 30, 45 & 60 minutes). Feeding rate by the number of mosquitoes during interval & eggs production from each cage was recorded. Feeding through the parafilm membrane gave the least feeding rate from all feeding intervals. Eggs production was highest in both animal feeding and peritoneal membrane from animal source. No significant difference in 45 to 60 minutes feeding was recorded in feeding rate and eggs production.

Effect of larval diets on mosquito dimorphism

The effect of various indigenous based diets on male/ female differential development and sexual dimorphism in *Aedes albopictus* and *Aedes aegypti* was tested under laboratory conditions. Results revealed that

Stevia 75% + Bovine Liver 20% + Yeast 5% diet in mixture when fed to larvae produced 42-48% larger size female pupae than in control followed by the diet with Carrot powder 75% + Bovine Liver 20% + Yeast 5%. The diet effect on the male pupae size was at par with control. This trend of sexual dimorphism is being used in sex separation. Larval diet at 400 µg/larva/day was standardized as reference line for quality production of Aedes mosquitoes.

In another experiment eggs quantification, average fecundity, percent hatching in fresh / stored eggs were also standardized for improvement in the rearing efficiency. Survival curves were also estimated (using the Kaplan-Meier method) for mated males and females mosquitoes. Eggs production was higher (989±11) in small cages as compared to mass production cages (896±83), which may be attributed to higher chances of maximum mating due to close interaction in small production cages.

Effect of larval density on the sexual dimorphism and biological parameters of Aedes mosquitoes

The effect of the Stevian larval diet was further tested at various larval density (1-5 larvae/ml) for the sexual dimorphism / biological parameters of the dengue vectors. Results showed significantly higher success rate at larval density (1-2 larvae/ml) in the repeated trials. Based on the results regarding the success rates due to various factors (diet composition, diet concentration, larval density) a Binary Logistic Model was developed for using the rearing and production of quality mosquitoes.

Exploiting the natural protandory in the separation of male/female

Natural Protandory i.e. male pupation take place first than the female in the same pupal cohorts. Data were recorded by collecting the pupae after onset of male/female pupae at different time intervals. Data of pupae production with percent male / female for each time were recorded and ratio was determined. Data on different subsequent generations were recorded regularly. Result showed that after the first onset of pupae production, the time period from 09:00-11:30 A.M was found as best in term of zero female pupae and thus useful in the separation of male pupae needed for sterility through irradiation in the SIT program. The male ratio was significantly higher on the first day of onset of pupae production and was found acceptable up to 04:00 P.M. at the same day.

Comparative efficacy of sieving tools of different mesh size and John Hock apparatus in sex separation after dimorphism through larval diets

After the observance of successful induction of sexual dimorphism at pupal stage in Aedes species through nutritional means, the available tools for mechanical separation were tested. From the results

regarding mechanical sex separations, mesh size of 1250 µm separated both the sexes effectively with a mean accuracy range (97-100%). However, the John Hock apparatus was comparatively low in accuracy and resulted the range of 96-99% in case of pupal separation.

Comparative efficacy of conventional and locally available plant extracts against mosquitoes

Conventional & Novel insecticides

The percent susceptibility and resistant status of 3rd instar larvae of Aedes mosquitoes in field population were analyzed against the conventional chemicals (Lamda-cyhalothrin, Permathrin, Deltamathrin, Pyrethroids) and were found in range of low to medium level of resistance. Theses insecticides were found effective when used in concentrations higher than the recommended. Similarly, the new chemistry insecticides (Spinosad, Emamectin, microbes based insecticides) were also scrutinized and were found highly effective and with negligible resistance to mosquitoes.

Botanical extracts

Botanical pesticides are promising in a way that they are effective, environment friendly, easily biodegradable and inexpensive. Botanical pesticides have been used traditionally by human communities in many parts of the world against pest species of insects. Bioassays were carried out to find the larvicidal properties of various plant extracts against dengue vector at 3rd and 4th instars larvae of Aedes mosquitoes. Result revealed that various plant extracts in 100ml Ethanol, 50ml Ethanol + 50ml tap water and 25ml Ethanol + 75ml tap water showed 100% mortality of tested mosquitoes. Thus environment friendly plant based pesticides can be integrated with SIT for population suppression.

C. PLANT PATHOLOGY

Wheat Disease Epidemiology, Resistance and Management

Status of airborne diseases in Khyber Pakhtunkhwa

Sets of 260 diversified wheat genotypes were raised as stationary sentinel plots for surveillance and epidemiological studies of yellow rust, leaf rust and powdery mildew in three zones of Khyber Pakhtunkhwa. Yellow rust (Yr) was prevalent at all test sites in the province with highest mean severity of 56% in Peshawar 1 which was followed by Nowshara (34%), Peshawar 2 (19%), Abbotabad (9%) and Swat (8%). Yellow rust was not recorded in Bannu. Leaf rust was not recorded at test sites while powdery mildew was recorded at Swat only where disease severity reached 46%.

Variability in yellow rust pathogen metapopulation

Information regarding *Puccinia striiformis f. sp. tritici* virulence, availability of

resistance sources and cultivation value of resistance genes/sources are the prerequisite for rust management, cultivars development and deployment. Eight yellow rust races including 126E14, 126E199, 126E239, 126E255, 46E188, 127E255, 119E255 and 102E255 were found in central, southern and northern zones of Khyber Pakhtunkhwa and number of virulences associated with these races ranged from 14 to 35. Over time, yellow rust virulence's spectra became broadened in Peshawar. Yellow rust virulences including *v1*, *v6*, *v7*, *v8*, *v9*, *v25*, *v27* and *v32* were consistently observed from 2017 to 2018 and corresponding race specific all stage resistance genes performance was very poor and the genes were ineffective. Virulences were observed for *Yr3*, *Yr5*, *Yr10* and *Yr15* in Khyber Pakhtunkhwa but virulence frequency needs to be investigated over extended period of time in metapopulation. Seven yellow rust resistance genes, not deployed in Pakistan were studied for their epidemiological consequences. Five gene (i.e. *Yr41*, *Yr52*, *Yr62*, *Yr64* and *YrSp*) were found better as final rust severity ranged from 0-40% in comparison with control which carried 100% rust infection.

Slow rusting wheat

Out of the total, 70% of the wheat acreage lies in 13 low altitude districts in Khyber Pakhtunkhwa ranging from 174 to 688 m. Remaining mid and high altitude districts play a critical role in the yellow rust epidemiology as pathogen survive summer in this region on grasses and provide initial inoculum for rust development on wheat in 13 low altitude districts. To avoid and manage rust epidemic by reducing both allo and auto infection cycles on wheat in low altitude districts, reduction of initial rust inoculum from the source area i.e. mid and high-altitude regions is essentially required. To achieve this goal, 368 registered/ approved wheat cultivars, land races and elite CIMMYT genotypes were tested and analysed for a special slow rusting resistance trait. Results of temporal data captured under yellow rust infection experiment indicated that high variability in five disease parameters including initial disease (y0), maximum disease (ymax), disease increment (Δ) as ymax-y0, area under disease progress curve (AUDPC) and final infection type (F-IT) was recorded in the tested material. Maximum values of these five parameters reached up to 10% (y0), 100% (ymax), 100% (Δ), 1900 (AUDPC) and 9 (F-IT). Results were indicative of the fact that the tested genotypes carried both all stage resistance and adult plant resistance. Slow rusting efficacy and stability need further testing against rust meta-population.

Yellow rust resistance in national elite and candidate varieties

Under this national collaborative program, NIFA is fostering the development of disease resistant wheat germplasm and varieties, and have received 485 elite genotypes in National Wheat Disease Screening Nursery (NWDSN) and a set of 59 candidate varieties for testing during the period under report. Total 544 genotypes were sown, managed and evaluated at appropriate stages under artificially induced rust infection experiments. Yellow rust was not recorded on 79 genotypes, while 90 displayed high susceptibility. Remaining genotypes displayed either moderately resistant or moderately susceptible infection types.

Scab resistance in local cultivars

Locally available and adopted 17 apple cultivars including Anna, Pink Lady, Gala Must, Jonica, Florina, Negareen-V2, M. Gala, Smoothe, Fuji, Sparton, T. Gala, Jonagoard, Oregon Spur, K.T, Read Chief, Royal Gala and Feeta were previously raised and maintained as nursery at NIFA and were used for scab resistance tests. *In-vitro* apple detached leaf scab screening technique was optimized in the previous study. An aggressive *Venturia inequalis* isolate PLK-10-2017 collected during 2017-18 from Kalam, Swat was maintained and used for screening in this study. Results indicated that Fuji and Sparton were the most resistant apple genotypes as both displayed scab severity <15%. This preliminary scab screening apple germplasm needs further confirmatory study.

Adding novel scab resistance

In order to diversify local apple germplasm, novel scab resistance was transferred on locally adopted rootstocks previously established at NIFA Experimental Farm. Buds of 16 sources carrying scab resistance genes including Gala, Golden Delicious (Rvi1), TSR 34T15 (Rvi2), Q71 (Rvi3), TSR 33T239 (Rvi4), 9-AR2T196 (Rvi5), Priscilla (Rvi6), M.X Floribunda 821 (Rvi7), B45 (Rvi8), J34 (Rvi9), A723-6 (Rvi10), Malus Baccata Jackii (Rvi11), Hansenaes Baccata (Rvi12), Durella di Forli (Rvi13), Duelmener Rosen (Rvi14) and GMAL 2473 (Rvi15) were introduced from Switzerland. A total of 292 apparently healthy imported buds were transferred using T budding technique to the local rootstocks. Four resistant sources including Rvi1, Rvi2, Rvi6 and Rvi11 were unable to generate after budding while 2-12 buds of the remaining sources developed and survived now and needs further increase in coming season.

Laboratory studies

Growth variability in *Venturia inequalis* population

Apple fruit, leaves and twigs/dormant buds derived 129 scab samples were studied for

radial growth variability and cultural characteristics following isolation and pure culture development using standard techniques and PDA as growth medium. Results indicated significant variability in radial growth of the tested population. Based on radial growth, isolates were placed in different groups including group-1 (2.1-3.0 cm), group-2 (3.1-4.0 cm), group-3 (4.1-5.0 cm), group-4 (5.1-6.0 cm), group-5 (6.1-7.0 cm), group-6 (7.1-8.0 cm), group-7 (8.1-9.0 cm) and group-8 (9.1-10.0 cm). Highest frequency of isolates was recorded in group-3 (33%) which was followed by group-2 (30%), group-4 (16%), group-1 (15%), group-6 (4%), group-8 (2%), group-5 (1%) and group-7 with no isolate.

Cultural characteristics of *Venturia inequalis* population

A sub set of 47 isolates from this population was studied for cultural characteristics including colony color, shape, texture, distribution, margin, growth pattern, elevation, aerial hyphae and sporulation. White to dark grey color was recorded in all isolates while some were observed with tan color in the middle. The texture for various isolates was recorded in the range of wooly to cottony and some were velvety. A minor difference was noticed in colony margin of different isolates. In most of the isolates, a ciliated margin was observed. Radiate growth pattern was recorded in most of the isolates and some were with flowery appearance. The aerial hyphae were present but with minimum aerial growth. A very light to moderate range of spores developed in different isolates of *V. inaequalis*. The colony distribution and shape were recorded as periphery and scattered. A flat to raised surface of colony was observed in all isolates. Other growth media needs to be tested for comprehensive morphological characterization of these isolates.

Fungicides sensitivity of *Venturia inequalis* population

Venturia inequalis isolates are being subjected to fungicides sensitivity trials. During the period under report, a fungicide "Aliettle" was tested @ 0.625g/250ml against a sub set of 47 isolates using a food posion technique. Significant variability was recorded in the radial growth reduction in treated isolates in comparison with their untreated control. Simple criterion was adopted to classify sensitivity of isolates and effectiveness of the tested fungicide. Isolates were considered sensitive which have <50% radial growth reduction while above 50% were considered resistant. Results indicated that 40% (N:19) and 60% (N:28) of the isolates were found sensitive and resistant to the tested fungicide. It was concluded that fungicide "Aliettle" is not effective for the *V. inequalis* population studied.

Barley Yellow Dwarf incidence in wheat

Barley Yellow Dwarf (BYD) is insect transmitted viral disease caused by Barley Yellow Dwarf Virus (BYDV) infecting cereals including wheat and other grasses. In Khyber Pakhtunkhwa (KP), BYD is a commonly occurring disease in wheat and other cereals. During the season 2018-19, BYD symptoms were masked by yellow rust infection at early stage of wheat crop where BYD symptoms could develop and it became epidemic through repeating infections by urediospores in the later stages of wheat crop. National elite wheat material in National Wheat Disease Screening Nursery (NWDSN) was evaluated for BYDV infection under natural field conditions. BYD symptoms were largely masked by yellow rust infection and it became epidemic during the season where only 2% of entries exhibited symptoms with low level of severity. During the month of February at NIFA Peshawar, mean temperature and rainfall ranged from 9.4 to 15.5 °C and 2.2 to 24.6 mm, respectively. Light rain showers with an interval of 5, 7, 5, 4 and 2 days coupled with bright shiny days boosted up yellow rust infections, constituted many disease cycles and masked BYD symptoms. Similarly, no infection was recorded on the lines (50) in National Uniform Wheat Yield Trial (NUWYT) nursery.

Barley Yellow Dwarf wheat differentials deployment in Khyber Pakhtunkhwa

Previously confirmed wheat lines possessing BYDV resistant genes i.e. Bdv1, Bdv2 and Bdv1+Bdv2 were deployed at different six locations in Khyber Pakhtunkhwa (KP) representing low, medium and high rainfall regions. During the season, yellow rust infection occurred early in the season across Khyber Pakhtunkhwa and had completely masked BYD symptoms development and rust disease develop further in the season due to repeated infection cycles by urediospores. Factors of yellow rust epidemic synchronized and constituted favourable environment for yellow rust development. Yellow rust pustules development, eruption and release of urediospores for further infections resulted into many cycles have completely masked BYD symptoms development and no expression of BYDV resistant genes against available BYDV virulence could be recorded from all the six locations.

Wheat seed pathology

Seeds of wheat are subjected to many pathogens and, therefore, seed borne inoculum is of great economic importance because it poses a serious threat of disease transfer in time and space. Seed pathology of 592 entries belonging to National Wheat Disease Screening Nursery (NWDSN) season 2018-19 was undertaken and analyzed for Black Point (BP) & Karnal

Bunt (KB) diseases under light inbuilt magnifying lens. Hundred percent entries/lines were infected with BP disease with incidence of 2 to 252 infected kernals per 1000 seeds while KB was not recorded at all.

SOCIO-ECONOMIC IMPACT

PLANT BREEDING & GENETICS DIVISION

10 tons quality seed (pre-basic, basic and certified) of NIFA's mandatory crops varieties has been distributed to Department of Agriculture Extension, seed companies and farming communities of KP for 2019-20 cropping season.

FOOD AND NUTRITION DIVISION

Development of technologies for preservation/value addition of fruit and vegetables is a strong component of Food and Nutrition Division (FND). Trainings were conducted to transfer technologies to farmers/entrepreneurs to improve their socioeconomic stability. Limited scale production of food products within the institute yielded around Rs. 1.0 million during year 2018-2019. Irradiation services were provided to gemstone traders for value addition of gemstones (Topaz, Kunzite, Tourmaline, Quartz, etc.). NIFA earned nearly Rs 0.8 million from gemstone irradiation services. However, the gemstone traders are the actual beneficiaries as the value of the gemstones enhanced 3 to 4 times by irradiation. Radiation services were also provided to R&D and academic organizations that earned a good name for NIFA.

Due to popularization efforts, demand for mushroom spawn has increased and NIFA is supplying spawn at subsidized rates as part of PSF funded project. Trainings were conducted in KP, Punjab and Baluchistan on mushroom cultivation to create opportunities for self-employment, especially in the rural areas where women can also grow mushroom to enhance their income. Free spawn was provided to 50 growers for starting their own businesses. A total of Rs. 171,000/- was earned from the sale of mushroom grown at NIFA experimental mushroom farm. Similarly, popularization of mushroom cultivation has been carried out through print and electronic media. Different events are covered in newspaper like Daily Shamal, Daily Chand, Daily Akhbar, Daily Aaj and Dawn News. Moreover, five radio talks have been delivered for Karkeela program broadcasted by Radio Pakistan, Peshawar. Data regarding consumption of wheat flour showed that 45% of the studied individuals (volunteers) utilized chaki atta (whole wheat flour) and 51% used the fraction wheat flour mills flour (iron fortified wheat flour). However, 4% individuals under study used the both types of flours i.e. whole wheat flour and fraction wheat flour. Purchasing power of the individuals was taken as the income earned per month. Food nutrient composition data were collected using the 24 hours

food questionnaire. The data showed that none of individuals used foods enriched with iron and vitamin A. Vitamin A and Iron spot kits worth Rs. 5 million were supplied to Food Fortification Program Pakistan, provincial food authorities and food departments, regulatory bodies and nutrition programs that are working to eliminate micronutrient deficiency in the country.

Work on food bio-preservatives produced by various lactic acid bacteria has been initiated. These bio-preservatives have potential to replace the existing harmful chemical preservatives. Water testing services for physical, chemical & microbial analysis were provided at very low cost to the surrounding communities and various organizations. The overall activities of FND have contributed to food and environmental safety and security as well as nutritional well-being of the Pakistani population besides generating income for sustaining the R&D activities of the institute. Training and supervision of students from universities is an integral part of the activities of FND.

SOIL AND ENVIRONMENTAL SCIENCES DIVISION

Farming community of KP is keen to adopt packages of technologies being developed by the scientific team of Soil and Environmental Sciences Division. These technologies are swiftly gaining grounds in the province on account of their simplicity, cost effectiveness and potential for improving yield and productivity of major field and horticultural crops. Use of integrated packages of water and fertilizer management has the potential to raise yield of major crops up to 30%. Through the adoption of tunnel farming technology, small vegetable farmers are getting 15 times more income than conventional vegetable production. Farmers are making better use of available farm labour and inputs under the farm friendly practices being identified through applied research activities of the division with the consequences of enhancement in socio-economic conditions.

PLANT PROTECTION DIVISION

The developed technologies/ products by PPD have been transferred to the academia, researchers, agriculture extension specialists, farmers as end users and community leaders through trainings, workshops, seminars and print materials. Dengue Guard, a mosquito repellent product for protection against mosquitoes and other biting insects, is supplied to various PAEC establishments. NIFA Fly Guard, Fruit Fly Traps, and Rat Nil are also being provided to end users against their demand. The sale of these products on concessional rates

has generated income to the institute besides its positive effect on environment and economic returns to farmers in terms of low cost and environment friendly properties. Crop diseases have a serious and wide impact as they can spread readily within season and also from season to season. Costs arise directly from yield losses, chemical control and maintenance of disease resistance preemptive control program to mitigate the risk of new pathotypes and virulences. Major damaging wheat diseases prevalent in the Khyber Pakhtunkhwa include yellow rust, leaf rust, powdery mildew, barley yellow dwarf and blights which are suspected to have caused >1% yield losses in different production zones. Under the national wheat improvement sub-program on rust resistance, it contributes annually $12.3 million to the total economic value ($123 million) of the control provided by resistance to rusts in Pakistan.

PUBLICATIONS

1. Ali R, Shah SJA and Ullah S (2019) Role of onion weed in tomato root knot nematode management. LAP LAMBERT Academic Publishing, Germany. 61pp
2. Ali S, Sharma S, Leconte M, Shah SJA, Duveiller E, Enjalbert J and Vallavieille-Pope, C (2018). Low pathotype diversity in a recombinant *Puccinia striiformis* population through convergent selection at the eastern Himalayan centre of diversity (Nepal). Plant Pathol, 67: 810-820. doi:10.1111/ppa.12796.
3. Ali Z., Haroon, Raza A. (2018) Response of Potato to fulvic acid and inorganic fertilizers. Pak. J. Agri., Agril. Engg. Vet. Sci. 34 (2): 120-125.
4. F. Ullah, H. Gul, T. Badshah, T. Nawaz , G. Z. Khan, A. Ali, K. Tariq and D. Song. 2018. Evaluation of NIFA bio-larvicide in natural habitats of *Culex quinquefasciatus* under field conditions at district Mardan. IJAER (2018): 4(3): 130 - 133.
5. Farman Ali, Khan, J., Anwar Zada, Khan, I & M. Salman 2019. Bio-insecticidal efficacy of Botanical extracts of Citronella and Cinnamon against *Tribolium castaneum*, *Sitophilus oryzae* and *Drosophila melanogaster* under laboratory conditions. Fresenius Environmental Bulletin Volume 28 (4A): 3104-3109.
6. Hu, A., S. Li, L. Zhang, H. Wang, J. Yang, Z. Luo, A. Rashid, S. Chen, W. Huang, C.-P. Yu. (2018). Prokaryotic footprints in urban water ecosystems: A case study of urban landscape ponds in a coastal city, China, Environmental Pollution 1–11.
7. K. Farhadullah, M. I. Khan, S. Khan, M. A. U. Zaman, H. Rasheed and A. R. Khan (2018). Evaluation of agronomic traits for yield and yield components in wheat genotypes with respect to planting dates. Mal. J. Sust. Agric. 02(01): 07-11
8. Khan A.U., W. Ahmad, A. Raza, F. Khan, M. Sharif (2019) Assessing Suitability of Wheat Genotypes for Growth, Yield and Nutrients Uptake under Sand Culture. Sarhad J. Agric. 35 (3).
9. Khan J, Khan I, Ghaffar A, Khalid B. 2018. Epidemiological trends and risk factors associated with dengue disease in Pakistan (1980–2014): a systematic literature search and analysis. BMC *Public Health*, 18(1):745
10. Khan. P., W. Muhammad and M. Imtiaz, 2019. Influence of integrated application of phosphorus on wheat yield and phosphorus uptake. IJAER. 5(1): 278-284.

11. Khattak, G.S.S., I. Saeed and M. Ibrar. 2019. New high yielding and disease resistant mungbean [*Vigna radiata* (L.) Wilczek] variety "NIFA Mung-19". Pure Appl. Biol. 8(2): 1444-1455.
12. Li, Y., A. Rashid, H. Wang, A. Hu, L. Lin, C.-P. Yu, M. Chen, Q. Sun. 2018. Contribution of biotic and abiotic factors in the natural attenuation of sulfamethoxazole: A path analysis approach, The Science of Total Environment 633:1217–1226.
13. Li, X., Ahmad, S., Ali, A., Guo, C., Li, H., Yu, J., Zhang, Y., Gao, X. and Guo, Y., 2019. Characterization of Somatic Embryogenesis Receptor-Like Kinase 4 as a Negative Regulator of Leaf Senescence in Arabidopsis. Cells, 8 (1), p.50.
14. Li, X., Ahmad, S., Guo, C., Yu, J., Cao, S., Gao, X., Li, W., Li, H. and Guo, Y., 2018. Identification and characterization of LRR-RLK family genes in potato reveal their involvement in peptide signaling of cell fate decisions and biotic/abiotic stress responses. Cells, 7 (9), p.120.
15. Li, X., Guo, C., Ahmad, S., Wang, Q., Yu, J., Liu, C. and Guo, Y., 2019. Systematic Analysis of MYB Family Genes in Potato and Their Multiple Roles in Development and Stress Responses. Biomolecules, 9 (8), p.317.
16. Li, X., Hamyat, M., Liu, C., Ahmad, S., Gao, X., Guo, C., Wang, Y. and Guo, Y., 2018. Identification and characterization of the WOX family genes in five Solanaceae species reveal their conserved roles in peptide signaling. Genes, 9 (5), p.260.
17. M. Ashfaq, Q. Sun, C. Ma, A. Rashid, Y. Li, S.I. Mulla.2019.Occurrence, seasonal variation and risk evaluation of selected endocrine disrupting compounds and their transformation products in Jiulong river and estuary , China, Mar. Pollut. Bull. 145 370–376.
18. Ashfaq, M., Y. Li, Y. Wang, D. Qin, M.S.U. Rehman, A. Rashid, C.-P. Yu, Q. Sun. (2018). Monitoring and mass balance analysis of endocrine disrupting compounds and their transformation products in an anaerobic-anoxic-oxic wastewater treatment system in Xiamen, China, Chemosphere. 204: 170–177.
19. M. Chourio, F. Slais-Fierro, Z. Mehmood, S. I. Manrtinez-Monteagudo and M. D.A. Saldana. 2018. Inactvation of peroxidase in coconut water using pressure-assisted thermal processing. Innovative Food Science and Technologies. 49, 41-50
20. Mahmood T, T. Masud, A. Qayyum, A. Mehmood, W Ahmed, M. Liaquat, M. Saeed, S. Khan and S. Ali (2019) Functional and technological attributes of probiotic yoghurt prepared with dahi micro-flora during refrigerated storage. Food Science and TechnologyhttpI//dx.doi.org/10.1590/fst.12317

21. MK Khattak, M Hanif, M Khan, M Ramzan. 2019. Comparison of drying process and preservatives on drying kinetics, texture and antioxidants retention in mulberry fruits. Journal of Animal & Plant Sciences 29 (3).
22. Muhammad Faisal Nisar, Muhammad Sajid Arshad, Muhammad Yasin, Muhammad Umair Arshad, Muhammad Tahir Nadeem. (2019) Influence of irradiation and moringa leaf powder on the amino acid and fatty acid profiles of chicken meat stored under various packaging materials. Journal of Food Processing and Preservation 43:9.e14166
23. Muhammad Sajid Arshad, Zaid Amjad, Muhammad Yasin, Farhan Saeed, Ali Imran, Muhammad Sohaib, Faqir Muhammad Anjum & Shahzad Hussain (2019) Quality and stability evaluation of chicken meat treated with gamma irradiation and turmeric powder, International Journal of Food Properties, 22:1, 154-172, DOI: 10.1080/10942912.2019.1575395
24. S. Anwar, G. Hassan, F. Azam, J. Amin, A. Ahmad and F. Ghani (2018). Estimation of Genetic Parameters and Interrelationship among Important Traits in Bread Wheat. IJFAS. 7(3): 93-99
25. S. Anwar, J. Amin, S. Ali, A. Rab, S. Hayat, Z. Wahab, F. Azam, M. Zakir, F. Ghani, M. R. Khan, G. Hassan and A. Ali (2019). Genetic variability, heritability and genetic advancement in F_3 population of wheat. Pure Appl. Biol., 8(1): 117-126
26. Suanon, F., Q. Chi, X. Yang, H. Wang, A. Rashid, B. Asefi, D. Mama, C.P. Yu, Q. Sun. 2018. Diagnosis and ecotoxicological risk assessment of 49 elements in sludge from wastewater treatment plants of Chongqing and Xiamen cities, China, Environ. Sci. Pollut. Res. doi:10.1007/s11356-018-2888-z.
27. Wang, Y., Y. Li, A. Hu, A. Rashid, M. Ashfaq, Y. Wang, H. Wang, H. Luo, C.P. Yu, Q. Sun. (2018). Monitoring, mass balance and fate of pharmaceuticals and personal care products in seven wastewater treatment plants in Xiamen City, China, J. Hazard. Mater. 354: 81–90.
28. Zamir, R., A. Rab, S. T. Shah, S. A. Khalil and I. Ahmad. 2018. Estimation of genetic diversity in Pakistani guava (*Psidium guajava* L.) accessions using microsatellite markers. Proc. of 7th international and 16th National Conference on Plant Resources; Current trends, challenges and solutions at Uni. of Peshawar. March. 23-26, 2018. P. 182.

FUNDED RESEARCH PROJECTS

Sr. #	Project Title	Project Duration	Total Funds	Principal Investigator	Funding Agency
1.	Breeding high yielding mungbean (*Vigna radiata* L. *Wilczek)* genotypes for the agro-climatic conditions of Kuram agency	2016-2019	Rs. 2.219 M	Gul Sanat Shah	PSF
2.	Adaptation of Electron Beam to Treat MREs and Fruits and Vegetables in Pakistan (CRP-19231)	2015-2019	€ 18,000	Alamgeer Khan	IAEA/CRP
3.	Commercialization of existing technology of mushroom cultivation among farming and landless communities of KP, Punjab and Baluchistan	2017-2019	Rs. 4.17 M	Dawood Khan	PSF
4.	Production of indigenous food bio-preservatives from Microflora isolated from fermented dairy products ALP/AS 221.	2018-2020	Rs. 2.87 M	Talat Mahmood	ALP
5.	Electron Beam Applications for Value Addition to Food and Industrial Products and Degradation of Environmental Pollutants in the Asia Pacific region (Phase 2)	2017-2019	-	Alamgeer Khan	IAEA/RCA
6.	Development of low cost zero-energy cooling chamber for field heat removal & storage of fruits and vegetables, and its transfer to small farmers	2019-2022	Rs. 5.6 M	Zahid Mehmood	ALP
7.	Improving off-season vegetables production under high and walk-in tunnels through integrated management of nutrients, water and diseases	2017-2019	Rs. 1.4133 M	Wisal Mohammad	AUP Endowment Fund Secretariat (EFS)
8.	Pilot scale production and popularization of compost tea as organic fertilizer nutrient source	2018-2020	Rs. 2.7 M	Zahid Ali	PSF
9.	Sustainable Control of Apple Scab	2017-2019	Rs. 3.0 M	Syed Jawad Ahmad Shah	AIP, PARC, Islamabad

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Dr. Syed Tariq Shah, Ph.D. Genetics & Breeding	SS
Dr. Iqbal Saeed, Ph.D. Breeding & Genetics	SS
Dr. Salman Ahmad, Ph.D. Genetics & Breeding	SS
Dr. Akhtar Ali, Ph.D. Breeding & Genetics	SS
Mr. Khurshid Ahmad, M.Phil. Chemistry	JS
II. FOOD & NUTRITION DIVISION	
Dr. Maazullah, Ph.D. Agricultural Food Engineering	Head / DCE
Dr. Azhar Rashid, Ph.D. Biology	PS
Mr. Muhammad Zubair Shah, M.S. Chemical Engineering	PE
Dr. Zahid Mehmood, Ph.D. Food Science and Technology	PS
Mr. Dawood Khan, M.Sc. Chemistry	SS
Mr. Alamgeer Khan, M.S. Medical Physics	SS
Dr. Talat Mahmood, Ph.D. Food Science and Technology	SS

Mr. Ali Raza, M.Sc. (Hons.) Food Science and Technology	JS
Mr. Saeed Gul, B.Sc. Chemistry	RO
III. SOIL & ENVIRONMENTAL SCIENCES DIVISION	
Dr. Muhammad Imtiaz, Ph.D. Soil Science	Head / DCS
Mr. Mukhtiar Ali, M.Sc. (Hons.) Soil Science	PS
Dr. Syed Azam Shah, Ph.D. Agronomy	PS
Dr. Amir Raza, Ph.D. Natural Resources & Life Sciences	PS
Mr. Parvez Khan, M.Sc. (Hons.) Soil Science	PS
Mr. Zahid Ali, M.Sc. (Hons.) Soil Science	PS
Mr. Shahzada Asif Ali, M.Sc. (Hons.) Agronomy	JS
Mr. Noor ul Basar, M.Sc. Environmental Sciences	ARO
IV. PLANT PROTECTION DIVISION	
Mr. Alam Zeb, M.Sc. (Hons.) Entomology	Head / DCS
Dr. Syed Jawad Ahmad Shah, Ph.D. Plant Pathology	DCS
Mr. Muhammad Zahid, M.Sc. (Hons.) Entomology	PS
Dr. Inamullah Khan, Ph.D. Entomology	PS
Dr. Gul Zamin Khan, Ph.D. Entomology	PS
Dr. Muhammad Ibrahim, Ph.D. Plant Pathology	PS
Dr. M. Misbah ul Haq, Ph.D. Entomology	SS
Mr. Muhammad Salman M.Sc. (Hons.) Entomology	JS
Mr. Muhammad Arfan, M.Sc. (Hons.) Entomology	JS
V. TECHNICAL SERVICES DIVISION	
Mr. Fiaz-ud-Din, B.Sc. Engineering	Head / DCE
Dr. Muhammad Amin, Ph.D. Statistics	PS
Mr. Asif Murad, B.Sc. Engineering	PE
Mr. Jahangir Khan, M.S. Engineering	SE
VI. ADMINISTRATION & ACCOUNTS	
Mr. Muhammad Shakeel Khan, M.B.A.(HR) & M.A. Polt. Science	Pr. Admin Officer
Mr. Abdul Hadi Khattak, M.B.A. (Finance) & M.A. English	Pr. Accounts Officer
Mr. Rauf Ullah, M.L.I.Sc. / DIT	Sr. Librarian

PROMOTIONS/ TRANSFERS/ RETIREMENTS/ APPOINTMENTS

Promotions:

Sr. #	Name	From	To	On
1.	Dr. Syed Jawad Ahmad Shah	Pr. Scientist	Dy. Chief Scientist	01.12.2019
2.	Dr. Maazullah Khan	Pr. Engineer	Dy. Chief Engineer	01.12.2019
3.	Mr. Zahid Ali	Sr. Scientist	Pr. Scientist	01.12.2019
4.	Dr. Zahid Mehmood	Sr. Scientist	Pr. Scientist	01.12.2019
5.	Dr. Muhammad Ibrahim	Sr. Scientist	Pr. Scientist	01.12.2019
6.	Mr. Muhammad Ayaz Khan	Sr. Admin Officer	Pr. Admin Officer	01.12.2019
7.	Mr. Noor ul Basar	Pr. Scientific Assistant	Assistant Research Officer (ARO)	29.11.2019
8.	Mr. Muhammad Asif	Sr. Plant Operator	Assistant Technical Officer	28.05.2019
9.	Mr. Masood Khattak	Pr. Technician	Foreman	28.05.2019
10.	Mr. Muhammad Shabbir	Sr. Computer Operator	Pr. Computer Operator	28.05.2019
11.	Mr. Fazli Rahim	Sr. Scientific Assistant	Pr. Scientific Assistant	28.05.2019
12.	Mr. Shamshad Ali	Sr. Scientific Assistant	Pr. Scientific Assistant	28.05.2019
13.	Mr. Masood Jan	Telecom Operator-I	Sr. Telecom Operator	28.05.2019
14.	Mr. Nasir Khan	Scientific Assistant-III	Scientific Assistant-II	28.05.2019
15.	Mr. Jamshed Akhtar	Tech-III	Tech-II	28.05.2019
16.	Mr. Tariq Samual	Sanitary Attendant-II	Sanitary Attendant-I	28.05.2019

Transfer / Posting:

Sr. #	Name	From	To	On
1.	Mr. Fawad Muhammad, Sr. Accounts Officer	NIFA, Peshawar	Education Centre, Chashma, Kundian	12.02.2019
2.	Mr. Abdul Hadi Khattak, Pr. Accounts Officer	SPF, Islamabad	NIFA, Peshawar	19.02.2019
3.	Mr. Ajab Khan, Sec. Supervisor	NIFA, Peshawar	MDP-208, Islamabad	22.03.2019
4.	Mr. Amir Nawas Khan, Supdt.	NMC-II, Qabul Khel	NIFA, Peshawar	01.04.2019

5.	Mr. Karim Nawaz Khan, Sec. Supervisor	ISF, Jauharabad	NIFA, Peshawar	18.04.2019
6.	Mr. Mukamal Shah, Tech-I	KCP-II, Jauharabad	NIFA, Peshawar	20.05.2019
7.	Mr. Muhammad Asif, ATO	NIFA, Peshawar	DINAE, D.I. Khan	30.08.2019
8.	Mr. Nazakat Ali, Sec. Soldier	NIFA, Peshawar	SES, Islamabad	17.09.2019
9.	Mr. Muhammad Shakeel Khan, Pr. Admin Officer	CPC, D.G. Khan	NIFA, Peshawar	27.11.2019
10.	Mr. Muhammad Ayaz Khan, Sr. Admin Officer	NIFA, Peshawar	PAEC HQs., Islamabad	02.12.2019

Retirement:

Sr. #	Name	On
1.	Mr. Shah Alam, Sr. Storekeeper	05.05.2019
2.	Mr. Muhammad Islam, Pr. Tech	05.05.2019
3.	Mr. Yaqoob Khan, SA-III	01.07.2019
4.	Mr. Liaqat Ali, Driver	01.07.2019
5.	Mr. Sher Alam, Assistant (Admin)	01.09.2019
6.	Mr. Aurang Zeg, Sec. Soldier	23.10.2019
7.	Mr. Tariq Khan, Sr. Scientific Assistant	28.12.2019

Appointment:

Sr. #	Name	On
1.	Mr. Mustajab, Mali-II	09.01.2019
2.	Mr. Shakeel Khan, Mali-II	09.01.2019
3.	Mr. Muhammad Sohail, Mason	01.02.2019
4.	Mr. Muhammad Sajjad, Driver-III	17.07.2019

SCIENTIFIC EVENTS/ TECHNOLOGY TRANSFER PICTORIAL VIEW

One-day training workshop on "Mushroom Cultivation and its Popularization as a Cottage Industry" – 19th February, 2019

Farmers' Day – 13th March, 2019

One-day training workshop on "Soil Fertility, Plant Nutrients & Water Management in Tunnel Farming" – 27th March, 2019

Awareness Seminar on "Food Bio-preservation, Food Safety and Bio-hazards Management" – 17th April, 2019

One-day training workshop on "Biological Control of Insect Pests in Vegetables" 24th April, 2019

One-day training workshop on "Value Addition of Fruits and Vegetables" 19th June, 2019

Director NIFA presenting vote of thanks during QMS ISO 9001:2015 Certification audit of NIFA

Farmers' Awareness Seminar on "Diseases Insect Pest Management Strategies for Fruit Orchards in Swat Area" – 27th to 28th August, 2019

35th Post-graduate Training Course on the Use of Nuclear and other Techniques in Food & Agriculture Research – 7th to 18th October, 2019

GROUP PHOTOS

DIRECTOR OFFICE

PLANT BREEDING AND GENETICS DIVISION

FOOD AND NUTRITION DIVISION

SOIL AND ENVIRONMENTAL SCIENCES DIVISION

PLANT PROTECTION DIVISION

TECHNICAL SERVICES DIVISION

ADMINISTRATION

ACCOUNTS

STATE CARE WITH DIRECTOR NIFA

FIELD STAFF WITH DIRECTOR NIFA

CANTEEN STAFF WITH DIRECTOR NIFA

SANITARY STAFF WITH DIRECTOR NIFA

CSP ISO 9001:2015 Q-67 QMS Certified

PNAC Pakistan National Accreditation Council CB 005 QMS

Nuclear Institute for Food & Agriculture NIFA PAEC Peshawar

ISO 9001 : 2015 Certified

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