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Annual Report 2017

Nuclear Institute for Food and Agriculture, Peshawar

NIFA

Annual Report

2017

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C O N T E N T S

PREFACE:

Nuclear Institute for Food and Agriculture (NIFA) is striving for sufficient, nutritious environmental friendly food production in the country as food security under changing climate is the biggest challenge faced by the country. The main focus is to meet rather 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 & GENETICS:

The R&D activities of Plant Breeding and Genetics Division resulted in the release of improved wheat variety NIFA-Aman and NIFA-Mung approved for commercial cultivation by KPK Seed Council in 37th meeting held on 19-09-2017.

NIFA-Aman is a high yielding, widely adapted endowed with high protein contents and possesses resistance against yellow, leaf and stem rusts (*Yr, Lr* & *Sr*). Continuous efforts are being made to maintain the genetic purity through production of Breeder Nucleus Seed (BNS) of the released wheat varieties. NRL-1123 (Rainfed wheat line) has out yielded all the check cultivars in national / provincial yield trials and its proposal for approval as a new variety under the name "AWAZ" is in progress. A total of 9.2 tons quality Pre Basic seed was produced which will be distributed among Agric. Extension, seed companies and farming communities of Khyber Pakhtunkhwa (KP). Two candidate wheat lines (CT-12176 and NRL-1123) were evaluated in the national trials. The candidate line CT-12176 secured 1st position and produced highest mean grain yield (5488 kg ha^{-1}) over all the candidate lines in KP and showed resistance to all three types of rusts i.e. *Yr, Lr* & *Sr* as reported by Crop Disease Research Institute (CDRI report 2016-17). Based on proving worth for higher yield and yield components in provincial multi-locational trials, 3 candidate lines, i.e. CTG-154013, CTG-154028 (for irrigated areas) and NRL-1206 (for rainfed areas) were provided to national wheat coordinator for evaluation in the National Uniform Yield Trials (NUYT). In the variety popularization program six demonstration plots of NIFA-Aman and NIFA-Insaf were planted at the progressive farmers' fields in the districts of Nowshera, Charsada, Swabi, Timergarah, Attock and Kohat during Rabi 2016-17. Encouraging results of seed yield up to 5094 kg ha^{-1}were reported by the farmers.

The genetic purity of oilseed brassica varieties *viz*., Abasin-95, NIFA-Raya, Durr-e-NIFA and NIFA-Gold was maintained through production of BNS. A total of 865 kg Pre Basic Seed of these varieties was produced and distributed. In the variety popularization program 10 demonstration plots of NIFA-Gold, Durr-e-NIFA and Abasin-95 were planted at the progressive farmers' fields in the districts of Swabi and Mardan during Rabi 2016-17. The program yielded encouraging results as farmers reported the crop yield in the range of 1.8 to 4 tons per hectare. Two oilseed brassica candidate mutant lines one each of rapeseed (011 K-16-

3) and mustard (MM-I/011-56) were evaluated for the first year mandatory testing in National trials inclusive of eighteen candidate lines of each rapeseed and mustard. The rapeseed mutant (011 K-16-3) exhibited 4% higher seed yield (1772 kg ha^{-1}) than commercial check Faisal-Canola and showed worth by exhibiting 3 to 21 % higher seed yield over seven of eleven locations.

In Mungbean advanced yield trials, 10 out of 18 recombinants, produced statistically significant ($p \leq 0.05$) higher seed yield (1434-1864 kg ha^{-1}) as compared to the check variety Ramzan (Average 1276 kg ha^{-1}). Two candidate lines, NIFA-Mung-4 (NFM-3-3) and NIFA-Mung-5 (NFM-5-36-27) were contributed in NUYT to evaluate for adaptability. Both lines showed better yield than standard national check variety. These candidate lines have also been contributed in NUYT to evaluate for second year in 2017.

Eighteen advanced chickpea mutant lines along with check variety NIFA-2005 were evaluated in 2 different sets of replicated yield trials during 2016-2017. A total of 12 advanced mutant lines in the two yield trials produced statistically significant ($p \leq 0.05$) higher seed yield (2836-3547 kg ha^{-1}) as compared to the check variety, NIFA-2005 (Average yield of 2605 kg ha^{-1}). These mutants exhibited 20.5-24g/100 seed weight and better plant type. Three chickpea candidate lines i.e., NIFA-1, NIFA-2 and NIFA-3 had been contributed for adaptability evaluation in NUYT during 2016-17 but performance was not better. These lines have been contributed again for the second year evaluation in NUYT during 2017-18.

The biotechnology group is engaged on the improvement of sugarcane and stevia for higher yield/brix and steviosides contents. The seed of high yielding with high brix content sugarcane lines CPSG-169 and CPSG-316 was multiplied and will be included in national trials for varietal development.

The group is also working on the improvement of stone fruits (peach) for higher yield, quality and insect/pest resistance. Different rootstocks of stone fruits (Peshawar/Swat local) irradiated with gamma rays and budded with two commercial peach varieties (Early Grand and Florida King) for fruit quality, yield and insect/pest resistance.

FOOD AND NUTRITION

High protein snack food product was prepared through extrusion cooking of legumes & cereals. The resultant product have 17% protein and 2.15g/total phenols with better expansion ratio & bulk density. For the preservation of fruits and vegetables, low cost infra-red heating dryer was designed for the drying of cantaloupe. In an effort to reduce the post-harvest losses in horticulture crops, guava drink and strawberry jam were prepared by using stevia 3% and 2% liquid stevia extract as a non-caloric sweetener, respectively.

Irradiation, autoclaving and their combination treatments were carried out to preserve the meal. Combined autoclaved & irradiation treatments at the dose rate 7.5 kGy for 5min and 5 kGy for 10 minutes exhibited no microbial counts during the entire storage period of six months. In

another experiment, nutrient enrich meal was prepared by minced meat with 10% enrichment of alfalfa and treated with 10 kGy, 12 kGy & autoclaved (121°C for 15 min). The results showed that no bacterial count was noted in any treated samples during 90 days storage study. Mushroom cultivation technology was transferred to farming and landless community of KP, upper Punjab and Baluchistan. More than 10 workshops have been organized so far in different districts of KP and Baluchistan and around 12 model farms have been established. For button mushroom, casing soil or peat mass was prepared by mixing the clay soil with loamy soil & dung manure with adjusted pH. The dosimeters were calibrated with the guidelines of IAEA, the results were found equivalent to target doses.

Vitamin A was quantified in various brands oil available in the Peshawar vicinity through spectrophotometer and HPLC methods and found that vitamin A content varied from 15 to 37 iu/g. Moreover, NIFA canteen menu showed average per capita consumption of vitamin A as 97.06IU which is about to 25% of daily requirement of an adult. Nutrition section also successfully developed the vitamin A spot test kit for the qualitative analysis of vitamin A in dietary oils. These kits were supply to the Global Alliance for Improved Nutrition (GAIN) Islamabad for the distribution in the oil industry for fortification quality control monitoring.
Analytical grade table salt was adulterated with same element having similar concentration of element present in poor rock salt of KP and noticed that iodine retention was significantly affected by iron which is present in salt. Moreover, iodine losses were recorded in the range of 37.5 to 52.5 % in the poor salt composition due to these impurities.

PLANT PROTECTION

Plant Protection Division has three main research groups; agriculture entomology, plant pathology and medical entomology. The agriculture entomology is involved in the IPM of fruit fly, chick pea pod borer and termite control. Scientists within this group are also involved in the biological control using trichogramma and have also developed irradiation doses for control of quarantine insect pests posing barriers for export of our fruits and vegetables to the foreign countries. The medical entomology group is involved in surveillance and control of dengue vectors and risk reduced management of disease carrying vectors. The plant pathology group works on the surveillance and control of pathogens of various crops and vegetables. The developed products and technologies under all three groups are transferred to the academia, researchers, agriculture extension specialists, farmers as end users and community leaders through training, workshops, seminars and print materials.

SOIL AND ENVIRONMENTAL SCIENCES

The natural resources (soil, water and nutrients) use efficiency and crop productivity are influenced by climate change. The agricultural production is mostly affected by the severity and pace of climate change in developing countries and face bigger repercussions.

Adoption of smart agriculture practices devised by the scientists of S & ESD are among the strategies to combat the negative impacts of climate change on natural resources use efficiency. These practices include the integrated management of nutrients and water for field and horticultural crops and have been transferred to the growers of various districts of KP at the eve of Farmers' day, Zinc day and other workshops.

The critical timing, methods and economical levels of fertilizer and irrigation for tomato and cucumber production under high tunnel were identified. The maximum fruit yield of tomato was recorded in the treatment receiving NPK (75:75:90 kg ha^{-1}) as soil application at 30 day interval starting after establishment of crop (20 days after transplantation) till mid of June and with drip irrigation (10:10:15 NPK kg ha^{-1}) at 7 days interval. The technology of tunnel farming was demonstrated to the vegetable growers under the University of Agriculture, Peshawar, Endowment Fund in which more than 100 growers, students, researchers and academicians participated.

Other salient findings include the identification of Zn and P efficient wheat genotypes. The zinc efficiency was determined by taking into account this variation in dry matter production that varied between 10.7 to 64.3%. The genotypes ranked as Zn-inefficient (NRL-1521, NRL-1524) produced significantly lower dry matter yields than the Zn-efficient cultivars NRL-1502 and NRL-1504 at the Zn-deficient level. Wheat genotypes NRL-1503 and NRL-1521 were found P-efficient while NRL-1504 and NRL-1520 were found P in-efficient genotypes.

The studies on efficient use of nutrients and water for improving bio-energy crops production on marginal lands revealed that the maximum average grain yield (2.6 t ha^{-1}), WUE (22.3 kg ha^{-1} mm^{-1}) and N uptake (83.56 kg ha^{-1}) were depicted by rapeseed line RM3 as compared to RM1 and RM2. It is concluded that 50 kg N ha^{-1} may be the economical and optimum level N for all three tested lines under present conditions.

Under root trait study it was observed that varieties had higher water use efficiency under rain-fed conditions than under irrigated conditions. NIFA-Lalma (51 kg ha^{-1} mm^{-1}) and NIFA-Aman (15 kg $ha^{-1}mm^{-1}$) were the most water use efficient varieties under rain-fed and irrigated conditions, respectively.

Under a grant jointly sponsored by Pakistan Science Foundation and Turkish Cooperation and Coordination Agency, twenty one (21) small and four (4) large bio-geysers were fabricated and demonstrated at community level in Hazara division and district Swat. A training workshop for one hundred (100) participants on the use and maintenance of dual technology of agro-waste composting and bio-geyser was organized at Chattar Plain, Mansehra.

Preliminary findings indicate positive effect of combined application of chemical and organic fertilizers (compost and compost tea) towards bringing an improvement in potato yield.

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Director NIFA

PLANT BREEDING AND GENETICS DIVISION

Wheat Irrigated

Seed production and maintenance of NIFA released wheat varieties

NIFA since its establishment has released a number of improved varieties like Baktawar, Fakhr-e-Sarhad and Bathoor-08 for irrigated areas that are continuously performing well in the province. There is an increasing demand of seed of these varieties from the government organizations, seed companies and farming community. A new wheat variety "NIFA-Aman" has been approved in 37th Provincial Seed Council meeting held on 19-09-2017 for commercial production in irrigated areas of KPK. In addition continuous efforts are being made by the wheat breeders at NIFA for maintenance of seed purity and production of quality seed. Progeny rows / blocks of NIFA wheat varieties were planted at experimental farm of the institute. Progeny rows / blocks having off-type plants were discarded. Breeder nucleus seed was planted for production of pre-basic seed duly inspected by the FSC & RD officials. A total of 5021 kg quality seed of NIFA-Aman, NIFA-Battoor-08 and Fakhr-e-Sarhad was produced, processed and got certified by FSC & RD. The seed was distributed to Department of Agriculture Extension, seed companies and farming communities of KP.

Evaluation of candidate wheat lines in National Uniform Yield Trials (NUYT) under irrigated conditions

The country-wide field evaluation of candidate varieties provided by wheat breeders is a vital link between genetic improvement and the production environment. Based on proving worth for higher yield and yield components in provincial multi-locational trials, two newly developed candidate lines, i.e. SRN-13121 and CT-12176 were subjected to the first and second year mandatory evaluation in the national trials. Agronomic data of the trial recorded at NIFA was submitted to National Wheat Coordinator for necessary compilation at country level. Based on its yield performance and disease resistance the line CT-12176 was included in the NUYT 2016-17 for the second year mandatory evaluation. NUYT pooled analysis showed that CT-12176 secured 1st position and produced higher mean grain yield (5488 kg ha^{-1}) over all the candidate lines in KP. Moreover, this line was also found resistant to all three types of rusts i.e. Leaf Rust, Yellow Rust and Stem Rust as reported by Crop Disease Research Institute (CDRI report 2016-17).

Evaluation of advanced wheat lines in Khyber Pakhtunkhwa Yield Trials (KPWYT) under irrigated conditions of KP

Multi-location testing/zonal trial of advanced wheat lines is pre-requisite for development of new genotypes with wider adaptability and selection of suitable candidate varieties for evaluation in NUYT. For assessment of grain yield stability, six promising genotypes (CTRN-140070, CTRN-140085, CTG-154013, CTG-154022, CTG-154028 and CTG-

154029) along with local commercial check *cv*. NIFA-Aman were tested at 13 locations of KP. The result received so for revealed that the genotypes CTG-154013 and CTG-154028 secured 1st and 2nd position at Peshawar, Nowshera, Bunir, Seri Naurang and D.I.Khan. These lines will be included in the 1st year mandatory national trials in order to test their grain yield performance on country level. The lines will also be evaluated for prevailing diseases by Crop Disease Research Institute (CDRI), Islamabad. As usual, NUWYT sets will be planted at NIFA and data for individual candidate variety will be recorded.

Agronomic evaluation of elite wheat genotypes in advanced yield trials under irrigated conditions:

Evaluation of desirable elite genotypes on the basis of field performance in advanced yield trials is a prerequisite for further evaluation in Multi-location trials. The selected genotypes are being tested in advanced yield trials at NIFA.

A total of 66 genotypes were evaluated in three advanced selection yield trials under normal and late planting conditions.

In **ASYT-1**, 10 genotypes out yielded both the check cultivars. Genotype CT-151098 produced the highest grain yield (7764 kg ha^{-1}), followed by WPEP-15212 (7553 kg ha^{-1}) and CT-151103 (7386 kg ha^{-1}) in comparison to check cultivars.

In **ASYT-II**, twelve genotypes out yielded both the check cultivars while six genotypes out yielded low yielding check Paktunkhwa-15; (5986 kg ha^{-1}). The highest yielding genotypes were CTRN-156108; (7386 kg ha^{-1}) followed by CTRN-156127 (7253 kg ha^{-1}) and CTRN-156153 (7219 kg ha^{-1}).

In **ASYT-III**, 15 genotypes out yielded both check cultivars while three genotypes out yielded low yielding check cultivar. The genotype CTES-16135 produced the highest grain yield (7330 kg ha^{-1}) followed by CTES-16114 (7108 kg ha^{-1}) and CTES-16123(7053 kg ha^{-1}). The selected four genotypes on the basis of plant type, grain yield and disease reaction will be evaluated in KPWYT at different locations for grain yield and resistance to prevailing diseases of wheat.

Preliminary evaluation of new genotypes:

Preliminary yield trials provide an important platform for detailed assessment with regards to yield and yield components of the newly selected wheat genotypes from non-replicated observation nurseries, mutant population and recombinants. One hundred and twenty genotypes were evaluated in PYT-I, PYT-II and PYT-III including three check varieties (NIFA-Aman, Pirsabak-2013 and Pakhtunkhwa-15). Each trial consisted of 40 genotypes and was evaluated under both normal and late planting conditions at NIFA. Based on yield performance and disease reaction, 41 genotypes were selected which will be further evaluated in advanced selected yield trials.

In **PYT-I**, 14 genotypes were selected based on their field performance and grain yield. Eight genotypes produced higher grain yield (7666 kg ha^{-1} to 8266 kg ha^{-1}) than the high yielding check (NIFA-Aman; 7266 kg ha^{-1}), while 6 genotypes out yielded low yielding checks (Pakhtunkhwa-15; 6000 kg ha^{-1} and Pirsabak-2013; 6100 kg ha^{-1}). The highest grain yield was recorded for genotype CT-

161130 (8266 kg ha^{-1}) followed by CT-161187 (8166 kg ha^{-1}).

In **PYT-II,** 16 genotypes were selected based on grain yield and disease resistance**.** Out of which 13 genotypes out yielded the high yielding check cultivar (Pakhtunkhwa-15; 7666 kg ha^{-1}). The highest yielding genotype was CTHN-162056 (8583 kg ha^{-1}) followed by CTHN-162074 (8466 kg ha^{-1}). In addition, 3 genotypes produced higher grain yield than the low yielding check cultivar Pirsabak-13 (7166 kg ha^{-1}).

In **PYT-III** based on grain yield and disease resistance, 11 genotypes were selected**.** Out of which 2 genotypes out yielded the high yielding check cultivar (Pakhtunkhwa-2015; 7833 kg ha^{-1}). The highest grain yield was recorded for genotype NON-16053 (8166 kg ha^{-1}) followed by NON-16078 (8066 kg ha^{-1}). In addition 9 genotypes produced higher grain yield in the range of 6700 to 7233 kg ha^{-1} than the low yielding check cultivar Pirsabak-13 (6666 kg ha^{-1}).

Field evaluation of exotic wheat germplasm

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

49th IBWSN (International Bread Wheat Screening Nursery) consisting of **294** genotypes received from CIMMYT, Mexico, was evaluated with local check NIFA-Bathoor. Based on plant type, yield performance and disease reaction (*Yr, Lr* & *Ls*), a total of **28** genotypes were initially selected for further evaluation. The selected genotypes out yielded the check cultivar Bathoor-08 (4888-7110 kg ha^{-1}) by producing grain yield in the range of 6310 to 7999kg ha^{-1}.

11th SRN (Stem Rust Nursery) consisting of **171** genotypes was evaluated for yield performance and diseases (*Yr, Lr* & *Ls*) reaction with local check NIFA-Aman. Five genotypes were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety (6148 kg ha^{-1}) by producing grain yield in the range of 6222 - 6666 kg ha^{-1}.

37th ESWYT (Elite Selection Wheat Yield Trial**)** consisting of **50** genotypes (with 2 replications) was evaluated for yield performance and reaction against diseases (*Yr, Lr* and *Ls*) with local check NIFA-Aman. Nine genotypes were selected for further evaluation and confirmation of desired traits. The selected genotypes out yielded the check variety by producing grain yield in the range of 7164 to 7747 kg ha^{-1}.

17th SBWN-HT (Spring Bread Wheat Observation Nursery for Heat Tolerance) consisting of **160** genotypes was evaluated for yield performance and reaction against diseases (*Yr, Lr* & *Ls*) with local check NIFA-Aman. Based on poor performance with respect to yield and disease, none of the genotype was selected for further evaluation.

17th ESBWYT (Elite Spring Bread Wheat Yield Trial) consisting of **50** genotypes (with 2 replications) was evaluated for yield and disease resistance (*Yr, Lr, Ls* & BYD) with local check NIF-Aman. Only one genotype i.e. IC-17012 with grain yield 6699 kg ha^{-1} and desirable disease response was selected for further evaluation and confirmation of its desired traits.

27th HRWSN (High Rainfall Wheat Screening Nursery) consisting of 116 genotypes was evaluated for yield performance and reaction against different diseases in comparison with local check NIFA-Aman. Seven genotypes were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety (5155 to 6399 kg ha^{-1}) by producing grain yield in the range of 5866 to 7110 kg ha^{-1}.

17th DSBWYT (Dry Spring Bread Wheat Yield Trial) comprising of 50 genotypes was also evaluated in 2 replications for yield performance and resistance against diseases (*Yr, Lr, Ls* & BYD) with local check NIFA-Aman. Based on yield performance and resistance against the prevailing diseases, three genotypes were selected for further evaluation. The selected genotypes out yielded the check cultivar (5047 kg ha^{-1}) by producing mean grain yield in the range of 5237 to 5713 kg ha^{-1}.

4th WYCYT (Wheat Yield Consortium Yield Trial) consisting of 30 genotypes was evaluated in two replications for yield performance and resistance against diseases (*Yr, Lr, Ls* & BYD) in comparison with local check NIFA-Aman. However, no selection was made based on low yield performance and disease response.

NON (NIFA Observation Nursery) consisting of 16 exotic genotypes, was evaluated with local checks Paktunkhwa-15 and NIFA-Aman. Two genotypes i.e. Aust-45 (7110 kg ha^{-1}) and Aust-32 (6765 kg ha^{-1}) out yielded the high yielding check Paktunkhwa-15; 6745 kg ha^{-1}). Whereas, the genotypes Aust-21 and Aust-37 out yielded (6666 kg ha^{-1} each) the low yielding check NIFA-Aman (6577 kg ha^{-1}).

Creation of new genetic variability and raising of segregating populations

Raising and maintenance of different segregating populations developed through conventional hybridization and single gene mutation, using gamma irradiation as mutagen, is the most important breeding strategy routinely carried out as a part of wheat improvement program at NIFA. The effort may ultimately result in the development of high yielding, disease resistant and widely adaptable homozygous genotypes to be released as genetically improved wheat varieties for boosting wheat production.

A crossing block consisting of 137 genetically variable 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, twenty new cross combinations among desirable wheat genotypes were attempted. F_0 seeds were separately harvested from 14 successful cross combinations. Following modified pedigree / bulk selection method, 10

desirable disease resistant and high yielding recombinants were selected from F_4 population resulted from 25 cross combinations. Similarly, 24 out of 342 desirable recombinants with yellow rust resistance and higher tillering capacity were retained from F_6 population. The populations were the result of 15 cross combinations. Two desirable mutants of Fakhr-e- Sarhad (irradiated @ 150 Gy with disease resistance and better idiotypes) were retained from M_4 population. The M_4 was the result of two varieties i.e. Bathoor and Fakhr-e- Sarhad with 150, 200 and 250 Gy doses of gamma rays. The selected recombinants as well as mutants will be further evaluated in NIFA Observation Nursery (NON) and yield trial (PYT) for confirmation of their resistance against diseases and yield performance.

Wheat Rainfed:

Seed production

A total of 4199 kg quality seed of rainfed wheat varieties i.e., NIFA-Insaf, NIFA-Lalma and Tatara was produced and got certified by Federal Seed Certification and Registration Department (FSC & RD) at the institute. The seed was distributed to Department of Agriculture Extension, seed companies and farming communities of KP

Candidate wheat lines in National Uniform Yield Trails

NIFA elite lines NRL-1123 and NRL-1206 were subjected for mandatory evaluation in National Uniform Wheat Yield Trials (NUWYT- Rainfed) at different sites in the country. NRL-1123 ranked 1st throughout the country during Rabi 2014-15 and 3rd during Rabi 2016-17. The elite Line NRL-1123 also showed excellent results under irrigated conditions in NUWYT-Irrigated (2014-15) and ranked 1st in Khyber Pakhtunkhwa by producing grain yield of 4187 kg ha^{-1} with 8% increase over grand check Pirsabak-13. The candidate line was evaluated for the prevailing rust races in the country by CDRI-Islamabad and it expressed high level of resistance with RRI value of 9 to yellow rusts for consecutive 3 years. It also showed resistance against leaf rust with RRI value of > 8.5 (2014-17).

Evaluation of candidate wheat lines in KPWYT-R

Four elite wheat lines of NIFA (NRL 1406, 1435, 1448 and 1451) were tested across different locations in KP under moisture stress conditions. The data (agronomic/ disease) were recorded at different growth stages of the crop. At NIFA site the line KPWYT-10 out yielded all the candidate lines and produced higher grain yield of 3833 kgha^{-1} followed by KPWYT-07 having grain yield of 3777 kg ha^{-1}.

Advanced Barani Trials (ABT)

Forty-eight promising wheat genotypes were evaluated for grain yield, yield components and disease resistance along with check cultivar NIFA-Lalma in advanced barani trial (ABT) at the institute. Based on grain yield and disease resistance six promising genotypes were selected. NRL-1546 ranked 1st by producing highest grain yield of 6000 kg ha^{-1} followed by NRL-1564 and NRL-541.

Preliminary Barani Trials (PBT-I and PBT-II)

Eighty newly selected wheat genotypes were tested for grain yield, disease resistance and other agronomic traits in two preliminary yield trials (PBT's) under moisture stress conditions at the institute. The trials were planted according to alpha lattice design with two replications. NIFA-Lalma and PR-15 were included as standard checks in these trials. A total of 20 genotypes were selected from these trials. NRL-1637 and NRL-1640 ranked 1st in PBT-I and PBT-II respectively. These selected lines were found resistant to the prevailing races of *Yr*/*Lr*. These selections will be further screened in Advanced Barani Trials in the coming season.

Exotic nurseries and trials:

Semi-Arid wheat screening nursery (34th SAWSN)

A total of 272 exotic genotypes were screened for grain yield, disease resistance and other agronomic traits in non-replicated nursery including local check NIFA-Lalma under rainfed condition at the Institute. Twenty five (25) best genotypes were identified and selected on the basis of higher grain yield and disease resistance.

Semi-Arid Wheat Yield Trial (24th SAWYT)

The semi-arid wheat yield trial consisting of 50 entries was planted on the experimental field of NIFA according to Alpha-lattice design with two replications. Nine genotypes were selected on the basis of higher grain yield and disease resistance.

Stress Adaptive Trait Yield Nursery (6th SATYN)

Twenty seven (27) exotic wheat genotypes were evaluated for grain yield and diseases (*Yr* and *Lr*) in stress adaptive trait yield nursery at NIFA under moisture stress conditions. Statistical design of the trial was alpha lattice with two replications. Based on grain yield and disease resistance only one genotype was selected.

Heat Tolerant Wheat Yield Trial (15th HTWYT)

Due to recent climatic change, heat stress occurs during grain filling stage that reduces grain production in wheat. To develop wheat germplasm for heat stress, 50 exotic wheat genotypes along with NIFA-Lalma as standard check were screened in 15th HTWYT at the institute, according to alpha lattice design with two replications. Five genotypes were selected for further studies.

Development and selection of new germplasm

To broaden the genetic base of the genotypes and keeping in view of our breeding objectives, new crosses between selected lines and varieties were attempted. F_1-F_7 population of different cross combinations were raised and desirable selections were made.

Response of wheat genotypes to disease reaction

Yellow and leaf rust are critical wheat diseases that reduces grain yield. Twenty five wheat genotypes were screened for *Yr*/*Lr* at different hot spots in the country. Four genotypes i.e., NRL-1540, NRL-1541, NRL-1544 and NRL-1545 were

found resistant to both yellow and leaf rust.

Oilseed Brassica:

Genetic purity maintenance and popularization of Oilseed Brassica varieties.

To ensure timely and quality seed availability of oilseed brassica varieties *viz.* Abasin-95, NIFA-Raya, Durr-e-NIFA and NIFA-Gold developed at NIFA, a continuous varietal maintenance cycle is maintained through raising progeny blocks and progeny rows to produce Breeder Nucleus Seed (BNS). True to type progeny blocks were selected on the basis of varietal characteristics. A total of 353 kg Pre Basic Seed (PBS) of Durr-e-NIFA, 251 kg of NIFA-Gold, 211 kg of Abasin-95 and 50 kg of NIFA-Raya were produced. Following variety popularization programme among the farming community of KP province, 10 demonstration plots of NIFA-Gold, Durr-e-NIFA and Abasin-95 were planted at the progressive farmers' fields in the districts of Swabi and Mardan during Rabi 2016-17. The programme yielded encouraging results as farmers reported the crop yield range of 1.8 to 4 tons per hec.

Improvement of rapeseed *(Brassica napus)* and mustard (*Brassica juncea*) through induced mutations and classical breeding techniques

Performance of oilseed brassica candidate lines in National Uniform Yield Trial (NUYT):

Two oilseed brassica candidate mutant lines one each of rapeseed (011 K-16-3) and mustard (MM-I/011-56) were evaluated for the first year mandatory testing in National Uniform Yield Trial (NUYT-2016-17) inclusive of eighteen candidate lines of each rapeseed and mustard contributed by other oilseed breeders of the country and two commercial checks viz., Hyola-401 and Faisal-Canola for rapeseed; Coral-432 and Khanpur-Raya for mustard *spp*. at eleven locations across the country. The mustard mutant (MM-I/011-56) was not noteworthy and remained ordinary to the both checks and some other candidate lines as well. However, the performance of the rapeseed mutant (011 K-16-3) was reasonable. It exhibited 4% higher seed yield (1772 kg/ha) than commercial check Faisal - Canola on overall mean basis. It showed the worth by exhibiting 3 to 21 % high seed yield over seven of eleven locations mean value while remained superior to high yielding commercial check Hyola-401 at four locations by exhibiting 4 to 21 % more seed yield.

Performance of rapeseed recombinants and mustard mutant lines in Multi-location Adaptation Yield Trial:

Based on high yield and better agronomic traits, four mustard (*Brassica juncea*) mutants (MM-27-2; MM-31-3; MM-31-4 and MM-31-5) and eight rapeseed (*Brassica napus*) recombinants (RR-33-1; RR-33-2; RR-33-3; RR-34-1; RR-34-2; RR-40-1; RR-41-4 and RR-41-2) were evaluated against respective commercial check varieties viz., Coral-432 and Hyola-401. The adaptation trial was devised to study the genetic stability and adaptability of advanced lines at different agro-climatic zones in the KP and the Punjab provinces. The trial was laid out in RCBD, replicated

thrice and sown at Nuclear Institute for Food & Agriculture (NIFA), Peshawar, Agricultural Research Station(ARS), Sarai Naurang, Bannu, Agricultural Research Station (ARS), Buffa, Agricultural Research Institute (ARI), Mingora, Swat, Barani Agricultural Research Station (BARS), Kohat, Arid Zone Research Centre (AZRC), D.I. Khan**,** in the KPK; Regional Agricultural Research Institute (RARI), Bahawalpur and Barani Agricultural Research Institute (BARI), Chakwal in Punjab during Rabi 2016-17.

The results were received from BARI, Chakwal, RARI, Bahawalpur and NIFA, Peshawar. The data were statistically analyzed that showed mustard mutant lines MM-31-3 (3222 kg ha^{-1}) and MM-31-5 (3056 kg ha^{-1}) and MM-31-4 (2667 kg ha^{-1}) significantly out yielded commercial check variety Coral-432 (2167 kg ha^{-1}). In case of rapeseed genotypes, the results revealed that only one recombinant line RR 41-4 exceeded with seed yield of 5111 kg ha^{-1} compared to 4639 kg ha^{-1} of commercial check variety Hyola-401. The data of three locations (NIFA, Peshawar; BARI, Chakwal; and RARI, Bahawalpur) subjected to GGE Bi-plot analysis. Eight rapeseed and four genotypes of mustard lines showcased significant difference for genotypes, locations and for G x E interaction. Furthermore, the stability analysis revealed that mustard mutant line MM-31-4 presented yield advantage over commercial check Coral-432 and also confirmed the most stable mustard mutant over three locations while rapeseed recombinant line RR-41-2 (4639 kg ha^{-1}) gained no yield advantage over check variety Hyola-401 (4639 kg ha^{-1}) but expressed higher stability over check variety and rest of the advanced rapeseed recombinant lines.

Agronomic evaluation of mutants/ recombinants in Advanced Yield Trials (AYTs) at NIFA

Four recombinants and five rapeseed mutants viz., RR 3-1, RR 8-1, RR 8-2, RR 9-1, RM 112-2, RM 156-1, RM 183-2, RM 193-1 and RM 276-1 and ten mustard recombinants viz., MR 78-1, MR 80-1, MR 80-2, MR 82-1, MR 83-1, MR 84-1, MR 84-2, MR 86-1, MR 87-1 and MR 88-2 were evaluated separately in two Advanced Yield Trials (AYT-I-rapeseed; and AYT-II-mustard) along with commercial checks Hyola-401 (rapeseed) and Coral 432 (mustard), respectively, at NIFA experimental farm, during 2016-17. The trial was laid out in RCBD, replicated thrice. The outcome of the trials is as under:

Advanced Yield Trial-I:

The results revealed significant difference among the genotypes and the check. The significantly high seed yield was manifested by RR 8-2 (4917 kg ha^{-1}) followed by RM 276-1 (4444 kg ha^{-1}) and RM 112-2 (4416 kg ha^{-1}) against the check Hyola-401 (3139 kg ha^{-1}). Rest of all the entries in the trial produced numerically higher seed yield than the check. All the test entries in the trial also exhibited higher thousand seed weight from 3.63-4.06 g compared to check (3.46 g) while non-significant difference were noted for days to maturity and plant height.

Advanced Yield Trial-II:

Ten mustard recombinants were tested for seed yield and other agronomic characters.

The results revealed non-significant differences either among the test entries or with the check. Three entries produced reasonably high seed yield (8–12%) compared to check (1944 kg ha^{-1}) while rest were either at par or inferior to check Coral 432. None of the entries could perform better than the Coral 432 in respect of earliness however; seven entries exhibited thousand seed weight 4.0 – 4.96 better than check (3.80 g).

Performance of stable mutants for yield and other agronomic characteristics in Preliminary Yield Trials (PYTs)

Stable and high yielding fourteen rapeseed mutants viz., RM/014-1-2; RM/014-1-5; RM/014-2-1; RM/014-2-2; RM/014-3-5; RM/014-3-11; RM/013-1-9; RM/013-3-2; RM/013-1-3; RM/013--10; RM/013-3-10; RRM/013-106-1; RM/013-3-6; RM/013-3-9 and six rapeseed recombinants viz., RR/013-1-5; RR/013-2-6; RR/013-4-3; RR/013-1-9; RR/013-1-4 and RR/013-3-1 were evaluated in three Preliminary Yield Trials; PYT-I, PYT-II and PYT-III along with a commercial checks Hyola-401. The trials were laid out in RCBD, replicated thrice. The outcome of the trials is as under:

Preliminary Yield Trial-I:

Six rapeseed mutants were evaluated in PYT-I along with the commercial check Hyola-401. The multiple comparisons revealed that all the test entries performed better than the check. However, RM/014-1-5 significantly out yielded all the test entries and the check by producing seed yield 6513 kg ha^{-1} followed by RM/014-1-2 and RM/014-2-1 exhibited 5667 and 5458 kg per ha, respectively compared to control Hyola-401 (4083 kg ha^{-1}). With regard to days to maturity, no differences were found while afore mentioned entries also attained bold seeds.

Preliminary Yield Trial-II:

In PYT-II, four recombinants and two rapeseed mutants were evaluated against Hyola-401 (check). The rapeseed mutant RM/013-1-9 harbored highest seed yield (6486 kg ha^{-1}) with good thousand seed weight (3.8g) followed by RR/013-2-6 that achieved 5180 kg ha^{-1} seed yield numerically higher than the check Hyola-401 (4981 kg ha^{-1}). The later was featured with bold seed and attained 4.3 g thousand seed weight. The rapeseed recombinant RR/013-1-9 recorded short stature by exhibiting 162 cm plant height.

Preliminary Yield Trial-III:

In this trial, five mutants, one recombinant mutant and two rapeseed recombinants were tested for their yield performance along with the check Hyola-401. Five rapeseed entries produced more seed yield than the check signifying RM/013-1-3 that produced 6171 kg ha^{-1} compared to check followed by RM/013-3-9 that exhibited 5329 kg ha^{-1}. However, four among the five better performer though produced high seed yield but remained statistically non-significant compared to the check (4728 kg ha^{-1}) and featured with medium to bold size seed.

Field Assessment of newly developed genotypes at an early stage of selection

One hundred and forty one single plant progenies in F_3/M_3 generation were raised

during 2016-17 for their phenotypic assessment towards genetic stability and seed yield performance compared to their respective parents to isolate and select better genotypes/families. The single plant progenies developed from a cross NIFA-Gold x ECH-386; nineteen single plant progenies produced 10-44% more seed yield than the average parent performance while ten out yielded the better parent by 9-41%. Three single plant progenies of the cross Punjab Sarson x NIFA Gold gave good performance and out yielded the average parent and better parent values by 16-23 and 9-17 % respectively. Ten progenies of the cross Shiralee x NIFA-Gold produced 13-47 % more seed yield than the average check while five performed better than the better check by signifying 13-42% higher seed yield.

The aggregate results of single plant progenies revealed that twenty six (26) rapeseed recombinants exhibited 10-47 % increase over the average check value while seventeen (17) out classed the better check by margin of 10-41 % in seed yield.

Handling of breeding populations

F_0 - M_1 / F_1 – M_2 / F_2 generations

A crossing block consisting of forty four rapeseed and mustard germplasm was raised including the parental material of developed breeding population and advanced rapeseed & mustard genotypes. Four diversified mustard lines *viz.* JS-13, Dhoom-Mustard, NIFA-Raya and 45S46 and four rapeseed genotypes *viz*. Abasin-95, Durr-e-NIFA, NIFA-Gold and AZRI rapeseed (NR-2/2016) were utilized in different combinations *viz.* Abasin-95 x NR-2/016; NR-2/016 x Abasin-95; Durr-e-NIFA x NR-2/016; NR-2/016 x Durr-e-NIFA; NIFA-Gold x NR-2/016; NR-2/016 x NIFA-Gold; NIFA-Raya x 45S46; JS – 013 x 45S46 and Dhoom-Mustard x 45S46. In total; one hundred and one (101) crosses were attempted by pollinating five hundred and five (505) stigmas.

Six F_1s developed from crosses Pb. SARSON x SONG-1; SONG-1 x Pb. SARSON; HOP x SONG-1; SONG-1 x HOP; SONG-1 x NR-22/10-11 and NR-22/10-11 x SONG-1 and same number of M_1 by irradiating one each rapeseed and mustard genotype at three gamma doses viz., 1.0, 1.2 and 1.4 kGy were separately bulk harvested cross and dose wise for maintaining the continuity in oilseed breeding to develop early maturing, short stature and high seed yielding varieties endowed with high oil content and better quality.

Single plant selection was executed in line with the objectives laid out for oilseed breeding programme; forty two (42) single plants were selected from F_2 segregating mustard population developed from four crosses. Seed yield per plant ranged from 19-78 g. Few selections exhibited heterotic and heterobeltiotic response while in M_2; one hundred and sixty seven (167) single plants were isolated and selected on the basis of their phenotypic worth over parent and confirmed on post harvesting observations. A part of this material also selected on the basis of high oil and high erucic acid contents to tailor bioenergy crop for marginal land productivity (RAS151070). Twenty six (26) single plants excelled their parents with fifteen (15) exhibited 20% more seed yield per

single plant compared to parent. The selected mutants overall showed 5-50 % high seed yield than parent while single plant seed yield ranged from 14.5-134 g.

Zero Gravity approach to induct genetic variability

To see the effect of zero gravity on the agronomic and quality parameter on rapeseed, one stable genotype was clinostat rotated @ 90 rpm for 72 and 96 hours and planted at NIFA experimental farm. The material was treatment wise harvested. The segregates, if any, will confirm the effect on the genetic material in the following generation.

Quality characterization of oilseeds through NIRS

Near Infrared Reflectance Spectroscopy (NIRS) is a non-destructive, cost, time and labour effective technique for quality analysis of oilseeds. For ongoing project at NIFA, about 642 samples of oilseed germplasm and breeding materials were analyzed for fatty acid profile and glucosinolates contents. Under the Routine Quality Analysis Service to this effect, 4,916 samples of different crops were analyzed with breakup of 4,304 samples of brassica; 287 samples of sunflower; 68 samples of sesame and 257 samples of wheat for academician, researchers of different universities and R & D organizations both at provincial and federal levels.

Pulses Improvement

Mungbean

Advanced recombinants and mutants developed at NIFA were planted to evaluate for seed yield and yield components in 2 sets of advanced and 5 sets of preliminary replicated yield trials at NIFA research farm during 2016. In case of advanced yield trials, 10 out of 18 recombinants, produced statistically significant ($p \leq 0.05$) higher seed yield (1434-1864 kg ha^{-1}) as compared to the check variety Ramzan (Average 1276 kg ha^{-1}). In preliminary yield trials, out of 71 mutants, 45 produced statistically significant ($p \leq 0.05$) higher seed yield (1134-1958 kg ha^{-1}) as compared to the check variety Ramzan (Average 1098 kg ha^{-1}). Two candidate lines, NIFA-Mung-4 (NFM-3-3) and NIFA-Mung-5 (NFM-5-36-27) were contributed in NUYT to evaluate for adaptability. Both lines showed better yield than standard national check variety. These candidate lines have also been contributed in NUYT to evaluate for second year in 2017.

One hundred and sixty one lines were selected from F_4 generation of six different cross combinations i.e., Var. 6601x Ramzan, V 2709 x NM 92, V 2802 x NM 92, NM 51 x NM 98, NM 98 x NFM 5-36-24 and NFM 5-36-24 x NFM 5-36-18 on the basis of morphological traits uniformity and more pods bearing during kharif 2016. Similarly, 80 lines from F_5 generation of 3 different cross combinations i.e., V1128 x Ramzan, V2802 x Ramzan and V2817 x Ramzan were selected on the basis of more pods bearing and good plant types during kharif 2016. The selected lines have been planted in kharif 2017 as line progeny rows for confirmation of their breeding behavior and seed increase for evaluation in preliminary yield trials during kharif 2018. 28 single plant selections from F_3

generations of two cross combination i.e., Ramzan x Kuram Green mung and ML-5 x Kuram Green Mung were selected during kharif 2015 and planted as plant progeny rows in kharif 2017. F_2 populations of 7 different cross combinations i.e., ML-5 x NM 2006, Kuram Green Mung x Ramzan, Sona Mung x NM 2011, ML-5 x NM 2011, Kuram Green Mung x NM 2011, Kuram Green Mung x NM 2006 and ML-5 x Sona Mung have been planted during Kharif 2017 to make selection for more No. of pods and good plant type. 37 mutants from M_3 generation of V2802 (400 Gys) and 29 mutants from M_2 generation of Kuram green (400 Gys) were selected as single plants on the basis of resistance to MYMV (Mungbean Yellow Mosaic Virus) and more pods per plant during kharif 2015 and planted for generation advancement and further selection in kharif 2017.

In case of breeding for black seeded mungbean genotypes, 113 single plant selections were made during kharif 2016 from F_2 generation of a cross 'NIFA-Black Mung x Kuram Black Mung' on the basis of MYMV resistance, seed colour and more pods per plant and planted as plant progeny rows in kharif 2017 for further selection. Bulk populations of M_2 (8000 plants) and M_3 (2000 plants) generations derived from Kuram Black Mung at 400 and 300 Gys, respectively were planted in kharif 2017 for developing MYMV resistant and high yielding black seeded mungbean genotypes. F_1 generations of four 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 were raised during kharif 2016 and picked hybrid plants. F_2 populations of these four cross combinations have been planted in kharif 2017 and selections will be made on the basis of MYMV tolerance, black seed colour and more pods per plant. Eight new 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 Mung were attempted during summer 2016 and F_1 will be raised during summer 2018.

Chickpea

Eighteen advanced mutant lines along with check variety NIFA-2005 were evaluated in 2 different sets of replicated yield trials during 2016-2017. A total of 12 advanced mutant lines in the two yield trials produced statistically significant ($p \leq 0.05$) higher seed yield (2836-3547 kg ha^{-1}) as compared to the check variety, NIFA-2005 (Average yield of 2605 kg ha^{-1}). These mutants exhibited 20.5-24g/100 seed weight and better plant type. Three chickpea candidate lines i.e., NIFA-1, NIFA-2 and NIFA-3 had been contributed for adaptability evaluation in NUYT during 2016-17 but performance was not better. These lines have been contributed again for the second year evaluation in NUYT during 2017-18.

F_4 populations of six cross combinations i.e. Thal-2006 x NIFA-2005, BRC390 x NIFA-2005, Dasht x NIFA-2005, NIFA-88 x NIFA-2005, NIFA-2005 x NDC-6-I-6 and NIFA-2005 x NDC-6-I-7 were raised during 2016-17, and selected 179 recombinant lines on the basis of more pods per plant and good plant type. F_1

generations of 8 cross combinations i.e., NDC-6-15-6 x BRC 390, CM541/05 x BRC 390, CM156/05 x BRC390, BRC390 x NIF-2005, CH 16/06 x NIFA-2005, Pb 2008 x CM156/05, D-08025 x NIFA-2005 and D-075-09 x NIFA-2005 were raised, and a total of 59 hybrid plants were picked, threshed and bagged individually.

To create genetic variability for yield and yield components, 12 new cross-combinations viz. D-09-027 x D-08-025, D-09-013 x D-08-025, NIFA-2500 x BRC390, D-075-09 x CH24/07, D-10008 x NDC-6-15-6, BRC390 x D-075-09, CH24/07 x D-09-013, D-09-027 x D-08-025, NIFA-2005 x D-08-025, Pb-2008 x NDC-6-15-6, D-075-09 x NDC-6-15-6 and D-08-025 x NDC-6-15-6, were attempted and all hybrid seed were collected.

Seeds of D-075-09 were irradiated at 400 Gys gamma rays to create genetic variability for more pods and better plant type, and M_1 generation was raised during 2016-17. All M_1 plants were picked, threshed, and bagged individually, which will be sown as plant-progeny-rows in M_2 generation during 2017-18 for further single plant selection. From M_2 populations of CM541/05, Pb-2008 and NDC-6-I-7 comprising of 2000, 2100 and 2100 single plants, respectively, irradiated at 300 Gys, a total of 603, 73 and 06 single plants, respectively, were selected on the basis of desired traits. 1000 and 1100 single plants selected from M_2 generations of Pb-2008 (300 Gys) and CM541/05 (300 Gys), respectively, during 2015-16 were raised as M_3 generations during 2016-17, and 68 and 179 single plant selections, respectively were made based on more pods and better plant type.

Biotechnology

Sugarcane improvement:

Seed multiplication of advanced lines

Seed of high yielding and high brix content sugarcane lines NIFA-1, CPSG-169 and CPSG-316 was multiplied. The plot size of each line was 20 x 20 meter, one meter apart. One line is under evaluation for confirmation in the National trials for varietal development.

Evaluation of sugarcane genotypes in Preliminary yield trials

Twenty one sugarcane genotypes were evaluated in two preliminary yield trials PYT-1 and PYT-2 at NIFA for high cane and sugar yield. Commercial line CP 77/400 was included as a check variety and the plot size was 6x4 m^2. The experiment was laid out according to RCBD. The performances of the genotypes are summarized below:

Agronomic evaluation

Number of nodes/plant: Out of 21 genotypes, the highest number of nodes (15.8) was recorded in line CPSG-239 and US-165. This was followed by line HOSG-315 with 13.9 number of nodes per plant.

Internode length: The highest inter-node length of 20.2 cm was recorded in line HOSG-1021 followed by 17.4 cm inter-node length in line US-694. The lowest internode length of 6.9 cm was recorded in line US-165.

Cane thickness: The data on cane thickness showed variation among all the genotypes. The maximum cane thickness of 25.0 mm was recorded in line CPSG-159

followed by line HOSG-1257 with cane thickness of 24.8 mm. The lowest cane thickness of 20 mm was recorded in line US-165.

Stalk/plant: The highest stalk/plant (5.1) was recorded in line HOSG-1257. Line HOSG-315, HOSG-1607 and HOSG-1657 were at par with CP 77/400 where 5.0 stalk/plant were recorded. The lowest stalk/plant of 4.0 was recorded in line HOSG-200, HOSG-104, HOSG-1021 and QSG-69.

Plant height: The data on plant height of all the genotypes showed significant variation. The highest plant height (187.0 cm) was recorded in Line HOSG-315 followed by line US-127 with height of 167 cm. The lowest plant height of 116 cm was recorded in line US-165.

Cane yield: Significant variations in yield were observed among all the genotypes under study. The highest yield of 91.0 t/ha was recorded in line HOSG-315 followed by line US-127 with 84.5 t/ha. The lowest yield of 51.8 t/ha was recorded in check line CP 77/400.

Quality evaluation:

Brix (%): The highest brix of 23.0% was recorded in line US-127 and US-165. This was followed by line HOSG-315, HOSG-1257 with 21.0 % brix.

Sugar Recovery (%): The data regarding sugar recovery of all the genotypes showed significant variation. According to the results, highest recovery of 13.2 % was recorded in line HOSG-1257 and US-133 followed by Line HOSG-315 with recovery of 10.8 %. The lowest recovery of 9.0 % was recorded in line CPSG-159.

Purity (%): The highest purity of 93% was recorded in line HOSG-1257 followed by line US-133 and CP 77/400 with purity of 90.82%. While the lowest purity of 80 % was recorded in line US-778.

Pol%: The highest Pol of 20.37% was recorded in line HOSG-1257 followed by line US-127 with 18.0 % Pol. The lowest Pol of 17 % was recorded in line HOSG-315.

Evaluation of sugarcane genotypes in advance yield trial

Sugarcane advance yield trial consisted of thirteen genotypes with a commercial check CP 77/400 to compare various parameters like percent germination, tillers/plant, maturity, brix percent, and cane yield etc was executed. The trial was sown using standard plot size of 6 x 4 m^2 in RCBD. The highest plant height of 224.2 cm was recorded in line CPSG-468 followed by 203.1cm in line CPSG-1550. The Longest internode length of 10.4 cm was recorded in the line CPSG-1004. Similarly the highest number of nodes (19.3) was recorded in line CPSG-676 followed by CPSG-468 with internode length of 19.1 cm. The highest stalk/plant (5.3) was recorded in line HOSG-1145. The highest cane thickness of 36.3mm was recorded in line CSSG-668. In quality characters, the highest recovery of 11.2% was recorded by CPSG-1004. This was followed by Line CPSG-1550 with 11.01% recovery. Similarly the highest commercial cane sugar (CCS) of 13.6 % was recorded by line - CPSG-1004. The highest purity of 84.6 % was recorded in line CPSG-1004. The highest Pol of 20.1% was recorded in line CPSG-1550 followed by line CPSG-3453 with 20.0 % Pol.

Performance of national uniform varietal Trial

Ten lines were evaluated in National Uniform Varietal Trial, three lines received from ARRI, Faisalabad, four from NARC and two from NSCRI Thatta. The trial was executed using standard plot size of 7 x 4 m^2. The commercial variety CP77/400 was used as check**.** The highest Stalk/plant (5.0) was recorded in line Aus- 104, the highest Internodes (19.3) was recorded in line CPSG-85, Longest internode with length of (11.5cm) was recorded in line US 469 and maximum plant height (201.3 cm) was recorded in line NARC-1. The highest cane thickness (29.9 mm) was recorded in line CPSG-85. The highest yield of 95.3 t/ha was recorded in line NIFA-1 followed by line SP-576 with 90 t/ha. In sugar recovery all the lines were inferior and could not compete with check. The highest recovery of 10.2% was recorded in line NARC-1 followed by Aus-383 with recovery of 10%. The highest brix of 20.7% was recorded in line Aus-104.

Transplantation of seedlings from sugarcane fuzz:

Sugarcane fuzz received from National Sugar Crops Research Institute, Thatta was sown in control environment in the lathe house. The highest germination was shown by HoTh-326 followed by CPSG-3453. Seedling plants of HoTh-326 were transplanted to the field for evaluation.

Creation of genetic variability in sugarcane/ raising of M_1 generation:

Sugarcane variety CP-77/400 commercially grown in KP province was subjected to gamma rays for creation of genetic variability for frost tolerance, early maturity with high cane and sugar yield potential. Five hundred buds were exposed to 0.05, 0.1, 0.15 and 0.20 KGy gamma rays using ^{60}Co gamma cell source. The radiated material was sown in the field along with control to raise the M_1 generation.

Genetic diversity studies in sugarcane

Genomic DNA was extracted from 30 genotypes using CTAB method with little modification. The genomic DNA was quantified on agarose gel with a standard. In this study, 8 % PAGE gel was standardised first time for obvious and clear banding pattern with modified silver staining method for sugarcane diversity/traits. For diversity studies 16 micro-satellite (SSR) primers were used to assess molecular variation and diversity in 30 promising sugarcane accessions. Among all 30 selected sugarcane genotypes internodes/plant**,** internodes length**,** stalk/plant**,** cane thickness, plant height**,** sugar recovery, cane yield and chlorophyll range were studied. In agronomic data of sugarcane genotypes maximum yield (94.00 t/ha) in CPSG1550, highest recovery (13.58%) in genotype CPSG-3453 and maximum chlorophyll value (32.63%) were recorded in line CP-77/400. However, in molecular study a total of 16 SSR markers were used for diversity and a total of 152 bands identified in which 116 were polymorphic bands with a range of 33-100%. Primer STMS34 amplified bands (150, 200 and 300bp), UGMS39 (150bp) and UGMS118 (300bp) in high sugar content genotypes. Furthermore, for red rot studies the primer SMC31CUQ and SMC597CS showed tolerance in genotypes at 600/300 bp and high tolerance at 200/600

bp banding pattern respectively. The dendrogram result showed two clusters with 13 genotypes in cluster I and 17 genotypes in cluster II. However, analysis of correlation such as in *S. officinarum* genotype high rate of yield CPSG1550, maximum sugar recovery percentage CPSG3453 and high level of the chlorophyll value CP77/400 found in group III in cluster II of the dendrogram.

Stone fruits improvement

Peach stones and bud wood was irradiated with different doses of gamma rays to develop high yielding and pest resistant rootstocks and mutants of peach. The irradiated peach stone were sown in November, 2016 along with control in 4 replications using randomized complete block design. The peach stones were also subjected to different concentrations of HCl and GA_3 for germination and dormancy breaking. Effect of irradiation, chemical treatments and GA_3 will be investigated on percent germination, days to germination and seedling height.

Stevia improvement

Effect of different Polyethylene Glycol concentrations on Callus Growth:

The study was conducted on the effect of different PEG concentrations on callus growth of *stevia rabaudiana*. MS media was supplemented with 2 ml 2 4, D/lit for callus induction. Results showed that application PEG had detrimental effect on most of the morphological characteristics of callus. Maximum callus induction was recorded in control treatment, while minimum callus induction was noted in treatment containing 4% PEG. Callus fresh and dry weight decreased with increase in PEG concentration.

Effect of different Polyethylene Glycol concentrations on Morphological & Biochemical Characters

Calli were then cultured on the shooting media having different PEG concentrations. MS media were supplemented with 2 ml BAP/liter for shoot development. Various morphological characteristics like shoot length, number of leaves, shoot fresh weight and chlorophyll content were studied. All the morphological traits exhibited negative correlation with poly ethylene glycol concentration. All the above mentioned parameters showed a decrease in their growth. It indicates that PEG in the nutrient medium shows detrimental effect on normal growth and development. Biochemical compounds such as phenols, flavonoid and anti-oxidant activity have positive correlation with PEG application.

Effect of different polyethylene glycol concentrations on root performance

Shoots were selected and cultured on rooting media according to the treatments. MS media were supplemented with IAA and IBA 2ml/liter with PEG concentrations. Different traits were studied such as root length, number of roots $plant^{-1}$, root fresh and dry weight. Results showed that almost all the parameters related to plant growth were negatively affected by the application of PEG to culture media.

PLANT PROTECTION DIVISION

Agricultural Entomology

Fruit flies

Fruit flies cause tremendous losses and damages to fruits and vegetables at farm level, as well as to traders, retailers and exporters. The nature of problem is complex and the presence of flies impedes trade by facing quarantine restrictions and costly treatment procedures. 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. Male Annihilation Technique (MAT) provides an easy and environmentally safe approach of fly control in fruit and vegetable orchards if applied properly on area wide basis. Our efforts are therefore directed to improve the efficiency of MAT by adding various chemicals in the commercial lures.

Effect of mixing food attractants in Cue-lure on trapping efficiency of melon flies

To synergize the attraction of cue lure, different concentrations i.e. 5%, 10%, 15%, 20%, 25%, 30% and 50% of cue lure blended in mixture of three preferred food attractants i.e. protein hydrolysate, yeast and molasses in equal ratio along with 5% dipterex and 10% sugar, were tested on bitter gourd at Wadpaga village, Peshawar against melon fly. Five ml test material was applied in each trap on cotton wicks. Traps were installed at a height of 1.5-2m above ground in the field. Cue lure standard traps (100% cue lure) were also installed as check for comparison of results. There were nine treatments including control and replicated four times in RCB design. Weekly data were recorded since 1st June to 27th July, 2017. The results indicated that maximum number of flies (277 mean flies/treatment) were captured in 20 % cue lure followed by 25 % cue lure (261 mean flies/treatment) as compared to 261 mean flies/treatment in the standard traps, whereas, lowest number of flies (35.25 mean flies/treatment) were captured in traps having no cue lure. Thus, it is concluded that very cheap formulation (20% lure) attracted significantly greater number of flies than the rest of the formulations and can be used for efficient trapping of fruit fly in bitter gourd.

Effect of mixing food attractants in Methyl Eugenol on trapping efficiency of fruit flies

To synergize the attraction of methyl eugenol, different concentrations i.e. 5%, 10%, 15%, 20%, 25%, 30% and 50% of cue lure blended in mixture of three preferred food attractants i.e. protein hydrolysate, yeast and molasses in equal ratio along with 5% dipterex and 10% sugar, were tested in pear orchard at Chamkani village, Peshawar against fruit fly. Five ml test material was applied in each trap on cotton wicks. Traps were installed at a height of 1.5-2m above ground in the trees. Methyl eugenol's standard traps (100% Methyl eugenol) were also installed as check for comparison of results. There were nine

treatments including control and replicated four times in RCB design. Weekly data were recorded since 18th May to 27th July, 2017. The results indicated that maximum number of flies (463 mean flies/treatment) was captured in the standard traps (100% cue lure) followed by 50 % cue lure (226.25 mean flies/treatment) and 20 % cue lure (160 mean flies/treatment), whereas, lowest number of flies (21.75 mean flies/ treatment) was captured in traps having 10% cue lure. Thus, it is concluded that the standard traps attracted significantly greater number of flies than the rest of the formulations and should be used for efficient trapping of fruit fly in pear orchards.

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

The investigations are being undertaken in guava orchard at the experimental farm of NIFA. Ten lure baited traps were randomly installed in the orchard for trapping and counting the adults (September, 2016-Semptember, 2017). Each trap serves as an experimental unit. Daily degree day summations was calculated since September, 2016 to September, 2017 and matched with the actual field observations of adult. The results so far achieved, indicated that the pest was active in November (7.43, 4.85, 18.6 flies/trap) and December (30.71 flies/trap). Thereafter, the population declined till 4th January (0.14 flies/trap) and disappeared onward. The pest remained hibernated till mid-February. The next brood started on 22nd February (0.71 flies/trap) and attained its peak (101 flies/trap) on 26th July. The experiment is still in progress and after the data completion, the overall insect activity will be correlated with the temperature, humidity and rainfall etc. and a degree day model will be developed.

Quarantine Pests

Pakistan has a wide range of tropical, sub-tropical and temperate fruits, vegetables and spices. Many of the fruits and vegetables are consumed indigenously while a meager part is exported to foreign countries. Citrus is exported to Russia, Iran, Afghanistan and the Middle East countries and mangos are mainly exported to Dubai, Saudi Arabia, Oman, UK, Kuwait, Bahrain, France and Germany. Our dry fruits and spics have demand worldwide. The WTO regulations for export of these commodities require disinfestations of quarantine pests before export. Plant Protection Division has developed and reported irradiation doses for control of citrus and mango pests when applied prior to their export will ease in export barriers. The fruit flies traps were also introduced to provincial Agric. extension department, farmers and training, workshops, were organized at NIFA. Adoption of fruit fly traps as an IPM component at field level and irradiation of harvested fruit for control of various pests will lead to positive socio-economic impact on farmer's life and pesticide free fruits and vegetables to the end users. Major damaging wheat diseases prevalent in the province include yellow rust, leaf rust, stem rust, powdery mildew and Barley Yellow Dwarf which are suspected to have caused >1% yield losses in different production zones. Effective race non-specific wheat germplasm was identified in the national material and if released will have visible economic benefits for growers. Slow

rusting wheat cultivars with Yr18/Lr34 genes identified previously are being cultivated on large area in Pakistan.

Quarantine pests inflict both direct and indirect losses to the fruits and vegetables, pose problems in the export of fresh fruits and vegetables to the pest free countries. Pakistan consequently loses export of these fruits. Currently very few researches in Pakistan have focused on this problem.

We investigated several doses of gamma irradiation as a phytosanitary treatment for quarantine pests of citrus and mangoes. Doses of 200-220 Gy were found effective in controlling quarantine pests of citrus and mangoes. Recommend reports were conveyed to IAEA for quarantine security of citrus and mangoes.

Biological Control

Egg Parasitoid, *Trichogramma chilonis* (Ishii) is the most important bio-control agent in many agricultural systems worldwide for the control of different insect pests in egg stage. *Trichogramma* is reared on fictitious host of Angoumois moth, *Sitotroga cerealella* (Oliv.) in laboratory conditions and their periodic releases made against eggs of fruit worm, *Helicoverpa armigera* (Hub.) in tomato and okra crops. Bio-control is environment friendly, non-pollutant, safe method, cheaper, long lasting, self-perpetuating and most compatible IPM tool. e.g., egg parasitoid.

Field efficacy of egg parasitoid, *Trichogramma chilonis* against tomato fruit worm:

The experiment was conducted to evaluate the parasitizing effect of *Trichogramma chilonis* against tomato fruit worm. Minimum tomato fruit worm population (0.85/ plant) was recorded in treatment 1500 Nos. of *Trichogramma* released plot followed by 1000 & 500 *Trichogramma* i.e., 1.08 & 1.22 fruit worms per plant and maximum population was recorded 1.79/ plant in un-treated plot. Maximum tomato yield (41.87 kg) was recorded in 1500 Nos. of *Trichogramma* released plot followed by 1000 nos. (32.00 kg) and 500 nos. (25.50 kg) and minimum yield (20.70 kg) was recorded in un-treated plot. Overall results showed that the tomato plot treated with 1500 Nos. *Trichogramma* was less affected by tomato fruit worm and also tomato yield was more than other treated plots.

Field releases of egg parasitoid, *Trichogramma chilonis* for the control of okra fruit borers:

The experiment was conducted to assess the parasitizing effect of *Trichogramma* against okra fruit borers. Minimum prevalence of okra fruit borers (0.51/plant) was recorded in treatment of 1500 Nos. of *Trichogramma* released plot followed by 1000 and 500 *Trichogramma* i.e., 0.71 and 0.85 borers/ plant and maximum mean population was 1.30/ plant in check plot.

Chickpea Pod Borer

Chickpea is a potential cash crop for the dry land areas of Pakistan and southern parts of KP. Pod borer, being ubiquitous and polyphagous in nature begins to flare up and appear in large numbers during vegetative growth, at pod formation and grain filling stages of chickpea. The larva is the only feeding damaging stage in the life cycle of pest and causes maximum losses to chickpea crop. Trials conducted on

chickpea crop showed that unprotected chickpea can suffer up to 90% damage from pod borer.

Field studies on efficacy of botanical bio-pesticides against pod borer larvae damaging chickpea

A field trial was conducted using chickpea variety NIFA-2005 during November 2016 at the experimental farm of NIFA. The experiment was comprised of six treatments including control, each consisting of four replicates. The total number of plots was 24 having a plot size of 16 m^2 with row spacing 40 cm and plant to plant distance 10 cm. All the botanical bio-pesticides were applied as a foliar spray using knapsack sprayer. Two sprays were conducted for the control of pod borer larvae on chickpea crop. First spray was carried out at the onset of pest attack and second spray was after 8 days of first spray. Larval attack was observed on 10.4.2017.

The data regarding larval population revealed that all the treatment showed efficacy in minimizing pest population. Data on pre-treatment larval population were recorded 24 hr before spray and post treatment after two, three and four days after first and second sprays. Pods infestation and grain yield data were recorded. The efficacy of each insecticidal treatment was based on % population reduction associated with grain yield. The data indicated that among the tested botanical bio-pesticides along with synthetic chemicals showed efficacy in reducing pod borer larval population and giving crop protection against pest attack. Comparing the treatments, Emamectin (as a check) treated plots had minimum mean larval population of 1.1 larvae/7 plants with maximum grain yield of 1778 kg ha^{-1} associated with 90% larval reduction control followed by treatment Chloro + NIFA adjuvant with 88.2% larval reduction having grain yield 1486 kg ha^{-1}.

Field efficacy of synthetic insecticides against chickpea pod borer, (*Helicoverpa armigera*) on chickpea

A field trial was conducted to determine the efficacy of insecticides for controlling pod borer larvae damaging chickpea crop. Chickpea variety NIFA-2005 was sown in November 10, 2016 in RCB design with four replications. Each replication was comprised of five plots for respective insecticidal treatments including control. Insecticides viz, polytrin C, karate, curacron, emamectin, were applied according to recommended doses during onset of pest larval attack. Two sprays of each insecticide were conducted. First spray was carried out on 12.4.2017 and second spray 8 days after first spray.

Observations on pre and post treatment larval population were recorded on seven randomly selected plants in each plot including control during different pest developmental stages. Pods infestation and grain yield data were recorded.

The results indicated that pretreatment counts regarding mean number of larvae ranged from 6.6 to 8.8 larvae/plant while in post treatment, a decrease in mean larval population, was recorded which ranged from 1.06 – 3.4 larvae/7 plants in treated plots. Minimum larval population (1.06 larvae/7 plants) associated with maximum grain yield 1120 kg ha^{-1} was recorded in

insecticidal treatment (Polytrin C) with 94% population reduction over control followed by curacron reducing larval population and maximizing grain yield up to 1090 kg ha^{-1}.

It is concluded from the present studies that polytrin C was found most effective in the controlling pod borer larval population with crop protection produced maximum grain yield. Based on field observation in connection with pod borer larval attack, infestation and pest developmental stages, it is recommended that spray should target on young or newly hatched larvae, where the stage is quite sensitive, susceptible and are readily controlled by chemical spray in the very initial pest developmental stages. When the larvae cross third instar, none of the pesticides give effective control.

Termites

Reduced-hazard techniques for the successful management of subterranean termites:

Termites are one of the most serious pest of agricultural crops and buildings all over the world and causes billions of dollar losses annually. Most of these termites are subterranean and cryptic in nature and single colony may have millions of individuals which can spread over a large area. Conventionally, soil liquid insecticide is considered to be major choice for control of termites for last many decades, but it's quite costly and environmental hazardous method. Therefore, we focused in our research program to develop some alternative termite control methods which are more effective, permanent and environmental friendly.

Fitness of novaflumuron and diflubenzuron to be used in bait against subterranean termites

Experiments were executed to evaluate IGRs to see their potential for use as slow-acting toxicants against subterranean termites. Commercial bait having 0.25% Diflubenzuron and 0.5% Novaflumuron was tested for its toxicity against subterranean termite. Both IGRs baits were found effective in killing termites. Number of protozoa (flagellates) were also counted in both bait-fed and un-fed termites. Significant reduction in the number of alive protozoa was recorded i.e. 4500/gut to 1125/gut which ultimately led to termite mortality. Furthermore, transfer of these IGRs from bait fed termites (donors) to unfed termites (recipients) were evaluated in 1:1, 1:4 and 1:9 (D:R) ratios. Maximum mortality was recorded in 1D:1R followed by 1D:4R and 1D:9R.

Exploration of antitermitic activities of heartwood extractives of durable woods against *Heterotermes indicola.*

Extractives of the four durable wood species i.e. *Tectona grandis, Dalbergia sissoo, Cedrus deodara, Pinus roxburghii* were tested against subterranean termites. Two non-durable wood species, *Pinus taeda* L.(SYP) and *Populus deltoides*.(CW) were pressure treated with different concentrations (2.5, 5, 7 and 10 mg/ml) of durable wood extractive. Air dried shavings (12 g) of durable wood were soxhlet extracted using 300 ml of ethanol: toluene (2:1) as solvent. A total of 400 termites were released to feed on these treated blocks for four weeks. It was concluded that all the wood extractives reduced the

weight loss and caused high mortalities at concentration of 10 mg/ml. These extracts showed potential to be used as environmental friendly termiticides.

Possibility of controlling termite with entomo-pathogenic nematodes

Two species of entomopathogenic nematodes; *Stenernema carpocapsae* (Sc) and *Heterorhybdtis bacterophors* (Hb) were tested for their efficacy as biological control agent against termites. Round filter paper (Whatmann) was treated with 5 different concentrations of nematodes (30, 40, 50, 60 and 160 nematodes/ 1 ml of water) and placed in glass petri dishes. Two hundred termites were released in each petridish for total six days. results showed that morality increased with the days by both nematodes (Sc and Hb). Similarly mean mortality was increased with the increase in concentration and maximum mortality was recorded @ 160 Nematodes/1ml water.

Medical Entomology

In our continuous efforts to mitigate vector borne diseases particularly dengue and malaria in the country, Plant Protection Division has joined hands with international community to promote awareness among the employees of public health department and other stake holders in the province. Interactive workshops were arranged at the public health department for their training on identification and control of dengue vectors. Printed literature was distributed among the participants and NIFA Dengue Guard was introduced for personal protection against vector borne diseases. The technology was highly appreciated by the public health workers/ employees to combat against the devastating vectors. The awareness workshops raised the knowledge level of public health department employees from 20 % base level to as much as 80%. This will leave a positive impact to combat dengue disease in coming years and provide additional protection to common people and internal displaced effects of flood and unexpected disasters.

Vector borne diseases are emerging threats in Pakistan and require special attention. The recent spread of dengue vectors to the non-endemic areas in Pakistan show the potential challenge of dengue vectors in the country.

Assessment on radiation induced sterility of Aedes mosquitoes

Sterilization of the male *Ae. aegypti* pupa was conducted with radiation doses of 0,30, 60, 70, 90 105 gray (Gy) using gamma source (^{60}Co) at the Nuclear Institute for Food and Agriculture (NIFA) Peshawar. Induced sterility of 100% was achieved in males with a target dose of 70 Gy. Females irradiated with 105 Gy were 100% sterile, but all of them were in-fecund and laid 0 eggs.

Ovitraps for Vector Surveillance: In our efforts to monitor and combat mosquito vectors of deadly diseases, plant based infusions were used in ovitraps at field experiments. Ovitraps were also installed both outside and inside houses at three hot spots (villages) in Swat, Timerghera, and Peshawar. It was found that plant infusions of hay and grasses were effective and attracted mosquito to ovitraps. The data

also indicated that *Aedes aegypti* mosquitoes are predominantly present in Swat, However, *Ae. albopictus* were recorded from Thmirghera and Peshawar.

Exploring mechanical and nutritional methods of sex separation in Aedes species of Mosquitoes

As no vaccine for the dengue disease is available globally, therefore, vector control is the only option in the present scenario. The use of insecticides for vector control have environmental constraints, health hazards and resistance development in mosquitoes, thus environment friendly vector control strategies like Sterile Insect Technique (SIT) are needed. Sex separation of target species plays integral part in a SIT program.

Simulation of rearing system on the larval diet that lead to distinct sexual dimorphism

The idea of protein and carbohydrate rich diets tested with their effect on male/ female differential development and sexual dimorphism in *Aedes albopictus* and *Aedes aegypti* under the IAEA ongoing umbrella project at NIFA Peshawar. The results revealed that Stevia 75%+ Bovine Liver 20% + Yeast 5% diet in mixture when fed to larvae produced 47% larger size female pupae than in control. However, the effect of this diet combinations did not favor the sexual dimorphisim in Culex species.

Evaluation of the mechanical sex separation by sieving through different mesh size and Jonh Hock apparatus after nutritional effect

After successful induction of sexual dimorphisim at pupal stage in Aedes species thruogh nutrional effect, different means for mechancinal seperation were tested. From the results regarding mechanical sex seperations, mesh size of 1.25mm separated both the sexes effectively with a mean accuracy range (97-100%). However, the john Hock apparatus was comaratively low in accuracy and resulted in the range of 96-99% in case of pupal seperation.

Effect of larval diet and density at various water depths on the sexual dimorphism of *Aedes aegypti* under laboratory conditions

Sex separation of *Aedes* mosquitoes by inducing/enhancing dimorphism at pupal stage through nutritional means may provide opportunities for future launching of SIT program in KP and finally in Pakistan. The effect of different larval diets; IAEA diet, NIFA diet and Stevia diet at different water depth were tested for the sexual dimorphism of *Aedes aegypti* at the pupal stage as a pre-requisite of SIT program of the dengue vectors. Larval density (30 larvae) was tested at six different water depth in plastic cups as 0.5, 1, 2, 3, 4 and 5cm and 3% concentration of each diet. The results showed the maximum size of female as 12.73mm in stevia treatment followed by IAEA diet and NIFA diet as 7.99 and 7.93mm respectively. Non-significant results were observed for each water depth on the size of male mosquitoes pupae. It was concluded that the stevia diet showed significant effect on sexual dimorphism and can be exploited for the

production of distinct sexual dimorphism in male/female pupae of *Aedes aegypti*.

Eliminating female Aedes adult mosquitoes by spiking blood meals with different toxicants as a sex separation method in the context of the sterile insect technique

Blood meals were spiked with various toxicants as Deltamethrin, Agenda, Boric Acid, and NIFA bio-larvicide, Temephos with control at different concentrations like 0.1, 0.5 and 1ppm. The Adults (female/males) were exposed to different concentrations after 1, 2 and 3 hours and killing effects were observed. Varying concentrations of the most effective substance were then tested in subsequent trials to obtain an optimal dose for quick and total female elimination. The most promising substance at the optimal concentration was further tested on a larger number of adults. In the samples of 50 female Aedes adults, NIFA bio-larvicide eliminated females most quickly and thoroughly, with 58.33% kill after 1 hrs exposure period followed by Boric Acid, Agenda, Temephos and Deltamethrin as 28.33%, 18.33%, 15% and 6.66% respectively. Mortality rate was directly proportional to the exposure period and the maximum mortality was observed with the same extract and concentration (95%) while minimum 16.66% in Deltamethrin at 3 hrs exposure period. Based on these results NIFA bio-larvicide and Boric Acid were selected as the most promising and used for the following experiment. Spiking blood meals with different toxicants, the NIFA bio-larvicide has shown its potential as a viable treatment to eliminate female Aedes from laboratory colonies although its practical use in a mass-rearing facility still needs to be tested for further study.

Efficacy of plant extract against dengue vectors in the context of conventional vector control

In our efforts to integrate SIT with conventional methods of control, some locally available eco-friendly plant extracts form *Piper nigrum*, *Curcuma longa* and Bitter Gourd were carried out against the 3rd and 4th instars larvae of Aedes Mosquitoes. Result revealed that plant extracts (100ml Ethanol), (50ml Ethanol+ 50ml tap water), (25ml Ethanol +75ml tap water) and (100ml tap water) when use in 2:2:1 showed 100% mortality of tested mosquitoes. Thus environment friendly plant based pesticides can be integrated with SIT for population suppression.

Dengue Guard: A mosquito repellent product was supplied to various PAEC organizations at low piece than the market rate. Over 18389 bottles were produced and a net profit of Rs. 491722 was generated for NIFA during 2015. During 2016-17, 14000 bottles of fifty ml were supplied to various PAEC organizations for protection against mosquito bite with net income of Rs. 362000.

Plant Pathology

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 from maintenance of disease resistance preemptive control program to mitigate the risk of new pathotypes and virulences. Major

damaging wheat diseases prevalent in the province 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. In-order to minimize rust production losses in KP, resistance genes including Yr5, Yr10, Yr15, Lr9, Lr11, Lr18 and Lr2 4 need deployment. Ten cultivars had specialized slow rusting behavior which carries potential for deployment in the over summering and source regions for rust control. Seed quantity of 2720 Metric Ton of four slow rusting wheat cultivars with Yr18/Lr34 resistance genes identified previously were produced on the government farms in KP.

Wheat Pathology

Disease status and regional variability

Sets of 260 selected wheat genotypes were raised as stationary sentinel plots for surveillance and epidemiology of yellow rust, barley yellow dwarf (BYD) and powdery mildew in three zones of Khyber Pakhtunkhwa. Yellow rust and BYD were prevalent at all test sites in the province while powdery mildew was recorded from Mingora and Swat only. Mean severity of Yellow rust in Khyber Pakhtunkhwa ranged from 5-45% with least in Haripur and maximum in Peshawar region. Similarly, least (3%) and maximum (5%) BYD severity values were recorded in Haripur and Nowshara respectively. Variability of six test locations for yellow rust was compared in all pair-wise combinations using similarity index which was based on absolute differences in the percent rust severity on the differential series. Low similarity of yellow rust populations was recorded among different location pairs including Abbotabad and Swat, Peshawar2 and Nowshara, Nowshara and Abbotabad, Peshawar2 and Abbotabad, Peshawar2 and Bannu, Bannu and Abbotabad and Peshawar 1and Bannu.

Avoidance and management of wheat diseases

Rust pathogen races and resistance genes risk warning

Wheat is vulnerable to *Puccinia striiformis f. sp. tritici*, *P. triticina f. sp. tritici* and *P. graminis f. sp. tritici* in Pakistan which are obligate trans-boundary pathogens and exist in many different biological forms or races which constantly evolve and change. Race analyses and resistance sources or cultivation value of resistance genes are the prerequisite for rust management. Result of recent six seasons studies on these important aspects from Khyber Pakhtunkhwa and other parts of Pakistan reveled the existence of 35 races of *P. striiformis f. sp. tritici* and *P. triticina f. sp. tritici*. Early warning studies regarding 12 yellow rust and 20 leaf rust resistance genes indicated that *Yr5*, *Yr10*, *Yr15*, *Lr9*, *Lr11*, *Lr18* and *Lr24* were at low risk and can be used for rust control.

Slow rusting wheat

Wheat is grown in all districts of Khyber Pakhtunkhwa from an altitude of 174 m to 2950 m. Out of the total, 70% of the KP wheat acreage is in 13 low altitude districts ranging from 174-688 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 repeated infection cycles on wheat in low altitude districts, we have to reduce initial inoculum from the source area i.e. mid and high altitude regions. To achieve this goal, 125 registered/approved wheat cultivars were tested and analysed for slow rusting resistance. Only ten cultivars displayed slow rusting behaviour in this preliminary study.

Barley Yellow Dwarf

Post released monitoring for resistance status of BYD was carried out for released cultivars in Khyber Pakhtunkhwa. Results indicated that out of 130 tested cultivars, 29, 10, 19, 15, 9 and 14% were found sensitive to BYD in Peshawar1, Peshawar 2, Nowshara, Bannu, Swat and Haripur respectively. Similarly, in another set of 93 characterized genotypes of which 31 carried *Bdv1*, 16 *Bdv2* and 46 *Bdv1* plus *Bdv2*. Both *Bdv1* and *Bdv2* and their combination had strong effect as very limited number of genotypes carrying these genes supported BYD symptoms at Peshawar2, Haripur and Bannu. Temporal BYD epidemic analyses indicated that out of 93 characterized genotypes, 87 had low AUDPC values and carries potential for future use.

Screening of national elite germplasm and candidate varities

Under this national program, NIFA is collaborating and fostering the development of disease resistant wheat germplasm and varieties and have received National Wheat Disease Screening Nursery (NWDSN), NUWYT nursery and Commercial Varieties during the period under report. Total 780 genotypes were sown, managed, and evaluated under artificially induced rust infection experiments. No rust was observed on 114 genotypes while 291 were highly susceptible. Remaining genotypes displayed different levels of resistance. Out of 780 genotypes, 132 displayed sensitivity to BYD.

Seed health risk analyses and forcast

Many of the wheat diseases have been reported as seed borne and their inoculum is of great economic significance and therefore, seed health risk analyses were carried out for 412 upcoming wheat genotypes for black point caused by *Alternaria alternata* (Fr.) Keissl. Black point was observed in all tested genotypes with overall mean incidence of 5%. Lowest incidence remained at 1% while highest incidence reached 19%. Based on the current black point incidence, seed rate and 1000 grain weight of each genotype it is predicted that up to 56 infected seeds will enter/Sq. meter capable of causing disease in the next season against the permissible standard of 3% in certified seed.

Vegetable pathology

Tomato disease scouting and diagnosis

Tomato is a major vegetable crop in Khyber Pakhtunkhwa which is vulnerable to many diseases caused by fungi, viruses, bacteria and nematodes. Work on tomato is being undertaken by PPD and S&ESD at NIFA. Work on pathological aspects was

initiated on raised plots of tomato cultivar "Leriqa". Temporal disease scouting and subsequent laboratory work was carried out for its diagnosis. Tomato Yellow Leaf Curl Virus and early blight/late blight were detected throughout the growing season. Buckeye rot of tomato fruit was detected in the early and mid-season while anthracnose was detected in the late season.

Zero gravity instrument project

Zero-gravity instrument project was awarded under the capacity-building activities of the Human Space Technology Initiative of the United Nations Office of the Outer Space Affairs (UNOOSA), Austria. Following results were achieved during its second and final year.

Pathological studies

Effect of clinorotation on radial growth of *Aspergillus niger*

Comparison of radial growth (cm) of *A. niger* colonies subjected to three treatments at 25 ^{0}C over 5 days was studied. Initial colony radial growth was uniform (i.e.2.82 cm) prior each treatment. A stress was observed in clinorotated treatment after 24 h on September 21, 2016 where radial growth was 2.65 cm. In the subsequent four observations each recorded after 24 h in the clinorotated treatment, *A. niger* radial growth was enhanced. Radial colony growth in the horizontal and vertical treatments was also enhanced from the initial colony size. Final radial colony size was maximum in vertical (i.e. 3.34 cm) which was followed by horizontal (i.e. 3.15 cm) and clinorotated (i.e. 3.03 cm) treatment. .

Effect of clinorotation on black point transmission from seed to seedling

In this study, none of the black pointed seeds of five test genotypes subjected to three treatments was germinated. This failure of germination may be due to several other factors which were not part of this study viz. inoculum level of the pathogenic fungi involved which might have killed embryos in the tested seeds as occurrence of *A. alternata* is reported from embryo and endosperm of wheat seeds. Previously, loss in germination due to black point in wheat is reported by many researchers. However, future studies may be carried out with more number of seeds with bigger sample size.

Studies on cereals, legumes and muskmelon

Effect of clinorotation on germination, root length and root angle

Effect of clinorotated (treated) and 1g vertical control on germination, root length and root angle of wheat, maize, legumes and muskmelon were carried out. Germination was not affected by clinorotation and 1g vertical control in NIFA-Barsat and NIFA-Lalma while it was reduced in Tatara (40%) and Pirsabak 13 (20%). The maximum root length in 1g vertical control was 5.08 cm recoded for NIFA-Lalma while in clinorotation treatment it was 4 cm for NIFA-Barsat. Maximum root length was reduced in the clinorotated treatment of Tatara which was 2.8 cm in comparison with 4.54 cm in 1g vertical control. Root length of Pirsabak 13 was almost similar in both treatments while overall reduction in other three cultivars

was recorded. Root angle was enhanced in Tatara, NIFA Barsat and Pirsabak 13 while little reduction was recorded in NIFA Lalma. Germination of maize cultivar "Azam" was reduced by 20% in clinorotated seeds in comparison with 1g vertical control. Three fold reductions in root length of Azam were recorded in clinorotated treatment. Root angle was enhanced by 4 degrees in clinorotated treatment.

Chickpea germination remained 80% in both treatments. Root length was 1.56 cm in treated chickpea which was 2.73 cm in 1g vertical control. Root angle was 5 degrees greater in treated chickpea. In case of red bean, no seed was germinated in clinorotated treatment. Germination was reduced by 60% in muskmelon treated seeds in comparison with 1g vertical control. Root length was reduced in treated muskmelon which was 2.59 cm while it was 3.27cm in control treatment. Wide variation was recorded in root angle of treated muskmelon which was 116 degrees as compared to 37 degrees in vertical control.

a. Effect of clinorotation on wheat seedling vigor

Effect of clinorotation treatments of 90 rpm in clockwise mode on germination, shoot length, root length and seedling vigor of wheat cultivar Pirsabak-2008 was carried out. Germination percentages were at par in 1h, 2h, 4h and 5h clinorotation and control treatments. Germination was reduced by 11% in 3h treatment. Shoot length of control (i.e. 12.67 cm) and 3h (12.41 cm) treatments were at par while in the remaining treatments it was reduced. Minimum shoot length of 7.5 cm was recorded in 5h treatment. Root lengths were at par in all treatments including control. Overall seedling vigor index was maximum in 3h treatment which was followed by 2h, control, 1h, 4h and 5h.

Food and Nutrition Division

Extrusion Cooking for Development of Snack Product

High protein & antioxidants cereal based snack food product was developed by using red bean (15%), chickpea (15%) wheat flour (50%) and corn flour (20%) as major ingredients. Raw beans, chickpea, wheat flour and corn flour have protein content of 25, 30, 13 and 11%, respectively. These commodities also contained 12.36, 11.87, 1.61 and 1.3g/kg of total phenols in term of antioxidants. Sieve analysis of the flour showed large variations in the fineness modulus in prepared flour which were 2.36, 0.316, 2.17 and 2.36 for beans, chickpea, wheat and corn flours, respectively. The ingredients were dry mixed, ground and passed through a 40 mesh screen and with adjusted moisture content of 25%. The resultant high protein raw material was extruded at 400 rpm through a 5 mm die. Heating was provided through the extruder barrel. The product temperature measured with thermocouple inside the die reached o above 100°C at the die. The resultant extrude had an expansion ration of 2.36 and bulk density of 0.45 $g.cc^{-3}$. The final product was dried in oven at 170°C to attain 4.5% moisture content. The resultant product had 17% protein, 2.15g/total phenols with acceptable texture.

Drying of fruits and vegetables

Low cost and high energy efficient infra-red heating dryer was developed using compressed natural gas as a fuel for the drying of fruits and vegetables. Distance from the heaters plats linearly affected the temperature evaporation rate and internal temperature. Maximum evaporation rate was recorded as 0.65 and minimum was noted as 0.17 ($cm^3hr^{-1}cm^{-2}$) at 23 and 74 cm from the heaters. The most suitable distance for quick drying of the product was found to be 40 cm based on the drying of cantaloupe slices.

Reduction of post-harvest losses by product development/ value addition

Low caloric fruit based products were developed by incorporation of stevia to minimize the post-harvest losses/value addition of horticultural crops. Stevia is non-caloric sweetener with known nutritional benefits. Appropriate formulation of guava drink and strawberry jam with lab stevia liquid extract along with commercially available stevia and sugar were developed and stored for three months. In the first experiment seven treatments were prepared for ready to serve guava drink with different concentrations of stevia. Results revealed that treatment with guava pulp with 2% commercial stevia and treatment with guava pulp with 3% liquid stevia extract performed better during three months storage period. In the second experiment, five treatments were prepared for strawberry jam with different concentrations of stevia. Results showed that treatment with strawberry pulp with 2% liquid stevia extract and treatment with strawberry pulp + 2% commercial stevia performed better during three months storage period.

Figure. Stevia based food products

Development and popularization of long shelf life meals for victims of natural calamities and other target groups:

In continuation of the previous work under IAEA funded project, experiment on preservation of meals by irradiation, autoclaving and their combination was carried out. Meals from mix vegetables were prepared, packed in tetra pack pouches and were sealed by vacuum sealing machine. The prepared meals were divided into different lots and treated with autoclaved, irradiation and their combination. All the samples were stored at ambient storage conditions and analyzed for total viable count, fungal count, coli forms, fecal coli form. The prepared meal also assessed organoleptically one month interval for a period of six months. During the experiment, the control samples were found spoiled and discarded from the experiment lots after 24 hours while some pouches were found swollen in the samples treated with 10 kGy after 4 months storage period. The both treatments having combined autoclaved & irradiation treatment at the dose rate 7.5kGy for 5min and 5kGy for 10min were found without any microbial counts during the entire storage period of six months.

Development of MRE fortified with plant based natural minerals and multivitamins:

Under IAEA funded project on irradiated food for immuno-compromised patients, different meals, fortified with alfalfa (rich source of minerals and vitamins) were prepared. The sample were prepared by (minced meat + 10 % alfalfa), packed in tetra pack pouches and sealed by vacuum sealing machine. The samples were divided into three lots, two of them were irradiated at doses of 10 kGy, 12 kGy, respectively, while the 3rd was autoclaved (121°C for 15 min). Treated samples were stored at ambient temperature for a period of 90 days. All the samples were analyzed for vitamin C, phosphorus, potassium, iron, zinc and total bacterial counts initially and after 15 days intervals up to 90 days. Better retention of vitamin C was observed in the sample with 10% alfalfa in all the treated samples. From the results, it was concluded that at least 10 kGy radiation dose is needed for preservation of packed meals. The effect on phosphorus, potassium, iron and zinc shows significant differences in all the treated samples with the passage of storage period. The prepared ready to eat meal (MRE) food products potentially safe for immune-compromised patients and are likely to prove beneficial in minimizing the prevailing minerals and vitamins deficiencies. No bacterial counts were noted in any treated samples except control during the entire storage period. The control sample was discarded due to spoilage after 24 hours.

Technology transfer of oyster, milky and button mushroom to the landless community of KP, upper Punjab and Baluchistan

Mushroom cultivation and its technology transfer was initiated many years ago at NIFA. For the dissemination of this technology in farming and landless community of KP, upper Punjab and Baluchistan, Pakistan Science Foundation Islamabad has awarded a funded project of worth 4.166 million rupees. Under this project more than 10 workshops has been organized so far in different districts of KP and Baluchistan with the help of Agriculture Extension Department and around 12 model farms have also been established in the respective districts and for the interested farmers and PMNH Islamabad as well. More than 400 people from farming community, different R & D organizations and students has been trained in these workshops.

NIFA has successfully developed cultivation technologies and standardized their compost composition like Oyster, Milky, King Oyster and Button mushroom. Button mushroom has been successfully grown for the first time at NIFA where the main problem was the casing soil or peat mass which is highly nutritive soil and can be found in the mountainous areas of Chitral, for which transportation cost is very high. To cover this problem, normal soil *i.e* clay soil + loamy soil + dung manure was used in the ratio of 3: 1: 1 to get a soil equivalent to peat soil and mix lime in a small amount for pH adjustment as button mushroom required a pH around 8 to 9. A total of almost 30 kg of button mushroom was produced from 20 bags.

Similarly, summer season milky mushroom was tissue cultured and multiplied on sorghum/wheat grains for spawn preparation. The spawn has already been provided to some growers like PMNH, Islamabad, mushroom model farms. Milky mushroom required no supplements and the casing soil however 3-5 % lime mixing is needed to adjust the pH.

Mushroom cultivation workshop at Karak

Production of button mushroom at NIFA

Inter-comparison of Dosimetry Systems

Four alanine dosimeters were irradiated with target doses of 1, 5 and 10 kGy respectively at NIFA and sent to IAEA for analysis/dose measurement. IAEA issued a certificate to NIFA in which close agreement was found both in the target and measured doses. The values obtained for

the performance evaluator designed for this activity were Z1=0.050195, Z2=0.057881 and Z3=0.236204 respectively, which lies in the acceptable limits set by the IAEA

Weighing of chemicals

Proper mixing of chemicals

Oxygenation of the chemicals

Vitamin A quantification in available processed edible oil through spectrophotometer and HPLC

Among the micronutrients deficiencies, vitamin A deficiency is one of the main public heath dilemma all over the globe especially in developing countries. In Pakistan 1/5th of pregnant women and children under five are severe deficiency of vitamin A. For the monitoring of vitamin A in dietary fats and oils limited number of specialized laboratories are present in Pakistan. Therefore, it is worthwhile to modify and validate a vitamin A estimation protocols according to our limited resources to determine the efficacy of oil fortification program of Pakistan. To validate the vitamin A protocol for precise quantification in dietary fats and oils and oil based products. The eight samples of available brands from Peshawar market showed the variations in vitamin A contents from 15 to 37 iu/g. Moreover, NIFA canteen one week menu also quantified for the vitamin A content and results showed that average per capita consumed was 97.06IU which is about to 25% of daily requirement of an adult.

Vitamin A Spot Test Kit

Vitamin A spot test kit is unique in nature which detect the vitamin A in dietary oils less than one minute using simple protocols. This kit contained two reagents and instruction leaflet. Reagent-1 (one milliliter) is mix with two to three drops of oil subsequent reagent 2 (one milliliter) was added. Record the color development in the test tube. If blue color is developed, vitamin A is present in the sample otherwise vitamin A is absent or limited quantity is

present in the sample. The intensity of blue color provides the partial information of concentration of vitamin A in the sample oil. Global Alliance for Improved Nutrition (GAIN)-Islamabad placed the order of 3000 for this kit which will generated an income of about Rs. 600,000/-. Currently Food Fortification program Islamabad also interested to buy vitamin A spot test kits for quality control/quality assurance purposes. This kit is cost effective, easy to use for industry personal, regulatory bodies and other related organizations in the Pakistan.

Vitamin A spot test kit

Before reagent 2 addition

After reagent 2 addition

Effect of different elements on iodine retention/rublimation of iodized table salt

Iodized salts of different areas/grades including washed and dried, good quality rock salt of Punjab, sea salt and low-quality salt of KP were studies from the standpoint of iodine sublimation/retention. These samples were packed in high density polythene bags. The experimentation continued for more than one year to observe the effect of different conditions/places on sustainability of iodine by the samples. It was found that iodine in low-quality salt of KP sublimed within few days at almost all places while in rest of the samples iodine sustained for more than one year.

Keeping in view the above finding, all salt samples were sent to PINSTECH, Islamabad, for the estimation of mineral contents especially Ca, Mg, Sr, B, Si, Fe *etc.* through ICP technique. The results revealed that the concentrations of the proceeding elements (S=7530ppm, Fe=30ppm, Si=166 ppm, B=875ppm,

Ca=8963ppm, Mg=357ppm, Sr=199ppm) were much higher in low-quality KP salt than those in other salt samples.

Analytical grade table salt (NaCl) was iodized @ 33ppm. The salt was then divided into 8 equal parts and contained in high density polythene bags. Iodized salt was adulterated with same elements having similar concentration by using their respective salts in the laboratory. The concentrations of iodine were determined in the span of 24 hours to 04 months in artificially adulterated analytical grade salt. The sublimation /loss of iodine in table salt in the presence of above quoted elements were in the rage of 37.5 to 52.5 %. These results open the new horizons for the proper refining of salt (wet process or common ion effect refining) may be carried out before the iodization process.

Soil and Environmental Sciences Division

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

Growing off-season vegetables under high tunnel in Khyber Pakhtunkhwa has wide scope and likely to generate economic opportunities particularly for small landholders. Tomato and cucumber are important vegetables crops in Pakistan. To get maximum yield under high tunnel farmers commonly apply nitrogenous fertilizers with each irrigation without research based recommendations. The over fertilization resulted in reduced plant health , increased susceptibility to plant pathogens and insects in high tunnel. Heavy nitrogen application can induce blossom-end rot in crops like tomato, pepper and stimulate vegetative growth at the expense of fruit yield. For the control of diseases under high tunnel farming on an average 16-18 sprays of fungicide are applied to each crop, which is injurious to health of the consumers and also create environmental pollution problem. Hence there is a great need to rationalize the use of fertilizers and fungicide to save the nutrient losses, environmental repercussion for sustainable resource management. In Khyber Pakhtunkhwa 53% of the cultivated area is rain-fed and it needs proper attention. The farmers normally grow traditional crops using traditional methods of irrigation even though having water scarcity. Thus they have very low income from traditional farming. High tunnel farming including efficient irrigation system for growing off-season vegetables are particularly suitable for the farmers of rain-fed areas having scarce water and nutrients sources. The integrated nutrients and water management may be the environment friendly option to improve yield, fertilizer use efficiency and quality of produce. Owing to the importance of this technology for growers of KP, 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. The maximum fruit yield of tomato was recorded in the treatment receiving NPK(75:75:90 kg ha^{-1}) as soil application at 30 day interval starting after establishment of crop (20 days after transplantation) till mid of June and with drip irrigation (10:10:15 NPK kg ha^{-1}) at 7 days interval. The technology of tunnel farming was demonstrated to the vegetable growers under the University of Agriculture, Peshawar Endowment Fund on April 12, 2017 in which more than 100 growers, students, researchers and academicians participated.

Bio-fortification of zinc in wheat for balanced human nutrition

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

In future, nutrient efficient plants will play a major role in increasing crop yields mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally, and increasing environmental concerns. Furthermore, at least 60% of the world's arable lands have mineral deficiencies and on such soils fertilizers applications are essential for achieving improved crop yields. Fertilizer inputs are increasing cost of production for farmers, and there is a major concern of environmental pollution due to excess fertilizer inputs. Higher demands for food and fiber by increasing world populations further enhance the importance of nutrient efficient cultivars that are also higher producers. During the last three decades, much research has been conducted to identify and/or breed nutrient efficient plant species or genotypes/ cultivars within species and to further understand the mechanisms of nutrient efficiency in crop plants. However, success in releasing nutrient efficient cultivars has been limited. The main reasons for limited success are that the genetics of plant responses to nutrients and plant interactions with environmental variables are not well understood. Complexity of genes involved in nutrient use efficiency for macro and micronutrients and limited collaborative efforts between breeders, soil scientists, physiologists, and agronomists to evaluate nutrient efficiency issues on a holistic basis have hampered progress in this area. In view of these considerations, a study was undertaken to investigate the relative Zn-efficiencies of a range of cultivars of wheat. Ten wheat cultivars were grown in chelate-buffered nutrient solution in a net house under prevailing environmental conditions. The seeds 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 thermo pore sheet placed in stainless steel container of 50L capacity filled with 40L of the chelate-buffered nutrient solution. 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) until 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 draught oven at 70 ± 1 °C for 48 hours (until constant weight) and were analyzed for micronutrients and P by standard procedures of analysis. The usual symptom of Zn deficiency like stunted growth and whitish-brown necrotic spots developed on the middle parts of the leaves were obvious on the plants grown in Zn deficient medium. The increase in the levels of Zn^{2+} activity showed an affirmative effect on

wheat growth and led to vigorous dry matter production. The genotype NRL-1521 has the maximum dry matter production at 40 pM Zn^{2+} which was 9.47 g/pot. In the Zn deficient solutions (2 pM Zn^{2+}), shoot dry matter production was distinctly lower and the genotype NRL-1511 produced the lowest DM of 0.89 g/pot. All the genotypes responded variably to various levels of Zn activity creating immense variation in DM production. Thus Zn efficiency was determined by taking into account this variation in dry matter production that varied between 10.7 to 64.3%. The genotypes ranked as Zn-inefficient (NRL-1521, NRL-1524) produced significantly lower dry matter yields than the Zn-efficient cultivars NRL-1502 and NRL-1504 at the Zn-deficient level. Zinc concentrations in the shoots of the different cultivars varied between 14.8 µg g^{-1} and 38.3µg g^{-1}.

Evaluation of Zn efficiency under field conditions

Although the technique used to determine Zn efficiency in solution culture provides the same growth conditions and Zn activity as in soil, however, there are many other factors which are suppressed or affect plant growth. On the basis of above hypothesis, an experiment was executed under field conditions with 5 genotypes, (2 Zn-efficient, 1 medium, 2 Zn-inefficient) 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 0.31 µg g^{-1}. The soil also contained 0.88% O.M, 7.9 µg g^{-1} Olsen P having pH 7.8 and ECe 2.9 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 results showed that generally yield of all genotypes increased with Zn application, however, the response of each genotype was variable to applied Zn. The wheat genotype NRL-1434 produced the highest biological yield of 19.5 t ha^{-1} with application of 5 kg Zn ha^{-1} which was significantly higher than rest of the genotypes. As for grain yield is concerned the same genotype produced maximum yield of 4556 kg ha^{-1} when applied with 5 kg Zn ha^{-1} . Under Zn stress conditions NRL-1411 (medium in efficiency) depicted higher grain yield of 3430 kg ha^{-1} which was significantly higher than rest of the genotypes. 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.

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

Phosphorus (P) deficiency impedes plant growth and development in more than 30% of the world's cultivated soils. Application of synthetic P fertilizers is generally recommended to overcome the P limitation problem. However, ever-rising prices of P fertilizers and its low use efficiency makes

this practice both uneconomical and environmentally unsafe. Exploitation of genetic resources of crops to get more yields under resource poor and problem soil environment like Pakistan seems inevitable. Variety and environment are two most important factors, which determine the fate of crop yield. High yielding varieties need suitable soil environment to show their maximum potential. Low fertilizer use efficiency and imbalanced use of phosphatic fertilizers are important factors responsible for low yield. Genetic differences for absorption and utilization of mineral nutrients has received much attention during recent past. Differential response of different varieties of a crop to phosphorus (P) has also been reported. Economy of fertilizer application and nutrient use efficiency in crop plants may be improved by understanding internal and external adaptive mechanisms under and adequate levels of nutrient; and comparing and selecting such crop genotypes for commercial cultivation. The objective of this study was to select genotypes of cotton giving good results under deficient and adequate levels of P fertilization. These variations can be exploited through selection and breeding for P efficient crop genotypes to sustain crop productivity and soil health. Therefore, solution culture study was planned to evaluate genetic variations among ten advance wheat genotypes which is an important cereal crop of Pakistan

Ten wheat cultivars were grown in chelate-buffered nutrient solution in a net house under prevailing environmental conditions. The seeds 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 transplantation. Three days after germination, 2 seedlings of each cultivar were transplanted into white thermo pore sheet placed in stainless steel container of 50 L capacity filled with 40L of the chelate-buffered nutrient solution. 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 were arranged according to completely randomized factorial design. Each treatment had three replications. Two seedlings were transplanted in one hole of a thermo pole sheet and each hole was considered as one repeat. Experiment was harvested 30 days after transplanting and the data were recorded for dry biomass. Substantial differences in growth parameters such as total plant dry matter (TDM), shoot dry matter (SDM), root dry matter (RDM), root: shoot ratio and some phosphorus related parameters were obvious at deficient and adequate P levels. Total dry matter ranged from 1.25 to 0.43 at deficient and 1.37 to 0.73 g plants^{-1} at adequate P levels. Genotype NRL- 1503 produced almost three times more SDM than NRL-1504 at deficient P level while NRL- 1521 produced the highest RDM at adequate and deficient P level. Differences in SDM indicate that 60 % of genotypes produced SDM less than the mean average shoot dry matter at both the P levels. The differences for phosphorus utilization efficiency and phosphorus stress factor (PSF) were also observed among these genotypes. Two out of ten genotypes

depicted PSF greater than 50% and the rest less than 50%. Five genotypes NRL 1502 NRL-1503, NRL-1514, NRL-1521 and NRL-1524 showed PSF < 10 %. Significant ($P \leq 0.05$) differences for P uptake, absorption rate and utilization rates were also observed in wheat genotypes at deficient and adequate P levels. Maximum root shoot ratio was exhibited by NRL 1514 and minimum by NRL 1503 at deficient P, however, root shoot ratio was higher at deficient P level than that at adequate P level. Wheat genotypes NRL-1503 and NRL-1521 were found P-efficient while NRL-1504 and NRL-1520 were found P in-efficient genotypes. Results showed the existence of genetic differences among wheat genotypes with regard to P absorption and utilization. These P efficient genotypes will be tested under field conditions during 2016-2017 to confirm hydroponic results. A field study was executed during 2016-2017 to confirm the results of 2015-2016 hydroponic experiment. The results of previous year (2015-2016) showed that wheat genotypes NRL-1402 and NRL-1438 were found P-efficient while NRL-1412 and NRL-1424 were found P in-efficient genotypes in culture solution. However, the field study during previous years indicated that the chelate-buffered nutrient technique used for screening of wheat genotypes for P efficiency was reliable as the results from this technique are similar to those obtained from field cultivation. Wheat genotypes NRL-1402 and NRL-1438 were found P-efficient while NRL-1424 and NRL-1438 were found P in-efficient genotypes.

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

Phosphorus nutrition is indispensable for plant growth and development. P is considered as the second macronutrient after nitrogen, which is essential for plant growth. Plants absorb P as primary orthophosphate ($H_2PO_4^{-1}$) or secondary orthophosphate (HPO_4^{-2}). Relative quantities of these ions taken up by plants depend on soil pH. In acidic soil, $H_2PO_4^{-1}$ dominates, while alkaline soils have abundance of HPO_4^{-2}. The inorganic P is derived from the weathering of rocks containing mineral apatite, while organic P is derived from plants and animals' residues. The inorganic form of P is present in a variety of combination with Fe, Al, Ca and Mg plus other elements. The relative importance of each type in a soil will be largely dependent on soil pH and amount of clay. In alkaline calcareous various factors include pH, nature and amount of clay minerals, Fe and Al oxides and presence of free calcium carbonate controlled P availability. Organic materials have beneficial effects on soil fertility and physical properties of soil. The physical properties of soil play an important role in influencing the behaviors of plant growth, thereby contributing to efficient crop production. Farm yard manure (FYM) on an average contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. Application of organic materials to the soil reduces the dependence on chemical fertilizers. The addition of organic materials to the soil helps microorganisms to produce polysaccharides and organic acids which improve the soil structure and help in P solubilization. The availability of P can be

increased if mixed with FYM and other organic materials. Repeated incorporation of FYM application to soil increase water holding capacity, water infiltration rate, improve soil aeration, conserve soil moisture, porosity and decrease soil bulk density, thereby contributing to efficient crop production. Therefore, judicious and efficient use of inorganic P fertilizer and recycling of organic amendments is inevitable to maximize agricultural productivity on sustainable basis. This study was therefore, initiated with the objective of increasing the efficiency of applied P fertilizers through integration with organic matter using wheat as a test crop.

The previous year experimental soil was used for this experiment. Along with same treatments i.e. Control, FYM (2.5 & 5 g kg^{-1}), TSP, SSP, RP @ (40 mg kg^{-1}), TSP + (2.5 g FYM kg^{-1}), TSP + (5 g FYM kg^{-1}), SSP + (2.5g FYM kg^{-1}), SSP+ (5g FYM kg^{-1}), RP+ (2.5g FYM kg^{-1}), RP+ (2.5g FYM kg^{-1}). Soils in pots were irrigated up to their respective saturation percentage. After a week when soils 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 (NIFA-INSAF-15) 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. Experiment was harvested at maturity and the yield data were recorded.

The results indicated that highest grain yield of (134.57 g/pot) was recorded in treatment where TSP + 5 tons FYM ha^{-1} was applied followed by the treatment SSP + 5 tons FYM ha^{-1}. Grain yield from the pots treated with PR+5 tons FYM ha^{-1} was higher than where only TSP and SSP was added however, the difference was non-significant. The minimum yield was observed in control treatment.

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

The experiment was conducted at NIFA experimental farm. Three varieties of wheat Fakhar-e-Sarhad, Bathoor and NIFA-Aman (SRN-0911) evolved at NIFA were tested for three different sowing dates i.e. 3rd week of October, 2nd week of November, and 1st week of December at the interval of 20 days. Three fertilizers treatments @ (80:40:0), (120:80:40) and (160:120:60) (N: P: K) kg ha^{-1} were applied to crop making the treatments as subplots. Three replicates of the experiment were made for each date of sowing. Phosphorus and K were be applied as a basal dose at the time of sowing while nitrogen was applied in split doses; half at the time of sowing and half with first irrigation. Each plot was of 1.5mx3m. Uniform seed rate of 100 kg ha^{-1} was used. Recommended row to row distance for sowing and other cultural practices were followed. Plant height in (cm) was recorded at early maturity stage before harvesting. The crop was harvested at physiological maturity in the end of April and after drying in field, gross yield (biological yield) (kg/ha), grain yield (kg/ha), spike length (cm), and 250 grain weight (g) for each plot were recorded. The overall performance of the experiment was good. All the three varieties (Fakhar-e-

Sarhad, Bathoor & NIFA-Aman) yielded significantly high grain yield at early sowing (3768, 3595 and 4079 kg/ha, respectively) as compared to late sowing. The different fertilizer levels had no significant effect on yield but grain yield generally increased by increasing fertilizer levels. However, wheat variety NIFA-Aman performed better in terms of grain yield (4135 kg ha^{-1}) even at low NPK level under late sowing. It indicates that variety has the potential to perform better under low fertilizer input even if sowing is delayed due to heavy rainfall or shortage of moisture for timely sowing. To confirm these results, the study will be repeated in next year.

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

Wheat is the most important staple food crop in the world. It is cultivated in Pakistan on more than 9 million hectares with a production of 24 million tons. 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 realized and potential yield, balanced use of suitable types of fertilizer is of key importance as proper combination of fertilizer can increase the yield by 50%. The combined use of NPK fertilizers plays an important role in wheat production. Application of NPK in balanced share at proper time has great impact on wheat yield. Plant species, even varieties within species vary in their behavior to obtain and utilize NPK for grain production. Two advance wheat lines of NIFA (CT-12176 and SRN 13121) were treated with 13 levels of NPK fertilizer (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 NPK kg ha^{-1}). Split plot design was used where wheat lines were kept in main plots and fertilizer treatments in sub plots. The net plot size was 2.5 m × 2 m. Experiment was sown in November 2016 and harvested on physiological maturity in May 2017. The soil analysis showed that experimental field was silty loam in texture with pH of 7.7, organic matter 0.85%, 0.041% N and 5 ppm available phosphorus. Phosphorus and potash were applied at the time of sowing along with 1/3 of the recommended N fertilizer. The remaining nitrogen was applied in two equal splits with first irrigation and at booting stage. Results showed that maximum grain yield of (5 tons ha^{-1}) was recorded for the wheat line SRN-13121 where NPK was applied at 140-90-60 kg ha^{-1} respectively. Similarly wheat line CT-12176 produced maximum grain yield of (4.6 tons ha^{-1} when NPK was applied at the rate of 140-90-30 kg ha^{-1}. Maximum P concentration of 0.48% in grain of wheat line SRN-13121 was found in the treatment where NPK was applied at the rate of 140:60:30 kg $ha^{-1}$and maximum K concentration of 0.51% was also found in wheat line CT-12176 in the same treatments. It is concluded from the study that wheat line SRN 13121 performs better at 140-90-60 kg ha^{-1} NPK levels when nitrogen is applied in three different stages.

Efficient use of nutrients and water for improving bio-energy crops production on marginal lands

Marginal land is defined as a land that is not suited for cost-efficient production of crops that the harvest-generated incomes do not cover the production costs, due to poor soil conditions. Marginal land is often suggested as a land reserve potentially suitable for the cultivation of bioenergy crops. Using marginal land for producing bioenergy feedstock has the advantage of reducing land-use conflicts between food and bioenergy. The objective of this research is to improve/enhance production of bioenergy crops on marginal lands. Three rapeseed lines of NIFA (RM1, RM2 and RM3) were treated with 4 levels of N (0, 50, 75,100 kg ha^{-1}) fertilizer. P and K fertilizer were applied @ 60 kg ha^{-1} applied to all plots as a basal dose at sowing time. The net plot size was 3 m × 5 m. The crop was sown in October 2016 and harvested in April 2017. The soil analysis showed that experimental field was silty loam in texture with pH of 8.1, organic matter 0.6%, 0.035% N and 7 ppm available phosphorus. Results showed that maximum average grain yield (2.6 t ha^{-1}), WUE (22.3 kg ha^{-1} mm^{-1}) and N uptake (83.56 kg ha^{-1}) were depicted by rapeseed line RM3. The N level effect showed that no significant increase in yield and N uptake was observed among the various N levels. It is concluded from results that 50 kg ha^{-1} may be the economical and optimum level N for all three tested lines under present conditions.

Studies on water and nutrient uptake of wheat genotypes in relation with root traits

Root yield is seldom studied in field experiments on account of difficulties associated with excavation of roots despite the fact that root residues contribute to build up of soil organic matter in the long run. Current era emphasizing sustainability necessitate identifying varieties having higher grain and root yield besides being efficient in the use of water and uptake of nutrients. Information on root yield and water and nutrient uptake of varieties is generally lacking. To bridge this knowledge gap, a field experiment was conducted at experimental farm during Rabi 2016-2017 using three wheat varieties (NIFA-Lalma, NIFA-Aman, and NIFA-Insaf). Experiment was laid out in randomized complete block design with three replicates under both irrigated and rain-fed conditions. Neutron scattering moisture probe was used to monitor changes in soil water content (0-90cm) for determining water use efficiency.

Significant ($P \leq 0.05$) differences were observed between irrigation treatments while varieties did not differ significantly for grain yield. NIFA-Lalma produced the highest grain yield (4.5 t ha^{-1}) under irrigated conditions while NIFA-Aman produced the highest grain yield (3.5 t ha^{-1}) under rain-fed conditions. Differences among varieties and irrigation treatments were non-significant for root yield (0-50cm). NIFA-Insaf and NIFA-Aman had the highest root yield of 2.2 t ha^{-1} and 2.4 t ha^{-1} under rain-fed conditions and irrigated conditions, respectively.

Significant ($P \leq 0.05$) differences were observed between irrigation treatments while varieties did not differ significantly in water use efficiency. Varieties had

higher water use efficiency under rain-fed conditions than under irrigated conditions. NIFA-Lalma (51 kg ha^{-1} mm^{-1}) and NIFA-Aman (15 kg $ha^{-1}mm^{-1}$) were the most water use efficient varieties under rain-fed and irrigated conditions, respectively.

Differences among varieties and irrigation treatments were found significant ($P \leq 0.05$) for nitrogen, phosphorus and potassium uptake. Varieties had higher nutrient uptake under irrigated than under rain-fed conditions. NIFA-Aman exhibited the highest nitrogen uptake under both irrigated (231 mg $plant^{-1}$) and rain-fed conditions (213 mg $plant^{-1}$). NIFA-Aman had the highest phosphorus uptake under both rain-fed (53 mg $plant^{-1}$) and irrigated conditions (57 mg $plant^{-1}$). NIFA-Aman exhibited the highest potassium uptake under both irrigated (768 mg $plant^{-1}$) and rain-fed conditions (694 mg $plant^{-1}$).

Enrichment of compost for nitrogen content

Compost offers suitable alternative to chemical fertilizers for improving plant growth and yield with multiple benefits of long term buildup of soil fertility and reduction in environmental degradation. Nitrogen (N) content is low in compost usually prepared from agro-wastes. We tested different organic and chemical materials with the objective to produce N enriched composts. Urea, poultry manure, dairy manure and mungbean residues were used @ 2, 10, 20 and 40%, respectively on weight/weight basis during usual process of composting. Finished composts were evaluated for their N content and we found that compost obtained from combination of poultry manure and maize straw had the highest N content of 1.85%. The lowest N content was found in compost from dairy manure and maize straw.

Pilot scale demonstration and popularization of dual technology of bio-geyser and agro-waste composting

Under a grant jointly sponsored by Pakistan Science Foundation and Turkish Cooperation and Coordination Agency, Islamabad, twenty one (21) small and four (4) large bio-geysers were fabricated and demonstrated at community level in Hazara division and district Swat. A training workshop for one hundred (100) participants on the use and maintenance of dual technology of agro-waste composting and bio-geyser was organized at Chattar Plain, Mansehra.

Response of potato to combined application of compost tea and inorganic fertilizers

Organic fertilizers like compost are required to be applied in large quantities and there are problems associated with their storage and transportation. One viable option is to use compost tea as its handling is relatively easy compared to composts. Use of compost tea also reduces transportation costs associated with huge amounts of compost. Compost tea can be applied over a larger area than would be possible by incorporating the same amount of compost in the soil.

An experiment was conducted to study response of potato towards combined application of compost tea (CT) and inorganic fertilizers. Experiment was laid out at experimental farm during 2016-2017. Treatments included control (no fertilizer,

no compost), 250-150-150 kg ha^{-1}, compost @ 22 t ha^{-1}, compost @11 t ha^{-1}, 125-75-75 kg ha^{-1} + compost @11 t ha^{-1}, 250-150-150 kg ha^{-1} + CT , 125-75-75 kg ha^{-1}+ compost @ 11 t ha^{-1}+ CT. The compost tea used in the present study was formulated by mixing 1kg compost in 5L of water. The results indicated that maximum potato tuber yield (14 t ha^{-1}) was recorded under 125-75-75 kg ha^{-1} + compost @ 11 t ha^{-1} + CT. It was followed by tuber yield of 13 t ha^{-1} received under 250-150-150 kg ha^{-1} + CT. Chlorophyll content and plant height were also improved due to the use of compost tea. Preliminary findings indicate positive effect of combined application of chemical and organic fertilizers (compost and compost tea) towards bringing an improvement in yield but these results need further confirmation before developing reliable recommendations for end-users.

Response of tomato to combined application of compost and chemical fertilizers

An experiment was conducted to study the effect of compost /inorganic fertilizer on yield and quality of tomato at NIFA. The treatments included control (no fertilizer)**,** NPK (full dose), half N P K, compost(full dose), Half N, P and K + full compost, Full N, P and K + half compost, Full N, P and K + full compost. Randomized complete block design was used during the study with three replications. The plot size was 15 m^2. The results revealed that maximum fruit yield was 39 tons ha^{-1} recorded in treatment receiving full NPK and half compost followed by 32 tons ha^{-1} received half NPK and half compost as compared to other treatments, which is 100 % increase over control. The soil analysis showed that field was silt loam in texture with pH 8.0, organic matter 0.8%, nitrogen 0.043 %, phosphorus 4.37 ppm, and potash 160 ppm. The other parameters like density, quality (vitamin C), NPK status of plants/soil, its uptake and value cost ratio (VCR) were relatively higher in compost treated plots as compared to control. Preliminary findings indicate positive effect of compost over chemical fertilizers but these results need further confirmation before developing reliable recommendations for end-users.

SOCIO-ECONOMIC IMPACT OF R&D ACTIVITIES

Plant Breeding & Genetics

NIFA released high yielding, disease resistant and widely adopted varieties of wheat, oilseed brassica, chickpea and mungbean are continuously playing a pivotal role not only in boosting per acre yield but is also upgrading the financial status of the farmers of KPK. These crop varieties are cultivated on appreciable area in the province with yield advantage up to 20% over other commercial varieties. A total of 9.2 tons quality wheat seed was produced and duly certified by Federal Seed Certification and Registration Department, was provided to provincial agricultural extension department, seed companies and progressive farmers of Khyber Pakhtunkhwa. The provision of improved NIFA wheat varieties to private seed companies may also generate employment opportunities for the local farming communities. In addition a recent release of wheat variety i.e. NIFA-Aman and NIFA-Mung will further fill the gap by its adaptation in a range of environments in the country. A total of 850 kg quality seed of rapeseed & mustard varieties was produced at NIFA experimental farm and distributed among the farmers of the KPK. More than two tons certified seed of NIFA chickpea variety NIFA-2005 was produced during 2016-17 by Arid Zone Research Center, D. I. Khan at their research farm and sold to chickpea progressive growers in KP for 2017-2018 cropping season. Sugarcane is an important industrial cash crop of Pakistan. It fetches high cash return to the growers and provides jobs to the labors throughout the year. The development and commercial cultivation of high yielding, high sugar content with frost tolerance cultivars will thus increase the domestic production of sugar, which will ultimately reduce the sugar import considerably, resulting in saving of precious foreign exchange of the country.

Food and Nutrition:

Food and Nutrition Division was able to draw consideration of the relevant stakeholders through its ongoing projects on food fortification, products development, food preservation and the value addition of the fruits. Likewise, technical guidelines for nutritional monitoring and management were also provided by this section at national level. Highlights in this regards are vitamin A & iron fortification of dietary oils and wheat flour, respectively and universal salt iodization program. Three type of quantification kits namely iron, iodine and vitamin A spot test kits were prepared and supplied to the nutrition programs for industries, regulatory bodies and other associated personal. The multiple use of meal-ready-to-eat (MRE) has expressed its importance in the public welfare, immune-compromised patients and to cater the needs of disaster hit communities. Moreover, for the development of MRE, millions of rupees were saved during 2013-17 in term of ration purchases from abroad for remote area arm forces personnel. Value addition of gemstone by the irradiation was undertaken to optimally utilize the irradiation facilities of the institute, enabling the local gemstone industry and traders for better economic returns.

Plant Protection:

Pakistan has a wide range of tropical, sub-tropical and temperate fruits vegetables and spices. Many of the fruits and vegetables are consumed indigenously while a meager part is exported to foreign countries. Citrus is exported to Russia, Iran, Afghanistan and the Middle East countries and mangos are mainly exported to Dubai, Saudi Arabia, Oman, U K, Kuwait, Bahrain, France and Germany. Our dry fruits and spices have demand worldwide. The WTO regulations for export of these commodities require disinfestations of quarantine pests before export. Plant Protection Division has developed and reported irradiation doses for control of citrus and mango pests when applied prior to their export, will ease in export barriers. The fruit flies traps were also introduced to provincial Agric. extension department, farmers and training, workshops, were organized at NIFA. Adoption of fruit fly traps as an IPM component at field level and irradiation of harvested fruit for control of various pests will led to positive socio-economic impact on farmer's life and pesticide free fruits and vegetables to the end users. Major damaging wheat diseases prevalent in the province include yellow rust, leaf rust, stem rust, powdery mildew and Barley Yellow Dwarf which are suspected to have caused >1% yield losses in different production zones. Effective race non-specific wheat germplasm was identified in the national material and if released will have visible economic benefits for growers. Slow rusting wheat cultivars with Yr18/Lr34 genes identified previously are being cultivated on large area in Pakistan.

In our efforts to mitigate vector borne diseases particularly dengue and malaria in the country, the plant protection division of NIFA has developed Dengue Guard for personal protection against vector borne diseases. The technology was highly appreciated by the public health workers/ employees for protection against the dengue vectors and gained popularity in PAEC establishments. Its sale has earned 20% benefit to income generation.

Soil and Environmental Sciences:

The economical, environment and farmer friendly nutrients and water management technologies have been devised at NIFA for field, horticultural crops and tunnel farming. These techniques are being widely used by the farming community of KP and the farmers are getting 20 to 30% higher income by the adoption of these technologies. The dual technology of bio-geyser and agro-waste composting was popularized by fabrication and successful demonstration of 25 bio-geysers at community level in five districts of KP.

Publications:

1. Afridi, K., Khan, N. U., Mohammad, F., Shah, S. J. A., Gul, S., Khalil, I. A., Khan, S. M. (2017). Inheritance pattern of earliness and yield traits in half-diallel crosses of spring wheat. *Canadian Journal of Plant Science, 97*(5), 865-880. doi: 10.1139/cjps-2016-0309
2. Ali, Hafiz Farhad, & Shah, Syed Jawad Ahmad. (2017). *Vegetable diseases and farming practices in Pakistan*: LAP LAMBERT Academic Publishing, Germany.
3. Atta, Babar Manzoor, Subhan, Fazle, Khan, Muhammad Irfaq, Khan, Abdul Jabbar, Farooq-i-Azam, & Ali., Akhtar. (2017). Evaluating exotic wheat germplasm for improved yield and disease resistance under international coordination. *Annual Wheat Newsletter (Kansas State University, USA), 63*, 48-52.
4. Khan, Abdul Jabbar, Subhan, Fazle, Atta, Babar Manzoor, Khan, Muhammad Irfaq, Farooq-i-Azam, & Ali, Akhtar. (2017). Socio-economic impact and progress in wheat breeding. *Annual Wheat Newsletter (Kansas State University, USA), 63*, 47-48.
5. Khan, Gul Zamin, Khan, Inamullah, Alamzeb, Khan, Imtiaz Ali, Salman, Muhammad, Badshah, Tahir, & Zahid, Muhammad. (2017). Monitoring of resistance status in dengue vector Aedes albopictus (Skuse) (Culicidae: Diptera) to currently used public health insecticides in selected districts of Khyber Pakhtunkhwa-Pakistan. *International Journal of Mosquito Research, 4*(3), 123-127.
6. Khan, Inamullah. (2017). *The secrets of human heart, its condition and influence on speech and actions.* Paper presented at the Pakistan Congr. Zool.
7. Khan, Jehangir, Khan, Inamullah, Ali, Ijaz, Iqbal, Aqib, & Salman, Muhammad. (2017). The Role of Vertical Transmission of Dengue Virus among Field-Captured Aedes aegypti and Aedes albopictus Mosquitoes in Peshawar, Khyber Pakhtunkhwa. *Pakistan Pak. J. Zool. , 49*(3), 777-784.
8. Khan, Parvez, Mohammad, Wisal, & Imtiaz, Muhammad. (2017). Importance of Phosphorous for crop. *Zaraat Nama Khyber Pakhtunkhwa, 41* (1-2), 21-25.
9. Khan, Parvez, Muhammad, Wisal, & Imtiaz., M. (2017). Differential growth and phosphorus uptake by wheat cultivars at different p levels. *Int. J. Biol. Biotech., 14*(3), 451-459.
10. Kolmer, J. A., Mirza, J. I., Imtiaz, M., & Shah, S. J. A. (2017). Genetic Differentiation of the Wheat Leaf Rust Fungus Puccinia triticina in Pakistan and Genetic Relationship to Other Worldwide Populations. *Phytopathology 6*(0031-949X (Print)), 786-790.
11. Salman, Muhammad, Zahid, Muhammad, Alamzeb, Zamin, Gul, Misbah ul Haq, Muhammad, & Khan, Inamullah. (2017). Insecticidal efficacy in reducing gummosis attributed to peach flat-headed borer in plum trees. *Journal of Entomology and Zoology Studies, 5*(3), 748-752.
12. Subhan, Fazle, Atta, Babar Manzoor, Khan, Muhammad Irfaq, Khan, Abdul Jabbar, Farooq-i-Azam, & Ali, Akhtar. (2017). Introducing, evaluating, and selecting wheat genotypes for higher yield and disease resistance under local environmental conditions. *63*, 48.
13. Zamir, R., A. Rab, M. Sajid, Khattak, G. S. S., Khalil, S. A., & Shah., S. T. (2017). Effect of Different Auxins on Rooting of Semi Hard and Soft Wood Cuttings of Guava (Psidium guajava L.) cv. Safeda. *The Nucleus 54*(1), 46-51.
14. Zamir, Roshan, Abdur Rab, Muhamad Sajid, & Ahmad, Izhar. (2017). Influence of zeatin, glutamin and auxins on root and shoot organogenesis of Guava (Psidium guajava L.) cv. safeda seedling explants. *Pure Appl. Biol., 5*(4), 1171-1175.

Funded Research Projects- Ongoing

Sr#	Project Title	Amount	Duration	Principal Investigator
1.	Wheat Production Enhancement Program (WPEP-CIMMYT)	Rs. 15.075 *(Million)*	2011-17	Abdul Jabbar Khan
2.	Breeding high yielding mungbean (*Vigna Radiata) L.Wilczek)* genotypes for the agro-climatic conditions of Kuram agency	Rs. 2.219 *(Million)*	2016-19	Gul Sanat Shah
3.	Environment friendly management of fruit worm, *Helicoverpa armigera* (Hub.) through SIT coupled with bio-control agent, *Trichogramma chilonis* (Ishii) in tomato/okra in greenhouse and field conditions. (Awarded) 2. IAEA CRP 17926/R3 entitled "Exploring mechanical and Nutritional methods of sex separation in *Aedes albopictus* species of mosquitoes	Euro 20000	2017-21	Muhammad Zahid
4.	Promoting the Sharing of Expertise and infrastructure for Dengue Vector Surveillance towards Integration of the Sterile Insect Techniques with Conventional Control Methods among South and South East Asian Countries	RAS#5066/IAEA	2014-18	Alamzeb
5.	Sharing Knowledge on the Sterile Insect and Related Techniques for the Integrated Area-Wide Management of Insect Pests and Human Disease Vectors	INT# 5055/IAEA	2016-20	Inamullah Khan

Sr#	Project Title	Amount	Duration	Principal Investigator
6.	Exploring mechanical and Nutritional methods of sex separation in *Aedes albopictus* species of mosquitoes	Euro 30,000.0	2013-18	Gul Zamin Khan
7.	Pilot scale demonstration and popularization of dual technology of bio-geyser and agro-waste composting	Rs. 1.217 *(Million)*	2016-17	Amir Raza
8.	Improving off-season vegetables production under high and walk-in tunnels through integrated management of nutrients, water and diseases	Rs. 1.433 *(Million)*	2017-18	Wisal Muhammad
9.	Plant Mutation Breeding of Bio-energy Crops for Optimizing Marginal Land Productivity- ().	RAS/5/070/IAEA	2015-18	Iftikhar Ali
10.	Strengthening climate change strategies for food security through the use of food irradiation.	RAS/5/071/IAEA	2015-19	Tariq Nawaz Khattak
11.	Zero-Gravity Instrument Project (ZGIP)	UNOOSA	2015-16	S. Jawad Ahmad Shah
12.	Development of Electron Beam and X-ray Applications for Food Irradiation (DEXAFI), (D60124)	Euro 18000	2015-19	Alamgeer Khan
13.	Commercialization of existing technology of mushroom and popularization of Oyster and Milky mushrooms as cottage industry for economic uplift of landless communities of KPK, Balochistan & upper Punjab.	Rs. 4.166 *(Million)*	2017-20	Dawood Khan

Detail list of Officers:

#	Name	Designation
I.	Mr. Abdul Jabbar Khan, M.Sc. (Botany)	Director / CS
II.	**PLANT BREEDNG & GENETICS DIVISION**	
	Dr. Iftikhar Ali, Ph. D (PBG)	Head/DCS
	Dr. Gul Sanat Shah Khattak, Ph.D. (Botany)	DCS
	Dr. Babar Manzoor Atta, Ph.D (Breeding)	PS
	Dr. Roshan Zamir, Ph.D. (Horticulture)	PS
	Dr. Fazle Subhan, Ph.D. (Agronomy)	PS
	Mr. Hafiz Munir Ahmad, M.Sc. (Hons. Agric.)	PS
	Dr. Muhammad Irfaq Khan, Ph.D. (Breeding & Genetics)	PS
	Dr. Muhammad Amin, Ph.D (Statistics)	SS
	Mr. Shahid Akbar, M.Sc. (Hons. Agric.)	PS
	Dr. Farooq-i-Azam, Ph.D (Genetics & Breeding)	PS
	Dr. Syed Tariq Shah, Ph.D (Genetics & Breeding)	SS
	Mr. Salman Ahmad, M.Sc (Hons. Agric.)	SS
	Dr. Iqbal Saeed, Ph.D. (Breeding & Genetics)	SS
	Dr. Akhtar Ali, Ph.D. (Breeding & Genetics)	ARO
	Mr. Mumtaz Ahmad, M. Phil (Biotechnology)	ARO
III.	**FOOD & NUTRITION DIVISION**	
	Dr. Taufiq Ahmad, Ph.D. (Chemistry)	DCS / Head
	Dr. Maazullah, Ph.D. (Agricultural Engineering)	PE
	Mr. Misal Khan, M.Sc. (Hons. Agric.)	PS
	Dr. Azhar Rashid, Ph.D. (Biology)	PS
	Mr. Muhammad Zubair Shah, B.Sc (Engineering)	PE
	Mr. Zahid Mehmood, M.Sc. (Hons. Agric.)	SS
	Mr. Dawood Khan, M.Sc (Chemistry)	SS
	Mr. Alamgir, (M.Sc.) Medical Physics	SS

	Dr. Muhammad Yaseen, Ph.D (Food Science and Technology)	SS
	Mr. Ali Raza, M.Sc	JS
	Mr. Saeed Gul, B. Sc. (Chemistry)	ARO
	Mr. Tariq Nawaz, M. Sc. (Chemistry)	ARO
IV.	**PLANT PROTECTION DIVISION**	
	Mr. Alam Zeb, M.Sc. (Hons. Agric.)	DCS / Head
	Dr. Syed Jawad Ahmad Shah, Ph.D. (Pathology)	PS
	Mr. Muhammad Zahid, M.Sc. (Hons. Agric.)	PS
	Dr. Inamullah Khan, Ph.D. (Entomology)	PS
	Dr. Gul Zamin Khan, Ph.D. (Entomology)	PS
	Mr. Muhammad Ibrahim, M.Sc. (Hons. Agric.)	SS
	Dr. M. Misbahul Haq, Ph.D. (Entomology.)	SS
	Mr. Muhammad Salman M.Sc (Hons. Entomology)	JS
	Mr. Muhammad Arfan, M.Sc (Hons. Entomology)	JS
V.	**SOIL & ENVIRONMENTAL SCIENCES DIVISION**	
	Dr. Wisal Mohammad, Ph.D. (Soil & Environment)	DCS/Head
	Dr. Muhammad Imtiaz, Ph.D. (Soil Science)	PS
	Mr. Mukhtiar Ali, M.Sc. (Hons. Agric.)	PS
	Dr. Syed Azam Shah, Ph.D. (Agronomy)	PS
	Dr. Amir Raza, Ph.D. (Agric. Sciences)	PS
	Mr. Zahid Ali, M.Sc. (Hons. Agric.)	SS
	Mr. Parvez Khan, M.Sc. (Hons. Agric.)	SS
VI.	**TECHNICIAL SERVICES DIVISION**	
	Mr. Faiz-ud-Din	DCE/Head
	Dr. Muhammad Amin	PS
	Mr. Asif Murad	PE
	Mr. Raufullah, M.L.I.Sc.	Sr. Librarian
	Mr. Jahangir Khan	SE

VII. ADMINISTRATION & ACCOUNTS		
	Mr. Muhammad Ayaz Khan	Sr. Admin Officer
	Mr. Muhammad Fawad, MBA (Finance), CFA Level – 1	Account Officer

Promotion:

S.No	Name	From	To	On
1.	Mr. Abdul Jabbar Khan	DCS	CS	01.12.2017
2.	Dr. Muhammad Amin	Sr. Scientist	Pr. Scientist	01.12.2017
3.	Mr. Asif Murad	Sr. Engineer	Pr. Engineer	01.12.2017
4.	Dr. Iqbal Saeed	Jr. Scientist	Sr. Scientist	01.12.2017
5.	Mr. Arshad Ali	Sr. Scientific Assistant	Pr. Scientific Assistant	02-05-2017
6.	Mr. Aurangzeb Khan	Sr. Scientific Assistant	Pr. Scientific Assistant	02-05-2017
7.	Mr. Muhammad Waseem Jan	Sr. Tech	Pr. Tech	02-05-2017
8.	Mr. Aftab Ahmad	Tech-I	Sr. Tech	02-05-2017
9.	Syed Muhammad Kamran	Tech-I	Sr. Tech	02-05-2017
10.	Mr. Mujahid Hamid	Scientific Assistant-II	Scientific Assistant-I	02-05-2017
11.	Mr. Muhammad Saeed	Scientific Assistant-II	Scientific Assistant-I	02-05-2017
12.	Mr. Abdul Sami	Jr. Assistant-I	Assistant (Admin)	02-05-2017
13.	Mr. Fazli Nabi	Jr. Assistant-I	Assistant (Admin)	02-05-2017
14.	Mrs. Naila Mushtaq	Telecom Operator-I	Sr. Telecom Operator	02-05-2017
15.	Mr. Muhammad Shah	Driver-III	Driver-II	02-05-2017
16.	Mr. Niaz ud Din	Driver-III	Driver-II	02-05-2017
17.	Mr. Muhammad Tariq	Driver-III	Driver-II	02-05-2017
18.	Mr. Aslam Khan	Scientific Assistant-II	Scientific Assistant-I	13.01.2017

Transfer / Posting

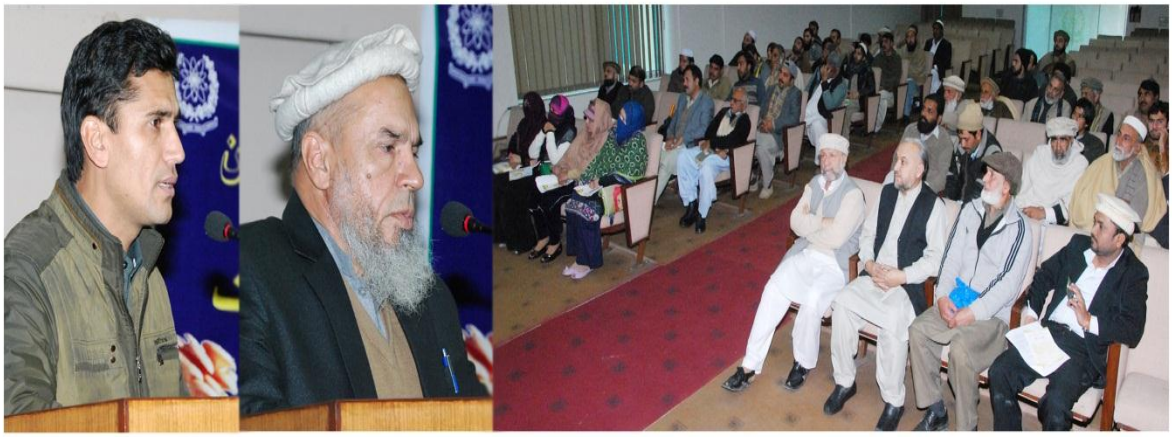
S.No	Name	From	To	On
1	Mr. Hikmat Shah, Sldr	NIFA, Peshawar	KNC, S&F	01.02.2017
3	Mr. Shah Aurang Zeb, Sldr	NIFA, Peshawar	MPB-II, Karak	01.02.2017
4	Mr. Nafees Hussain, Tech-II	NIFA, Peshawar	PINSTECH	09.02.2017
5	Mr. Muhammad Sheraz, DEO	PINSTECH	NIFA, Peshawar	08.03.2017
6	Mr. Latif Khan, S.Sup-III	NIFA, Peshawar	Chashma, Kundian	04.05.2017
7	Mr. Muhammad Shabbir, SCO	DGNFC	NIFA, Peshawar	09.05.2017
8	Mr. Rafique Khan, S.Sup-IV	NIFA, Peshawar	DTD, Islamabad	07.07.2017
9	Mr. Muhammad Karim, SCO	NIFA, Peshawar	PAEC HQs.	31.07.2017
10	Mr. M. Ayaz Khan, SAO	PIEAS	NIFA, Peshawar	11.09.2017
11	Mr. Saif-ur-Rehman, SA-III	NIFA, Peshawar	Chashma, Kundian	15.09.2017
12	Mr. Khalid H. Shah, PAO	NIFA, Peshawar	ACL, Islamabad	27.09.2017
13	Mr. M. Nasir Hayat, ARO	NIFA, Peshawar	NORI, Islamabad	27.09.2017
14	Mr. M. Zubair Shah, PE	DGD, Islamabad	NIFA, Peshawar	10.10.2017
15	Mr. Ali Salaman, CO	PAEC HQs.	NIFA, Peshawar	11.10.2017
16	Mr. Jahangir Khan, SE	ACS, Islamabad	NIFA, Peshawar	25.10.2017

Retirement

S.No	Name	Date
1	Syed Wahid Gul, Admin Officer	01.01.2017
2	Mr. Niaz Ali, SA-I	01.01.2017
3	Dr. Aurang Zeb, CS / Director	16.08.2017
4	Mr. Misal Khan, PS	12.12.2017

Appointment

S.No	Name	Date
1	Mr. Muhammad Irfan, JS	13.07.2017



Popularization of Mushroom Cultivation among Farmers under PSF Project

Development of Bio-Energy Crops in Pakistan – Status & Opportunities

Workshop on Role of Zinc in Crops & Human Nutrition
Chaired by Dr. Nayyar Iqbal (Director A&B PAEC)

Farmers' Day 2017, Chaired by Agric. Minister KP

Integrated Nutrient Management Workshop on Plum & Off Season Vegetables under UAP Endow. Fund, Chaired by Prof. Dr. Jamal Khattak

Management Strategies for Vectors of Human Diseases

Development of Fruits / Vegetables Based Products

Interdisciplinary Statistical Data Analysis Workshop
Chaired by Dr. Habib Ahmad (Vice Chancellor – Islamia University Peshawar)

33rd Postgraduate Training Course
Chaired by Dr. Abid Mehmood (DG Agric. Govt. of Punjab)

Agro-waste Composting & Bio-geyser Technology Demonstration at Hazara
Chaired by Dr. Akram Sheikh (Member Crops, PSF)

Gemstones workshop by Gamma Irradiation
Chaired by Mr. Naveed Masood (Director GGIP)

National Seminar on Seed Borne Diseases of Cereals, Legumes & Vegetables Chaired by Director FSC&RD

Chines Delegate Visit to NIFA for Research Coordination

PAF staff Training on MRE

NIFA & Shaheed Benazir Bhutto Women University Peshawar MOU in the presence of Hon. KP Chief Minister Mr. Parvez Khattak

Head of Divisions with Director NIFA

Plant Breeding & Genetics Division

Food & Nutrition Division

Plant Protection Division

Soil & Environmental Sciences Division

Technical Services Division

NIFA Admin Staff

NIFA Accounts Branch

ISO 9001 : 2008 Certified

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