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NATURAL RESOURCES



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Natural Resources Division has been focusing on efficient soil nutrient management and management of salt affected soils for improved land productivity. The idea of Solar desalinization of brackish water at household level was well cherished at national level. Watershed management is an important area for sustainable agricultural water productivity which is being given a due focus under NRD. Exploring alternate sources energy for agriculture is an area where NRD has created a success story. Improvement in range management and value addition of honey continued a priority during the past years.

1. Efficient Soil Nutrient Management

1.1. Effect of Plant and Coal Derived Humic Acid

Wheat

Effect of coal derived humic acid (CDHA) and plant derived humic acid (PDHA) on wheat under greenhouse condition was studied under two soil types i.e. clayey and sandy soils. The application of PDHA @ 50-100 mg/kg resulted increase of 18% in straw yield in clay soil and 9% in sandy soils (Figure 1A and 1B). The application of 50-100 mg/kg CDHA in clay soils increased grain yield by 21 % and straw yield by 16%. A relative increase of 9-14 % (means 11 %) in clay and 35-56 % (45%) increase in sandy soil was observed (Figure 1C&1D).

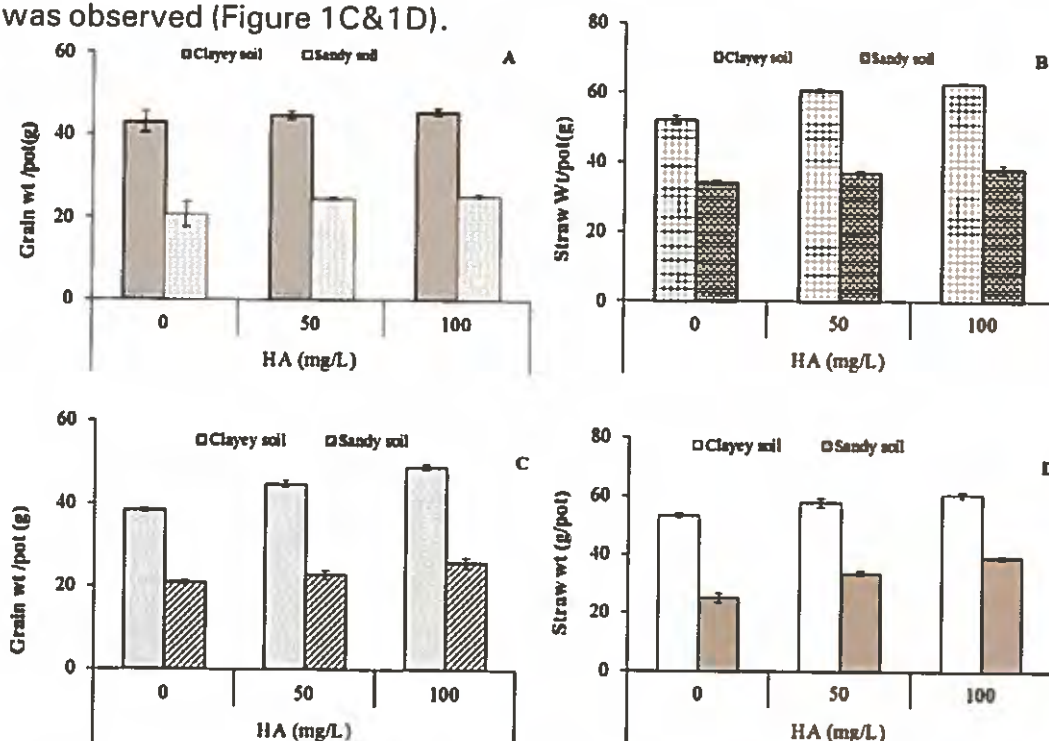


Figure-1 Effect of Plant and Coal derived humic acid on wheat grain and straw weight (A, B, C and D).

Onion

Effect of CDHA and PDHA was also studied on onion, the results showed that 20 kg ha^{-1} of CDHA is the optimum dose for getting maximum onion yield. While in case of PDHA (sunflower) optimum dose was 30 kg ha^{-1} as further increase in dose decreased the onion yield.

1.2 Use of Boron for Enhancing Peanut Productivity

Boron (B), one of the essential micronutrients, plays a vital role in plant growth. Field experiment was carried out at 4 farmers' fields (each ~ 2 acre area) in district Chakwal. The experimental sites were located at village Marth, Gah, Mari, DohkAwan. All field sites were low in organic matter, alkaline, calcareous and deficient in essential plant nutrients. Treatments included: Farmers' Practice (FP) and $\text{FP} + 1.0 \text{ kg B ha}^{-1}$ as borax. Peanut showed substantial pods yield increases when treated with B as compared to farmers' practice. The increase in pods yield with B application ranged from 10 – 19 %.

1.3 Nutrient Management by Conjoint Use of Organic and Inorganic Fertilizers

For developing nutrient management strategies for Bt and non-Bt (traditional) cotton, crop was sown on farmers' fields at 4 sites in Sahiwal division. Nutrient management effects of organic and inorganic fertilizers on seed cotton yield and boll weight were investigated for Bt and non-Bt cultivars. Lowest seed cotton yield of both cultivars was observed with farmers' fertilizer use practice ($200 \text{ kg N ha}^{-1} + 75 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$). While application of recommended fertilizer dose ($400 \text{ kg N ha}^{-1} + 150 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1} + 125 \text{ kg K}_2\text{O ha}^{-1}$) increased seed cotton yield from 16 to 24% for Bt and 12 to 22% for non-Bt cultivars. Balanced nutrient management (75% of recommended dose + micronutrients) increased seed cotton yield from 14-23% for Bt and 12-23% for non-Bt cotton. The highest seed cotton yield was observed consistently with integrated nutrient management which varied from 17-25% for Bt and 14-23% for non-Bt cotton.

1.4 Application of Zinc Nutrition on Maize: Productivity and Grain Zinc Content

Two maize cultivars (hybrid and local) were assessed for yield and Zn requirement of leaves and grain using various Zn application methods. The increase in grain yield at NARC site-I & II is shown in figure-2. Zn concentration in leaves and grain of both cultivars also increased to varying extent as a result of applied Zn rates and techniques. Fertilizer Zn requirement for near-maximum grain yield (kg ha^{-1}) was: broadcast - hybrid,

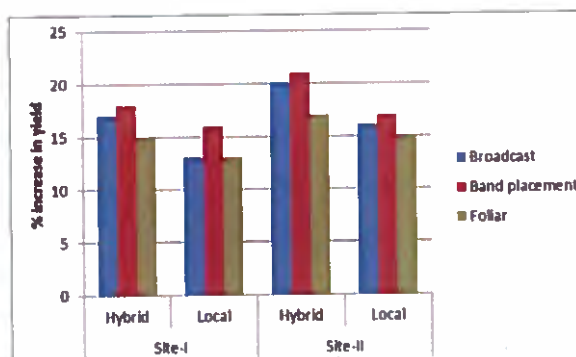


Figure-2 Zinc application on mize

4.6 & local, 1.9; band placement - hybrid, 1.8 & local, 1.5; and foliar - hybrid, 0.28 & local, 0.26.

2. Soil Salinity

2.1 Potassium Sulphate Induced Salinity Tolerance in Brassica Napus

Under salt stress, higher application of potassium sulphate decreases sodium ion and increases crop growth. Electrolyte leakage (EL) influences salinity tolerance of a crop and EL may be affected by potassium application. A study was conducted on the effect of enhanced level of potassium sulphate application on EL and dry mass of Brassica napus seedlings under salt stress (60 mM NaCl) using CRD. With 10mM K_2SO_4 application, dry mass of Cv. Pakola and Cv. Faisal Canola increased significantly ($p \leq 0.01$) by 52% than 2mM K_2SO_4 application. Under salt stress with 10mM K_2SO_4 application, EL of Cv. Pakola and Cv. Faisal Canola decreased 25% and 30% than 2mM K_2SO_4 application. Therefore, five folds application of potassium sulphate is beneficial to increase salt tolerance of B. napus resulting increase biomass and decreasing EL (Fig. 3).

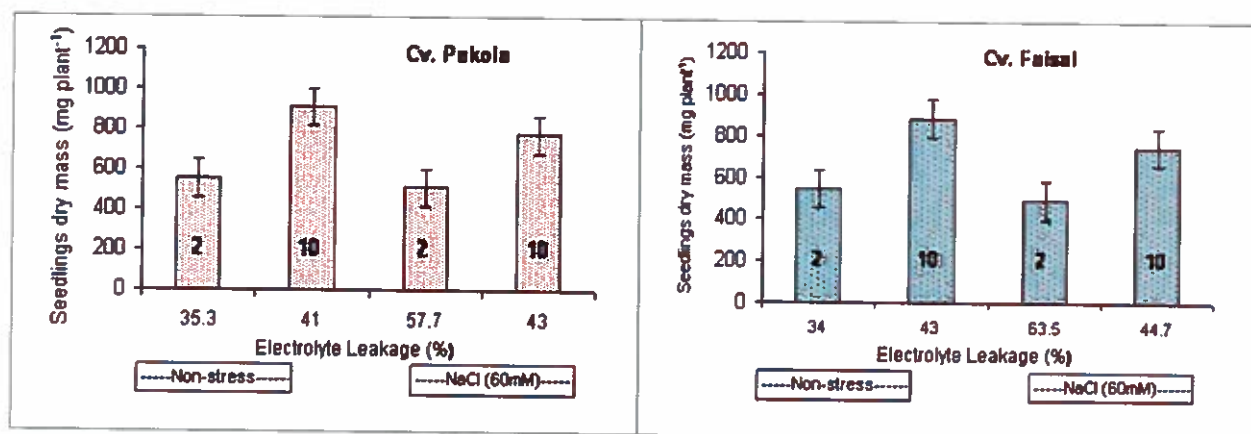


Figure-3 Seedling dry mass vs electrolyte leakage (%) in two varieties of Brassica napus

2.2 Response of Zn Application on Direct Seeded Rice under Salt-Affected Soils

Zinc availability in rice under saline conditions is affected due to imbalanced nutrients. High pH value and high calcium concentration in most saline soils are responsible for low availability of zinc for rice plant. An experiment was conducted to investigate the optimum dose of Zn for direct sowing of rice (Cv. Super basmati) under naturally salt-affected soils ($EC_e = 5.8 \text{ dS m}^{-1}$, $SAR = 25.15$). Zinc was applied @ 0, 5, 10 and 15 kg ha^{-1} as $ZnSO_4$ using randomized complete block design with three replications. The highest paddy yield (2.59 t ha^{-1}) was attained with application of 1.5 kg $Zn ha^{-1}$. The results showed that paddy yield was increased at all levels of Zinc as compared to control (Table 1).

Table 1 Effect of different levels of Zn on paddy yield under salt affected soil

Zinc sulphate applied	Paddy Yield t ha ⁻¹
0 kg ha ⁻¹	1.89 d
0.5 kg ha ⁻¹	2.27 c
1.0 kg ha ⁻¹	2.38 b
1.5 kg ha ⁻¹	2.59 a
Mean	2.28

2.3 Solar De-Salinization System:

Introduced and indigenized a household level solar desalination technology which can convert Sea/Brackish water to a level of 0-10 mg/liter of total dissolved salt (TDS). Farming community can use this water for kitchen gardening and livestock watering, marginal land utilization, High Value Agriculture, grow vegetable in hydroponics system, domestic drinking water, and poultry farming in saline areas. So far 8 units have been installed in Umerkot Sindh, 4 units in Hub Balochistan, 1 at NARC, Islamabad which are being used for agriculture and potable drinking water purpose in saline areas.



Figure-4 Solar Desalinization Unit in Sindh

2.4 Impact of Green Manuring and Crop Residue Incorporation

Efficacy of gypsum with or without green manuring (GM) and crop residue (CR) incorporation and its impact on paddy yield (cv. Super kernel) grown under salt-affected soil was determined in a field experiment. The results showed increase in paddy yield by application of gypsum along with crop residue (5 t ha⁻¹) and green manuring (Jantar). The maximum paddy yield 2.39 t ha⁻¹ was attained by the application of 100% gypsum along with green manure where by 2.28 t ha⁻¹ paddy yield was with 100% gypsum application along with crop residue. The results are shown in table-2.

Table 2 Effect of gypsum along with crop residue and green manure on paddy yield

Gypsum applied	Paddy yield (t ha ⁻¹)	
	With CR application	With GM application
0% of GR	1.98 e	2.01 e
50% of GR	2.09 d	2.17 c
75% of GR	2.20 c	2.27 b
100% of GR	2.28 b	2.39 a
Means	2.14	2.21

Means sharing similar letter(s) of a parameter do not differ significantly at $p < 0.05$
LSD = 0.12

3. Soil Biology & Biochemistry

3.1 Biozote (Crop Specific Inoculant) technology for improving soil health

3.1.1 Biozote Technology on Groundnut In Rainfed Area of Chakwal:

Five demonstration sites were selected under “Improving Soil Fertility & Soil Health” project funded by ICARDA-USDA for demonstration and dissemination of Biozote Technology under rainfed conditions in Chakwal for groundnut and wheat whereas under irrigated conditions in Sheikhupura and Hafizabad districts for rice and wheat crops. During 2014-15, groundnut was sown at five sites from medium to low rainfall areas of Chakwal with three treatment i. e., 1) Farmer Practice, 2) Farmer Practice + Biozote, 3) Biozote + recommended NP. The yield data showed Biozote inoculation increased peanut yield 18- 25% over farmer practice whereas recommended NP + Biozote showed increase of 21-32%.

Table 3: Effect of Biozote N on groundnut productivity at various locations in Chakwal

Treatment	Groundnut yield (t ha ¹)				
	Village Marth	Village Gah	Village Mari	DhokeAwan (Mazhar)	DhokeAwan (Noor)
Farmer Practice (FP)	1.46	0.82	1.32	0.866	1.22
FP + Biozote	1.83	1.01	1.56	1.076	1.53
Recommended NPK + Biozote	1.86	1.08	1.60	1.103	1.57

3.1.2 Field Demonstration of Biozote Technology on Rice in Irrigated Areas

Five demonstration sites were selected in Sheikhupura and Hafizabad districts for rice crop. The paddy seed were treated with Biozote at the time of nursery sowing and root dipping at the time of transplanting. The crop was harvested and yield data showed

that due to Biozote inoculation paddy yield was increased 10-17% over FP while with application of 75% NP of recommended dose the yield increase was 14-34% over FP. The yield increase was 20-41% over FP when Biozote + recommended NP were used.

The technology was also disseminated by organizing two field days, about 100-150 farmers participated in this activity. At field days farmers were briefed about the technology and farmer feedback about technology, Q & A session and field visit of farmers.

Table 4: Effect of Biozote application on rice productivity at various locations in District Hafizabad and Sheikhupura.

Treatment	Paddy yield (t ha ⁻¹)					
	Hiran Minar	Khankan Dogran	Kakkar Gill	Washuki	Bhaka Bhattian	Kakar Gill
Farmer Practice (FP)	4.25	3.79	3.35	3.64	3.13	3.37
FP + Biozote	4.72	4.36	3.82	4.18	3.65	3.94
75% Recommended NPK + Biozote	4.85	4.88	4.27	4.35	3.77	4.53
Recommended NPK + Biozote	5.13	4.91	4.45	4.41	3.85	4.75

3.2 Effect of Vermicompost Derived Humic Acid on Yield of Tomato

Vermicompost significantly affected yield of tomato fruit. Results showed that maximum fruit yield 4.383t ha⁻¹ where vermicompost was applied @ 2.0 t ha⁻¹ followed by 3.226 t ha⁻¹ where vermicompost was applied @ 1.5 t ha⁻¹. It was due to humic acid derived from vermicompost having more readily available nutrients and growth regulating substances such as urease, phosphomonoesterase, phosphodiesterase and arylsulphatase.

3.3 Effect of Biozote and Vermizote on growth and yield of peas

Biozote and vermicompost significantly affected yield of peas (CV. Meteor). Results in figures showed the maximum yield 15.47t ha⁻¹ was registered where recommended dose of N and P fertilizer (30: 80 kg ha⁻¹) was applied followed by 13.38 t ha⁻¹ where Biozote and vermicompost was applied @ 2 t ha⁻¹.

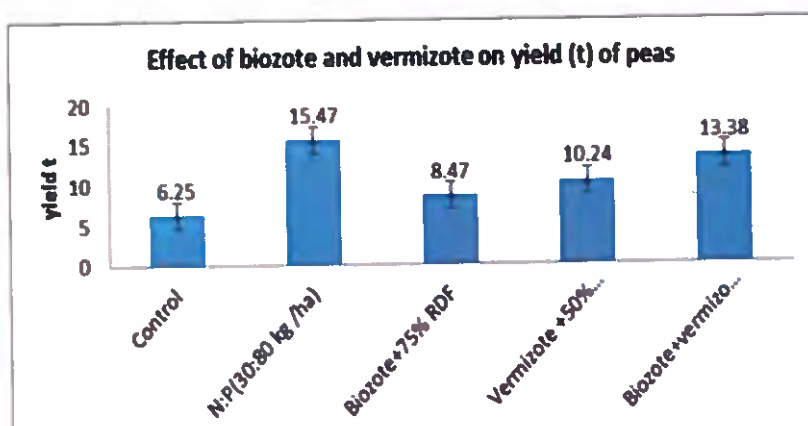


Figure-5 Effect of biozote and Vermizote on yield (t) of peas

3.4 Effect of Vermizote on growth and yield (t ha^{-1}) of Turnip

Vermicompost significantly affected yield of turnip. Results showed that maximum yield 39.52 t ha^{-1} was registered where vermicompost was applied @ 2.0 t ha^{-1} followed by 33.57 t ha^{-1} where vermicompost was applied @ 1.5 t ha^{-1} . It was due to humic acid derived from vermicompost having readily available nutrients and growth regulating substances such as urease, phosphomonoesterase, phosphodiesterase and arylsulphatase.

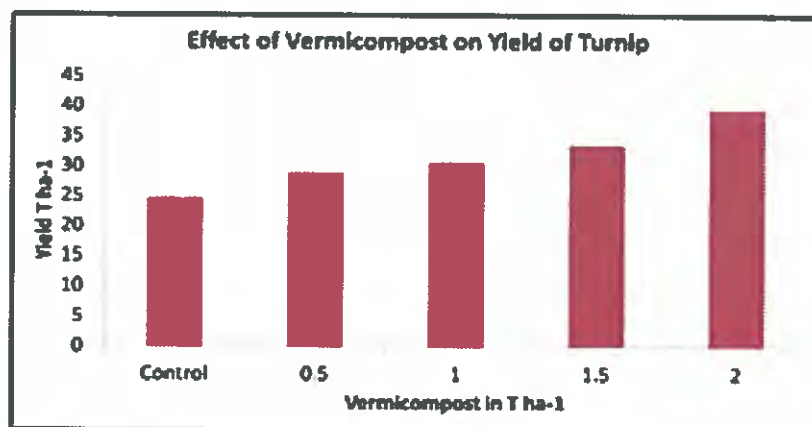


Figure-6 Effect of vermicompost on yield (t) of turnip

3.5 Formulation of Carrier for Bio-inoculant and its Evaluation on Maize (*Zea mays* L.)

Different combinations of material were prepared for suitable carrier for bio-inoculant from locally available clay soil (35-50%), fly-ash (30-45%), Press mud (5-15%) and lignite (5-15%). Clay soil (53% clay) was used for adhesion purpose but considering free of lump formation an important property of a good carrier, mixing 40% of soil with other material was found suitable. Using 40% of soil, six different treatments were formulated and physico-chemical characteristics were determined. Four combinations in the range of 40% clay, 30-40% fly-ash, 10-15% press mud and 10-15% lignitic coal were selected which had good adhesion capacity, moisture holding capacity, nutrient contents and investigated for microbial shelf life. Significant difference regarding microbial survival was observed between different formulations as well as between different incubation intervals. Among different carrier tested the FC-4 supported the maximum population of 33.5×10^8 to $10.8 \times 10^8 \text{ cfu g}^{-1}$ for MR-8 and 32.6×10^8 to $7.2 \times 10^8 \text{ cfu g}^{-1}$ for MR-5. Results showed that the required population of PGPR was sustained in all the formulation tested up to six months of storage period. These four bioinoculant formulations were evaluated on maize crop using Biozote carrier as reference. Formulated carrier 4 was found best regarding different growth parameters and nutrient contents of maize plants.



Figure-7 Reponce of maize to different bioinoculant formulations

4. Soil Physics

4.1 Effect of Green Manuring on Soil Physical and Hydraulic Properties under different Tillage Practices in Wheat

A field experiment was conducted to observe the effect of tillage and green manuring on wheat yield and temporal changes in soil physical and hydraulic properties. *Sesbania* was sown as green manure crop. The green manure was incorporated in soil with disk harrow and tillage treatments were applied to their respective plots before seedbed preparation. Soil physical and hydraulic properties were determined two and five months after tillage and sowing. Agronomic parameters (Grain yield, straw yield, plant height and one thousand grain weight) were recorded at the end of the experiment. The data show that soil bulk density ρ_b increased significantly over time and the magnitude of increase was more in case of cultivator at 10 cm depth and where green manuring was not done but at 20 cm depth the magnitude of increase in ρ_b over time was more in case of moldboard plow and where green manuring was done (Figure 8).

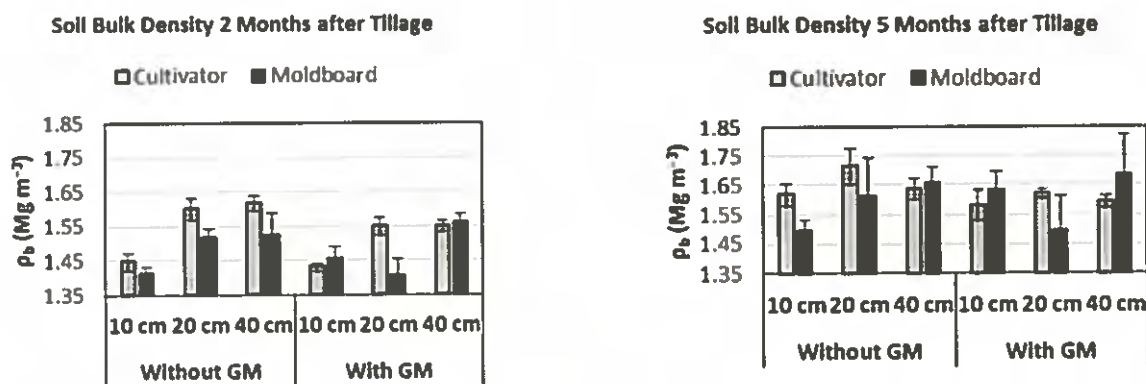


Figure-8 Temporal variation in soil bulk density (ρ_b) as affected by green manuring and different tillage treatments.

4.2 Effect of Farm Yard Manure and Sesbania Green Manuring (GM) on Soil Hydraulic Properties in Rice- Wheat System

Effect of farmyard manure (FYM) and sesbania green manuring (GM) on rice growth performance and soil physical and hydraulic properties was evaluated in District Sheikhpura. The study comprised of 4 treatments each treatment was applied to a plot of 10 acre. Well decomposed cattle manure and 75 days old Sesbania was mixed in soil. Rice nursery of Super Basmati was transplanted. At maturity crop was harvested and data on agronomic parameters i.e. paddy yield, plant height, tillering, panicle length and 1000 grain weight were recorded. Intact soil samples were collected and soil physical and hydraulic characteristics were determined under laboratory conditions subsequently. Data indicated that combined application of GM + FYM resulted in 2 fold greater water retention than in control while application of GM or FYM alone also improved water retention however, differences between the two were non-significant. A similar trend was observed for pore size distribution.

5. Soil Environment

5.1 Kinetics of Heavy Metals Sorption onto Chemically Modified Agricultural Byproduct Lignocellulose Materials

In this study, Cadmium (Cd), chromium (Cr) and lead (Pb) adsorption potential of unmodified and modified sugarcane bagasse and ground wheat straw was explored from aqueous solution through batch equilibrium techniques. Both the materials were chemically modified by treating with sodium hydroxide (NaOH) alone and in combination with nitric acid (HNO_3) and sulfuric acid (H_2SO_4). The Pb removal by both the materials was the highest followed by Cr and Cd. The chemical treatment invariably increased the adsorption capacity and NaOH treatment proved more effective than others. Langmuir maximum sorption capacity (q_m) of Pb was utmost (12.8 – 23.3 mg/g of sugarcane bagasse, 14.5 – 22.4 mg/g of wheat straw) and of Cd was least (1.5 – 2.2 mg/g of sugarcane bagasse, 2.5 – 3.8 mg/g of wheat straw). The q_m was in the order of $\text{Pb} > \text{Cr} > \text{Cd}$ for all the three adsorbents. Results demonstrate that agricultural waste materials used in this study could be used to remediate the heavy metals polluted water.

5.2 Impact of Spent Wash irrigation on Maize (*Zea mays* L.) Growth

Bio-methanated spent wash (after gas production) is a very rich source of plant nutrients, i.e., nitrogen, phosphorus, potassium, magnesium, calcium, zinc, iron and copper but due to high BOD and COD, not used for irrigation. In this study, the spent wash nutritional values and its irrigation effect on Maize (*Zeamays* L.) Growth were assessed.

Bio-methanated spent wash was collected from Noon Sugar Mills Ltd. Bhalwal and was characterized for EC, pH, total soluble solids, sodium, nitrogen, phosphorus, and

potassium using standard methods. Five kg (air dried and ground) portions of soil was placed in plastic pots and five treatments; 1) control, 2) 25% spent wash, 3) 50% spent wash, 4) 25% spent wash + 1/2 dose NPK, 5) 50% spent wash + 1/2 dose NPK and 6) Full dose of NPK were applied and maize was test crop.



Figure-9 Impact of spent wash on maize

The bio-methanated spent wash used in this experiment was a rich sources of plant nutrients and had high concentration of nitrogen (0.33%), phosphorus (324 mg/kg), potassium (10140 mg/kg) and organic carbon (3.40%). It was slightly alkaline in reaction (pH 7.8) but had high EC (47.7 dS m⁻¹) and sodium concentration (6053 mg/kg). The maize shoot yield was statistically higher in the case of 25% spent wash irrigation than control and was equal half dose of 1/2 NPK (Table 1), while maize growth was very poor in 50%. Similar trend was observed in N and P uptake. Because of high BOD, this can only be used for irrigation after appropriate mixing (\approx 5 times) with good quality canal/underground irrigation water.

Table 5 Maize dry shoot yield and nitrogen and phosphorus uptake as affected by spent wash application

Treatment	Dry mater yield (g/plant)	Up take (mg/plant)	
		Nitrogen	Phosphorous
Control	1.20	9.00	1.80
25% SW	5.27	53.75	11.59
50% SW	0.85	8.50	1.70
25% SW + 1/2 NPK	7.67	93.57	18.41
50% SW + 1/2 NPK	0.75	9.38	1.58
Full PNK	8.25	111.38	21.45

5.3 Improvement of Rapeseed Growth and Heavy Metal Uptake by Metal Tolerant Bacterial Strains

Microbial communities, living in rhizosphere (rhizobacteria) are able to withstand the heavy metal concentrations. Microorganisms and their products have been reported for efficient removal of soluble and particulate forms of metals (bioremediation) due to their sequestration ability (solubilization, accumulation, transformation) to heavy metals. A greenhouse bioremediation study was planned and heavy metal tolerant bacteria were used to enhance the remediation process. Rapeseed seeds were

inoculated with heavy metal tolerant bacteria strains and were grown in heavy metal contaminated soil for 90 days.

Inoculation of heavy metal tolerant bacteria enhanced dry shoot (DSH) and dry root weight irrespective of strains over control. Chromium concentration in shoot was also increased by microbial inoculants up to 53.5% over control while in roots, the increase was only up to 26 %.

The enhanced concentration resulted in higher Cr uptake. Maximum (60% increase over control) was observed where all bacteria were applied together. Inoculum of consortium (all strains) increased the phytoextraction of Cr up to 100% compared to individual inocula.

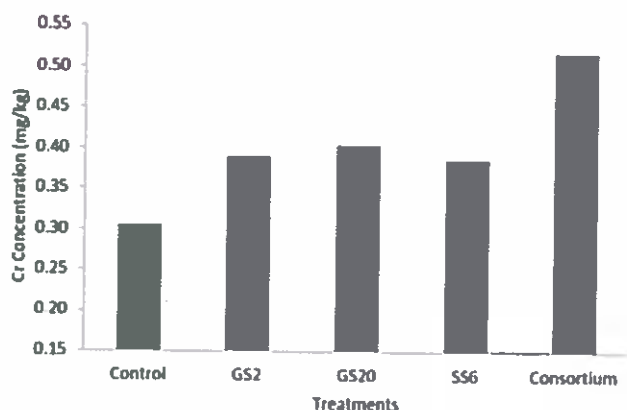


Figure-10 Effect of heavy metal tolerant bacteria on total Cr uptake in rapeseed

5.4 Metals Adsorption By Saw Dust: Isotherms, Kinetics And Thermodynamics

A study was designed to explore metal sorption characteristics of inexpensive and commonly available tree sawdust of parital (Piceasmithiana). Lead, chromium and cadmium adsorption experiments were performed by varying pH (4-10), contact time, adsorbent dose (5-30g/L), temperature (25°, 35° and 45° C) and metals concentrations (5-200 mg/L) to optimize absorption conditions. Results showed that the metal sorption is strongly pH dependent and was optimum at 6-7 pH and maximum metal is removed after ≈ 1.5 hrs. shaking at 100-175rpm while 30g/L sorbent was optimal. The amount of lead sorbed was relatively higher (7.40 mg/g) than chromium (4.41 mg/g) and cadmium (3.50 mg/g) (Table 6). Similarly, lead was adsorbed strongly than rest of the metals and binding affinity of the saw dust was in order of lead > cadmium > chromium. The free energy changes for the interaction also confirm that the adsorption process was spontaneous with a high preference of Pb then Cr and Cd.

Table 6: Isotherm sorption parameters of saw dust

Heavy metal	Langmuir			Freundlich		
	q (mg/g)	K _L (L/mg)	r ²	K _F (mg/g)	N (L/mg)	r ²
Lead	7.40	0.207	0.99	1.41	2.63	0.96
Chromium	4.41	0.073	0.99	0.55	2.32	0.97
Cadmium	3.50	0.110	0.99	0.63	2.80	0.96

6. Agricultural Water Management

6.1 Optimizing Irrigation Management of Conventional Surface Irrigation Methods for Improving Irrigation Efficiency

For improving irrigation efficiency three surface irrigation systems i.e. border, flat basin and furrow bed were evaluated on thirteen fields, seven at NARC farm and six at Mardan KPK Province (Figure-11). Irrigation performance including application efficiency (E_a), requirement efficiency (E_r) and distribution uniformity (DU), of 17 irrigation events were evaluated and further potential for improvement was identified using Infiltration Parameters from Water Advance Model (IPARM) and surface irrigation evaluation models (SIRMOD III).



Figure-11 Irrigation application to flat basin

Water application efficiency was found to be 64 % under border, 58 % under flat basin and 70 % under furrow bed irrigation methods at farm level. Moreover, simulation modelling study shows that there is provision to improve the water application efficiencies from 12 -18 % under border, 4-15 % under flat basin and 21-23 % under furrow bed irrigation systems.

Table 7: Potential for improving application efficiency under different irrigation systems

Irrigation Systems Fields	FP	Strategy 1	Strategy 2
Border	64 (31.4,22.4) *	76 (31.4,18.6)	82 (43.8,11.4)
Flat Basin	58 (23.5,97.5)	62 (23.5,90.5)	73 (44,41)
Furrow Bed	70 (1.92,27.7)	91 (1.92,15.05)	93 (2.05, 11.2)

* Values in parenthesis are (Q in lit/sec, Tco in minutes)

Temporal variation in the distribution of volumetric soil moisture across half bed width and 100 cm deep profile at after 7 hours of wetting wa evaluate using soil water movement simulation model Hydrus 2D. The results are shown in Figure -12.

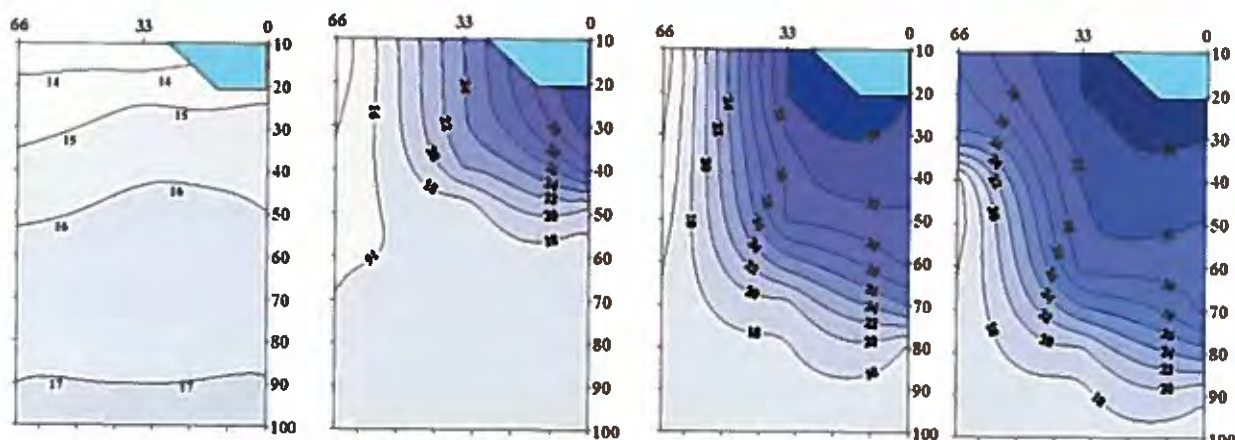


Figure-12 Temporal variation in the distribution of volumetric soil moisture

6.2 Water Requirement of Crops and Fruit Plants in Various Ecologies

Crop water requirement (CWR) for wheat and oat crop was determined by using NARC climatic data using FAO CROPWAT model (Table 8). The results showed that average monthly ET_c for wheat crop ranged from 26 mm in December to 145 mm in April, 2015. For Oat crop average monthly ET_c ranged from 24 mm in November. The maximum ET_c was 111 mm during April and followed by 87 mm during March.

Table 8 Water requirement and crop coefficients of wheat and oat, NARC, Islamabad

Month	Wheat		Oat	
	ET _c (mm)	K _c	ET _c (mm)	K _c
November	-	-	23.56	0.70
December	25.55	0.7-0.76	30.05	0.76-0.89
January	33.47	0.95-1.01	36.10	0.95-1.08
February	55.55	1.01-1.15	57.84	1.15
March	99.82	1.15	96.60	1.15
April	144.90	1.15	110.88	1.15
May	54.15	0.25	31.19	0.25
Total	413.43		386.21	

CWR of pistachio and Banana was determined by using the model. For pistachio in Quetta the average monthly ET_c ranged from 36 mm in February to 183 mm in June. For banana in Tandojam the average monthly ET_c ranged from 2.0 mm in November (at sowing) to 289 mm in May. The total CWR of banana was 1700 mm at Tandojam, Sindh.

6.3 Research Cum Demonstration Sites of Efficient Irrigation Systems

Five research-cum-demonstration sites of efficient irrigation systems were established in all the four provinces and capital territory. The high efficiency irrigation systems consists of drip, micro sprinkler, bubblers and furrow bed were designed and installed at different locations i.e. NARC (Capital), Bahawalpur (Punjab), Tandojam (Sindh), Quetta and Shinkiari (KPK). At AZRI Bahawalpur, overhead micro sprinklers for nurseries and pc emitters for date fruit plants were installed (Table 9).

Table 9. Research cum demonstration sites of efficient irrigation systems in provinces

Site location	Area (acres)	Province	Irrigation system's type	Crops
BARDC, Quetta	1.0	Baluchistan	Drip System	Pistachio
AZRI, Bahawalpur	0.25 0.10	Punjab	Micro sprinkler and Drip System	Nurseries and date fruit plants
ARI, Tandojam	1.0	Sindh	Drip System	Banana
NTHRI, Shinkiari	1.0 0.25	KPK	Micro sprinkler and Drip System	Mother fruit plants and nurseries
NARC	1.25	Islamabad	Bubblers and Drip systems	Citrus & grapes fruit plants and vegetables



Figure-13 Drip irrigation system on pistachio at Quetta and banana at Tandojam

7. Integrated Watershed Management

7.1 Integrated Watershed Management Practices for Enhancing Crop Water Productivity

A demonstration site of integrated watershed management practices was developed at Kambrial, Pindigheb. To efficiently utilize the harvested rain water storage (55 ac-ft), a 5hp solar pumping system was installed (Figure 17). An automatic agro-met (weather) station was developed for collecting daily climatic data. The overhead

tank was used for gravity fed drip irrigation, micro sprinkler and improved surface irrigation over 6 acres of the orchards and 1 acre seasonal vegetables. Moreover, 10 acres of segregated land was brought under irrigation using solar operated portable rain gun system.

Furthermore, a drip irrigation system was installed over 2 acre area for olive and grapes plants. Eyebrow micro catchments were developed and demonstrated over 2 acre orchards for in-situ water harvesting. Walking and high tunnels were established and irrigation was ensured through solar operated drip and micro sprinkler irrigation system for off season crops.

Dissemination of developed technologies was carried out by organizing farmer field days. Farming community was invited from nearby villages and they were briefed about the interventions/activities. 200 farmers participated in three farmer field days and one seminar at Kambrial.



Figure-14 Installation of solar system for drip and sprinkler at Kambrial

7.2 Solar Powered Pumping System for Command Area Development of Small Dams

The extent of command area served by the Solar Powered typical Pumping System for typical cropping pattern (wheat-maize) was function of irrigation technology choice. Four irrigation technologies were selected to be integrated with typical SPPS of Fatehjang and by using available flow rates per day, following scale of agricultural development was possible (Table 11). The maximum benefits from available solar pumping were possible by choosing water smart Drip Irrigation technology both for cereals and horticultural purposes and net 22.70 acres were brought under agriculture, along with substantial water balance of 5.68 MG (nearly 31 % of total solar pumping, offering substantial diversification potential).

Table 11. Potential utilization of solar pumping through various irrigation technologies

Annual Solar Pumping Volume	Irrigation Technology	Annual Command area			Annual Water Balance
(MG/Year)		Cereals (Acres)	Horticulture (Acres)	Total (Acres)	(MG/Year)
18.19	Conventional Flooding	11.3	2.3	13.6	5.61
	Sprinkler Irrigation	16.9	-	16.9	9.69
	Drip Irrigation	19.1	3.6	22.7	5.68
	Bed Furrow Irrigation	14.70	-	14.70	9.66
	Sprinkler + Drip Irrigation	16.9	3.6	20.5	5.66
	Sprinkler Irrigation + Flooding	16.9	2.3	19.2	5.65
	Bed Furrow + Drip System	14.70	3.6	18.3	5.63
	Bed Furrow + Conventional Flooding	14.70	2.3	17	5.61

7.3 Capacity Building on Solar Powered High Efficiency Irrigation System

Solar powered HEIS demonstration and capacity building of professionals were carried out. During reporting period 05 professional training courses were organized whereby about 185 professionals from various Federal, Provincial, Academic and NGO sectors were trained through interactive lectures, in class exercises and practical sessions at Fatehjang. Similarly 12 technology specific farmer field days (solar powered irrigation systems, tunnel farming with drip irrigation, sprinkler irrigation systems etc.) were also organized at various project locations to disseminate efficient irrigation systems among farming community. The total farmers benefited from training were about 620 during reporting period. In addition 5 international delegations, 10 in formal field visits by various stakeholders were also facilitated during reporting period.

8. Climate Change and Geo-informatics

8.1 Assessment of Soil Erosion and Risk Mapping of Simly Watershed

Risk of soil erosion was investigated in Simly watershed, Potowar region using Revised Soil Loss Equation (RUSLE) and Geographic Information System (GIS). Results showed that the method of incorporating RUSLE soil equation with geospatial tool resulted in effective evaluation of soil erosion risk in variable topographic and landuse state of

Simly watershed in Pothwar region. More than 57% of Simly watershed was found under low risk of soil erosion (<10 tons/ha/yr) while about 30% area were under medium risk of soil erosion (10-30 tons/ha/yr) Figure 18. Erosion rate was estimated high in agriculture land i.e. about 120 tons/ha/yr whereas it was about 11 tons/ha/yr in forest area. The erosion was found higher under very steep slopes (>30 deg) i.e. about 34.9 tons/ha/yr whereas it was about 10.6 tons/ha/yr under gentle slope (5-15 deg) and 4.8 tons/ha/yr under flat to gentle slope (<5 deg). Mean monthly erosion was observed high in the month of July (2.93 tons/ha/month) and in August (2.68 tons/ha/month). It was minimum in November i.e. about 0.19 tons/ha/month.

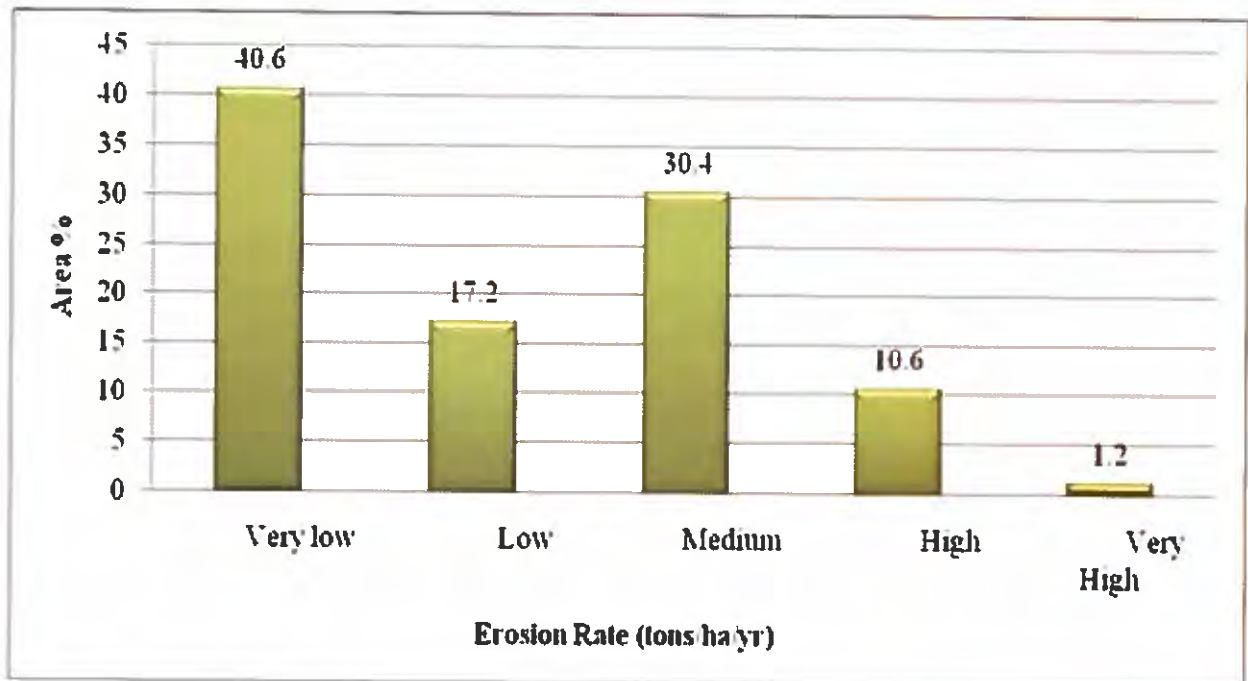


Figure-15 Percentage coverage of various risk zones of soil erosion in Simly watershed

8.2 Evaluation of Heterogeneous Expansion of Glacial Lakes in HKH Region

The detection of glacial lakes is a crucial not only for managing potential water resources but also as first step in investigating their hazard potential and in the prevention of sudden and unexpected catastrophes. In this study, end-moraine dammed lakes in HKH ranges of Pakistan were evaluated for 2001-2013 period to get insight of their response to changing climate in this region. The results showed that total of 482 end-moraine dammed lakes were identified in the three HKH ranges out of which 339 lakes were characterized as major lakes (>0.02 km²) during 2001-2013 period (Figure 19). About 40% of the major lakes lie in the Karakoram range followed by 35% in the Himalaya and 25% in the Hindukush range. Overall cumulative lakes area in the HKH region increased from 26.28 km² ($\pm 9.0\%$) to 27.29 km² ($\pm 9.6\%$) within 2001-2013 at rate of about 0.084 km² y⁻¹. Among various size classes, the end-moraine dammed lakes smaller than 0.05 km² were dominant in all the three ranges (Figure 19). Maximum increase in the lakes coverage (about 5.9%) was exhibited by

the lakes of 0.05-0.1 km² class followed by lakes of <0.05 km² class (about 4.6%). Majority of the end-moraine dammed lakes (i.e. >70%) were found above 4,000 masl. The concentration of the lakes was highest within 4,000-4,500 masl elevation followed by greater than 4,500 masl range.

8.3 Analysis of Snow Cover Dynamics in Hunza River Basin

This study was based on snow cover mapping of Hunza River Basin for assessment of snow cover dynamics under changing climate. The results indicated that the percentage snow cover area is predominantly increasing with time in this high altitude cryospheric region. More than 80% of the basin area was found snow covered during the peak winter season (Jan, Feb, March) particularly during the time periods of 2003 (82 %), 2004 (92%), 2005 (84 %), 2009 (87 %) and 2011 (80 %). About 83 % of the total basin area was found snow covered during the months of January and March, 2011 while 80 % snow was observed in February, 2011. From the trend analysis of inter-annual snowline variations, snowline was observed almost stable during 2000 to 2011 indicating a limited influence of global warming in this part of the Karakoram Range. Overall shift in snowline over north and south aspects is constant. A significant gain in snow mass (e.g. an increase of about 719 km² in snow cover area) was observed during 2001-2011 period.

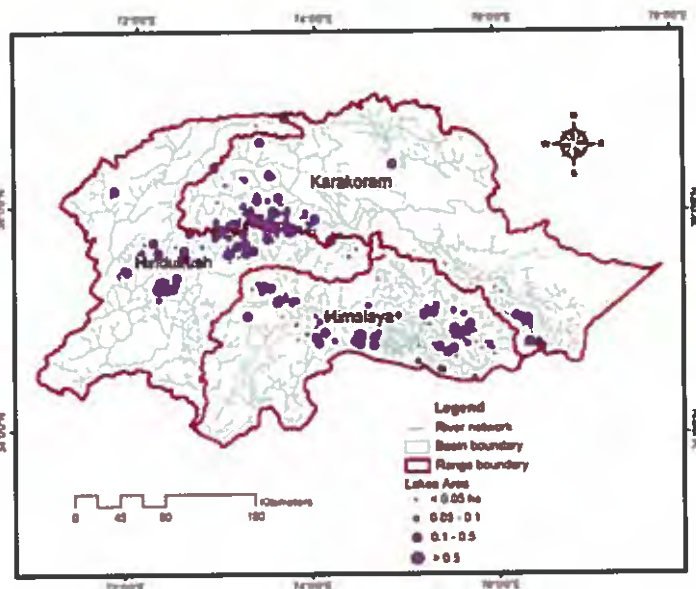


Figure-16 Distribution of end-moraine dammed lakes by area classes in three HKH ranges

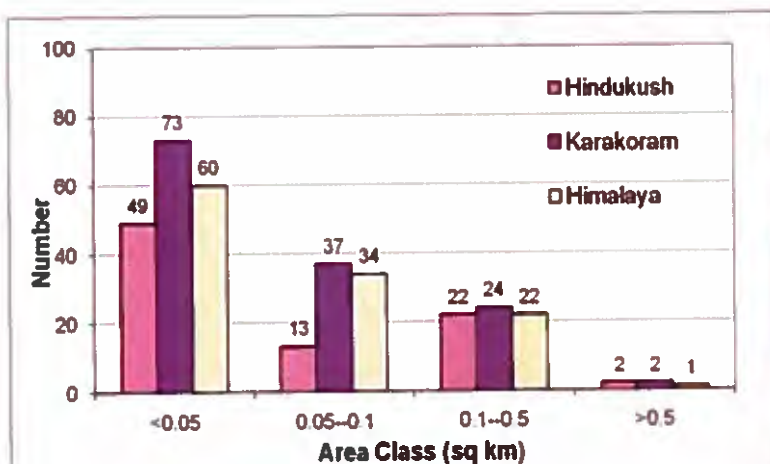


Figure-17 Comparison of various area classes of end-moraine dammed lakes in the HKH ranges

9. Range And Forestry

9.1 Maintenance of Multipurpose Tree and Shrub (MPTS) Nursery

About 20,000 plants of more than 30 species were raised in the nursery during period under report. Planting stock raised at the nursery utilized for planting in four selected sites of the AIP and ICARDA collaborating project, road side plantation and Landscaping, NARC (ornamental plans i.e. Lagerstroemia, Hibiscus), Kachnar, road side plantation, NARC etc. This planting stock is also available for sale purposes.

9.2 Evaluation of Exotic Germplasm:

Since the development of export market of forage hay to Dubai and other Gulf States, private seed companies have shown keen interest for import of high yielding and nutritious forage grasses. The companies approached to RRI for adaptation trials to get import permit. Fresh and dry biomass and height were evaluated of different varieties of perennial exotic grasses: Rye grass (*Lolium multiflorum*) varieties Makhani, Accelerate, Emerson and local Rye-I and Rhode grass (*Chloris gayana*) varieties: Sabre, Talgar, Katamber and soft cut at different growth stages i.e. vegetative, flowering and maturity growth stages. Fresh and Dry biomass and height of different Rye grass (*Lolium multiflorum*) were collected at different stages vegetative, flowering and maturity. The details are shown in Table 12.

Table 12. Yield and height of different rye grass varieties at different growth stages

S. No.	Grass Name	Vegetative Stage			Flowering Stage			Maturity Stage		
		Fresh biomassst /ha	Dry biomassst /ha	Height cm	Fresh biomassst /ha	Dry biomassst /ha	Height cm	Fresh biomassst /ha	Dry biomassst /ha	Height cm
1.	Accelerate	1.11	0.55	75	2.46	0.95	91	0.21	0.10	92
2.	Makhani	1.93	1.03	85	3.18	0.94	109	0.76	0.18	101
3.	Emerson	1.21	0.77	56	2.83	0.95	76	0.63	0.14	87
4.	Rye-I	1.28	0.89	100	1.77	0.86	135	0.30	0.11	101

9.3 Range Improvement Activities

Four villages in district Chakwal were selected for conservation and rangeland activities together with the local farming community. An area of 25 ha at all the four sites (Latifal, Mial, Begal and Dhulli) belonging to 10 and 15 households at each site was conserved for rangeland activities.

The activities were started for an appraisal assessment of the current conditions. An inventory of the important range plant species of the area was conducted using the line transects method. Total above-ground biomass was collected by clipping whole aerial parts of herbaceous plants, shrubs and grasses from 1x5 m² alternative quadrates

established on a 35 m transect line. The plant samples were weighed, dried in oven at 60°C until constant weight was reached and dry matter (DM) was determined. The results are summarized below):

Table.13 Current biomass production (kg/ha) at Begal, Chakwal district

Site	August 2014	August 2014	November 2014	November 2014
	Fresh wt	Dry wt	Fresh wt	Dry wt
Hill top	350	210	470	350
Southern slope	660	480	780	580
Northern slope	310	160	420	300
Flat area	880	530	1050	780
Average	550	345	680	500

9.4 Silvo-Pastoral Intervention

Introduction of a silvo-pastoral system is one option proposed to alleviate the gap in feed resources. Several species of fodder trees and grasses have been identified for testing. Most of the suggested species can be found locally as they are native to the region with the exception of *Leucaena leucocephala* which originated from Mexico but has been introduced to Pakistan for a long time. The important fodder trees and grasses grown in the area are Phulai (*Acacia modesta*), Ipil-ipil (*Leucaena leucocephala*), Mulberry (*Morus alba*), Babul (*Acacia nilotica*), Mulberry (*Morus alba*), Ber (*Zizyphus mauritiana*), Dhamman grass (*Cenchrus ciliaris*), Elephantgrass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), Blue panic grass (*Panicum antidotale*) and Guinea grass (*Panicum maximum*).

This intervention was started through a pilot experiment at all sites on communal lands. Contours were laid out with a mould-board plough and saplings of *Leucaena leucocephala* (ipil-ipil) were planted with one meter spacing. More than 3000 saplings per hectare have been planted on both sites. Survival rate of ipil-ipil saplings was 92%. Forage grasses (*Panicum maximum*, *Chloris gayana*, *Panicum antidotale*) were grown in the alleys to provide a balanced feed regime. Success of tuft planting was in the range of 70 to 80% while germination of grass seed was 40 to 50%.



Figure-18 Rehabilitated land for shrubs plantations

9.5 Plantation of Spineless Cactus

Another promising option to increase fodder supply in dry areas is spineless cactus (*Opuntia ficus indica*). The cactus pads were supplied by NARC and kept under shade for one week; then transported to the site. A total of 3,000 pads were planted at a spacing of 1 x 2 m along the slopes on marginal lands of 20 farmers. Eye-brows (semi-circular micro-catchment) and furrows were made against the catchment to harvest rain water. Survival was almost 100% and most of the pads have started sprouting.



Figure-19 Plantation of cactus at farmer's field

9.6 Introduction of Exotic Cactus Accessions:

Under the CGIAR Research Program (CRP) Dryland Systems (DS), new cactus accessions have been added to the germplasm collections at NARC which were introduced from Brazil and Italy. One cladode from each accession was handed over to PGRI for germplasm conservation. All the accessions are being multiplied and eventually most promising accessions will be introduced to the farmers field in the dry areas.

9.7 Animal Performance in Rotational Grazing System in RRI Pasture Area

In this experiment, 12 beetal does performance was evaluated in rotational grazing system at RRI Pasture NARC. The does were of 1-3 years aged with average live weight 68.85 kg. All the does were vaccinated and de-wormed as for the recommended vaccination and de-worming schedule. The de-worming was further based on fecal analysis of internal parasitic load. In addition, all the animals were also screened for brucellosis through blood analysis from Animal Health Lab, ASI NARC. Twelve (12) Beetal does were divided into 3 equal groups (A, B and C) and further two sub-grouped (A1, A2, B1, B2, C1 and C2) as replicates to graze rotationally on *Morus alba*, *Acacia modesta* and *Leucaenaleucocephala* grasses respectively for 60 days on each field. The results showed that Beetal does gains highest mean live-weight gain (4.18 kg) in group C fed on *Leucaenaleucocephala* grasses followed by *Morus alba*, *Acacia modesta*, respectively (Table 14).

Table 14: Mean live-weight of Beetal does under rotational grazing on different plant species

Days	Acacia modesta (Phulai)		Morus alba (Mulbury)		Leucaenaleucocephala (Ipillp/grasses)	
	A1 (6 does)	A2 (6 does)	B1 (6 does)	B2 (6 does)	C1 (6 does)	C2 (6 does)
Initial wt	37.91	33.71	39.41	32.04	40.25	32.04
First 10 days each field	39.41	32.04	40.25	32.04	41.10	33.16
Second 10 days each field	41.83	34.41	43.16	34.08	44.33	36.22
Difference	3.92	0.7	3.75	2.04	4.08	4.18



Figure-20 Mixture of grasses and Ipillpil trees on full bloom at NARC Field



Figure-21 Beetal does grazing in *Acacia modesta* field at RRI, NARC

10 Honeybee

10.4 Integrated Pest Management in Honeybee *Apis mellifera* colonies

10.4.1 Comparative Performance of three Hornet Traps

In Pakistan the hornet species are *Vespa orientalis*, L., *V. basalis* Smith, *V. tropica* Beq., *V. velutina* Vecht., and *Vespa germanica* (F.) which prey upon honeybees. Of these five hornet species *V. velutina* and *V. basalis* were important and cause heavy losses by feeding on adults, brood and honey reserves of bees during the crucial floral dearth period extending from July to October. A study was conducted to determine the appropriate time that the bait should be placed so as to increase the effectiveness. Three types of traps (Wooden Trap with Plastic bottle, Iron Wire Gauze Trap and Wooden Trap) and three types of baits (grapes, fish and meat) were used.

The results showed that in all cases of traps and baits, the insect entrapment was more effective when the bait was placed in the morning (08.00 h) than in the early afternoon hour (14.00 h). The better efficacy during the morning may be due to the fact that the insects begin with an intense pace to find food at the beginning of the day. The data showed significant difference between wasp species, trap type and bait kind. In addition, fresh bait seems to be more attractive to wasps. When grapes, meat or fish bait was put in the early afternoon for 24 hours, fewer wasps were in traps next afternoon.

10.4.2 Efficacy of Essential Oils against Mites Infesting *Apis mellifera* Linn. Colonies In Relation to Honey Yield

Tropilaelaps clareae and *Varroa destructor* are of major importance to apiculture. These mites parasitizing the two economically important honey bee species, *A. mellifera* and *A. cerana* and causing serious complications in beekeeping. Therefore, colonies must be treated once or twice a year against *V. destructor* and *T. clareae* to maintain their populations below the economic injury level.

Essential oils are good alternatives for control of *V. destructor* and *T. clareae* mites. Several essential oils have shown acaricidal activity in screening tests, but it is necessary to prove their efficacy and bee compatibility in field trials. Four oils (Lemongrass oil, Mint oil, Basil oil and Rosemary oil) along with formic acid were used for testing their efficacy against *Varroa destructor* and *Tropilaelaps clareae* mites. The mortality was counted after 24 and 48 hours of treatment by placing mite collection tray in each colony. Honey yield data (in kg) per colony was also be recorded in the treated and in the control (untreated colonies) with essential oils.

The results indicated that all the tested oils were toxic to *V. destructor* and *T. clareae* mites and not to bees in a dose dependent manner. Data indicated that the toxic action of *Cymbopogon citrates* oil was higher against *Varroa* and *Tropilaelaps clareae* than that of other plant extracts. Honey yield data showed more honey (8 kg/colony)

from colonies treated with essential oils as compared to check (2 kg/colony) honeybee colonies.

10.4.3 Efficacy of Screen Bottom Board Tray and Soft Chemicals for Controlling Ectoparasitic Mites

An experiment was conducted on sixteen *Apis mellifera* L. colonies. Bee hives with screen bottom boards placed throughout the treatment period in spring, summer and winter season with 3.2 % Oxalic acid, 2 gm thymol, 65 % Formic acid and screen bottom board. The results showed that the screen bottom board tray is an effective method in controlling honeybee mites in all active season. It is highly recommended that the use of screen bottom board tray improve the efficacy level via decrease in honey bee mites in beehive.



Figure-22 Training on screen bottom board

11 Arid Areas of Pakistan

11.1 Crops Research

AZRI, Umerkot Sindh

- Eight upcoming genotypes and 41 germ plasm of cluster bean were tested, 8 varietal trial of sesame and seven Guar yield trials were conducted at AZRI farm.
- Mulberry, Chiku and Falsa are introduced and tested in arid and semi-arid condition of Thar Desert.
- Ten Tomato varieties viz Avto-1422, 1456, 1417, 1420, 1288, 1405, 1418, 1424, 1409 and 1414 were cultivated under AVRDC-AIP project "Protected cultivation of



Figure-23 Date palm orchard in Sindh

vegetables” at Mian Muhammad Saleem Farm KotGhulam Muhammad and TalhoMalho.

- 10 mother wheat trials 10 baby wheat varietals trials under AIP-CIMMYT were conducted. NIA Amber variety produced higher yield.
- Date palm orchard has been planted on 2 acres area, the plants are at vegetative growing stage.
- Two groundnut varieties i.e. Tigori and china were cultivated on two acres area. The varieties are being tested for best performance under sandy soils of Umerkot, Sindh.
- An experiment on groundnuts National Uniform Yield Trial having eight entries plus three local check varieties is cultivated at AZRI farm Umerkot.
- Furthermore another solar pumping unit has been installed at AZRI farm. Grafted ber (Gola) 04 acre was also planted under drip irrigation system.

AZRC, D.I. Khan, KP

- For strengthening of center, 07 acres land was purchased at Tank on main Tank-DIKhan road by land acquisition process. The process for transfer of acquired /purchased land is completed with Section V, VI & XVII issued by the Commissioner, DIKhan Division. Another 05 acre land was purchased at Wana on main Wana-Angoor Ada road. Physical demarcation of purchased land at Wana (SWA) is in progress for transfer to AZRC (PARC), DIKhan. Site is selected / identified at Mauza Matora District Lakki-Marwat on main indus high way in consultation with district management. The Deputy Commissioner, Lakki-Marwat has been requested to issue section- IV for acquisition of land. Tender for topographic survey of Arid Zone Research Center (AZRC), DIKhan, Tank, Wana and LakkiMarwat under PSDP project is completed and after survey, the designing for building construction work will be carried out.
- Three steps for variety registration case of “SonaMung” has successfully been passed while final step is awaited.
- Rapeseed candidate line of AZRI “Mohsin-12” has been included in NUYT for wider adaptability studies for 2nd year, which is prerequisite for variety registration process.
- Data recorded on maize, sunflower, sesame, millet, sorghum, chickpea (Desi and Kabuli types), lentil, rapeseed, mustard and wheat NUYTs were compiled

and sent to National Coordinators, National coordinated programme, NARC, Islamabad.

- Last year's selected 23 accessions of chickpea (F5) were planted for generation advancement and homozygosity.
- Fifteen (15) best performing accession from International Fuassarium Wilt Nursery and seven (7) lentil entries from International Elite Nursery (Small seeded) were earmarked for further evaluation in successive generations.



Figure-24 Maize trials at AZRI, DIKhan

- Out of 328 wheat accessions/entries 57 best performing lines were selected on the basis of their best performance in grain yield and disease reaction for further testing and breeding program.

- Fertilizer application @ 90-60 NP kg ha⁻¹ produced maximum grain yield in rapeseed candidate line "Mohsin-12".



Figure-25 Wheat testing trials at AZRI

- While testing the efficacy of various insecticides it was observed that the application of Talstar 10 EC @ 20 ml acre⁻¹ gave maximum control of pod borer with 9 % infestation while 69 % infestation was recorded in untreated check.
- In the assessment trial for drought tolerance in wheat it was noted that the maximum grain yield 4.07 tons ha⁻¹ with four irrigations and minimum grain yield of 1.064 tons ha⁻¹ was recorded in case with no irrigation.
- Among five herbicides applied for control of broad leaf weeds in wheat crop maximum grain yield 2.855 tons ha⁻¹ was recorded in case of Buctril Super while the lowest grain yield of 1.3 tons ha⁻¹ was recorded in control treatment where no herbicide was applied.

AZRI, Bahawalpur, Punjab

- Nineteen (19) genotypes of Desi Chickpea and 10 genotypes of Kabuli Chickpea were compared. The coded genotype (8) of Desi Chickpea obtained the highest seed yield of 2155.6 kg/ha while coded genotype (7) of Kabuli Chickpea obtained the highest seed yield of 1835.2 kg/ha.



Figure-26 Chickpea testing trials at AZRI

- Sixteen (16) genotypes of mungbean were compared. The coded genotype (10) obtained the highest seed yield of 1508.3 kg/ha.
- Forty (40) genotypes of Wheat, 13 genotypes of Oat were compared during. The coded genotype (6) of wheat obtained the highest seed yield of 2670.9 kg/ha while genotypes "H" of Oat produced the highest green fodder yield of 65.0 t/ha
- Seven (7) genotypes of Sorghum were compared. The coded genotype (C) obtained the highest Green Fodder Yield of 54.7 t/ha.
- Eight (8) genotypes of Millet were compared. The coded genotype (D) obtained the highest Green Fodder Yield of 83.3 t/ha.
- Six different entries of Guar have been tested for their fresh fodder yield. The genotypes "D" produced the highest green fodder yield of 23.1 t/ha.
- Ten (8) genotypes of Sesame were compared. The coded genotype (6) obtained the highest seed yield of 425.4 kg/ha.

BARDC, Quetta, Balochistan

- Two lentil yield trials were evaluated at BARDC comprising 30 genotypes. On the basis of better yield, lodging and disease resistance 10 genotypes were selected for further testing.
- Six barley yield trials and nurseries were tested against biotic and abiotic stresses at BARDC, Quetta. Out of 235 genotypes 100 were selected for further testing based on their performance under rainfed conditions of Balochistan.

- Evaluation and seed multiplication trials of different Wheat varieties in Jhall Magsi Jaffarabad and Sibi District of Balochistan under W-PEP were harvested.

- Wheat yield trials and nurseries comprising 1300 genotypes were evaluated against, cold, drought and disease. Out of which two hundred and fifty genotypes were selected on the basis of better yield and disease resistance for further testing.



Figure-27 Wheat trials at BARDC, Nursery, Quetta

- Trial was conducted on application of different treatments of organic and inorganic fertilizers. Data revealed that maximum (2860) grain yield kg/ha was recorded from treatment-2 (Farm Yard Manure Mulching) followed by treatments-4, 3 and 5 (Straw Mulching), (Leaf Mulching) and (Rice husk Mulching) which produced (1970), (1810) and (1720) grain yield kg/ha whereas the minimum (1610) grain yield kg/ha received from the treatment - 1 (Control).
- Effect of NP and Zinc fertilizers on grain yield of wheat variety Shalkot-14 was evaluated the data revealed that the maximum (2289kg/ha) grain yield was recorded from treatment-3 (NP + Zn foliar application at vegetative growth) followed by treatment-2 (Np + Zn sowing time application) which produced (2105) grain yield kg/ha whereas the minimum (1942) grain yield kg/ha was produced by treatment-4 (Np + Zn fertigation applied at ear head formation stage) followed by treatment-1 (Control) which produced 5216 grain yield kg/ha.
- Initial results of evaluation of Exotic Grape Varieties revealed that the Crimson has produced highest fruits per plant (2.24 kg/plant) followed by Autumn Royal (1.67 Kg/Plant), and production of Thompson was (1.44 Kg/plant), whereas lowest production was recorded in case of Red globe (1.85 Kg/plant). Plants were also observed for pest attacks and no pest and diseases attacks were recorded during the reported year.
- Influence of foliar application of different micro and macro nutrients on Olive fruit yield was studied in Quetta. The results showed that highest values by spraying a mixture of (N.P.K = 3:3:3, Iron 4.5 %, Zinc 3.5 %, Boron 0.05 % , Mg 0.05%) significantly increased the fruit diameter (1.51 cm), fruit weight (2.85 gm), fruit length (2.07 cm) pulp weight (1.91 gm), pit weight (0.98

gm) and pit length (1.64 cm) as compared to control treatment. It can be concluded that a mixture of (N.P.K = 3:3:3, Iron 4.5 %, Zinc 3.5%, Boron 0.05% , Mg 0.05%) should be applied during the first week of June, July, August and September for improving the fruit size and weight of olive.

- Nine varieties of European olive (Arbiquina, Arbosana, koroniki, Chatoi, Frantoio, Laccino, Kalamata, Megaron and Pandolino) imported in the country are being checked for their production in the different olive growing areas of the country, in this regard a five year study has been started to identify promising new varieties with emphasis on high yield and better quality fruits and to promote olive farming in Balochistan. During the report period, young olive plants have been observed for pest and diseases attack, in this regard only a minor attack of Woolly Aphid has been observed. Overall growth of varieties was satisfactory.
- 2100 Nursery plants of Olive developed at BARDC through POCEDPA project and distributed in olive farmer fields of the Province.



Figure-28 Newly planted olive cuttings at BARDC Nursery, Quetta

11.2 Range Management in Arid Areas

- 04 acres Agro-forestry plants are cultivated at AZRI Umerkot farm while plants of *Conocarpus* are also being introduced in desert area of Thar.
- To promote the cultivation of medicinal herbs in desert area of Bahawalpur innovative trials were initiated to find out best suited sowing technique with the special focus to enhance the productivity of medicinal herbs (*Nigella sativa* Kavangi, *Foeniculum vulgare* Saunnf, *Plantago major* Ispaghool, *Lallementiaroyleana* Tukhame-balango, *Trachyspermum ammi* Ajwain, *Linum usitatissimum* Alsi, *Eruca sativa* Taramira) on commercial scale.
- Planted/transplanted medicinal herbs (lemon grass, french lavender, mathi, alkanet, oregano, thyme, chamomile, sage, mulethi, mallow and yarrow (*Achellia* sp.) for seed/flower/leaf purpose depending upon their usage.

- Developed and managed nurseries of local (8000) and American (1000) and Morakash (400) Saro plants and also developed the nurseries of Quetta pine (500), broom (300), Fourwing salt bush (4000), coke (200) and Geranium (150) plants at Tomagh station, district Ziarat and BARDC Quetta.



Figure-29 Range grasses in Cholistan desert

- Two cumin varieties (local and ICARDA) were evaluated on different sowing dates. Local showed promising results in late sowing while ICARDA in early sowing.

12. Mountain Agriculture

12.1 Crop Sciences Research

Fruits

- Bud wood of 31 cultivars of cherry were collected from ARI Sawat and ARS Kalam and grafted on Mahlab rootstock. While an orchard consisting 12 cultivars of cherry are under study for improvement.
- Produced 7000 certified plants of deciduous fruits (apricot, peach, plum, persimmon, almond, fig and pomegranate) in MARC and issued to the farmers, government organizations, Pak army and NGOs on subsidized rates. Eight Thousand plants have been propagated through budding grafting and cuttings and will be issued next year.
- Apricot, peach and almond fruit seeds have been sown on 7 kanals for the root stock production and will be grafted next year.

Vegetables

- Among the nine Brinjal varieties received from SAARC Agriculture Center (SAC), the highest yield of 24500Kg/ha was produced by V8. While the lowest yield of 14200 Kg/ha was produced by V2 in this field study this year.
- Eleven (11) varieties of tomato seed received from SAC were evaluated at MARC, Juglote for the selection of high yielding varieties with the better agronomic characters among the varieties the highest yield of 28400, 26800

and 23400 kg/ha were recorded in V 4, V1 and V5 respectively. While the lowest yield of 15200 kg/ha was recorded in V10.

- The China Cabbage was cultivated as winter vegetable with the purpose of demonstration and awareness raising of the communities for the commercialization of same vegetables during sever winter in Gilgit-Baltistan (GB). The centre produced seeds about 300 kg of China cabbage.

Crops

- Two (2) separate sets of National Uniform Yield Trials each consist 40 advance wheat lines were planted in Juglote. The normal sowing was made on 25th November 2014 and late sowing was made on 25thDecember 2014 with one month interval at MARC, Juglote. Among the varieties planted in early dates, E-33 produced the highest grain and straw yield of 4100kg/ha and among late sowing varieties, highest grains yields of 2860kg/ha were recorded by E-6. While lowest yield of 1958.89 kg/ha was produced by E-29 in late planting.



Figure-30 Wheat testing trials at MARC

- A trial consisting winter wheat 36 entries in 2 replications were planted at MARC, Juglote. Among the entries the highest yield of entries E-33 (5766.67 kg/ha) was recorded while lowest was for E-13 (4000.00 kg/ha) selected for further evaluation and demonstration at various farm as well as at farmers field to introduce the high yielding winter wheat varieties to boost up the existing low yield productivity of wheat in Gilgit Baltistan.
- Thirteen (13) entries of Oats were tested under national uniform yield trials (NUFYT) at MARC, Juglote. Among the thirteen entries, highest fresh fodder yield of 34700 kg/ha, followed by entry F with a fresh fodder yield of 32700 kg/ha. While lowest fresh fodder yield of 24000 kg/ha was recorded in entry L in this field.
- Nine (9) varieties of Alfalfa were planted at MARC, Juglote. Among the varieties, highest fresh and dry yield was produced by Bunji (a local variety) followed by an Australian variety.

12.2 Fisheries and Livestock Research

- A trout rearing trial was carried out to examine the effect of different feeds on growth and cost rainbow trout yearlings. Four different diets consisting of fish meal, corn gluten, soybean meal, wheat flour, cotton seed meal, rice polish, soybean oil, DCP and vitamin premix were fed in four different percentages D1 (50, 11, 10, 16, 6, 4, 2 and 1%), D2 (40, 18, 15, 15, 4, 5, 2 and 1%), D3 (0, 25, 30, 18, 12, 8, 4, 2 and 1%), and control (35, 15, 15, 18, 10, 4, 2 and 1%). The result revealed that rainbow trout maintain good growth reared in high percentage of fish meal in D1 while fish meal free diets represents lower growth.
- In another feeding trial of dietary fish meal partially replacement by soybean was conducted to investigate the cost effective and alternative protein level diet for growth of trout (*Oncorhynchus mykiss*). Growth & Survival was maximum (350 gm, 94%) by fish fed Diet containing 25% lipid and 45% crude protein and the diet also have low cost (Rs. 145.50/kg) than those of other diets.
- Improved breed of Bulls (Frisian & Jersey), Buck (Betal) and Ram (Damani) were introduced in Juglote for the local breed improvement. Data of natural crossing of a Frisian bull have revealed that the milk production of improved breeds has been enhanced from 2-3 litres to 8-10 litres at one time twice in a day.