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Nuclear Institute for Food & Agriculture
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NIFA

Annual Report

2016

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C O N T E N T S

HIGHLIGHTS:

Nuclear Institute for Food and Agriculture (NIFA) has played an active role to help ensure sufficient, nutritious and environment friendly food production in the country as food, nutrition, environment and livelihood security are the biggest challenges faced by the country. The main focus is to meet rather exceed the expectations of end-users through human resource development and the use of nuclear and other contemporary advanced research techniques. Results of the R & D efforts of four research divisions of the institute accomplished during the report period are summarized below:

PLANT BREEDING & GENETICS:

The research endeavors of Plant Breeding and Genetics Division culminated into the release of improved wheat variety NIFA Aman-2016 that has been approved by the VEC (PARC) Islamabad and the Technical Committee of KPK Seed Council for general cultivation in the province. This variety is high yielding, widely adapted endowed with high protein contents and possesses resistance against three rusts (*Yr, Lr & Sr*). Consistent efforts are being made to maintain the seed purity and a total of 9.4 tons quality seed of NIFA released wheat varieties was produced. The seed was distributed to Agric. Extension Department, seed companies and farming communities of KPK. Two candidate wheat lines (CT-12176 and NRL-1123) proved worth for higher yield and disease resistance in the national trials and were subjected to the subsequent mandatory evaluation. Based on proving worth for higher yield and yield components in provincial multi-locational trials, 02 candidate lines, i.e. SRN-13121 and NRL-1206 were subjected to the first year evaluation in the national trials. Oilseed Brassica popularization of Abasin-95, Durr-e-NIFA, NIFA Raya & NIFA-Gold through demonstration plots at 10 districts of KPK was carried out and an average seed yield of 2000 kg per hectare was achieved by farmers. Three candidate lines of rapeseed were tested in National Uniform Yield Trials 2015-16. On mean basis, the seed yield of two candidate lines 08-1/2-7 and RM-I/08-39 showed edge over Faisal Canola and performed better under poor environments. A total of 111 mutant/recombinant lines of rapeseed and mustard were evaluated for agronomic parameters in different yield trials and non-replicated nurseries. An advanced high yielding mungbean line NFM-6-5 has been recommended as variety by the technical committee of provincial seed council with the name NIFA Mung-2016 in 2016. Eighteen advanced mutants and recombinants lines of chickpea produced statistically significant ($p \leq 0.05$) higher seed yield (2755-3333 kg ha^{-1}) as compared to the check variety NIFA-2005 (Average 2560 kg ha^{-1}). Advanced lines of sugarcane CPSG-316, CPSG-1550 and CPSG-1004 were included in the national trials for countrywide field evaluation prior to varietal development. Desirable selections for higher yield and steviosides content in callus irradiated materials of stevia were completed.

PLANT PROTECTION:

The plant protection division has three main research groups; agriculture entomology, medical entomology and plant pathology. The agriculture entomology is involved in the IPM of fruit fly, chickpea 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 R&D work is focused 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.

FOOD & NUTRITION:

The experimental work on MI funded project on the stability of iodine in iodized salt, packaged in different materials under different climatic conditions was studied. Results indicated good stability of iodine in all types of salts except in the “poor quality rock salt from KPK that showed drastic iodine

losses during storage and was found unfit for fortification purpose. In an effort to minimize post-harvest losses, studies were carried out to determine drying rate for strawberries, carrot, and cantaloupe at different temperatures using infrared moisture analyzer. Over all, the drying time decreased to < 50% with increase in temperature from 55°C to 70°C. Mushrooms cultivation technologies for oyster, milky, king oyster and button types were developed and disseminated to farmers through training workshops at Hazara valley, Haripur, Chitral, Swat valley, Balakot, Shinkiyari, Batagram, Bunner, Charsadda, Mardan, Peshawar and Nowshera of KPK.

As part of the IAEA funded project on irradiated food for immuno-compromised patients, meals were prepared and the effect of irradiation on the storage stability was studies. In one study bean and round apple gourd were cooked to prepare round apple gourd mix curry. In the other study, the normal meal prepared with minced beef were fortified with alfalfa as a natural source of multivitamins and minerals. The meals were packed and vacuum sealed in tetra pack pouches and were irradiation sterilized. The meals were evaluated for physicochemical, microbial and organoleptic parameters over a storage period of 3 months. Pesticide residue monitoring and management studies were conducted in fruit and vegetables samples under PSF funded research project. Diverse pesticide residues chemistry was observed in the fruit and vegetable sample. In vegetable and fruits 3-24% and 3-19% samples exceeded MRL concentrations respectively. In pesticide management study, sonication @ 60 kHz and 25°C for 10 minutes was able to dissipate 60 – 70% imidachloprid residues. Effect of irradiation doses upto 0.5Mrad were studied for color enhancement in Kunzite. Optimum color change was achieved @ 2.5Mrad dose. The XRD, SEM and EDX techniques were used to elucidate structure and composition of Kunzite.

SOIL & ENVIRONMENTAL SCIENCES:

The scientists are mainly focusing to enhance use efficiency of natural resources (soil, water and nutrients) and to devise crop production technologies for mitigating the adverse effects of climate change. The climate smart agriculture practices including integrated management of nutrients and water for off-season vegetables under high tunnels, deciduous orchards and other crops have been developed and transferred to the growers in various districts of KP at the eve of Farmers' day, Zinc day and other workshops. Other salient findings include the identification of Zn and P efficient wheat genotypes. Among the tested genotypes NRL-1427 and Insaf-15 were found as Zn efficient while NRL-1402 and NRL-1434 were ranked as Zn-inefficient. The roots of Zn efficient genotypes have greater association with mycorrhiza and have up to 90 % infestation on roots at lower level of P and Zn. Wheat genotypes NRL 1402, NRL- 1427 and Chenab 2000 were P-efficient while NRL-1424 and NRL-1412 were P in-efficient genotypes. The results from field study suggested that integration of FYM with rock phosphate generated positive impact for wheat yield and phosphorus release from rock phosphate. In another study Fakhr-e-Sarhad was found to be a better variety for rain-fed conditions in terms of its root, grain yield and water use efficiency. An economical package of integrated nutrients management through foliar feeding was developed for plum orchards at farmers' field under PSF funded project. Under new PSF/TIKA funded project twenty one (21) small and four (4) large bio-geysers were fabricated and demonstrated in Hazara Division and Swat district.

ACKNOWLEDGMENTS:

The valuable guidance and continued support of Honorable Member Science (PAEC), Director (A&B) and Head of Divisions (NIFA) are commendable and admirable. The Annual Report compilation committee along with NIFA scientists/staff members for their valuable contributions certainly deserves high appreciation.

Director NIFA

Plant Breeding & Genetics

WHEAT- IRRIGATED

Seed production and maintenance of NIFA released irrigated wheat varieties:

NIFA since its establishment has released a number of improved varieties for irrigated areas like Fakhre Sarhad and Bathoor that are continuously performing well in the province and there is an increasing seed demand from the government organization, seed companies and farming community. A new candidate variety with its proposed name NIFA Aman has been recommended by PARC Variety Evaluation Committee (VEC, Islamabad) and Technical Committee of Provincial Seed Council. In addition, continuous efforts are being made by the wheat breeding team at NIFA for maintenance of seed purity and production of quality seed. Progeny rows / blocks of NIFA wheat varieties were planted on the available land at the institute. Progeny rows / blocks having off-type plants were discarded. Breeder nucleus seed was planted for production of Pre-basic / Basic seed duly inspected by the FSC & RD officials. A total of 4200 kg quality seed of these varieties was produced and after processing and certification by FSC & RD the seed was distributed to Agric. Extension Department, Seed companies and farming communities of KPK.

Evaluation of candidate wheat lines in National Uniform Yield Trials under irrigated conditions:

The country-wide field evaluation of candidate varieties provided by wheat breeder's are 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, 02 newly developed candidate lines, i.e. CT-12016 and CT-12176 were subjected to the first 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. The NUYT pooled analysis showed that CT-12176 produced higher mean grain yield in Punjab (27 sites), KPK (6 sites) and Pakistan (38 sites) over the local check variety. In KPK it showed an edge of 7% enhanced yield. 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 2015-16). On the basis of its yield performance and disease resistance the line CT-12176 were included in the NUYT trials 2016-17 for the second year mandatory evaluation.

Evaluation of advanced wheat lines in KPWYT under irrigated conditions of KPK:

Multi-location testing / zonal trials of advanced wheat lines is a pre-requisite for development of new genotypes with wider adaptability and selection of suitable candidate varieties for evaluation in national uniform yield trials. For assessment of grain yield stability 04 promising genotypes (WL-15, SRN-13121, CT-13052 and CT-13169) along with local commercial check cultivar (NIFA Bathoor) were tested at 13 locations in the KPK. The high yielding and disease resistant line SRN-13121 was selected for testing in national uniform yield trials during 2016-17.

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

Evaluation of desirable selections on the basis of better field performance in preliminary yield trials is a prerequisite for attaining the elite status. The selected elite genotypes are being regularly tested in advanced yield trials conducted at the institute, as well as on few selected locations in Peshawar valley.

A total of 54 genotypes were evaluated in three advanced selection yield trials under both normal and late planting conditions at NIFA. In ASYT-1, only one genotype (CT-14059) out yielded both the check cultivars. However, genotypes CTRN-140085, CT-14156 and CTRN-140070 produced higher yield than the check cultivar Bathoor-08 (4043 kg ha^{-1}). In ASYT-II, none of the genotypes out yielded the high yielding check cultivar. Genotypes CTG-154013, CTG-154029 and CTG-154022 produced higher yield than the low yielding check cultivar Bathoor-08 (4032 kg ha^{-1}). In ASYT-III, only one genotype (CTES-15125) out yielded both the check cultivars (Pirsabak-2013; 4954 and Bathoor-08; 4665 kg ha^{-1}). The selected genotypes (06) 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 provides an important platform for detailed assessment with regards to yield/ yield components of the newly selected wheat genotypes isolated from non replicated observation nurseries, mutant population and recombinants. One hundred and fifty genotypes were evaluated in PYT-I, PYT-II and PYT-III including two check varieties (Bathoor-08 and Pirsabak-2013). Each trial consisted of 50 genotypes and were evaluated under both normal and late planting conditions at NIFA. Based on yield performance and disease reaction, 36 genotypes were selected in these trials for further evaluation in advanced selected yield trials.

In PYT-I nine genotypes were selected based on their field performance and grain yield. Three genotypes produced higher grain yield than the high yielding check (Pirsabak-13; 7233 kg ha^{-1}), while 06 genotypes out yielded the low yielding check (Bathoor-08; 4700 kg ha^{-1}). The highest yielding genotype was WPEP-15042 (8450 kg ha^{-1}) followed by WPEP-15099 (7449 kg ha^{-1}).

In PYT-II 13 genotypes were selected based on grain yield and disease resistance out of which 05 genotypes out yielded the high yielding check cultivar (Pirsabak-13; 6466 kg ha^{-1}). The highest yielding genotype was CT-151098 (7000 kg ha^{-1}) followed by CT-151168 (6933 kg ha^{-1}). In addition 08 genotypes produced higher grain yield than the low yielding check cultivar Bathoor-08 (5666 kg ha^{-1}).

In PYT-III 14 genotypes were selected based on grain yield and disease resistance out of which 9 genotypes out yielded the high yielding check cultivar (Bathoor-08; 6599 kg ha^{-1}). The selected highest yielding genotype was CTRN-156153 (7116 kg ha^{-1}) followed by CTRN-156025 (7100 kg ha^{-1}). In addition 05 genotypes produced higher grain yield than the low yielding check cultivar Pirsabak-13 (5800 kg ha^{-1}).The selected genotypes will be evaluated in advanced yield trials, 2016-17.

Field evaluation of exotic wheat germplasm:

Global exchange of wheat germplasm, in particular, CIMMYT / ICARDA through provision of observation nurseries to cooperating institutions always play a positive role for having desirable ideotype by the breeders.

36th ESWYT (Elite Spring Wheat Yield Trial) consisting of 50 genotypes (with 2 replications) was evaluated for yield performance and disease (*Yr*) reaction with local check Bathoor-08. Out of 50 genotypes, 15 were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety (4457 kg ha^{-1}) by producing grain yield in the range of 4499 to 5706 kg ha^{-1}.

16th ISBWYT (International Spring Bread Wheat Yield Trial) consisting of 24 genotypes (with 2 replications) was evaluated for yield performance and disease (*Yr*) reaction with local check Bathoor-08. No selection was made as none of the genotype could perform better than the check cultivar.

3rd WYCT (Wheat Yield Consortium Trial) consisting of 42 genotypes (with 2 replications) was also evaluated for yield performance and disease (*Yr*) reaction with local check Bathoor-08. Out of 42 genotypes, 9 were selected for further evaluation and confirmation of their desired traits. The selected genotypes out yielded the check variety (4911 kg ha^{-1}) by producing grain yield in the range of 5262 to 6578 kg ha^{-1}.

48th IBWSN (International Bread Wheat Screening Nursery) consisting of 300 genotypes received from CIMMYT, Mexico, was evaluated with local check Bathoor-08. Based on plant type, yield performance and disease reaction (*Yr* and *Lr*) a total of 48 genotypes were selected. The selected genotypes out yielded the check Bathoor-08 (3555 - 5511 kg ha^{-1}) by producing grain yield in the range of 4444 to 6222 kg ha^{-1}.

CWANA 16th SBWON (Central and West Asia 16th Spring Bread Wheat Observation Nursery) consisting of 130 genotypes received from ICARDA, was evaluated with local check Bathoor-08. Based on plant type, yield performance and disease reaction (*Yr* and *Lr*) a total of 10 genotypes were selected. The selected genotypes out yielded the check Bathoor-08 (3733 kg ha^{-1}) by producing grain yield in the range of 3733 to 4711 kg ha^{-1}.

26th HRWSN (High Rainfall Wheat Screening Nursery) consisting of 117 genotypes received from CIMMYT Mexico, was evaluated with local check Bathoor-08. Based on plant type, yield performance and disease reaction (*Yr* and *Lr*) a total of 24 genotypes were selected. The selected genotypes out yielded the check Bathoor-08 (4144 - 5155 kg ha^{-1}) by producing grain yield in the range of 4444 to 5777 kg ha^{-1}.
NON (NIFA Observation Nursery) consisting of 117 genotypes (wheat genotypes imported by Dr. Babar from Australian and genotypes developed through hybridization at NIFA), was evaluated with local check Bathoor-08. Based on plant type, yield performance and disease reaction (*Yr* and *Lr*) a total of 28 genotypes were selected. The selected genotypes out yielded the check Bathoor-08 (4622 - 5342 kg ha^{-1}) by producing grain yield in the range of 4711 to 6222 kg ha^{-1}.

Genetic variability and selections from segregating populations:

Development and rising of different segregating populations achieved through cross combination and single gene mutation is the most important breeding strategy that ultimately results in the availability of homozygous genotypes.

A gene pool consisting of 160 variable genotypes was planted on two different sowing dates for achieving floral synchrony for cross among early and late maturing parents. F_0 seeds were harvested from 53 successful cross combinations attempted during Feb-March 2016. F_3 generation resulted from 25 cross combinations was raised (space planting) in the field for evaluation. Based on disease (*Yr, Lr*, LS and BYD etc.), lodging resistance, high tillering capacity and desirable spikes, 175 desirable recombinants were selected and threshed cross combination wise. Similarly, 342 desirable recombinants were selected from F_5 population resulted from 21 cross combinations. M_3 population resulted from the seed treatment of varieties Bathoor-08 and Fakhre Sarhad each with 15, 20 and 25 kR doses of gamma rays was planted in the field and 54 desirable mutants were selected and threshed separately for each variety.

WHEAT- RAINFED

Quality seed production of rainfed wheat varieties:

A total of 5500 kg quality seed of NIFA rainfed wheat varieties i.e., NIFA Lalma, Insaf and Tatara was produced and consequently certified by Federal seed certification and registration department (FSC & RD) at the institute. In addition to high yield, these cultivars showed resistance to prevailing yellow rust. Requests were received from the provincial agriculture departments, seed companies and progressive growers for quality seed of these cultivars. The seed was distributed among the provincial agricultural departments and farming community in Khyber Pakhtunkhwa.

NIFA candidate genotypes in national trials:

Two outstanding wheat lines NRL 1123 (2nd year) and NRL 1139 (1st year) were evaluated in the national wheat yield trials at different sites (moisture stress environments) in the country. Both of these lines exhibited excellent performance across the rainfed sites in the country and will participate in varietal release competition in VEC / Provincial seed council meeting for approval.

Botanical characterization of candidate lines:

NIFA candidate lines (i.e., NRL 1206, NRL 1314 and NRL 1316) that showed high yield performance and wider adaptation were grown for plant characterization. As a pre-requisite for varietal release, detailed botanical characteristics were recorded for each individual line at different growth stages.

NIFA elite genotypes assessment in KP Yield Trials:

For assessment of grain yield stability 04 promising wheat genotypes (NRL 1313, NRL 1314, NRL 1316 and NRL 1317) along with two commercial check cultivars (Lalma and Shahkar) were tested at different locations (moisture stress areas) in the province. All recommended cultural practices were carried out during the growing season. NRL 1314 and NRL 1316 showed good performance and will further be evaluated in NUWYT in the coming season.

Advanced Barani Yield Trials (ABT):

Twenty promising genotypes were evaluated for grain yield, yield components and disease resistance along with check cultivar Lalma in two advanced barani yield trials at the institute. Based on grain yield and disease resistance 09 promising genotypes were selected from these trails. Highest grain yield was produced by NRL 1406 (4689 kg ha^{-1}) followed by NRL 1448 (4608 kg ha^{-1}).

Preliminary Barani Yield Trials (PBT):

Thirty six genotypes along with local check NIFA Lalma was tested for grain yield, disease resistance and other agronomic traits in 03 preliminary yield trials (PBT-1, PBT-2 and PBT-3) under moisture stress conditions at the institute. Twelve genotypes were selected on the basis of higher yield and disease resistance (*YR & LR)*. Highest grain yield (4316 kg ha^{-1}) was produced by NRL1511 followed by NRL1507 (4272 kg ha^{-1}) and NRL1514 (4233 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 always play a positive role for having desirable ideotype by the breeders. NIFA regularly receives these nurseries and effectively use the same for boosting the ongoing breeding activities. During 2015-16 the following wheat observation nurseries and trails were received from CIMMYT and ICARDA.

33rd SAWSN CIMMYT Semi Arid Wheat Screening Nursery consisting of 285 genotypes was planted in a non replicated fashion at the institute under rainfed conditions. Based on yield performance and disease reaction (*Yr* and *Lr*) a total of 93 genotypes were selected.

16th SBWON A total of 160 entries with different genetic background were screened for grain yield, disease resistance and other agronomic traits in non-replicated observation nursery under rainfed conditions. Based on field performance 18 best genotypes were identified and selected. These entries also expressed resistance against the prevailing rust races.

16th DSBWYT Dry land spring bread wheat yield trial consisting of 24 genotypes (with 2 replications) was evaluated for yield performance and disease (*Yr* and *Lr*) reaction according to alpha lattice design. Out of 24 genotypes only one genotype was selected for further evaluation.

23rd SAWYT Semi arid wheat yield trial consisting of 50 genotypes (with 2 replications) was planted for yield performance and disease (*Yr* and *Lr*) reaction according to alpha lattice design with local check Lalma. A total of 20 genotypes were selected for further confirmatory evaluation.

1st SATYT Forty five genotypes were evaluated for yield performance and disease (*Yr* and *Lr*) in Stress adaptive trait yield trial at NIFA under moisture stress conditions. Statistical design of the trial was alpha lattice with 02 replications. Based on field performance a total of 08 genotypes were selected.

14th HTWYT Heat tolerant wheat yield trial consisting of 50 genotypes was planted at the institute under rainfed conditions according to alpha lattice design with 02 replications. Based on yield performance and disease resistance (*Yr* and *Lr*) 07 genotypes were initially selected.

Creation of genetic variability through hybridization / mutation and management of segregating population

Hybridization:

Segregating population of different cross combinations were raised as F_i generation (F_1 to F_7) at NIFA farm. Desirable selections were made in the segregating populations keeping in view the objectives. In order to create genetic variability for high grain yield and disease resistance, fresh crosses of wheat cultivars / genotypes with different genetic background were also attempted. Seed from the selected plants were harvested separately and stored after proper labeling.

Mutation M_3, M_4 and M_5 generations of Lalma, Barsat and Insaf were sown at the institute. Uniform progeny rows were identified in M_3 and M_4 generation and within each identified row 2-3 best plants were tagged on the basis of possessing desirable morphological traits and disease resistance in the field under natural epiphytotic conditions.

Response of wheat genotypes to disease reaction:

Biotic stresses such as rusts are the main factors that limits wheat yield in Khyber Pakhtunkhwa. Eighteen rainfed wheat genotypes were screened for stripe / leaf rusts at hot spots in the country in National Wheat Diseases Screening Nursery (NWDSN). Morocco was used as a susceptible check. Six advanced NIFA wheat lines showed high level of resistance both to leaf and yellow rust (CDRI Report 2016).

PULSES GROUP

MUNGBEAN:

Mungbean breeding material for kharif 2016 was planted and harvested but its threshing and compilation of data is in progress. Detail of planted breeding material is as bellow;

18 recombinants and 71 mutants were planted to evaluate for seed yield and yield components in 2 sets of advanced and 5 sets of preliminary replicated yield trials, respectively, at NIFA research farm during 2016. Adaptation trials consisted of 6 genotypes were sent to evaluate at ARS, Karak and AZRI, D. I. Khan and Kuram agency. Candidate lines NIFA mung-4 (NFM-3-3) and NIFA mung-5 (NFM-5-36-27) have been contributed to evaluate for adaptability in NUYT.

457 single plants selections in F4 populations of 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 were raised during kharif 2016. Similarly, 359 single plants selections were planted in F_4 populations of V 1128 x Ramzan, V 2802 x Ramzan, V 2817 x Ramzan, V 1128 x NM 2006, V 2802 x NM 2006, V 2817 x NM 2006 and V 2709 x NM 2006 and made further selections on the basis of more pods per plant and better plant type

In case of breeding black seeded mungbean genotypes, NIFA black mung was hybridized with Kuram black mung and raised F_2 populations during kharif 2016. Single plants selections were made on the basis of MYMV resistance, seed colour and more pods per plant.
M_2 generations of NIFA black mung and Kuram black mung were raised during kharif 2016 and single plant selections were made on the basis of MYMV resistance, seed colour and more pods per plant. Four new cross combinations i.e., NIFA Black mung x Kuram Black mung, NM 2006 x Kuram Black mung, Ramzan x Kuram Black mung and Kuram green mung x Kuram Black mung were attempted during summer 2016 and raised their F_1 generation during kharif 2016.

CHICKPEA:

18 advanced mutants and recombinants lines along with check variety NIFA 2005 were evaluated in 2 different sets of replicated yield trials during 2015-2016. . All advanced recombinants and mutants produced statistically significant ($p \leq 0.05$) higher seed yield (2755-3333 kg ha^{-1}) as compared to the check variety NIFA-2005 (Average 2560 kg ha^{-1}). These genotypes exhibited 21-24g/100 seed weight and better plant type.

410 single plant selections in F_3 populations of the six cross combinations viz., 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 and selected 530 single plant recombinants on the basis of more number of pods and better plant type to raise F_4 populations during rabi 2016-17. 8 new 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 attempted for creation of genetic variability for yield and its components. M_1 generations of Pb 2008, CM 541/05 and NDC 6-I-7 at 300 Gys were raised to create genetic variability for more number of pods and good plant type. All plants of each genotype were collected individually. M_2 generations of CM541/05 and Pb 2008 irradiated at 300 Gys were raised and selected 87 and 20 single plant mutants to raise M_3 during rabi 2016-17

Biotechnology group
Sugarcane improvement:
Seed multiplication of advanced lines:

High yielding and higher brix content sugarcane advance lines CPSG-316, CPSG-1550 and CPSG-1004 were multiplied. The plot size of each line was 30 x 20 meter, one meter apart. The lines will be tested in different locations for confirmation and testing in the National trials for varietal development.

Rising of seedlings from sugarcane fuzz:

50 grams seed (fuzz) of 10 self pollinated sugarcane varieties were received from National Sugar Crops Research Institute, Thatta. Seed was sown in control environment in the lathe house. The germination of all the varieties was satisfactory. The highest germination was shown by HoTh-326 followed by CPSG-3453. The seedlings plants were successfully 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.

Evaluation of sugarcane genotypes in Trials
Evaluation of Sugarcane genotypes in advance yield trial:

Twelve sugarcane lines were tested in the Advance yield trial in standard plot size of 7 x 4 m^2 having three replications using RCB Design. CP-77/400 was used as commercial check to compare various parameters like percent germination, tillers/plant, maturity, Brix percent, and cane yield etc. The highest plant height of 219 cm was recorded in line CPSG-1004 followed by 216.1cm in line CPSG-1550. The Longest intern ode length of 10.0 cm was recorded in the line CPSG-1004 followed by 9.6 cm by CPSG-1550. Similarly the highest number of nodes (19.6) was recorded in line CPSG-468 followed by CPSG-3453 with 1 9.2internodes per plant. The highest stalk/plant (5.7) was recorded in line CSSG-676 followed by 5.6 cm in Line CSSG-3453. The highest cane thickness of 30.5 mm was recorded in line CSSG-1004 followed by line CSSG-118 with 29.6 mm. In quality characters, the highest recovery of 13.2% was recorded by HOSG-118. This was followed by Line CPSG-1550 with 13.01% recovery. Similarly the highest commercial cane sugar (CCS) of 13.6 % was recorded by line- CPSG-1004. The highest purity of 89.6 % was recorded in line HOSG-118 followed by 89 % by line CPSG-3453. The highest Pol of 20.1% was recorded in lineCPSG-

1550 followed by line CPSG-3453 with 20.0 % Pol.

Preliminary yield trials

Evaluation of sugarcane genotypes in Preliminary yield trial-1:

Promising sugarcane genotypes were evaluated at NIFA in two PYTs for frost tolerant, high cane and sugar yield. The trial consisted of 11 lines with CP 77/400 as a check variety. Plot size was 6x4 m^2 with three replications. The performances of the genotypes are summarized below:

Agronomic evaluation:

Cane thickness: The data on cane thickness indicated variation among all the genotypes. Maximum cane thickness (27.3 mm) was recorded in line CPSG-159 followed by line HOSG-1257 with cane thickness of 25.4 mm. The lowest cane thickness of 20.11 mm was recorded in line US-165.

Stalk/plant: The highest stalk/plant (5.3) was recorded in line HOSG-315 followed by line HOSG-1257 where 5.1 stalk/plant were recorded. The lowest stalk/plant of 3.1 was recorded in Line US-778.

Number of nodes/plant: Out of twenty seven genotypes, the highest number of nodes (14.7) was recorded in line CPSG-239 followed by US-165 with 14.6 and 13.9 in line HOSG-315.

Internode length: The highest inter-node length of 16 cm was recorded in line HOSG-945 followed by HOSG-1021 with 15 cm inter-node length. The lowest inter-node length of 9.5 cm was recorded in line CPSG093.

Plant height: The data on plant height of all the genotypes showed significant variation. The highest plant height (189.6 cm) was recorded in Line HOSG-315 followed by line HOSG 945 with height of 189.1cm. The lowest plant height of 127.1 cm was recorded in line QSG-69.

Cane yield: Significant variations in yield were observed among all the genotypes under study. The highest yield of 91.1 t/ha was recorded in line CPSG-159 followed by line HOSG-315 with 91 t/ha. The lowest yield of 35.8 t/ha was recorded in line CPSG-93.

Quality evaluation:

Brix (%): The highest brix of 21.8% was recorded in line CSSG-239, CPSG-93 and US 469. This was followed by line HOSG-104, HOSG-945 and QSG-669 with 21.3 % brix.

Sugar Recovery (%): The data regarding sugar recovery of all the genotypes showed significant variation. According to the results, highest recovery of 10.5 % was recorded in line US 165 and Aus 384 followed by Line QSG-69 with recovery of 10.8 %. The lowest recovery of 5.8 % was recorded in line SP 576

Purity (%): The highest purity of 81.8 % was recorded in line Aus 384 followed by line HOSG-1021 with purity of 79.82%. While the lowest purity of 64.4% was recorded in line SP-576.

Pol%: The highest Pol of 17.3% was recorded in line US 165 followed by line QSG69 with17.0 % Pol.

Performance of National uniform varietal Trial:

National uniform varietal trial consisted of 11 lines; two lines were received from ARRI, Faisalabad, four lines from NARC and two from NSCRI Thatta, two from Shakkar Ganj Sugar Mills Jhang and one line was from NIFA. The trial was sown using standard plot size of 7x4 m^2. The commercial variety CP77/400 was used as check**.** The highest Stalk/plant (4.8) was recorded in line Us-469 followed by Aus 104 with 4.2 stalk/plant while the lowest (2.8) was recorded in line US-54. The highest Internodes (15.6) were recorded in line CPSG-85 followed by line SP-576 with 15.5 nodes/plant. The highest internodes length of (13.0cm) was recorded in line Aus-384 followed by 12.5 cm in line NARC-1. The highest plant height (200.0cm) was recorded in line SP-476 followed by line Aus 384 with 197cm. The highest cane thickness (28.8 mm) was recorded in line SP-576 followed by line CPSG-85 with 27.3 mm. The highest yield of 100.0 t/ha was recorded in line SP-576 followed by line CPSG 1550 with 95.0 t/hectare. In sugar recovery all the lines showed variation as compared to check. The

highest recovery of 11.2 % was recorded in line Aus-384 followed by CPSG-1550 and NARC-1 with recovery of 10.8 %. The highest brix of 20.7% was recorded in line Aus-104.

Genetic diversity studies in sugarcane:

Genomic DNA was extracted from 17 genotypes using CTAB method with little modification. The genomic DNA was quantified on agarose gel with a standard. The Sugarcane is an important cash crop of Pakistan grown on more than one thousand hectares. For diversity studies 16 micro-satellite (SSR) primers were used to assess molecular variation and diversity in 17 promising sugarcane accessions. Results showed that all accessions were polymorphic.

Improvement of stevia

Effect of gamma irradiation on callus proliferation:

In the present investigation, maximum callus proliferation (95.83 ± 4.17%) was observed on MS-medium containing BA (1.0 mg l^{-1}) in combination with NAA, IBA and GA_3 (0.3 mg l^{-1}) without irradiation. Different doses (5.0, 10, 15 and 20 Gy) of gamma irradiation significantly reduced callus proliferation (88.61 ± 2.74, 83.33 ± 9.62, 82.49 ± 3.16 and 79.16 ± 6.37%) as compared to untreated culture.

Effect of gamma irradiations on callus morphology:

Higher doses of gamma irradiation significantly changed callus color and morphology. Lower irradiation dose (05 Gy) slightly showed inhibitory effects on callus color (yellowish green) and morphology (compact) as compared to untreated callus culture (green and compact). Visual variation in callus color and morphology was clearly observed after 10, 15 and 20 Gy doses. Granular and yellowish green callus was observed in response to 10 Gy dose. White and green friable callus was observed in response to 15 Gy dose. Moreover, 20 Gy dose produced half white and green spongy callus. Such variation in calli is helpful for optimization of cell cultures in bioreactors for enhanced production of medicinally important metabolites.

Effect of gamma irradiation on callus biomass and growth kinetics:

The fresh callus biomass (FCB) and dry callus biomass (DCB) of treated and untreated callus cultures were documented after 3 days interval for a period of 30 days. Higher FCB of 1660 mg was observed in callus cultures irradiated with 15 Gy dose as compared to untreated cultures (1520 mg) after 30 days of incubation on MS-medium. However, 05, 10 and 20 Gy doses significantly reduced FCB (980, 1170 and 1150 mg). The possible reason in gradual decline in FCB may be due to the effect of radiation on endogenous growth regulators that stimulate cell division. Similarly, higher DCB (159.36 mg) was observed after 30 days of inoculation in callus cultures irradiated with 15 Gy doses as compared to the control (145.92 mg). Lower DCB (94.08, 112.32 and 110.4 mg) was observed in cultures irradiated with 05, 10 and 20 Gy doses. These results suggest that 15 Gy dose is slightly effective for accumulation of FCB and DCB as compared to the control.

Effect of gamma irradiations on biochemical parameters:

In this study, we observed that 15 Gy dose slightly enhanced stevioside content (0.251 mg/g-DW) over the control (0.232 mg/g-DW). However, other doses (05, 10 and 20 Gy) showed a negative effect (0.173, 0.216 and 0.219 mg/g-DW) on steviosides biosynthesis. On the contrary, maximum TPC (43.90 mg/g DCB) and TFC (6.87 mg/g DCB) were observed in 15 Gy treated callus cultures. However, higher antioxidant activity (88.73%) was observed in 20 Gy treated callus cultures. Therefore, in the present study, gamma irradiation plays the role of elicitor to enhance the production of phenolics and flavonoids content. The higher antioxidant activity is also due to stress conditions.

OILSEED BRASSICA

Genetic purity maintenance and popularization of Oilseed Brassica varieties:

It is indispensable to maintain genetic purity of approved/commercial varieties to ensure quality seed production. Thus, twenty progeny blocks of rapeseed varieties viz., Abasin-95, Durr-e-NIFA and NIFA Gold along with the same number of progenies rows inclusive of NIFA Raya were raised to produce Breeder Nucleus Seed (BNS). True to type progeny blocks were selected on the basis of varietal characteristics. A total of 113 kg BNS and 233 kg PBS of Abasin-95, NIFA Raya, Durr-e-NIFA and NIFA Gold were produced.

Succeeding Varietal Popularization Programme among the farming community of KPK, 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. The programme yielded encouraging results as farmers harvested more than 1800 kg per ha. The demand of NIFA source seed among farming community has shown up ward trend due to added economic benefit to the farmers with least input.

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

Performance of three new candidate lines in National Uniform Rapeseed Yield Trial:

Three candidate lines of rapeseed (DNC-23, RM-I/08-39 & 08-1/2-7) were evaluated for the second year mandatory testing in National Uniform Rapeseed Yield Trial (NURYT) along with other eighteen rapeseed candidate lines of other breeders of the country and two commercial checks viz., Faisal Canola and Hyola-401 at eleven locations across Pakistan. All three candidate lines produced 5 to 22 % higher seed yield than Faisal Canola at NARC, Islamabad. At Oilseed Research Institute, Faisalabad; the candidate lines 08-1/2-7 and RM-I/08-39 gave 5 to 10% yield advantage over both checks; while at NIFA, Peshawar, the same lines out yielded Faisal Canola by 10 to 20%. The candidate line DNC-23 showed maximum 21 % yield advantage at Barani Agricultural Research Station (BARS), Kohat over Faisal Canola. It was concluded that candidate lines performance varied over different stations with respect to checks; however on seed yield mean basis, candidate lines 08-1/2-7 and RM-I/08-39 showed edge over Faisal Canola. On summative assessment; none of the tested entries in the trial could significantly out yielded the check Hyola-401.

Performance of recombinants and mutants of rapeseed in Multi-locations Adaptation Yield Trial:

The best performing eight rapeseed and mustard mutants / recombinants viz., 011 K-16-3, 011 K-17-1, 011K-18-2, 011 K 1/11-5-3, MM-1/011-18, MM-1/011-25, MM-1/011-40 and MM-1/011-56 were evaluated against respective commercial checks viz., Faisal Canola and Khanpur Raya. The trial was conducted to study the genetic stability and adaptability of rapeseed and mustard lines at ten diversified locations (Nuclear Institute for Food & Agriculture (NIFA), **Peshawar**; Agricultural Research Station(ARS), Sari 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,** Regional Agricultural Research Institute (RARI), **Bahwalpur** and Barani Agricultural Research Institute (BARI), **Chakwal** in the KPK; University of Agriculture, **Faisalabad** and Nuclear Institute of Agriculture (NIA), Tando Jam, **Sindh** during 2015-16.

The results were received from BARS, Kohat; AZRC, D.I. Khan; BARI, Chakwal and NIFA, Peshawar. The data were statistically analyzed and revealed that rapeseed mutants 011 K-16-3 and 011 K 1/11-5-3 exhibited 2210 and 2140 kg ha^{-1}, respectively and surpassed the check Faisal Canola (1696 kg ha^{-1}) on locations mean basis apart from showing superiority in seed yield at four locations. The mustard mutants MM-1/011-18 and MM-1/011-56 out yielded the check by exhibiting yield margin of 16 to 7 % at AZRC, DI Khan and NIFA, Peshawar, respectively. With regards to over all performance, the mutant MM-1/011-18 yielded 2065 kg ha^{-1} compared to

Khanpur Raya (2048 kg ha^{-1}) on location mean basis.

Agronomic evaluation of mutants/ recombinants in Advanced Yield Trials:

Nine rapeseed recombinants viz., RR 23, RR 44-1, RR 33-1, RR 33-2, RR 33-3, RR 34-1, RR 34-2, RR 40-1, RR 41-1; eight rapeseed recombinants/mutants viz., RR 41-3, RR 41-4, RM 41-5, RR 13-2, RR 13-3, RR 13-4, RR 14-2, RR 41-2 and four mustard mutants viz., MM 27-2, MM 31-3, MM 31-4, MM 31-5 were evaluated separately in three Advanced Yield Trials (AYT-I, AYT-II and AYT-III) along with commercial controls Faisal Canola (rapeseed) and Khanpur Raya (mustard), respectively, at NIFA experimental farm, during 2015-16. The trial was laid out in RCBD, replicated thrice.

Advanced Yield Trial-I: The results revealed non significant differences compared to check and within test entries. However, seven rapeseed mutants viz., RR 23, RR 33-1, RR 33-2, RR 33-3, RR 34-1, RR 34-2, RR 40-1, produced higher seed yield and gave yield advantage of 12-21 % compared to Faisal Canola (2639 kg ha^{-1}). The mutant RR 34-2 also exhibited earliness as it took 71 days to flower and highest oil was recovered from mutant RR 33-1 (43.57%).

Advanced Yield Trial-II: Rapeseed recombinant RR 41-4 harbored 3361 kg ha^{-1} followed by RR 41-2 (3194 kg ha^{-1}) compared to check (2389 kg ha^{-1}). The recombinant RR 41-2 took least days to flower (77) and can be regarded early maturing, while RR 13-2 exhibited high oil contents (41%).

Advanced Yield Trial-III: Four better performing mustard mutants were evaluated in AYT-III; the data revealed that the MM 27-2, MM 31-3 and MM 31-4 out yielded the check by margin of 5 to 15% and mutants MM 31-3 and MM 31-5 took 65 days to flower and matured earlier than the check and rest of the mutants. Furthermore, the mustard mutant MM 31-3 also exhibited high oil contents (39%) better than check and other test mutants.

Performance of stable mutants for yield & other agronomic characteristics in Preliminary Yield Trials:

Stable and high yielding six rapeseed recombinants/ recombinant mutants/mutants viz., RR 3-1, RR 8-1, RR 8-2, RR 9-1, RRM 112—2, RM 148-2; six mutants viz., RM 152-1, RM 156-1, RM 173-1, RM 183-2, RM 193-1, RM 276-1; and sixteen mustard recombinants (eight each) viz., MR 78-1, MR 78-2, MR 79-1, MR 80-1, MR 80-2, MR 81-1, MR 81-2, MR 82-1, MR 83-1, MR 83-2, MR 84-1, MR 84-2, MR 86-1, MR 87-1, MR 88-1 and MR 88-2 were evaluated in the Preliminary Yield Trials; PYT-I, PYT-II, PYT-III and PYT-IV along with a commercial checks Faisal Canola (rapeseed) and Khanpur Raya (mustard), respectively. The trial was laid out in RCBD, replicated thrice.

Preliminary Yield Trial-I: Rapeseed recombinants RR 8-1, RR 8-2 and RR 3-1 produced significantly higher seed yield 4583 kg ha^{-1}, 4500 kg ha^{-1} and 3944 kg ha^{-1}, compared to check (3000 kg ha^{-1}), while RM 148-2 was recoded early maturing (69 DF). The recombinant RR 8-1 exhibited high oil content (45.20%).

Preliminary Yield Trial-II: Rapeseed mutant RM 193-1 out yielded all the test entries and the control by producing 3583 kg ha^{-1} while RM 173-1 took 80 days to flower and matured earlier than the rest. Rapeseed mutant RM 193-1 harbored 44 % oil contents.

Preliminary Yield Trial-III: In this mustard trial; highest seed yield was achieved by MR 80-1 (3333 kg ha^{-1}) followed by MR 78-1 (2889 kg ha^{-1}) however the differences among them and the control (2944 kg ha^{-1}) was non significant. Mustard recombinants MR 81-1 was recorded early maturing and MR 78-1 exhibited high seed oil content (38%).

Preliminary Yield Trial-IV: Mustard recombinant MR 83-1 produced 03 % high seed yield (3500 kg ha^{-1}) compared to check (3389 kg ha^{-1}) none of the other mustard recombinants could out yielded the check . MR 88-1 was featured with earliness while MR 87-1 harbored 40% oil in the seed.

Assessment of rapeseed & mutants/ recombinants in Non-replicated Yield Trial:

Sixty five rapeseed recombinants/mutants were evaluated at an early stage (F_4/M_4) for assessment of yield and other economic traits in a non-replicated trial planted in augmented design along with a commercial check Faisal Canola (C) replicated randomly fifteen times; thrice in each block . The results indicated that twenty test entries performed better than the highest seed yield of control (4888 kg ha^{-1}) by margin of 4 to 33% while many were superior than the control mean seed yield (2977 kg ha^{-1}). It was concluded that six rapeseed recombinants produced 5333–5777 kg ha^{-1} with 08 to 17%; thirteen rapeseed recombinants achieved 5111 to 6666kg ha^{-1} with 04 to 33% and 01 rapeseed recombinant/mutant yielded 5111kg ha-1 with 04 % higher seed yields over check (4888 kg ha^{-1}).

Development of breeding populations F_0/F_1 and $M_1/F_1/F_2$ generations:

A crossing block consisting of forty-eight rapeseed and mustard germplasm was raised including the parental material of developed breeding population and advanced rapeseed & mustard genotypes. Five diversified mustard lines viz., KJ-206, EMH-274, M-5121, CORAL-432 and NM-10/15-16 and four rapeseed genotypes viz., Punjab Sarson; SONG-1; HOP and NR-22/10-11 were utilized in different combinations viz., (EMH-274 X M-5121) x NM-10/15-16; (KJ-206 X M-5121) x NM-10/15-16; (KJ-206 X CORAL-432) x NM-10/15-16; (CORAL-432 X M-5121) x NM-10/15-16 and 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; NR-22/10-11 x SONG-1, respectively to incorporate earliness, reduced plant height and uniform maturity coupled with seed yield. Two hundred and fifty-eight stigmas were pollinated. Pods were harvested cross wise as F_0 generation and F_1 seed. Abasin-95 was irradiated @ four gamma rays doses viz., 1, 1.2, 1.4 and 1.6 k Gy with the objective to develop high erusic rapeseed mutant material that can be utilized to tailor oilseed brassica as bio-energy crop. To have an ideal representation of each and every plant in M_2, single plant of each dose were harvested separately.

First filial generation of five cross combinations of intra-specific crosses were harvested cross wise and bulked. The F_2/M_2 populations developed from seven recombinants/mutants; were worse affected by hail storm and the material resulted serious lodging, was saved by accomplishing composite samples. Therefore, twenty six single plant representative samples were collected along with one hundred and two single plants.

Quality assay of oilseeds through NIRS:

Near Infrared Reflectance Spectroscopy (NIRS) technique for quality analysis of oilseeds is cost, time and labour effective. It is a non-destructive technique featured with speedy analysis of samples. For ongoing project at NIFA, about 587 samples of oilseed germplasm and breeding materials were analyzed for fatty acid profile and glucosinolates contents. The quality of oilseed "Under the Routine Quality Analysis Service" (oil, protein, fatty acid profile and glucosinolate); 3, 955 samples of brassica; 241 samples of sunflower; 430 samples of cotton and 88 samples of sesame were analyzed for academician, researchers of different universities and R & D organizations both at provincial and federal levels.

IAEA RAS/5/070-Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques:

IAEA funded project entitled 'RAS/5/070-Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques' was commenced from January 2015. The major objective of this project is the development of rapeseed (*Brassica napus*) mutant lines with high erucic fatty acid suitable through the use of induced mutations. During first year of this project segregating populations were developed. Abasin-95 was irradiated @ four gamma rays doses viz., 1, 1.2, 1.4 and 1.6 k Gy. The mutagenized rapeseed generation (M_1) was raised in field. At maturity, experiments were harvested and seeds were threshed cleaned and collected genotype-wise and gamma radiation dose-wise.

AGRICULTURE ENTOMOLOGY

FRUIT FLY:

For some decades, fruit flies are recognized as one of the most damaging insect pests of fruits and vegetables in several regions throughout the world. 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 commercial lure.

Effect of insecticide renewal in methyl eugenol on the attraction of fruit fly catch in pear orchard in Charsadda:

Instead of replenishing the whole trap, only insecticide (dipterex) was renewed on the cotton wicks in traps at an interval of 15 days, up to 60 days. The results were compared with the standard check, installed on May 19 to August 31, in peach orchard at Charsadda. The results indicated that the trap captured 18-66% more flies than check when renewed after 15 days. The increase in number of flies ranged from 124 to 206% and 160 % in the traps replenished after 30 and 45 days respectively which indicated that trap efficiency was increased when replenished with toxicant only.

Management of melon fly using different concentrations of three food attractants with Cue-lure in bitter gourd field at Peshawar:

Cue-lure in the concentration of 05, 10, 15, 20, 30, 50% was blended with the mixture of protein hydrolysate, yeast and molasses. 05 ml test material was applied on wicks for capturing melon fly under field conditions. Weekly data was recorded since 14th June to 10th August, 2016. The results indicated that maximum number of flies (1060) was captured in 15 % cue lure followed by 982, 973 and 933 flies in 50%, 05% and 30% cue-lure respectively as compared to 680 flies in the standard check. The results indicated that very cheap formulation i.e 15% lure can be used for efficient trapping.

Chickpea Pod Borer:

Chickpea pod borer, *Helicoverpa armigera* is a major pest of chickpea tomato, tobacco, cotton and vegetables causing economic losses to tune of 70 to 95% in chickpea crop. Pod borer, being ubiquitous & Polyphagous in nature is commonly known as chickpea pod borer, American bollworm of cotton, tomato fruit worm, corn earworm and tobacco budworm. The extent of damage inflicted by pod borer to chickpea depends not only on the number of larvae but also on its developmental stages. The caterpillars have variable colours ranging from green, yellow or yellowish. The 1st instar larvae are yellowish white and the second being yellowish. Third and fourth instar larvae are yellowish green or greenish yellow with slight and dominant streaks respectively on the body while fifth and sixth are green in colour feeding voraciously on host crop plants.Keeping in view the pest severity, the present research has been designed to develop integrated approach to

manage the insect using IPM components such as host plant resistance and botanical biopesticides / synthetic insecticides with objectives to screen available NIFA developed chickpea varieties/ mutant lines for pod borer resistance and determine the efficacy of botanicals/synthetic insecticides for controlling larvae damaging chickpea crop.

Experiment 1: Chickpea Varietal Screening:

A field trial was conducted at the experimental farm of NIFA, Peshawar. Six advanced NIFA desi chickpea genotypes developed viz. NDC-4-30-2, NDC-6-15-4, NDC-20-6, NDC-6-15-5, NDC-6-15-10 and NDC-4-30-1 were sown during November 2015 in a RCB design with four replication. A distance of 40 cm and 10 cm between rows and plants was maintained respectively. Each experimental plot consisted of six rows, each of 5 meter length. Weekly observations on pod borer larvae counts were recorded on randomly selected 7 plants/plot. Total numbers of pods versus damaged pods per 7 plants by the pest were also recorded. Damage caused by chickpea pod borer was calculated and converted into percent damage by using the following formula.

$$\% \text{ pod damage} = \frac{\text{No.of damaged pods}}{\text{Total \# of pods}} \text{ X } 100$$

Data recorded on relevant parameters showed that mean larval population ranged from 3.4 – 4.6 per plant during the whole cropping season. Percent pods damage recorded were 91.5 --- 100%. It was visualized/ observed that during the flowering and podding stages, pest larval population was quite high & kept on increasing which played havoc with the crop. None of tested genotypes showed tolerance. No grain yield was recorded.

Experiment-2:Efficacy of botanical bio-pesticides against *Helicoverpa armigera* on chickpea crop:

A field trial was carried out to determine the efficacy of different insecticides against the larval density of pod borer on chickpea crop. The experiment was laid out in a randomized complete block design with six treatments including control and four replications. The plot size was 8 m2. Five botanicals viz. Bifenthrine +adjuvant, neem oil paste, amamectin adjuvant, white oil paste and synthetic chemical at the rate of recommended doses were sprayed twice at the onset of larval attack. Two pretreatment and 4 post treatment observations on larval populations were made. Data were recorded by counting the number of live larvae on randomly selected seven plants per plot. At maturity stage, the crop was harvested and grain yield per treatment was recorded. The results showed that pretreatment larval population ranged from 6.4 – 8.4 during 1st spray. The results indicated that due to high pest larval population crossing the permissible level of determining treatment efficacy, treatment (T3), was found effective as compared to control. The remaining treatments did not show efficacy in term of larval mortality, however minimum pods damage (77%) was recorded in treatments T3 (Emamectin+ adjuvant) followed by synthetic chemical where pods damage was 78%, having grain yield of 790 kg/ha+ 450 kg/ha respectively. The efficacy of botanicals will be retested in the new cropping season against pod borer population damaging chickpea crop. On the whole, the larval population in treated plots remained lower in all the observed days after application of both sprays in comparison with control. Maximum grain yield (1068 kg/ha) was recorded in treatment Steward followed by Regent (1043 kg/ha) while in control, grain yield recorded was 739 kg/ha. Steward proved best in reducing pod borer larvae and enhanced grain yield.

Experiment 3: Management of Bruchid beetles damaging stored mungbean grains:

Bruchids *Callosobruchus maculatus* (F.) are the principal post-harvest pest of mungbean and other stored pulses. In storage, the adult female lay eggs directly on seed coat. The newly hatched larva bore through the egg shell and penetrates seed coat, continue to feed and complete their development inside the seed. After completion, the insects emerge as adult beetles leaving behind a hole at the exit point. Bruchids infestation causes reductions in the

weight, seed viability, sale ability and infested grains unfit for human consumption. The alternative to chemicals and other control measures is to develop bruchids resistant genotypes. Under Joint PSF Research Project with Mungbean Breeding Group at NIFA on "Breeding for Bruchid Resistance in Mungbean" research work was carried out with an objective to identify bruchid resistant genotypes and incorporation of resistant genes in local high yielding well adapted genotypes.

Experiment 4: Evaluation of bruchids *Callosobruchus maculatus* resistance in mungbean genotypes:

Four coded mungbean genotypes were supplied by---breeding group were evaluated to ascertain their resistance to bruchid beetles. The resistance of mungbean genotypes to bruchids was evaluated on the basis of oviposition on grains, grain infestation and % grain damage. The results showed that out of four coded genotypes, three genotypes i.e. A, C and D had grain infestation of 70.25%, 55 and 55. 50% associated with grain damage of 25.75%, 44.25% and 53% respectively. Only a coded genotype B was found with minimum grain infestation of 25% having 5% of grain damage. The conclusion is that the tolerant genotype found to bruchid will be utilized in mungbean breeding programe for incorporation of the desired resistant characters in the local adopted mungbean genotypes.

BIOLOGICAL CONTROL

Experiment 1: Parasitizing effect of *Trichogramma chilonis* (Ishii) against tomato fruit worm:

The release of this agent in the experimental plots at NIFA research station showed minimum mean incidence of tomato fruit worm 1.25 borers/plant in T4 (800 pupae of *T. chilonis*) followed by (1.52 borers/plant) at (600 pupae of *T. chilonis* and (1.65 borers/plant) at 400 pupae of *T. chilonis* and finally (1.95 borers/plant) at release rate of 200 pupae of *T. chilonis*. Tomato fruit yield results showed that the maximum mean produce of tomato was recorded in treatment T4 plot i.e. 42.17 kg followed by T3 (38.83 kg), T2 (36.75 kg), T1 (30.83 kg) and minimum tomato produce was recorded in un-treated plot T5 (14.83 kg) respectively. Overall results showed effective control of the borer at release rate of 800 pupae of *T. chilonis*.

Experiment 2: Parasitizing effect of *Trichogramma chilonis* against okra fruit borer:

The minimum incidence of okra fruit borers were recorded in T3 & T4 (release of 600-800 pupae of *T. chilonis*) with 0.87- 0.90 borers/plant followed by T2 (400 pupae of *T. chilonis* = 1.03), T1 (200 pupae of *T. chilonis* = 1.27) & maximum mean infestation was 2.23 borers/plant found in T5 (Check plot).

Experiment 3: Effect of gamma irradiation on *Trichogramma chilonis* & *Sitotroga cerealella:*

Fresh pupae (50) of *Trichogramma chilonis* and eggs (50) of *Sitotroga cerealella* pasted on cards were radiated with different doses (35, 55, 75, 95) Gy with untreated control, replicated three times in CR design. The percent parasitization by *T. chilonis* of gamma irradiated host eggs varied significantly. Low doses proved better to prolong egg viability than high doses. 35 Gy resulted maximum hatching of *S. cerealella* and maximum adult emergence, percent parasitization in *T. chilonis* but remain lower than the untreated (control) where maximum parasitization and adult emergence were observed. Treatment of 95 Gy resulted in lowest incubation, adult emergence and parasitization. It is concluded that, gamma radiation prolonged the incubation period and viability of host eggs for *T. chilonis* parasitization.

Experiment 4: Effect of low temperatures on *Trichogramma chilonis* & *Sitotroga cerealella:*

Fresh pupae (50) of *Trichogramma chilonis* and eggs (50) of *Sitotroga cerealella* pasted on cards were placed in an incubator at temperatures of (4 & 8) °C with untreated control for different time intervals of (3, 5, 7, 10, 15) days, replicated

three times in CR design. After 3 days storage, the highest (89.6%) emergence was observed from *T. chilonis* parasitoids held at 04 ^{o}C and it was near to control (92.4%), followed by 79.1, 70.7, 65.9, and 61.7% held at 5, 7, 10, 15 days, respectively. The highest hatching percentage was also observed in 3 days storage which is close to values in the control treatment. Low temperature increases shelf life of *S. cerealella* and *T. chilonis* without maximum detrimental effects on the quality of parasitoid and the host that ensures the year around availability of parasitoids in insectaries for research and field releases.

TERMITE MANAGEMENT

Experiment 1: Evaluation of toxicity of diflubenzuron when used in bait against subterranean termites:

Commercial bait having 0.25% Diflubenzuron (Advance) was tested for its toxicity against subterranean termite specie *Heterotermes indicola.* A layer of 100 g sand having 20% moisture was made in petri dish (5 cm dia. and 1.5 cm high). Nile blue (biological dye) was mixed @ 1ml/g in bait (having Diflubenzuron as toxicant) to confirm the bait consumption. A known quantity having bait toxicant and was placed on the sand for termite feeding and in the similar way blank bait having no toxicant was also placed as reference or control. Diflubenzuron was found very effective in killing the *H. indicola* and at the end of one month 100% mortality was recorded and all the termites were blue in color confirming the consumption of bait. Number of protozoa (flagellates) were also counted in both bait fed termites and unfed termites. Significant reduction in the number of alive protozoan were recorded in bait fed termites. In untreated termite total average number of flagellates were 4500/gut whereas in treated number reduced to 1125/gut which indicated the toxic effect of diflubenzuron on number of flagellates in gut that ultimately lead towards the mortality of termite.

Experiment 2: Evaluation of horizontal transfer of diflubenzuron in*Heteroter-mesindicola*:

For transfer study of diflubenzuronfrom bait-fed termites to un-fed ones, the termites were divided in to two groups; donors and recipients. The donor termites were dyed by feeding on bait for three days dyed with 1% Nile Blue A (biological dye).The termites designated as recipient were not fed on dyed bait. Donors and recipients termite workers were then released together in 1:1, 1:4 and 1:9 (R:D) ratios in group of 50 in glass Petri dishes provided with 20% moist sand. Dead donors and recipients were counted at the end of experiment (2 weeks). It was found that maximum mortality i.e. 100% was recorded in 1D:1R followed by 45 % in 1D:4R and 21% in 1D:9R confirming the horizontal transfer of diflubenzuron in all the tested ratios but effective ratio was having 1 D verses 1 R for two weeks. Total number of flagellates was also counted in both donors and recipients in all the three ratios. Obviously, numbers were low in donors than recipients. But overall number of flagellates were significantly less in both donors and recipients 1D: 1R.

Experiment No.3 Anti-termitic activities of heartwood extractives against *Heteroter-mesindicola:*

Extractives of the four durable wood species i.e.Teak(*Tectonagrandis*), Shisham (*Dalbergiasissoo*), Cedar (*Cedrusdeodara*), Chir pine (*Pinusroxburghii*) were used to treat two non-durable wood species, Southern Yellow Pine (SYP, *Pinustaeda* L.) and Cottonwood (CW, *Populusdeltoides*). SYP and CW blocks (19×19×19 mm) were pressure treated with different concentrations (2.5, 5 and 10 mg/ml) of heartwoods extractive. Air dried shavings (12 g) of durable woods were soxhlet extracted using 300 ml of ethanol: toluene (2:1) as solvent.A total of 400 termites (396 workers and 4 soldiers) 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 increased concentration of 10 mg/ml. These extracts showed potential to be used as environmentally

friendly insecticides/termiticides for wood and wood based materials.

Experiment 4: Study of tunnelling behaviour of subterranean termites in medium treated with non-repellent insecticides:

Glass tubes (20 cm long with an inner diameter of 2.5cm) were filled with 3 cm (27 gm) treated sand on top for creating chemical barrier followed by10 cm (90 g) untreated sand. The treated sand was soaked with various concentrations of non repellent insecticides (w/w) such that the moisture contents of sand remain at 20% of sand (w/v). Twenty five termite workers and 2 soldiers were introduced from the top and allowed to tunnel. The cumulative tunneling distances were measured after 7 days. It was concluded that tunneling was dose-dependent, as the concentration was increased the tunneling length was decreased and vice versa. Fipronil found to be effective chemical in soil against *H. indicola* at $\geq$ 1ppm. Indoxacarb was able to suppress the ftunneling activity at all the tested concentrations. Chlorfenapyr did not repel the termites and allowed termites to forage freely in treated zone which resulted in high mortality of exposed workers. Whereas imidacloprid termites were not able to cross the barrier of 3cm of treated sand even at the lowest tested concentration of 20ppm.

MEDICAL ENTOMOLOGY

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 vector's spread in the country. The use of insecticides for vector control is the only option presently used. But due to environmental constraints, health hazards and resistance development in mosquitoes, other environment friendly vector control strategies with main emphasis on Sterile Insect Technique (SIT) are needed. Besides our research efforts towards SIT, we regularly carry out the entomological surveillance of *Aedes* species and seeking environment friendly conventional methods for vector control. Under this program several experiments on vector surveillance, control, vector identification habitat management and sterile insect techniques (SIT) have been conducted to stop the spread of the vectors to other parts of the country.

Experiment 1: Use of plant infusion in Ovitraps for Vector Surveillance:

Research data on the dengue vector surveillance using new approaches are currently limited. In our efforts to monitor and combat mosquito vectors of deadly diseases, we used plant based infusions in ovitraps at field experiments. We recorded more mosquitoes' catch in hay, grasses and eucalyptus infusions than in ovitraps of simple water at three hot spots (3 union councils of Mingora i.e Odigram, Rahimabad and Shahdara) and SINOR at Swat. Our data also indicated that Aedes aegypti mosquitoes are the main vectors of dengue transmission in Swat.

Experiment 2: Formulation of selective diets as mean for male/female separation of the mosquitoes:

The female's adults prefer to consume more proteinious food and blood meal especially for embryonic development of new batches of eggs while male survival depends on feeding upon carbohydrate contents. This hypothesis was tested at the larval stage of *Aedes albopictus* that whether this trend also exist at the larval stages or not. Larvae were provided with different food sources as Soyabean, Fine Flour, Peanut, Peanut+ Fine Flour and Stevia+ Bovin Liver+ Yeast (75%, 20 and 5%) some rich in carbohydrates and others rich in proteins. The pupal size (both male/females), percentage of male/female were determined. The effects of nutrition on their developmental periods were also calculated. For these experiments various food ingredients mostly, Stevia+ Bovin Liver+ Yeast) Fine Flour,Peanut were tested individually and in mixtures for recording their effect on the morphological dimorphism. The effect of each food was recorded on larval development, emergence time and pupal size etc. Measured quantities of each food were

given in proper required ratio daily, and loss of water due to evaporation was replenished regularly. Larval developmental period, pupation and any size difference in pupae were noted and recorded through microscope with measuring scale. In such experiments on diet ingredients for mechanical separation was done in which we investigated, protandry in developmental time, sex ratio and dimorphism in male/female of resulting pupae.

Results showed that the diet comprising mainly of carbohydrates were conducive for the growth of male sexes of *Aedes albopictus.* These diets favored the male size (9.000 F) and female as (60-67%). However the protein based diets skewed in favor of females both in term of size (380-390 µm) and mean number (50-60%) ratio to males. This was good idea to exploit for sexing; however, single diet did not resulted in remarkable difference in male/female size that may be exploited for the sex separation. However, it gave a clue for the potential of a distinct dimorphism. The developmental period was also prolonged (up to 11.65 days) due to single diet inputs especially the carbohydrate based ingredients. We therefore, tested the combination of protein and carbohydrates in different ratios. The combined diets in deferent concentration favored the dimorphism with size ranging (11.00 mm male, 13.00 mm female) remarkably for subsequent mechanical separation. However, these results are being confirmed by the repeated trials and need standardization.

By testing the different sources of protein and carbohydrates. It is concluded that besides the effect of these ingredients singly or in combinations, different nutrients of the diets does also have effect on the dimorphic development of mosquitoes both on their developmental time and on their size. The protein based diets favor the sexual dimorphism due to significant difference in size. The pupal size difference among the different formulation of diets can be exploited successfully in mechanical sex separation. It was concluded that carbohydrates Sources diet showed the Significant effect on Sexual dimorphism in female pupae of *Aedes* Species.

Experiment 3: Using different mesh sizes for the mechanical separation of the pupae from the mix culture:

Under sexual dimorphisms conditions it is pertinent to work out the standard mesh size for the mechanical separation of the male/female resulted due to nutritional effect. For this purpose different sieves of mesh size (1.25, 1.6 and 1.4mm) were initially tested for the purpose. One mesh is equal to the number of holes/cm^2. Mix cultures having male/female were kept in the tubs and the respective mentioned size of the mesh was tested for the separation of the sexes at the pupal stage. For each test the total numbers of pupae that moved from the bottom and passed through the mesh and remained on the surfacewere separated and the percent male/female was recorded for each trial.

Results showed that mesh size greatly affect the number of male/female ratio emerged after separation. The mesh size of 1.4 and 1.6mm were not helpful as they allowed all the pupae to pass through. The mesh size 1.25 was found useful in the initial trial that resulted in maximum results by producing 100% males and females.

It was concluded that the mish size of 1.25mm separated both the sexes is equally. It is therefore recommended for the mechanical separation of the male/female pupa of Aedes.

Experiment 4: Exploiting the effect of low temperatures in sex separation:

The hypothesis that female pupae build a protective Sheath formation around their body during low temperature regime for the survival of the species. Thus the low temperatures (0, 5 and 8 degree celsius) were tested for the possible sheath formation in both species of Mosquitoes as culex and Aedes. Sheath formation and mortality rate of the pupae was recorded at different temperatures. Different treatments like (Clay+ Sand+ Soil+ Composite+ Saw dust+ Water) and (Saw dust + Water), etc.

were also tested for facilitating the sheath formation.

Result revealed significant differences in pupae Size as sheet formation in Culex and Aedes mosquitoes. Pupae were recorded as 9.3333 and 9.6667 at (Clay+ Sand+ Soil+ Composite+ Saw dust+ Water) (Saw dust + Water) respectively**.** The highest female pupae size was perceived by 5 C. The maximum adult emergence and mortality were recorded at 8 and 0 c.
It was concluded that the protective sheet formation found at 5 ^{0}C in both species of mosquitoes pupae as Culex and Aedes. . It is therefore recommended for the Sex separation of the female resulted due to temperatures effect.

Experiment 5: Eliminating female Aedes Adult Mosquitoes by Spiking blood meals with different Slow acting toxicants as a Sex Separation method in the context of the Sterile Insect Technique:

Blood meals were spiked with various toxicants as Delta Methrin, Agenda, Boric Acid, and Plant extract, Temphos with control at different concentrations like 1, 0.5 and 0.1ppm. The Adults were offered to different concentrations at after 1, 2 and 3 hours exposure period 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, after they had been irradiated and partially eliminated of the method in amass-rearing, and SIT context.

In the samples of 50 female *Aedes* adults, Plant extract eliminated females most quickly and thoroughly, with 58.33% kill after 1 hrs exposure period followed by Boric Acid, Agenda, Temphose and Delta Methrin as 28.33, 18.33,15 and 6.66 (Table 1). The exposure period increasing, the mortality rate increased from 1 hrs to 2 and 3 hrs exposure. At 3 hrs exposure, the maximum mortality was observed at the same extract and concentration as 95% while minimum 16.66% in Delta methrin. Based on these results plant extract and Boric Acid were selected as the most promising and used for the following experiment.

Activity 1: Supply of 'Dengue Guard' to various organizations:

A mosquito repellent product was supplied to various PAEC organizations at low piece than the market rate. Over 18389 bottles with a net profit of Rs/ 491722 was generated to NIFA income generation during 2015. During 2016, 7000 bottles of fifty ml were supplied to various PAEC organizations for protection against mosquito bite.

Activity 2: Human Resource Development:

Several activities were arranged within the PPD for training and human resource development. Among these one day workshop on the use of bio-control agents for the control of Lepidopterist pests was arranged at NIFA Peshawar and two interactive training workshops for training the relevant health staff of KPK Health Department on the identification of larva, pupa and adult Aedes mosquitoes (aegypti & albopictus) were at the District Health Office Peshawar. The purpose of the workshops was to enhance the capability of malaria and dengue supervisors in dengue vector surveillance and identification in their respective union councils and to notify any evidence of Dengue to the Dengue Cell at the DHO Peshawar. Another one day workshop on the management strategies for dengue vector control was conducted at NIFA, Peshawar.

PLANT PATHOLOGY

Rusts and powdery mildew:

Surveillance and monitoring of economically important public risk diseases of wheat was conducted in three zones of Khyber Pakhtunkhwa. Yellow rust caused by airborne fungi *Puccinia striiformis* f. sp. *tritici* was recorded at all test sites in the province. Maximum average yellow rust severity was observed in Swat (53%) which was followed by

Abbotabad (39%), Nowshara (31%), Peshawar-1(27%), Bannu (21%) and Peshawar 2 (7%). Yellow rust severity was significantly high in 2016 in Bannu, Abbotabad and Swat when compared with previous season. Leaf rust initiated by *P. triticina* fungus was observed at four test locations with maximum severity in Bannu (18%). Powdery mildew was not observed at test locations in three zones of Khyber Pakhtunkhwa.

Barley Yellow Dwarf:

Barley Yellow Dwarf (BYD) disease is caused by Barley Yellow Dwarf Virus (BYDV) through aphid vectors. Occurrence and impact of Barley Yellow Dwarf (BYD) was established in different zones of KP Province. Two BYD virus vectors were identified from the southern zone including Oat bird-cherry aphid (*Rhopalosiphum padi*) and Corn leaf aphid (*R. maidis*). Similarly, four BYD virus vectors were identified from the central zone; two were common to the southern zone while the other two were English grain aphid (*Sitobion avenae*) and Green bug (*Schizaphus graminum*). English grain aphid was the only BYD virus vector identified from the northern zone samples. A batch of 188 BYD virus suspected wheat samples from 12 districts of the southern, central and northern zones were indexed using DAS-ELISA technique. Out of the total tested samples, 146 (80%) were found positive for BYDV-PAV.

Rust response warning and effectiveness of resistance genes:

Wheat is vulnerable to yellow, leaf and stem rusts in Pakistan. Sentinel plots of several genes of each rust were raised as an early warning system to monitor wheat rust virulence's in the southern, central and northern zones and effective/ineffective rust resistance genes were identified in KP Province. Stem rust was not observed while 3-yellow rust (*Yr5, Yr10, Yr15*) and 10-leaf rust (*Lr1, Lr2B, Lr3BG, Lr10, Lr11, Lr16, Lr18, Lr20, Lr22A, LR35*) resistance genes were found effective in KP Province for rust management. Sources of these effective genes include ILONA-CSK, ANGAS, SAVANNAH, RL-5711, AC-MINTO, AROONA, KALYANSONA, SONALIKA, PASQUA, ARZ, ARDITO, PAVON-F-76 and AZTECA-67.

Slow rusting wheat:

Important key step in wheat rust management is to reduce initial inoculum and infection cycles/generations in the low laying acreage of Khyber Pakhtunkhwa where 70% of the wheat crop is grown. To achieve this goal, identification of environment friendly slow rusting resistance was carried out in which six hundred genotypes were studied for slow yellow rusting adult plant resistance using epidemiological parameters. Two hundred and forty nine genotypes expressed slow rusting and race non-specific resistance behaviour with AUDPC value <500 against the prevalent races. Genotypes from this material can be recommended after further testing along with released cultivars for deployment in the high and mid altitude districts of Khyber Pakhtunkhwa for reducing the spread of rust inoculum to avoid and mange wheat rust in the region.

Yellow rust & BYDV resistance genotyping:

Two wheat sets were genotyped for yellow rust and BYDV resistance genes. set I included 330 genotypes which were studied for genetic bases of yellow rust resistance and it was postulated that 247 genotypes carried *Yr30*, 264 carried *Yr24-26*, 151 carried *Yr17*, 63 carried *Ltn* while 27 genotypes possessed *Yr9*. Similarly in set II, 100 genotypes were characterized for BYDV resistance genes and 77 carried *Bdv1*, 63 carried *Bdv2* and 46 were inferred to have both *Bdv1* and *Bdv2*.

Screening of national elite & candidate material:

Under this collaborative program, wheat disease screening nursery of 800 genotypes was received from Crop Disease Research Institute (CDRI), National Agriculture Research Center (NARC), Islamabad for study under local disease conditions which included material from all four PAEC agriculture and biotechnology centers. Significant variability of yellow rust resistance was observed in the studied material. Studied genotypes were postulated to carry

effective race specific resistance (49%), race nonspecific high resistance (37%), race specific moderate resistance (8%), race nonspecific low resistance (2%) while 5% of the genotypes were found susceptible. BYDV symptoms were prevalent in 11% of the studied material. Four NIFA candidate wheat lines were proposed to carry Yr18+Yr27+Yr31+; Yr18+Yr31+; Yr18+Yr31+ and Yr18+ while other 72 NIFA irrigated and rainfed lines displayed adequate resistance in the central zone of Khyber Pakhtunkhwa.

Wheat seed health testing & disease forecasting:

Many of the wheat diseases are seed borne and seed borne inoculum is of great economic significance. Under this project, 468 wheat genotypes were assessed for black point and karnal bunt diseases including 141 genotypes from NIFA-Peshawar, NIAB-Faisalabad, NIA-Tandojam and NIBGE-Faisalabad. Disease forecast was developed regarding black point and karnal bunt in wheat cultivars Fakhre-e-Sarhad, Tatara, Suleman-96, Pirsabak-2004, Pirsabak-2005, Sehar-2006, Faisalabad-2008, NARC-2011, Pirsabak-2013, Shahkar-2013 and Milat-2014. In these cultivars, 2-13 black point and 1-2 karnal bunt infected seeds were predicted to enter per square meter of field capable of producing disease.

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. Local crop and vegetable seeds were collected for use in the following experiments.

Effect of clinorotation on germination, hypocotyle length and its angle:

Chickpea, mungbean, radish and sunflower seeds were subjected to clinorotation in 9cm dia petri dishes containing 1% agar under aseptic conditions. In case of chickpea, germination was 100%, mean hypocotyl length was 2.80 cm while its mean angle/curvature was 61 degree in 1g vertical control treatment while in clinorotated treatment seeds were unable to germinate. Similarly, no germination was observed in sunflower seeds in either treatment during 70 h experiment. Both these experiments are being repeated. Germination was at par in both stationary 1g vertical control and clinorotated treatments of each mungbean and radish. Hypocotyle angle/curvature enhanced in clinorotated treatment when compared with 1g vertical control of mungbean. Hypocotyl length was maximum in clinorotated treatment which was followed by 1g vertical control and 1g horizontal control in both mungbean.

Effect of clinorotation on rapeseed quality:

This study was performed in collaboration with Oilseed Brassica group at NIFA to investigate the effect of clinorotation on quality parameter of s of intact seeds seven rapeseed genotypes (i.e. NIFA-Raya, Durr-e-NIFA, NIFA Gold, Abasin-95, 04K/12/13/10-1,NH-97 and NR-2/2012-13). Significant changes in oil and protein percentages were not observed in five genotypes. Clinorotation has reduced (7%) and enhanced (10%) oil in NH-97 and o4K/12/13/10-1 respectively. Similarly, 6% protein was enhanced in NH-97 while 6% reduction was observed in o4K/12/13/10-1. clinorotation treatment has no effect on oleic acid and linolenic acid of seven genotypes except 04K/12/13/10-1 while oleic acid was reduced by 17%. Clinorotation treatment has two directional effects on glucosinolates content which was reduced and enhanced in four and three genotypes respectively while erucic acid enhanced from 2-8% in all tested genotypes.

Food & Nutrition

Stability of Iodine in Iodized Salt in Different Packing Materials under Different Climatic Conditions:

In Pakistan, the law mandates that the salt for human consumption must have iodine levels >30 ppm at the production level and 15 ppm or more at the consumer level. Due to an increase in the price of potassium iodate in the international market, the cost of iodization has also increased that has highlighted the need to minimize the use of iodate and cost.

This gap of the iodine content provide margin for losses during transit and storage from production to the consumer end. Climatic conditions such as temperature, relative humidity (RH) and moisture content of the salt have momentous effect on the iodine losses in the storage. Study on the stability of iodine in iodized salts of different types packed in various packaging materials and stored for 12 months at various locations of Pakistan representing the 4 major climatic zones of the country was carried out with the financial assistance of Micronutrient Initiative Pakistan at NIFA, Peshawar.

Salt types including washed and dried lake salt, refined lake salt, good quality rock salt (Punjab), poor quality rock salt (KPK), refined rock salt, sea salt and the analytical grade salt (NaCl) was used as standard were studied. All salt types were iodized @ 30±2 mg/kg salt at the Hub-Salt Refinery, Hub Industrial Area. Iodized salt (800 g) was packed in (i) high density poly-ethylene (HDPE), (ii) low density poly-ethylene (LDPE), and (iii) laminated PE bags. Bulk storage (40 kg) was done in poly-ethylene woven bags. The iodized and packed salt samples were stored for 12 months at ambient room conditions at Atomic Energy Medical Center (AEMC) Karachi, Nuclear Oncology and Radiotherapy Institute (NORIN) Nawabshah , Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad and Swat Institute of Nuclear Oncology and Radiotherapy (SINOR) Saidu Swat to represent the (a) marine tropical coastland, (b) sub-tropical continental plateau (desert), (c), sub-tropical continental lowlands, and (d) sub-tropical continental highlands respectively.

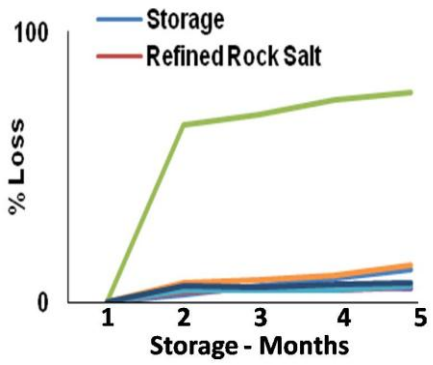

Figure 1. Iodine losses from different salt types during storage

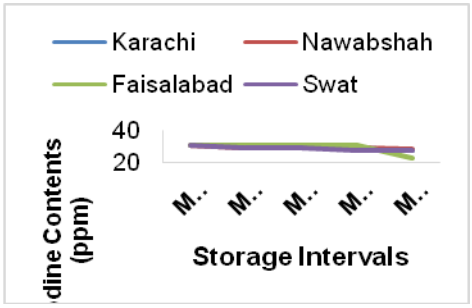

Figure 2. Iodine contents of standard salt at various storage location at different storage intervals

Hourly temperature and relative humidity (%) of the storage rooms were monitored during the entire storage period. Results of the study

indicated that there were significant differences in the stability of iodine in different salt types (figure 1). Location-wise iodine content over the storage period is given in figure 2. Influence of packaging material, location and storage period were also statistically significant. However, except for the poor quality rock salt from KPK, all the other types of salt showed quite a high degree of stability of iodine, where the iodine retention was >90% (>25 mg out of 30 mg of the added iodine per kg of salt) during storage period of 12 months. Among the packaging types, the PP 40 kg bulk packing showed the lowest iodine losses. However, none of the packing types could be rejected for the reason of iodine losses. Even in smaller sized packing from LDPE, HDPE or laminated, the average iodine losses (although significantly different from each other) were not high enough to reject these packing materials. Similarly, at none of the locations, iodine losses from any of the salt types in any of the packing types, were high enough to reject some of them for one location and some for the other. From the consumer's point of view the iodine losses will not be high enough to cause serious iodine deficiency concerns. The 30 ppm level of iodization is sufficient enough for a sound USI program.

The poor quality rock salt from KPK had some exceptional characteristics. The losses of added iodine from this particular salt type were so high and quick that within a few days of transit from the site of salt iodization at Hub to the storage locations and sample provision to lab for analysis, almost half of the added iodine had already sublimed (into air). That was visibly so with the laminated packing, in which case the packing turned yellow because the sublimed iodine could not leave the packing and hence was deposited on the inner walls of the impermeable packing. It was therefore recommended that this salt may not be used for iodization (and hence for edible) purpose in the un-processed, un-refined state. At least some sort of refining aimed at removing impurities needs to be given before its use for iodization.

Development of yellow colour in Poor Quality Rock Salt from KPK packed in Laminated pouches soon after the start of storage

Drying of Fruits and Vegetables:

Drying rate of carrots and strawberries at 50, 55, 50, 65 and 70°C was determined using the infrared moisture analyzer. For all the drying temperatures and for both carrots and strawberries, the moisture loss was described by a quadratic equation that had R^2 around 0.98 thus manifesting a close fit. Over all, drying time decreased to < 50% with increase in temperature from 55°C to 70°C. Strawberries took longer time for drying than carrots. In another experiment cantaloupe and carrots were treated with different preservatives and dried in a convection oven drier at 70°C. Treatment with 1% ascorbic acid retained the original color and gave a shiny look on drying. Dried cantaloupes looked attractive and were very acceptable during organoleptic evaluation. Cantaloupe drying can have commercial applications due to its abundant supply and the snack value of the dried product.

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 was carried out on shelf-life extension of prepared meals. The aim of the study was to develop and provide hygienic and long shelf life meals for immune-compromised patients, security forces, victims of natural disaster and other target groups. Bean and round apple gourd were cooked to make round apple gourd mix curry. Samples were packed in tetra pack pouches, sealed using vacuum sealing machine and irradiated at the doses of 6, 8 and 10 kGy. All the samples were stored at room temperature for a period of 3 months. The samples were analyzed for moisture content, ash, crude protein, crude fat, crude fiber, carbohydrate contents, total bacterial count, coliform bacteria, color and flavor initially and after one month intervals. No significant changes were recorded in moisture, ash, protein and fat contents irrespective of treatments and storage time. However, significant increase in the carbohydrate content was observed. The initial mean value of carbohydrate content (7.1%) increased to 71% after the three month storage period.

Significant effect of irradiation doses and storage period was also recorded on flavor and appearance of the meals. The mean score noted by the panel of judges was 8.6 which declined to 6.35 after the stipulated storage period. Bulging in some meal pouches irradiated at 6.0 kGy was observed at the end of 60 days storage time indicating bacterial growth. No bacterial growth was noted in meals irradiated @ 10 kGy during the entire storage period.

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)was prepared and irradiated. Two different types of Meals i.e. MRE-1 (10% alfalfa + 90% Minced beef and other ingredients) and MRE-11 (20% alfalfa + 80% minced beef and other ingredients) were prepared under highly safe and hygienic conditions and vacuum packed in aluminum pouches prior to irradiation @ 8, 10 and 12 kGy doses. Post irradiated MRE's were kept at room temperature for a storage period of 90 days and various physico-chemical, sensorial and microbiological analysis were carried out to check the quality as well as the safety aspects of the prepared meals. No significant differences were observed in the physico-chemical parameter of the meals during the whole storage period. Proximate analysis showed that the values of moisture, crude protein, crude fat and total ash were 63.3-64.6%, 20.1-22.4%, 3.4-4.8% and 1.5-2.2% respectively. Bacteriological analysis showed that the meals irradiated at 8 kGy dose were spoiled after first 30 days of storage while the others irradiated at 10 and 12 kGy were found free from any kind of bacteria and were considered as safe. Sensorially, the meals prepared with 10% alfalfa were found acceptable by the panel of judges. Better retention of vitamin C (25.02 mg/100g) was observed in the sample with 10% alfalfa. Minimum of 10 kGy radiation dose is needed for the preservation of packed meals. Non-significant effect was recorded in the ash and moisture contents, however, fats and protein showed significant difference with the passage of storage period. It was concluded that the fortification of MRE with alfalfa, improved the taste and nutritional profile of the product.The overall acceptance of MRE (having 10% Alfalfa) was found better than MRE (having 20% Alfalfa). While, 10 kGy irradiation dose was considered safe for the storage (90 days) of the product.

Development and Validation of Technologies for Pesticide Residue Management in Fruit and Vegetable Produce:

Pesticides chemistry keeps on changing owing to the pest resistance and introduction of new pest problems. Therefore, pesticide residue monitoring is necessary to understand the nature and magnitude of potentially hazardous

contaminants in foods. The information is also useful for the management and remediation of the hazards.

Pesticide residue monitoring in vegetables and fruit was carried out in the areas of Peshawar Division (Peshawar, Charsadda, Mardan), Swat (Mingora, Saidu Sharif, Khwaza Khela, Charbagh), Malakand (Batkhela, Thana, Dargei), Hazara Division (Haripur, Abbottabad, Mansehra, Balakot) and Rawalpindi Division (Attock, Rawalpindi, Jhelum). Almost all the fruit and vegetable samples were detected with pesticide residues. In vegetable samples, 3-24% samples exceeded MRL and 3-19% of fruit samples exceeded the MRL concentrations. The residues of pesticides from organophosphate and pyrethroid groups were predominantly detected along with new chemistry chemicals of neonicotenoid, oxadiazine, organothio-phosphate & phenylamide groups.Dissipation of imidachloprid residues was studied in tomato and cucumber fruits. Freshly picked mature organically produced (pesticide free) tomato and cucumber fruits were sprayed @ 3MRL concentration of imidachloprid that correspond to 3.0 mg/kg and 1.5 mg/kg for tomato and cucumber respectively. The untreated samples served as control. Separate batches of treated and untreated samples were sonicated in an ultrasonic bath operating at 60 kHz of frequency for 3, 7 and 10 minutes and 20°C, 25°C and 30°C temperatures. The results of the study are given in figure 3. Dissipation of Imidachloprid followed the First-Order Kinetics. Sonication at 25°C for 10 minutes was the best treatment to dissipate 60 – 70% imidachloprid residues.

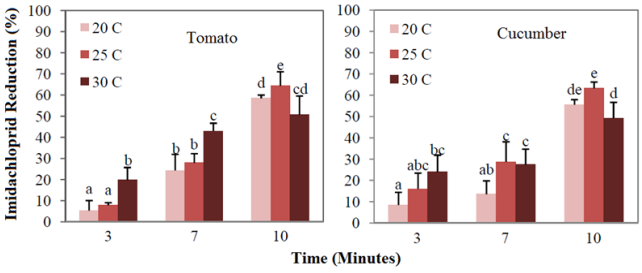

Figure 3. Imidachloprid reduction (%) at different time intervals & temperatures by ultra-sonication @ 60 kHz

Mushroom Cultivation Technology Improvement & Popularization as Cottage Industry:

In mushroom production, substrate sterilization is an important step that can potentially affect the health and production of mushrooms. In the present study, three sterilization methods viz. chemical treatment, heating and radiation were compared for efficacy and cost. Each treatment was replicated three times and the total duration of the experiment was three months. Effect of different sterilization methods on the growth performance and different biochemical parameters was studied.

Results showed that mycelium production, pin head formation and first harvest were taking less time in the heat treated substrate as compared to the chemical and radiation treated substrates. However, variation in the growth parameter was not significantly different in the three sterilization methods. Similarly, the biochemical analysis also showed a non-significant effect of the sterilization methods.

The successfully established cultivation technologies for different kinds of mushrooms viz. Oyster, Milky, King Oyster and Button mushrooms were disseminated to the farming community. For this purpose, one day workshops were organized for farmers of different areas of KPK viz. Hazara valley, Haripur, Chitral, Swat valley, Balakot, Shinkiyari, Batagram, Bunner, Charsadda, Mardan, Peshawar and Nowshera etc. More than 400 farmers benefitted from these workshops.

Value Addition of Kunzite, its Analytical and Microstructure Analysis before and after Gamma Irradiation:

Kunzite [AlLi $(SiO_3)_2$] is a lithium aluminum silicate mineral usually found in pegmatite veins of the earth. Its natural opaque form, Spodumene (Kunzite) a lithium ore is used in the manufacturing of ceramics, glass, batteries, steel, fluxing agents, medicine; and its pale and transparent form, popularly known as pink / violet Kunzite and green Hiddenite are widely used in jewelry.

In this study Kunzite samples were irradiated by using gamma radiation in dose steps of 0.5Mrad. Optimum color change was achieved @ 2.5Mrad dose. The XRD study validated by the software database of ICDD (International Center for Diffraction Data) indicated that the major elements in the sample were aluminum (Al), silicon (Si), lithium (Li) and oxygen (O). EDX study gave the composition of the sample in which the major elements were already specified by the XRD study. The major elements by percent weight indicated by EDX study were Si 70.69%, Al 19.31%, O 6% and Ca 5%. SEM analysis supported both XRD and EDX by providing some new micro structures after irradiation (different grain sizes and orientation). The concentration of the impurities in the gemstone causes the color enhancement in the gems. In this study with Kunzite, Ca impurities were found mainly responsible for the color enhancement and change.

Soil & Environmental Sciences

The rapid increases in population coupled with adverse impacts of climate change impel the researchers to develop crop production technologies for higher yield and improving efficiency in the use of natural resources. The scientists of Soil and Environmental Sciences Division are focusing to enhance the use efficiency of natural resources (soil, water and nutrients) and to identify crop production technologies to mitigate the adverse effects of climate change. The economical and environment friendly packages of chemical and organic fertilizers are being devised for different cropping systems of Khyber Pakhtunkhwa, which are being widely used by the growers for getting maximum net return. The outcome of these efforts during 2015-16 is as follows:

Integrated management of nutrients and water for growing off-season vegetables in high and walk-in tunnels:

To meet the future food and water demands for the growing population, the effective use of both water and soil in agriculture will be a challenge. In addition, because of high inflation, the farmers are forced to use imbalanced fertilizers for crop production that results in low nutrient use efficiency causing over 50% nutrients loss in soil-plant system. The studies conducted in Pakistan indicated that water use efficiency (yield per unit of water) could be increased by 50% or more with the use of drip irrigation as compared with other traditional irrigation methods. This method of irrigation is particularly suited for small land holders having limited water source (rainfed area) and for off- season vegetables farming under tunnels. The livestock is a major component of rainfed farming system and farmyard manure is easily available in these areas that can be utilized properly to integrate nutrients for growing off-season vegetables/nursery. However, the current practices of irrigation, fertilizer and fungicide application in tunnel farming are without any scientific basis which lead to a great economic loss and cause environmental and health problems. Therefore, the use of fertilizer through fertigation not only ensures enhanced nutrient and water use efficiency but also curtails economic losses caused by current fertilizer application practices. It is also helpful in reducing fungicide application by controlling humidity and disease susceptibility. Other potential benefits of cultivation of off-season vegetables under tunnels are higher yield, better quality and high net return. In addition to higher food production and improvement in socioeconomic status of small growers, this technology will also enhance the water/ fertilizer use efficiency with minimum use of fungicide. Thus the technology of growing off season vegetables in tunnel has been established at NIFA to demonstrate its benefits to the growers.

Experiments were conducted in high and walk in tunnels on off-season tomato and cucumber to improve fertilizer, nutrient and water use efficiency in these vegetables using fertigation and other management practices. The timing

of fertilizer application proved very crucial for growing said vegetables in high tunnels. The effect of integrated NPK and FYM treatments was studied on the yield of hybrid tomatoes and cucumbers. The properly decomposed FYM (total NPK content 0.6-0.44-1.0% and total organic carbon 8.46%) @ 50 kg/marla was applied before transplanting nursery while NPK was applied after establishment of crop (30 days after transplanting) at different intervals. The fruit yield data indicated that maximum tomato fruit yield was recorded in the treatment receiving NPK at 80 N + 80 P_2O_5 + 90 K_2O kg ha^{-1} (soil application) after 30 days interval starting after establishment of crop (30 days after transplanting) till mid of June. Application of Zn (5 kg ha^{-1}) along with NPK yielded an additional benefit of 25% in terms of tomato production. Likewise, in another high tunnel cucumber was grown and the maximum fruit yield was recorded in the treatment receiving NPK at 30- 30 - 40 kg ha^{-1} as fertigation + B spray (0.1%) at 14 days interval starting after establishment of crop till mid of May.

BIOFORTIFICATION OF ZINC IN FOR BALANCED HUMAN NUTRITION

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

Zinc deficiency is a global nutritional problem in crop production. Thirty per cent of the world soils are Zn deficient, including agricultural lands in Pakistan where it amounts to be 70%. Correction of Zn deficiency via fertilization is not always the ideal solution because of the influence of agronomic and economic factors including reduced Zn availability in dry topsoil, subsoil constraints, disease interactions, and the high relative cost of fertilizer in developing countries. Therefore, identification and cultivation of Zn-efficient genotypes that could use soil or tissue Zn efficiently is a realistic alternative to Zn fertilizer application in some edaphic environments. Differential Zn efficiency (ZE) has been reported in several crop species including wheat. Despite its complexity, there is substantial interest in ZE. Understanding the mechanisms of ZE can greatly contribute to the selection and breeding of genotypes with higher tolerance to Zn-deficient soils.

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 ^oC 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 plants. The plants were initially grown in nutrient solutions containing half strength 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 enhanced levels of Zn^{2+} activity showed a positive effect on growing wheat crop and led to vigorous growth and dry matter (DM) production. The genotype NRL-1438 has the maximum DM production at 40 pM Zn^{2+} which was 7.33g/pot. In the Zn deficient solutions (2 pM Zn^{2+}), shoot DM production was distinctly lower and the genotype NRL-1434 produced the lowest DM of 3.6 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 33.7 to 80.6 %. The genotypes ranked as Zn-inefficient (NRL-1402, NRL-1434) produced significantly lower DM yields than the Zn-efficient cultivars NRL-1427 and Insaf-15 at the Zn-deficient level. Zinc concentration in the shoots of the different cultivars varied between 10.4 µg g^{-1} and 39.7µg g^{-1}. Generally, the Zn-inefficient cultivars (NRL-1402 and NRl-1434) had lower Zn concentration (10.4 and 13.9 µg g^{-1}) than the Zn-efficient ones.

Pot experiment for Zn Efficiency:

Root architecture varies among plant species and cultivars within plants species that has been implicated in influencing plant Zn availability and ZE. As a consequence, thinner roots with increased root surface area may increase the availability of Zn along with other nutrients due to a more thorough exploration of the soil. Furthermore, roots of some plant species are colonized by mycorrhizal fungi that increase the uptake of diffusion-limited nutrients from soil including phosphorus and Zn. In particular, vesicular-arbuscular mycorrhizae (VAM) have been cited to benefit plants by expanding the volume of soil explored by root systems and consequently increasing Zn uptake. However, as genetic differences in ZE found in the field also can be seen in hydroponically grown plants that form no mycorrhizal associations, the role and importance of mycorrhizae in ZE is unclear. So to understand the mechanism an experiment was initiated in wire-house to study the mechanism of ZE with specific reference to the role of mycorrhiza in Zn uptake. Two genotypes (NRL-1312, Zn efficient and NRL-1302, Zn In-efficient) were used for this study. The plastic pots were filled with three kg Zn deficient soil having been applied with 3levels of each Zn (0, 2.5 and 5 mg kg^{-1} soil) and P (0, 25, 250 mg kg^{-1} soil) and arranged in completely randomized design. Nitrogen was applied at recommended rate to all pots at the time of sowing. Ten plants of each genotype were sown and maintained in pots. Two plants (each time) were harvested after 30, 60 days interval and roots were dug out for the assessment of mycorrhizal infection. The remaining plants were harvested after crop maturity. The plants of all stages were preserved for Zn, Fe, Cu, Mn and P determination. The results revealed application of Zn and phosphorus had pronounced effect on the growth of plants. The dry matter yield of the genotypes was significantly increased by the application of P and Zn as soil was already deficient in both of these elements. A significant variation was observed in dry matter accumulation by these genotypes at different levels of P and Zn. Zinc efficient genotype NRL-1312 produced the significantly higher biological yield of 12.2 g/pot with no application of Zn and P. The lower yield was always observed in the pots where none of these elements was added. Zinc inefficient genotype NRL-1312 yielded the lowest dry matter of 9.9 g/pot at Zn and P deficient level. However, genotype NRL-1312 produced maximum biological yield of18.3g/pot at Zn 5 mg and P 25 mg kg^{-1}soil. Same trend was observed for grain yield. Zinc concentration in the plants varied with the application of Zn and P in the soil. Application of Zn increased the Zn concentration within plant and application of P reduced its quantity indicating that there was a significant antagonistic interaction between Zn and P for uptake of these elements by the plants. Zinc efficient genotypes managed to extract more Zn from Zn deficient soil even in the presence of high P. Zinc concentration in these genotypes at Zn deficient level ranged between 10.51 to 11.05 µg g^{-1}. Absorption of Zn by inefficient genotype was affected severely by heavy application of P and it was reduced from 21.1 to 13.8 µg g^{-1} when P application was escalated from 0 to 250 mg kg^{-1}soil.

The roots of Zn efficient genotypes have greater association with mycorrhiza and have up to 90 % infestation on roots at lower level of P and Zn, however, the infestation was reduced to 30% with heavy application of P even in the presence of Zn. Zinc inefficient

genotypes have significantly lower infestation at normal rate of P (25 mg kg^{-1} soil) under Zn deficient conditions and it reduced to 10% at higher P level.

Evaluation of Zn efficiency under field conditions:

Although the technique used to determine ZE 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, (2Zn-efficient, 1medium, 2Zn-inefficient) and two levels of Zn (0, 5 kg ha^{-1}) to assess any change in their ZE. The experiment was laid out according to split plot design with wheat genotypes in the main plot and Zn treatments in subplots. Prior to initiation of experiment, soil samples were collected from different fields and analyzed for available Zn so as to select Zn deficient site. The available Zn in experimental site was 0.29 µg g^{-1}. The soil also contained 0.78% O.M, 7.4 µg g^{-1} Olsen P having pH 7.3 and ECe 2.4 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-1301 produced the highest biological yield of 14.66 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 2935 kg ha^{-1} when applied with 5 kg Zn ha^{-1}. Under Zn stress conditions NRL-1306 (medium in efficiency) depicted higher grain yield of 2123 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 availability is limited on most of alkaline calcareous soils and imparts a declining effect on crop productivity on these soils. Although plentiful in the earth crust, soil phosphorus often exits in insoluble mineral forms that render it unavailable to plants. The plant use efficiency of both applied and native soil P is quite low, as a large proportion of applied P becomes immobile due to high P fixation by calcium carbonate. Therefore selection of plant genotypes efficient in biomass accumulation under P stress (deficiency) is an important strategy for areas of low fertilizer inputs, especially in developing countries like Pakistan. The present experiment was conducted to evaluate wheat genotypes for P use efficiency in solution culture. The experiment was conducted in a rain protected wire house. Ten wheat genotypes studied in this experiment were (i) NRL-1402, (ii) NRL-1406, (iii) NRL-1411,(iv) NRL-1412, (v) NRL-1424, (vi) NRL-1427 (vii) NRL-1434 (viii) NRL-1438, (ix) Insaf-2015 and (x) Chenab-2000.
The seed of genotypes was germinated on moist filter papers in Petri dishes and five days old seedlings were transplanted in foam plugged holes of thermopole sheet floating on a continuously aerated modified Johnson nutrient solution in a severely P-deficient with low (20 µM) and adequate (250 µM) P supply. The pH of the solution was monitored and maintained daily at 5.5 ± 0.5 with HCI or NaOH as required. Completely randomized factorial design was employed to the experiment with three repeats of each genotype. The plants were harvested after five weeks of transplanting and thoroughly washed with distilled water and separated into root and shoot. The results indicated that at low P level, first visual symptom of P deficiency appeared as development of dark-green color in leaves and then there reduction in shoot elongation and leaf size of most genotypes. Dry matter yield was recorded after drying

these samples to constant weight at 70°C in a forced air driven oven. Dried plant samples were fine ground to 40-mesh sieve before digesting their 0.5-g portion with 10 ml of di-acid mixture of Nitric acid (HNO_3) and Perchloric acid ($HCIO_4$) (3: 1). Phosphorus concentration in plant digest was estimated by ammonium metavanamolybdate yellow color method using a spectrophotometer.

Growth behavior of the all genotypes under study was remarkably different at the deficient and adequate levels of P supplied in the root medium. It was revealed by significant interactive effect ($P \leq 0.05$) of P rates and genotypes on shoot dry matter (SDM), root dry matter (RDM) and root: shoot ratio (RSR). Such interactions are important for crop cultivar development. Shoot dry matter of wheat genotypes decreased two fold when P supply was reduced from 200 µM to 20 µM in the growth medium. In deficient P supply, NRL 1402, NRL- 1427 and Chenab 2000 produced higher SDM while minimum production was observed in NRL-1424 followed by NRL-1412. Genotypes differed significantly ($P \leq 0.05$) in terms of relative reduction in SDM due to P deficiency stress. At deficient P supply, reduced SDM is attributed to enhanced ability of plants to invest in root biomass which jeopardizes yield potential of above ground portions. The maximum reduction in SDM production due to P deficiency was observed in NRL-1424 while minimum reduction was observed by NRL-1402. Root growth had a non-significant effect on P uptake by plants at adequate level of P supply in the root medium. At deficient level of P supply root growth was of greater significance regarding P uptake by plants. All genotypes differed significantly ($P \leq 0.05$) for their RDM at low P supply. NRL-1402 had a maximum RDM at deficient P supply which was at minimum in NRL-1424. Phosphorus supply, in the root medium, significantly modified RSR in all the wheat genotypes. It increased significantly ($P \leq 0.05$) with decreasing P supply in the root medium, which can be attributed to translocation of photosynthates from shoot to root. NRL-1424 and NRL-1412 had maximum RSR at deficient P supply while NRL-1402 had minimum at both P levels.

A field study was executed during 2015-16 to confirm the results of 2014-15 hydroponic experiment. The results showed that wheat genotypes NRL-1302 and NRL-1306 were found P-efficient while NRL-1303 and NRL-1318 were found P in-efficient.

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

Phosphorus is the essential plant nutrient which plays major role for achieving the maximum agricultural production. Phosphorus deficiency is observed as the second most extensively occurring nutrient deficiency, after nitrogen stress, in cereal chain across the world. Crops phosphorus use efficiency (PUE) ranged from 10-30%. Organic and inorganic sources of P are applied to the soil in the form of both fertilizers when available P is less than crop's requirement. On account of continuing world energy crisis and spiraling price of chemical fertilizer, the use of organic manure as a renewable source of plant nutrients is assuming importance. In this endeavor proper blend of organic and inorganic fertilizer is important not only for increasing yield but also for sustaining soil health. 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 having same treatments i.e. Control, FYM (2.5 and 5 tons FYM ha^{-1}), TSP @ 60 Pha^{-1}, SSP@ 60 P ha^{-1}, rock phosphate (RP) @ 60 P ha^{-1}, TSP+ 5 tons FYM ha^{-1}, SSP+ 5 tons FYM ha^{-1}, RP+ 5 tons FYM ha^{-1}, TSP+ 2.5 tons FYM ha^{-1}, SSP+ 2.5 tons FYM ha^{-1},RP+ 2.5 tons FYM ha^{-1}. Triple super phosphate was applied to supply 100 mg P_2O_5 per kg soil while farmyard manure was added @ 10 g Kg^{-1}. Soil in pots was irrigated up to its saturation percentage. After a week

when soil reached to field capacity, pots were emptied and soil was remixed and refilled in the pots. This process was repeated thrice and various treatments were imposed in triplicate. Wheat genotype (NIFA- Insaf) 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 maximum grain yield of (75.8 g/pot) was recorded in treatment where TSP along with 5 tons FYM ha^{-1} was applied followed by the treatment SSP and 5 tons FYM ha^{-1}. The minimum yield was observed in control treatment. Wheat yield from the pots treated with RP and 5 tons FYM ha^{-1} was higher than where only TSP and SSP was added however, the differences were non-significant.

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

Plant growth and development depends on nutrients derived from the soil or air, or supplemented through fertilizer. There are seventeen essential elements for plant nutrition, each with its own functions in the plant, levels of requirement, and characteristics. Nutrient requirements generally increase with the growth of plants, and deficiencies or excesses of nutrients can damage plants by slowing or inhibiting growth and reducing yield. Two advance wheat genotypes from NIFA (CT-09137 and SRN 09111) were grown with 14 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, 140-90-60 and 120-90-60 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 second week of November, 2014 and harvested on physiological maturity in May 2015. 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. Phosphatic and potash fertilizers were applied at the time of sowing along with 1/3 dose of nitrogen. The remaining nitrogen was applied in two equal splits with first irrigations and at booting stage. Results showed that yield of both lines increased by increasing N level up to 140 kg ha^{-1}. The data showed that maximum grain yield of 3.18 tons ha^{-1} of wheat genotype SRN-0911 was found in the treatment where NPK was applied at 140-90-60 kg ha^{-1}. Wheat genotype CT-09137 gave maximum grain yield of 3.04 tons ha^{-1} in the same treatment. Among these genotypes SRN-09111 produced higher grain yield than CT-09137**.** Maximum N and P-uptake (48.34 and 17.17 kg ha^{-1} respectively) was observed in the same treatment by genotype SRN-09111**.** Value cost ratio of SRN-0911 was found maximum than CT-09137. It is concluded from the study that wheat line SRN 09111 performed better at 140-90-60 kg ha^{-1} NPK levels when applied in splits and at proper time.

Nutrient management of deciduous orchards (plum) through foliar feeding:

Under PSF funded project (# 253) foliar feeding technique, as a particular way to supply nutrients could avoid yield limiting factors and results in rapid absorption. Foliar feeding of nutrients generally is more effective and less costly. It is well known that soil application of NPK fertilizers may lead to some losses of these fertilizers. However, application of such nutrients as foliar spray may decrease such losses. Three field experiments one at NIFA and two at farmer's field in Peshawar and Nowshera districts are in progress. Plum bearing orchards of uniform size and age were selected. There are total seven treatments with three replications in RCB design and two trees per treatments. Treatments are as follows; T1 NPK (360 gm N +250 g P + 360 g K per $tree^{-1}$), T2 (Farm yard manure (FYM) soil application (on N basis 360 gm N per $tree^{-1}$), T3 (½ NPK + ½ FYM soil application , T4 (½ NPK+ ½ FYM (soil appl) + foliar N (0.5% N), T5 (½ NPK+ ½

FYM (soil appl) + foliar N (0.5% N) + Zn (0.1%)., T6 (½ NPK+ ½ FYM (soil appl) + foliar N (0.5% N) + humic acid (0.05%) and T7 (½ NPK+ ½ FYM (soil appl) + foliar N (0.5%N) + Zn 0.1%+ humic acid (0.05%). All soil applied mineral fertilizers and FYM were applied to the periphery of tree canopy. Half of N fertilizer was applied before flowering and half with combination of P and K after fruit picking. According to the treatment plan half dose of inorganic N (urea) with farm yard manure were applied before bud sprouting in January 2016 to the periphery of tree canopy in soil. Leaves samples from the orchards were collected in mid of August to November 2015 and mid of April – August 2016. Results showed that fruit yield was significantly increased in all treatments at all experimental orchards. Among the sites Mera Kachori orchard produced maximum fruit yield than NIFA and Khushmuqam. Among the treatment T6 (½ NPK+ ½ FYM (soil appl) + foliar N (0.5% N) + humic acid (0.05%) at all sites resulted in a significantly higher fruit yield compared to other treatments. Maximum fruit yield (69.2, 68 and 91.8 kg tree^{-1}) was recorded in the same treatment T6 at NIFA, Khushmuqam and Mera Kachori orchards respectively, followed by the T4 at NIFA and T2 at Khushmuqam and Mera Kachori. Value cost ratio of (9:1) was found maximum for T6 followed by (8:1) for T5. It is concluded from the study that combination of soil and foliar application significantly improved the yield of plum fruits and concentration of N and Zn in leaves.

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

Current changes in climate necessitate identifying varieties that are efficient in the use of available water and have higher uptake of nutrients. To achieve the said objective, a field experiment was conducted using three wheat varieties (Fakhr-e-Sarhad, Bathoor, Barsat). 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. Non-significant differences were observed among varieties and irrigation treatments for grain yield. The cultivar Barsat produced the highest grain yield (5.8 t ha^{-1}) under irrigated conditions while Fakhr-e-Sarhad produced the highest grain yield (5.4 t ha^{-1}) under rain-fed conditions.

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. Fakhr-e-Sarhad (55 kg ha^{-1} mm^{-1}) and Bathoor (23 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 non-significant for root yield (0-50cm). Varieties had higher root yield in rain-fed conditions than under irrigated conditions. Bathoor and Fakhr-e-Sarhad had the highest root yield of 5.7 t ha^{-1} and 4.8 t ha^{-1} under rain-fed conditions and irrigated conditions, respectively.Differences among varieties and irrigation treatments were found significant ($P \leq 0.05$) for nitrogen uptake. Varieties had higher nitrogen uptake under irrigated than under rain-fed conditions. Fakhr-e-Sarhad (87 mg plant^{-1}) and Barsat (74 mg plant^{-1}) exhibited the highest nitrogen uptake under irrigated and rain-fed conditions, respectively. Differences among varieties and irrigation treatments were found significant ($P \leq 0.05$) for phosphorus uptake. Barsat had the highest phosphorus uptake under both rain-fed (21 mg plant^{-1}) and irrigated conditions (22 mg plant^{-1}). Non-significant differences were observed among varieties and irrigation treatments for potassium uptake. Fakhr-e-Sarhad (96 mg plant^{-1}) and Barsat (80 mg plant^{-1}) exhibited the highest potassium uptake under irrigated and rain-fed conditions (74 mg plant^{-1}), respectively.

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

Twenty one (21) small and four (4) large bio-geysers were fabricated and demonstrated in Hazara Division and Swat under a grant jointly funded by Pakistan Science Foundation

and Turkish Agency for Cooperation and Coordination, Islamabad. Training material (brochure, display boards, etc) have been prepared to impart training to community for use and maintenance of dual technology of bio-geyser and agro-waste composting.

Technical support was provided for the fabrication and demonstration of a model bio-geyser at Pakistan Science Foundation, Islamabad. Efforts are in progress to patent the dual technology of bio-geyser and agro-waste composting.

Response of potato to foliar application of fulvic acid:

Fulvic acid (FA) has the potential to improve plant growth and yield. The response of potato to the foliar application of fulvic acid has not been investigated in planned experiments. A field experiment was conducted to evaluate influence of fulvic acid along with various combinations of inorganic fertilizers on the yield of potato. The experiment was laid out in randomized complete block design with seven treatments and three replicates. Findings of the study revealed that maximum potato tuber yield of 7.24 t ha^{-1} was achieved through application of 1/2 NPK+FA (0.05%) + $ZnSO_4$ (2.5kg ha^{-1}) and it was 6 % higher than control. Preliminary results revealed that fulvic acid may be useful to improve yield but results need to be verified through long term studies so as to develop recommendations for end-users.

Response of potato towards application of compost tea:

Chemical fertilizers need to be gradually replaced with organic fertilizers to improve crop yield and minimize environmental pollution. Compost and manures offer suitable opportunities but their use is constrained by high cost of transportation and labor requirements for handling at farm level. Compost tea (CT) offers an appropriate alternative to compost on account of ease of handling and saving of transportation cost.

A field experiment was conducted to study effect of compost and compost tea along with NPK on the yield of potato. Treatments included NPK, compost 1%, compost 0.5%, half NPK + half compost, NPK + compost tea, compost tea, half NPK + CT + half compost. The result revealed that maximum tuber yield was 10.1 t ha^{-1} in treatment receiving compost @ 0.5% counting to 17 % increase over control followed by the treatment receiving half NPK + CT + half compost the yielding 10 t ha^{-1} (16% increase over control). Preliminary results revealed effectiveness of compost and compost tea in increasing potato tuber yield. These results need further confirmation to develop reliable recommendation for end users.

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

The experiment was conducted at NIFA experimental farm. Three varieties/genotypes Fakhar-e-Sarhad, Bathoor and an advance line SRN-0911 developed at NIFA were tested for three different dates of sowing (early, normal and late). Three fertilizers treatments @ T1 (80-40-0), T2 (120-80-40) and T3 (160-120-60) (N- P-K) kg ha^{-1}were applied to all three dates of sowing making the treatments as subplots. The experiment was replicated thrice. The three sowing dates included early, normal and late with each sowing at about 20 days interval starting from Oct 25. Phosphorus and K were applied as a basal dose at the time of sowing while N was applied in splits; half at the time of sowing and half with first irrigation. The crop was harvested at physiological maturity in mid of May and after drying in field, data for biological yield (kg/plot), grain yield (kg/plot), spike length (cm), grains/spike and 100 grain weight (gm) for each plot were recorded. The yield of all the three varieties/lines increased with the increase in fertilizer rates for all three dates of sowing. Maximum grain yield up to 5500 $kgha^{-1}$ was recorded for SRN-0911 followed by Fakhar-e-Sarhad (4889 $kgha^{-1}$) at 160-120-60 NPK and normal sowing date, while Bathoor yielded 5361 $kgha^{-1}$ at same treatment but with early sowing date.

SOCIO-ECONOMIC IMPACT OF R&D ACTIVITIES

Plant Breeding & Genetics:

High yielding, disease resistant and widely adopted varieties of wheat, oilseed brassica, chickpea and mungbean developed at NIFA are continuously playing a role in boosting per acre yield coupled with upgrading the financial status of the farmers of KPK. The NIFA released crop varieties are cultivating on appreciable area in the province as showing yield advantage up to 20% over other commercial varieties. A total of 9.4 tons quality wheat seedwas produced and duly certified by Federal Seed Certification and Registration Department. As per standard procedure the seed was then collected by provincial agricultural extension linked with selected progressive growers in Khyber Pakhtunkhwa. The indirect effect of the availability of improved NIFA wheat varieties to private seed companies may generate employment opportunities for the local farming communities. In addition a recent release of wheat variety i.e. NIFA Amanwill further fill the gap by its adaptation in a range of environments in the country.Wheat diseases can have a wide impact therefore effective race non-specific germplasm was identified that will have visible economic benefits for growers.

More than 3 tons certified seed of NIFA chickpea variety NIFA-2005 was produced and sold among progressive growers for 2016-2017 crop season by Arid Zone Research Institute, D. I. Khan at their research farm.

Soil and Environmental Sciences:

To minimize the impact of climate change on use efficiency of natural resources and economy is the need of the hour. Environment friendly technologies developed at NIFA for field, horticultural crops and tunnel farming are being widely adopted by the farming community of KP and the farmers are getting 10 to 35% higher produce of different crops. The technology of biogeyser was popularized by establishing of a pilot scale composting facility and fabricating biogeysers in different localities of KP.

Food & Nutrition:

The food technology and nutrition section of the FND was able to draw attention of the relevant stakeholders through its ongoing projects on products development, food preservation, and the value addition of the fruits. Similarly, the requirements for nutritional monitoring and management were also catered by this section at national level. Highlights in this regard are iron fortification of wheat flour and universal salt iodization program. The scope “Meals-Ready-to-Eat” (MRE) technology developed for the immuno-compromised patients was widened to cater the need s of disaster hit communities and other special groups with special nutritional requirements. Food safety studies were conducted on fruits and vegetables for hazard analysis and risk assessment with special reference to pesticide residues. Value addition of the 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:

The division has developed and determined irradiation doses for control of citrus and mango pests when applied prior to export. Adoption of fruit fly traps as an IPM component will lead to positive socio-economic impact on farmer’s life and pesticide free fruits and vegetables. Similarly, 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. To mitigate vector borne diseases particularly dengue / malaria in the country interactive workshops were arranged at the public health department for their training on identification and control of dengue vectors. Printed literature was distributed and NIFA Dengue Guard was introduced for personal protection against vector borne diseases.

PUBLICATIONS

1. Abro, G. H., Syed, T. S., Khanzada, M. S., Khanzada, S. R., Salman, M., Anwar, S. . Abro, A. H. (2016). Arthropods associated with some medicinal plants under field conditions in Sindh province of Pakistan. *Journal of Entomology and Zoology Studies, 4*(1), 516-520.

2. Ahmad, M., Pikova, J., Ahmad, T., Liaqat, M., Farid, A., & Jahangir, M. (2016). Oxidation of Lipids in Foods (Review article). *Sarhad J. of Agriculture, 32*(3), 1-9.

3. Ahmed, M., Ahmad, T., Liaquat, M., Abbasi, K. S., Farid, I. B., & Jahangir, M. (2016). Tissue specific metal characterization of selected fish species in Pakistan. *Environ Monit Assess, 188*(4), 212. doi: 10.1007/s10661-016-5214-6

4. Ali, A., Imtiaz, M., Adnan, M., Arshad, M., Inayat-ur-Rahman, Jamal, Y., . . . Rahman, Z. (2016). Effect of Zinc Activities on Shoot, Root Biomass and Phosphorus Uptake in Wheat Genotype. *American-Eurasian J. Agric. & Environ. Sci., 16*(1), 204-208. doi: 10.5829/idosi.aejaes.2016.16.1.12848

5. ALI, A., & Shah, S. J. A. (2016). *Yellow rust virulences and resistance in candidate wheat* (Vol. Germany): LAP LAMBERT Academic Publishing.

6. Ali, M., Muhammad, W., & Ali, I. (2016). Yield of oil seed Brassica (napus and juncea) advanced lines as influenced by boron application. *Soil & Envt 35* (1), 30-34.
7. Ali, M., Muhammad, W., & Ali, I. (2016). Yield of oil seed Brassica (napus and juncea) advanced lines as influenced by boron application. *Soil & Environment 35*(1), 30-34.

8. Atta, B. M., Subhan, F., Khan, M. I., Khan, A. J., Farooq-i-Azam, & Ahmad., S. (2016). Agronomic evaluation of exotic wheat germplasm under irrigated conditions. *Annual Wheat Newsletter, 62* 43-44.

9. Gul, Z., & Shah, S. J. A. (2016). *Black point impact on important wheat traits* (Vol. Germany): LAP Lambert Academic Publishing.

10. Khan, A. J., Subhan, F., Atta, B. M., Khan, M. I., Azam, F., & Ahmad, S. (2016). Producing quality seed and maintaining released wheat cultivars in Pakistan. *Annual Wheat Newsletter (Kansas State University, USA). 62*, 41-42.

11. Khan, G. Z., Khan, I., Khan, I. A., Alamzeb, Salman, M., & Ullah, K. (2016). Evaluation of different formulations of IGRs against Aedes albopictus and Culex quinquefasciatus (Diptera: Culicidae). *Asian Pacific Journal of Tropical Biomedicine, 6*(6), 485-491. doi: http://dx.doi.org/10.1016/j.apjtb.2016.04.008

12. Khan, I. (2016). Phytosanitary irradiation of Diaphorina citri (Hemiptera: Liviidae) on Citrus × aurantium (Sapindales: Rutaceae). *Florida Entomologist, 99* (2), 153-155.
13. Khan, I., Zahid, M., Mahmood, F., & Zeb, A. (2016). Mortality and growth inhibition of γ-irradiated red scale Aonidiella aurantii (Hemiptera: Diaspdidae) on 'Kinnow' citrus (Sapindales: Rutaceae) fruits. *Florida Entomologist 99*(2), 121-126.

14. Khan, S., Ullah, R., Saleem, M., Bilal, M., Rashid, R., Khan, I., Nawaz, M. (2016). Raman spectroscopic analysis of dengue virus infection in human blood sera. *Optik - International*

Journal for Light and Electron Optics, 127(4), 2086-2088. doi: http://dx.doi.org/10.1016/j.ijleo.2015.11.060

15. Khanzada, M. S., Syed, T. S., Khanzada, S. R., Abro, G. H., Salman, M., Anwar, S., Abro, A. H. (2016). Occurrence and abundance of thrips, whitefly and their natural enemy, Geocoris Spp. on cotton crop at various localities of Sindh, Pakistan. *Journal of Entomology and Zoology Studies, 4*(1), 509-515.

16. Khanzada, M. S., Syed, T. S., Khanzada, S. R., Abro, G. H., Salman, M., Anwar, S., Abro, A. H. (2016). Survey on population fluctuations of thrips, whitefly and their natural Enemies on sunflower in different localities of Sindh, Pakistan. *Journal of Entomology and Zoology Studies, 4*(1), 521-527.

17. Liusha, H., Zaifeng, L., Xiaodong, W., Zhanhai, K., Lin, Z., Xing, L., . . . SJA, S. (2016). QTL mapping of adult-plant resistance to leaf rust in Chinese wheat cultivar Lantian 9. *Pakistan Journal of Botany, 48*(3), 1133-1137.

18. Misbah-ul-Haq, M., Khan, I. A., Farid, A., Ullah, M., Gpouge, D. H., & Baker, P. B. (2016). Efficacy of indoxacarb and chlorfenapyr against Subterranean termite Heterotermes indicola (Wasmann) (Isoptera: Rhinotermitidae) in the laboratory. *Turk. J. Entomol, 40* (3), 227-241.

19. Piepho, H.-P., Nazir, M. F., Qamar, M., Rattu, A.-u.-R., Hussain, M., Ahmad, G., . . . Kakar, M. S. (2016). Stability Analysis for a Countrywide Series of Wheat Trials in Pakistan. *Crop Science, 56*(5), 2465-2475

20. Raza, A., Ali, Z., Imtiaz, M., & Wisal, M. (2016). Identification of nitrogen use efficient and deep rooted wheat genotypes. *Pak. J. Agri., Agril. Engg., Vet. Sci., 32*(1), 1-8.

21. Saleem, K., Shokat, S., Arshad, H. M. I., Atta, B., & Arif, M. A. R. (2016). Seeking sources of resistance to Alternaria blight in wheat germplasm. *Annual Wheat Newsletter (Kansas State University, USA), 62* 44-45.

22. Sarwar, M., & Salman, M. (2016). From Production to Field Application Methodology of Generalist Predator Green Lacewing, Chrysoperla carnea [Stephens] (Neuroptera: Chrysopidae). *International Journal of Zoology Studies 1*(1), 35-40.

23. Shah, S. A., Mohammad, W., Shahzadi, S., Elahi, R., Ali, A., Basir, A., & Haroon. (2016). The effect of foliar application of urea, humic acid and micronutrients on potato crop. *Iran Agricultural Research 35*(1), 89-94

24. Shah, S. M., Khan, G. Z., Usman, A., & Maqsood Shah. (2016). Exploiting nutrition for sex separation in Culex quinquefasciatus (Say) species of mosquitoes. *Journal of Entomology and Zoology Studies, 4*(2), 267-272.

25. Subhan, F., Atta, B. M., Khan, M. I., Khan, A. J., Farooq-i-Azam, & Ahmad, S. (2016). Evaluation of wheat genotypes in preliminary and advanced trials under irrigated conditions. *Annual Wheat Newsletter, (Kansas State University, USA), 62,* 42-43.

26. Ullah, K., Khan, N., Usman, Z., Ullah, R., Saleem, F. Y., Shah, S. A. I., & Salman, M. (2016). Impact of temperature on yield and related traits in cotton genotypes. *Journal of*

Integrative Agriculture, 15(3), 678-683. doi: http://dx.doi.org/10.1016/S2095-3119(15)61088-7

27. Ullah, K., Khan, N. U., Gul, R., Gul, S., Irfaq Khan, M., & Ullah Khan, I. (2016). Genetic effects for controlling stripe rust (Puccinia striiformis f. sp.tritici) resistance in wheat through joint segregation analysis. *Acta Scientiarum. Agronomy, 38*(3), 317-328.

28. Wazir, K., Bacha, N., Ibrahim, M., & Shah, F. A. (2016). *Detection of Bdv1, Bdv2 and Bdv3 genes in wheat using molecular markers.* Paper presented at the 13th Biennial international conference on recent advances and challanges in biochemistry, biotechnology and molecular biology, Centre of Advance Drugs Research, COMSATS, Abbottabad.

29. Wazir, K., Bacha, N., Ibrahim, M., & Shah, J. (2016). *Barley yellow Dwarf distribution, detection and impact on wheat in Khyber Pakhtunkhwa, Pakistan*. Paper presented at the in the Proceedings of 4th Environmental Conference on "Water and Food security in changing environment" Baragali Campus, University of Peshawar.

30. Bitanni, S., Rahman, H. u., Khan, I., & Daud, M. K. (2015). Incidence and management of coconut scale, Aspidiotus destructor signoret (Hemiptera: Diaspididae), and its parasitoids on mango (Mangifera sp.). *Crop Protection, 74*(August 2015), 103-109. doi: http://dx.doi.org/10.1016/j.cropro.2015.03.019

31. Salahudin, Rahman, H. u., Khan, I., Daud, M. K., & Rashid, M. M. (2015). Biology of Coconut Scale, Aspidiotus destructor Signoret (Hemiptera: Diaspididae), on Mango Plants (Mangifera sp.) Under Laboratory and Greenhouse Conditions. *Pakistan Journal of Zoology 47*(4), 1163-1170.

32. Sohail, K., Khan, I. A., Haq, M. M. U., Usman, M., Shah, S. F., Mehmood, A., . . . Fakhruddin. (2015). Insecticidal studies on heterotermis indicola wasmann (Isoptera: Heterotermitidae) under laboratory conditions. *Journal of Entomology and Zoology Studies, 3*(3), 348-350.

33. Salman, S. M., Shaukat, A., Afridi, M. S., Dawood, K., & Abrar, A. (2015). Analytical characterization of fatty acids present in seed oils by gas chromatography-mass spectrometry and qualitative determination of various phytonutrients in dandelion plant. *International Journal of Biosciences (IJB), 7*(2), 36-44.

TECHNOLOGY TRANSFER (*Pictorial View*)

Farmer's Day at NIFA

Mushroom cultivation for promotion as a cartage Industry

Promotion & Development of Environmental Friendly Bio-pesticides

Role of Zinc in Crop and Human Nutrition

Awareness Seminar on Popularization of Stevia

Drying of Fruits and Vegetables

Management Strategies for Insect Pests of Medical Importance

32nd Postgraduate Training Course

National Workshop on Salt Iodization in Pakistan

Ms. Anisa Zeb Tahir Kheli, KP Minister inaugurate the workshop on "Irradiated Meals for Immuno-compromised Patients, Natural Calamity Victims and other Target Groups"

Dengi awareness day

Symposium on the Opportunities & Challenges in Halal Food

Officer's Hostel & Masjid Foundation at NIFA

Quality Surveillance Audit of NIFA by Bureau Veritas

FUNDED RESEARCH PROJECTS – ONGOING

S#	Project Name	Amount	Duration	Principal Investigator
1.	Wheat Production Enhancement Program (WPEP-CIMMYT)	M.Rs., 15.075	2011 - 17	Mr. Abdul Jabbar Khan
2.	Development of Wheat Mutants for Higher Yield and Improved Efficiency of water and Nitrogen use (IAEA RC17077)	M.Rs., 5.193	2011 - 15	Mr. Abdul Jabbar Khan
3.	Development of Innovative Nutraceuticals Products from Indigenous Herbal Ingredients for Improving SocioEconomic Status of the Communities (PSF-178)	M.Rs., 4.000	2012 - 15	Dr. Ihsanullah
4.	Development of Locally Adapted Canola FI Hybrid using Induced Mutations and Doubled Haploidy Techniques (PSF-202)	M.Rs., 2.464	2012 - 15	Dr. Iftikhar Ali
5.	Development and Validation of Technologies for Pesticide Residue Management in Fruit and Vegetable Produce (PSF-203)	Rs. 2.844 m	2012 - 15	Dr. Azhar Rashid
6.	Nutrient Management of Deciduous Orchards through Foliar Feeding (PSF253)	Rs. 2.91 m	2013 - 16	Dr. Azam Shah
7.	Exploring Mechanical and Nutritional Methods of Sex Separation in Aedes Albopictus Specie of Mosquitoes (RC17926)	M.Rs., 1.876	2014 – 16	Dr. Gul Zamin Khan
8.	Breeding High Yielding Mungbean (*Vigna Radiata) L.Wilczek) G*enotypes for the Agro-climatic Conditions of Kuram Agency (PSF492)	M.Rs., 2.219	2016 - 19	Dr. Gul Sanat Shah
9.	Pilot Scale Demonstration and Popularization of Dual Technology of Bio Geyser with Agro-Waste Composting	M.Rs., 1.217	2016-17	Dr. Amir Raza

MANPOWER

A. Details of Present Scientific Strength:

CS	DCS	PS	PE	SS	SE	JS	ARO	Total
01	08	17	01	11	01	03	05	**47**

B. Scientists / Officers:

S#	Officers	Sanctioned	In Position	Vacant	Total
1.	Scientists	49	44	05	49
2.	Engineer	04	03	01	04
3.	Non-technical	05	03	-	05
		58	**50**	**06**	**58**

C. Staff (Technical/Non-technical):

S#	Staff	Sanctioned	In Position	Vacant	Total
1.	Scientific Staff	49	46	03	49
2.	Technical	22	22	00	22
3.	Non-technical	81	74	07	81
4.	Security & Chowkidars	27	27	00	27
		179	**169**	**10**	**179**

Detail list of Officers:

	Name	Designation
I.	Dr. Aurang Zeb, Ph.D. (Nutrition)	Director / CS
II.	**PLANT BREEDNG & GENETICS**	
	Mr. Abdul Jabbar Khan, M.Sc. (Botany)	Dy. Director / Head
	Dr. Iftikhar Ali, Ph. D (PBG)	DCS
	Dr. Gul Sanat Shah Khattak, Ph.D. (Botany)	DCS
	Dr. Babar Manzoor Atta, Ph.D (Breeding)	PS
	Mr. Roshan Zamir, M.Sc. (Hons. Agric.)	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
	Mr. Muhammad Amin, M.Sc. (Statistics)	SS
	Mr. Shahid Akbar, M.Sc. (Hons. Agric.)	SS
	Dr. Farooq-i-Azam, Ph.D (Genetics & Breeding)	SS
	Dr. Syed Tariq Shah, Ph.D (Genetics & Breeding)	SS
	Mr. Salman Ahmad, M.Sc (Hons. Agric.)	SS
	Mr. Iqbal Saeed, M.Sc. (Hons. Agric.)	JS
	Mr. Akhtar Ali, M.Sc. (Hons. Agric.)	ARO
	Mr. Mumtaz Ahmad, M. Phil (Biotechnology)	ARO
III.	**FOOD & NUTRITION**	
	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. 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**	
	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, M. Sc. (Entomology)	PS
	Mr. Muhammad Ibrahim, M.Sc. (Hons. Agric.)	SS
	Mr. Misbahul Haq, M.Sc. (Hons. Agric.)	SS
	Mr. Muhammad Salman M.Sc (Hons. Entomology)	JS
V.	**SOIL & ENVIRONMENTAL SCIENCES**	
	Dr. Wisal Mohammad, Ph.D. (Soil & Environment)	DCS/Head
	Dr. Imtiaz Ahmad, 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.	**ADMINISTRATION & ACCOUNTS**	
	Mr. Khalid Hussain Shah	Pr. Admin Officer
	Mr. Raufullah, M.L.I.Sc.	Sr. Librarian
	Mr. Ihsan-Ul-Haq, MBA	Admin Officer
	Mr. Muhammad Fawad, MBA (Finance), CFA Level – 1	Acct. Officer
	Mr. Wahid Gul, BA, LLB	Admin Officer

Promotion:

S#	Name	From	To	On
1	Mr. Khalid Hussain Shah	Sr. Admin Officer	Pr. Admin Officer	01.12.2016
2	Mr. Shahid Akbar Khalil	Sr. Scientist	Pr. Scientist	01.12.2016
3	Dr. Farooq-i-Azam	Sr. Scientist	Pr. Scientist	01.12.2016
4	Mr. Syed Wahid Gul	Supdt.	Admin Officer	11.03.2016
5	Mr. Zahidullah Khan	Assistant (Admin)	Sr. Assistant (Admin)	02.05.2016
6	Mr. Saeedullah	Assistant (Admin)	Sr. Assistant (Admin)	02.05.2016
7	Mr. Iftikhar Gul	Assistant (Admin)	Sr. Assistant (Admin)	02.05.2016
8	Mr. Abdullah Khan	Jr. Executive-III (Ac)	Jr. Executive-II (Ac)	02.05.2016
9	Mr. Sultan Muhammad	Jr. Computer Operator	Computer Operator	02.05.2016
10	Syed Riaz Ali Shah	Driver-III	Driver-II	02.05.2016
11	Mr. Muhammad Hadi	SSA	PSA	21.09.2016
12	Mr. Midrar Ullah	SA-I	SSA	21.09.2016
13	Mr. Asghar Ali	Jr. Assistant-II Admin	Jr. Assistant-I Admin	21.09.2016
14	Mr. Rahid Pervez	General Attdt-II	General Attdt-I	21.09.2016
15	Mr. Niaz Ali	SA-II	SA-I	06.10.2016
16	Mr. Saif-ur-Rehan	SA-IV	SA-III	06.10.2016
17	Mr. Muhammad Islam	Sr. Asstt. (Ac)	Accountant	18.11.2016
18	Mr. Muhammad Ibrahim	Sr. Asstt. (Ac)	Accountant	18.11.2016

Transfer / Posting:

S#	Name	From	To	On
1	Mr. Ajab Khan, SS-IV	CROF, Karachi	NIFA, Peshawar	08.01.2016
3	Mr. Fiaz-ud-Din, DCE	INOR, Abbottabad	NIFA, Peshawar	13.02.2016
4	Mr. Khalid Hussain, PAO	PIEAS, Islamabad	NIFA, Peshawar	19.02.2016

S#	Name	From	To	On
5	Mr. Riyasat Munir, Sec. Slder	NIFA, Peshawar	DTD, Islamabad	11.03.2016
6	Mr. NIaz-ud-Din, Driver	PIEAS, Islamabad	NIFA, Peshawar	25.03.2016
7	Ms. Samreen Shahzadi, SS	NIFA, Peshawar	PINSTECH,Islamabad	31.08.2015
8	Mr. Asimullah, Tech-I	KCP-II, auharabad	NIFA, Peshawar	02.05.2016
9	Mr. Nazakat Ali, Sec. Soldier	DGRE Site Karachi	NIFA, Peshawar	17.05.2016
10	Mr. Baqar Ali, Sec. Sup.-II	NIFA, Peshawar	LINAR, Larkana	06.06.2016
11	Mr. M. Waseem Jan, Sr. Tech	KCP-II, Jauharabad	NIFA, Peshawar	03.06.2016
12	Mr. Nasir Hayat, ARO	NCC, Islamabad	NIFA, Peshawar	01.06.2016
13	Mr. Bashir Ahmad, Driver	KCP-III, Jauharabad	NIFA, Peshawar	05.08.2016
14	Mr. Ahsan-ul-Haq, Sec. Sup.-III	Y-Lab, Chashma	NIFA, Peshawar	02.09.2016
15	Mr. Amir Dad, Sec. Soldr	SPF, Islamabad	NIFA, Peshawar	06.09.2016
16	Mr. Mehboob Hussain, SS-IV	DGRE Site Karachi	NIFA, Peshawar	02.09.2106
17	Mr. Raham Wali, Sec. Soldier	DTD, Islamabad	NIFA, Peshawar	23.09.2016
18	Dr. Muhammad Sarwar, PS	NIFA, Peshawar	NIBGE, Faisalabad	09.05.2016
19	Mr. Aurang Zeb, Sec. Soldier	TISLP-II, D.G. Khan	NIFA, Peshawar	07.10.2016
20	Mr. Fateh Khan, Sec. Soldier	SPF, Islamabad	NIFA, Peshawar	26.10.2016
21	Mr. Hasnain Pasha, DEO	NIFA, Peshawar	PINSTECH, Islamabad	10.11.2016
22	Mr. Muhammad Ibrahim Acctt	NIFA, Peshawar	IRNUM, Peshawar	14.12.2016
23	Mr. Ihsan-ul-Haq, Admin Officer	NIFA, Peshawar	NIBGE, Faisalabad	16.12.2016
24	Mr. Adeel Khattak, SA-II	PINSTECH, Islamabad	NIFA, Peshawar	02.012.2016

Retirement:

S#	Name	Date
1	Mr. Fazal Mahmood, DCS	14.01.2016
2	Syed Rizwan Ullah, Jr. Assistant-I (Admin)	01.02.2016
3	Mr. Riaz Hussain, Sr. Admin Officer	08.02.2016
4	Mr. Latif Zaman, Dy. Chief Admin Officer	23.02.2016
5	Dr. Shams-ur-Rehman, Chief Scientific Assistant	03.03.2016
6	Mr. Zakirullah, Pr. Tech	21.04.2016
7	Mr. Atlas Khan, SA-II	30.04.2016
8	Mr. Abdul Jalil, General Attendant	21.04.2016
9	Mr. Sher Khan, General Attendant	01.07.2016
10	Mrs. Nizakat Bibi, DCS	01.08.2016
11	Mr. Amanullah Khan, DCS	22.09.2016
12	Dr. Ihsanullah, CS/ Director	01.12.2016

Removal

S#	Name	Date
1	Mr. Latif-ur-Rehman, Jr. Executive-I (Admin)	01.12.2016

Appointment:

S#	Name	Date
1	Mr. Fazle Haq, Imam-II (contract)	27.01.2016
2	Mr. Muhammad Bilal, General Attendant-II (contract)	22.04.2016

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