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**SOIL CHEMISTRY SECTION,
INSTITUTE OF SOIL CHEMISTRY AND ENVIRONMENTAL SCIENCES,
AARI, FSD**

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I. INTRODUCTION

Pakistani soils are generally deficient in nitrogen and phosphorus whereas the deficiency of potash and micronutrients especially zinc and boron has now established in many areas. The application of these nutrients and adoption of new technologies are essential for successful farming without damaging the environment and to combat with the hiking prices of fertilizer. Like fertilizer, plant protection measures are also important for increasing crop production. The use of pesticides has tremendously increased during the last decades therefore the availability of adulteration free pesticides is essential to reduce the quantity of pesticide use in the country and to save the cost on its import. To address these problems effectively, the Institute of Soil Chemistry and Environmental Sciences was established in 2009 by brining Soil Chemistry Section (established in 1907), Pesticide Quality Control Labs Faisalabad, Kala Shah Kaku, Multan and Bahawalpur (established in 1971, 1985, 1985 and 2005 respectively) and Pesticide Residue Research Lab Kala Shah Kaku (established in 2005) under one umbrella.

II. OBJECTIVES

The core objectives of the institute are as under:

- Use of chemical fertilizers and their effects on soil properties
- Use of macro and micronutrients for crops, vegetables and fruits
- Integrated use of chemical fertilizers and organic manures
- Studies on environmental pollution by agricultural inputs
- Safe use of domestic and industrial wastes for agriculture
- Organic farming and its prospective
- Pesticide quality control
- Pesticide residue research

III. STAFF POSITION

Sr. #	Designation	Posts	In position	Vacant
	Soil Chemistry Section Faisalabad			
1	Agricultural Chemist(Soils)	1	1	-
2	Associate Agricultural Chemist	1	-	1
3	Assistant Agricultural Chemist	1	1	-
4	Assistant Research Officer	10	10	-
	Total:	12	12	-

IV. BUDGET

A. Allocations for the year 2016-17 (Rs million)

Component	18-Agri.	36-Agri.	38-Agri.	42-Agri.	Total
Soil Chemistry Section, ISCES, AARI, Faisalabad.	41.748	2.343	-	-	44.091
Total:	**41.748**	**2.343**	**-**	**-**	**44.091**

B. Expenditure for the year 2017-18 (Rs million)

Component	18-Agri.	36-Agri.	38-Agri.	42-Agri.	Total
Soil Chemistry Section, ISCES, AARI, Faisalabad.	39.468	2.212	-	-	41.680
Total:	**39.468**	**2.212**	**-**	**-**	**41.680**

V. RESEARCH WORK

(SOIL CHEMISTRY SECTION)

A. ENVIRONMENTAL POLLUTION

1. REMOVAL OF HEAVYMETALS FROM CONTAMINATED WATER BY USING DIFFERENT LOW-COST AND AGRO-WASTE AS BIOSORBENTS

Heavy metals are posing severe threat to the environment. Disposal and safe removal of heavy metals from water is still an indispensable issue. This study was planned to assess the ability of different agro-waste materials to adsorb and remove heavy metals from waste water by using different plant raw materials and to provide economic solutions to this environmental problem. Rice, Wheat straw, Sugarcane bagasse, vegetables and fruit waste was used as bio-sorbents. Result (Table 1) showed the maximum adsorption capacity of sugarcane bagasse of Pb (0.29 mg/g), Cr (0.16 mg/g) and Ni (0.41 mg/g) followed by wheat straw that absorb Pb (0.25 mg/g) and Ni (0.37 mg/g) and least absorption of Cr (0.04 mg/g). Results also revealed that absorption of Cr by all bio-sorbents was negligible.

Table 1; Bio-sorbents and heavy metals adsorption capacity

Bio-sorbents	Pb	Cr	Ni
	Adsorption Capacity (mg/g)	Adsorption Capacity (mg/g)	Adsorption Capacity (mg/g)
Wheat straw	0.25	0.04	0.37
Sugarcane Straw	0.18	0.07	0.32
Sugarcane bagasse	0.29	0.16	0.41
Rice straw	0.21	0.13	0.33
Maize stalk	0.15	0.07	0.30
Banana Peel	0.21	0.11	0.35
Orange Peel	0.23	0.13	0.25

2. HEAVY METAL STATUS OF SOILS AND VEGETABLES GROWN AROUND THE CITIES

Sewage and industrial waste water is commonly used for growing vegetables near big cities. The water may contain heavy metals like Pb, Ni, Cd, Cr, Zn, Cu, Fe and Mn, and may contaminate the soil and vegetables. This study was therefore, planned to monitor the accumulation of these pollutants in soils and vegetables. The results of vegetable sample of district D.G Khan (Table 2.1) showed that out of 150 samples 8% vegetable samples were contaminated with Pb, 6% with Ni, 16% with Cd, 7% with Zn and 8% with Cu when compared with permissible limit.

Table 2.1; Heavy metal contents of vegetable samples from DG Khan District.

Metals (mg/kg)`	Range	Mean	Safe Limits	Samples above safe limit %
Pb	1.27-6.8	2.21	5	8
Ni	2.27-11.42	5.41	10	6
Cd	0.14-0.89	0.24	0.3	16
Zn	22.32-62.74	33.2	60	7
Cu	4.21-23.55	10.54	20	8
Total No of Samples = 150				***(WHO, 2007)**

Result of soil samples (Table 2.2) showed that mean Pb content were 1.21, Ni 0.42 and Cd 0.003 at 0-15 cm depth while at 15-30 cm depth, mean Pb contents were 0.96, Ni 0.31 and Cd contents were 0.001 mg/kgdepth in DG Khan District.

Table 2.2; Heavy metal contents of soil samples from DG Khan District

Metals (mg/kg)	Depth	Range	Mean	*Safe Limits	Samples above safe limit (%)
Pb	0- 15 cm	0.73- 1.98	1.21	13	Nil
	15-30 cm	0.64- 1.45	0.96	13	Nil
Ni	0- 15 cm	0.34- 0.54	0.42	8.1	Nil
	15-30 cm	0.23- 0.48	0.31	8.1	Nil
Cd	0- 15 cm	0.001- 0.04	0.003	0.31	Nil
	15-30 cm	ND-0.002	0.001	0.31	Nil
Total No of Samples = 300			***(Sultanpour, 1985; Maclean et al., 1987)**		

3. MONITORING OF HEAVY METALS IN MAIN SEWAGWE WATER DRAIN OF FAISALABAD

Since the chemical composition of sewage water is alarming due to mixing of industrial effluents containing heavy metals therefore, heavy metals such as lead (Pb) cadmium (Cd), Nickel (Ni) and chromium (Cr) is main problem for sewage water. Long term usage of wastewater for irrigation purposes in agricultural fields contributes to build up of elevated level of trace elements that are detrimental for soil and plant health. So, keeping in view the importance of this alarming issue, this survey study was planned to monitor the kinds of heavy metals present in sewage water of Faisalabad drains. Total 60 water samples were collected

Table 3.1; Heavy metals in main sewagwe water drain

Drains		Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Nickel (Ni)
		-----(µg/L)-----			
Satyana Road	**Range**	3- 25	7- 12	20-65	95-149
	Mean	10.3	9.11	33.8	125
Sargodha Road	**Range**	4-29	6-10	27.3-71	135-185
	Mean	14.0	7.0	45.8	159
Jhang Road	**Range**	2-18	6-9	21.6-63	110-171
	Mean	7.8	7	40.8	141
Safe Limits		**50.0 µg /L**	**50.0 µg /L**	**100 µg /L**	**1000 µg /L**

from three drains of Satyana Road, Sargodha Road and Jhang Road in month of June and September 2016. The samples were analyzed for Pb, Ni, Cd and Cr. Result showed that mean lead (Pb) contents in Satyana road drain were ranged 10.3 µg/ L, in Sargodha road drain 14.0 µg/ L and in Jhang road drain 7.8 µg/L. Mean Cadmium (Cd) contents were ranged from 9.1 µg/ L in Satyana road drain, 7.0 µg/ L in Sargodha road drain 6-9 µg/L in Jhang road drain. Mean Chromium (Cr) contents were 33.8 µg/L in Satyana road drain, 45.8 µg/ L in Sargodha road drain and 40.8 µg/L in Jhang road drain. Mean Nickel (Ni) contents were 125 µg/ L in Satyana road drain, 159µg/ L in Sargodha road drain and 141µg/L in Jhang road drain. The results of waste water analysis showed that heavy metal contents in all three drains of Faisalabad were within safe limits however, continuous use of this contaminated water lead to the buildup of heavy metals level in soil and ultimately in the vegetables grown on that soil with waste water.

4. ASSESSMENT OF HEAVY METALS IN GROUND WATER OF FAISALABAD

Water is the elixir of life and one of the most critical, scarce, precious and non-replenishable natural resource. Over exploitation of groundwater, natural and anthropogenic contamination is now a major problem for living beings. Water quality of major cities in Pakistan is deteriorating because of unchecked disposal of industrial wastewater and unscrupulous use of fertilizers, pesticides and insecticides. This study was planned to check the quality of

Table 4; Heavy metals (Cd, Ni) concentration in groundwater of Faisalabad Rukh Branch

Cd ($\mu g\ L^{-1}$)			Ni ($\mu g\ L^{-1}$)		
Range	**Mean**	**Detection**	**Range**	**Mean**	**Detection**
0.0-8.70	2.53	74 %	0.0-18.5	2.13	26 %
Safe Limit;	**Cd=10, Ni = 25 $\mu g\ L^{-1}$**			**(WWF, 2007 and WHO, 2007)**	

groundwater by quantifying the heavy metals content (Cd & Ni) from the district Faisalabad. Groundwater (42) samples were collected from Canal Road Faisalabad (Rakh Branch). The results of Ni & Cd contents in groundwater samples (Table 4) showed that 74% samples were above safe limit for Cadmium and for Nickel 26% samples were above permissible limit (WHO Standards).

5. DETERMINATION OF HEAVY METALS (CADMIUM AND ARSENIC) IN RICE GRAIN

Rice is a major dietary source of cadmium (Cd) and arsenic (As) for populations consuming rice as food. Excessive Cd and As accumulation in rice grain is of great concern worldwide. Therefore, this survey study was planned to assess cadmium (Cd) and arsenic (As) contents in rice grain samples taken from different markets of rice growing tract. The rice grain samples of both coarse and fine varieties were collected from the different markets of rice growing tract. The samples were analyzed for As and Cd. The results showed that mean Cd contents were 8.43, 5.42, 16.6, 10.2 and 9.82 ppb in Super Kernel, Pakistani Kernel, Indian Kynat, Duper Basmti, Basmati Dhagi and Sella sample respectively (Table5). While mean As contents were 5.32, 7.30, 8.32, 4.96 and 6.56 ppb found in Super Kernel, Pakistani Kernel, Indian Kynat, Duper Basmti, Basmati Dhagi and Sella sample respectively.

Table 5; Cadmium and Arsenic concentration in rice grain samples

Local Market Name	Cadmium (ppb)		Arsenic (ppb)	
	Range	**Average**	**Range**	**Average**
Super Kernel	5.63-19.6	8.43	3.10-10.3	5.32
Pakistani Kynat	4.93-20.4	5.42	4.16-12.2	7.30
Indian Kynat	8.63-32.6	16.6	4.96-18.5	8.32
Super Basmati	5.36-25.9	10.2	2.92-10.2	4.96
Basmati Dhagi	6.14-22.0	9.82	3.69- 9.63	6.56
Sella	5.84-25.6	6.86	3.21-9.38	4.98
Safe Limits:	**Cd = 0.30 ppm,**	**As = 2 ppm**		

6. NITRATE STATUS OF SOIL AND WATER IN AREAS WHERE HIGH DOSES OF NITROGEN ARE BEING APPLIED (SAHIWAL)

No data or information is available about nitrates pollution of surface water of uplands in Pakistan. So this survey was planned to assess nitrate concentration in surface water used for drinking purpose under the changing scenario of climate. A survey of Sahiwal district was carried out. Soil samples from 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths and water samples of hand pump and tube well were collected. Analysis results given in Table 6 showed that mean nitrate contents in water were 4.2 mg/L. However, in case of soil, mean nitrate

Table 6. Nitrate (mg/L) status of soil and water (Sahiwal)

Samples	Depth	Range	Average	SD
Soil	0-15 cm	10-25	18.0	3.2
	15-30 cm	11.0-23.2	16.8	3.8
	30-60 cm	6.0-17.5	13.4	4.2
	60-90 cm	3.0-13.4	9.0	3.7
	90-120 cm	3.50-10.0	6.9	2.9
Surface water		**2.6 to 7.6**	**4.20**	**1.42**
***WHO Safe limit of NO_3: 50 mg/L**				

contents in 0-15 cm depth were 18 mg/L, at 15-30 cm depth 16.8 mg/L, at 30-60 cm depth 13.4 mg/L, at 60-90 cm depth 9.0 mg/L and at 90-120 cm depth 6.9 mg/L. So the data reveled that NO_3 concentration is with in safe limit in ground water.

7. CADMIUM AND LEAD CONTENTS IN RICE GROWN ALONG THE HIGHWAYS

A survey was conducted to assess Pb and Cd contents in rice grain and straw grown across the highways especially in Sambrial, Gujrat, Lahore and Muridkay area. The 40 rice paddy and straw

Table 7; Concentration of lead and cadmium in soil and rice grown along with roads.

Particular	Pb content (ppm)		Cd content (ppm)		Rice Grain	
	Soil depth (cm)				Pb	Cd
	0-15	15-30	0-15	15-30	-ppb-	
Range	2.12-4.86	1.76-3.96	0.002-0.13	0.001-0.09	76 – 374	6.40 – 16.8
Mean	3.34	2.94	0.07	0.05	198	13.6
S.D	0.74	0.68	0.04	0.03	28	7.0
Safe Limits in Soil: Pb = 8.1 ppm, Cd = 0.30 ppm						
Plant Safe Limits : Pb = 5 ppm, Cd = 0.3 ppm						

samples were collected from the field adjacent to the highways. The samples were analyzed for Pb and Cd contents. The result (Table 7) showed that mean Pb contents in soil at 0-15 were 3.34 ppm and at 15-30 cm depth, 2.94 ppm. While mean Cd contents in soil at 0-15 cm depth 0.07 ppm and at 15-30 cm depth Cd contents were 0.05 ppm. While in rice grain, mean Pb and Cd contents were 198 and 13.6 ppb respectively.

8. HEAVY METAL STATUS OF VEGETABLES AND FODDERS IRRIGATED WITH WASTE WATER FROM MAIN DIVISIONAL DISTRICTS OF PUNJAB

Shortage of freshwater resources has forced the farmers to use of untreated wastewater for irrigation purposes in many countries of world especially developing countries. In Pakistan, 80% of inhabitants around big cities are using untreated wastewater for irrigation. Wastewater contains substantial amount of potentially toxic elements and heavy metals. The long-term use of industrial or municipal wastewater in irrigation may lead to accumulation of heavy metals in agricultural soil and plants those are injurious to the consumer's health. To monitor the accumulation of heavy metals in vegetables and fodder samples of different districts of Punjab where wastewater was commonly used for irrigation purposes, a survey was conducted. The results showed that substantial amounts of heavy metals were present in vegetables and fodders throughout the Punjab. Although the heavy metal concentration varies with vegetable and fodder types but chromium (Cr) was most abundant heavy metal (79%) in vegetable and fodder samples in all the districts of Punjab (Figure 8). After chromium, lead and cadmium were ranked at 2nd (57%) and 3rd (32%), respectively throughout the Punjab. While Ni was present in 8% vegetables and fodders samples.

A. Heavy metal status in Vegetables and Fodders:

Among districts, Gujranwala and Kasur were found most contaminated districts (91%) with chromium followed by Hazro (88%), Sahiwal (82%), Faisalabad (81%), Rawalpindi (77%), Sargodha (73%), Multan (72%), Lahore (69%) and Bahawalpur (68%) respectively (Figure 2).The data regarding lead (Pb) concentration revealed that Gujranwala was found the most contaminated (76%) followed by Multan (70%), Rawalpindi (69%), Lahore (68%), Bahawalpur (60%), Sargodha (58%), Kasur (48%), Sahiwal (47%),Faisalabad (37%) and Attock (Hazro) (20%).

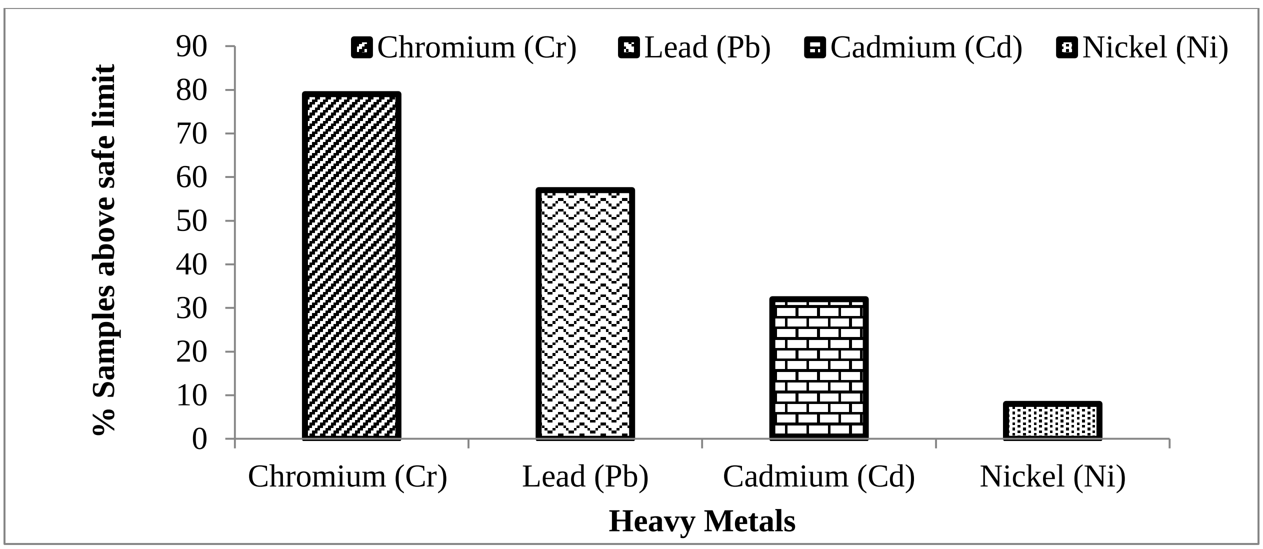

Figure 8.1; Heavy metal contamination in vegetable and fodder samples of Punjab

B. Districts wise Heavy metals status in Vegetables and Fodders

Gujranwala was most contaminated (69%) with cadmium followed by Rawalpindi, Faisalabad, Kasur, Sahiwal, Lahore, Multan, Attock (Hazro), Bahawalpur and Sargodha while Gujranwala was most contaminated with Ni followed by Faisalabad, Lahore, Bahawalpur, Rawalpindi, Sahiwal, Multan, Attock (Hazro), Sargodha and Kasur, respectively. Overall, heavy metals concentrations of Cr, Pb, Cd and Ni were most prevalent in vegetables and fodders produced by Gujranwala district.

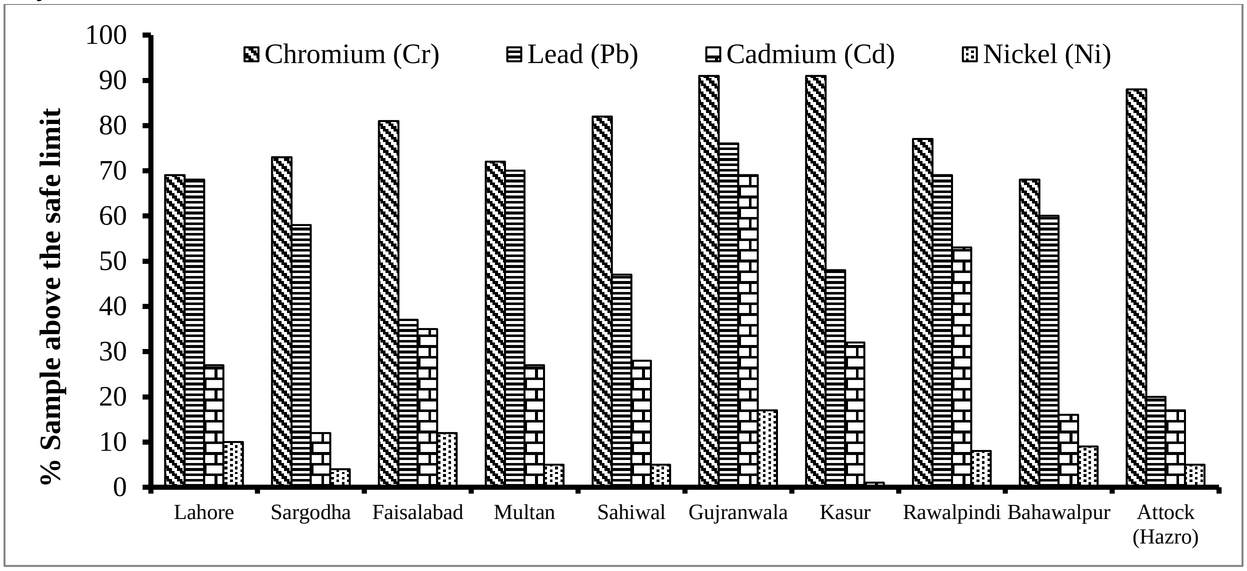

Figure 8.2; District wise level of contamination in vegetable/ fodder samples of Punjab

9. MICRONUTRIENTS AND HEAVY METALS STATUS IN VEGETABLES GROWN IN TUNNELS

Vegetables are the rich source of nutrients, carbohydrates, vitamins and proteins that are good for human health. The demand of basic dietary vegetables has increased manifold since 1947. To get high yield of vegetables to meet the population food requirements, farmers are compromising over the quality of products. Increase use of agricultural inputs (fertilizers, fungicides and pesticides) to enhance the quantities of vegetables grown in tunnels, a substantial quantity of heavy metals accumulated in vegetables as well as in soil due to that quality of vegetables grown in tunnels deteriorated. To assess the micronutrients and heavy status in tunnel grown vegetables in Faisalabad district this survey study was planned. Different vegetable samples were collected from different locations in Faisalabad district (Mamukanjan, Chak Jhumera, and AARI area). The results (Table 9.1) showed that substantial amounts of heavy metals (Cd and Pb) were present in all vegetable samples. 100% samples of spinach, cabbage, Hybrid Brinjal, bell pepper, 95% of cucumber, 86% of tomato, 50% of cauliflower and 33% of Fenugreek samples were above safe limits for Cadmium and Lead. On the other hand the micronutrients concentrations (Table 9.2) were below the required limits. Micronutrients contents in all vegetables were low but the overall trend indicated that Cadmium (Cd) and Lead (Pb) concentration was too much high in all vegetables samples while in case of zinc, iron, copper and manganese concentrations was found low.

Table 9.1; Cadmium and lead status of different vegetables grown in tunnels in district Faisalabad

Vegetables	Cadmium (Cd)			Lead (Pb)		
	Range	Mean	% sample above safe limit (0.3 ppm)	Range	Mean	%sample above safe limit (5 ppm)
Spinach	0.60-1.74	1.35±0.65	100	1.94-9.65	5.53±3.88	67
Cabbage	0.68-1.64	1.27±0.52	100	1.17-6.17	3.09±2.70	33
Cucumber	0.29-1.26	0.79±0.21	95	2.9- 23.5	7.45±4.28	75
Cauliflower	0.49- 0.78	0.15±0.9	50	8.1- 8.49	8.3± 0.28	100
Tomato	0.29- 1.38	0.65±0.36	86	0.545- 9.26	5.6± 3.02	29
Leaf of Bell Pepper	1.14- 1.5	1.31± 0.2	100	10.8- 15.4	12.5± 2.2	100
Bell Pepper	0.42- 1.05	0.68±0.16	100	4.63- 8.49	3.52± 3.38	40
Cucumber Leaf	0.7- 0.84	0.77±0.07	100	13.04- 16.2	14.1± 1.8	100
Green Chili	0.25- 1.32	0.62±0.39	83	3.46- 7.72	2.83± 3.69	17
Fenugreek	0.45- 0.5	0.02± 0.5	33	2.7- 5.78	4.5± 1.6	67
Coriander	0.47- 0.76	0.30±0.66	67	0.23- 5	1.8± 2.8	33
Hybrid Brinjal	0.54- 0.6	0.57±0.04	100	3.09- 7.72	5.4± 3.3	50

Table 9.2; Micronutrients (Zinc, Copper, Iron and Manganese) status of different vegetables grown in tunnels in district Faisalabad

Vegetable	Zinc	Copper	Iron	Manganese
	Mean± SD			
Spinach	26.2±20.8	11.36±3.15	9.78±1.86	89.4±11.8
Cabbage	16.3±3.9	9.28±0.21	0.32±0.51	17.09±2.90
Cucumber	48.5±42.9	8.42±8.28	2.25±2.0	16.9±7.77
Cauliflower	33.3±7.18	13±2.46	2.15±3.04	28.7±17.1
tomato	28.3±2.50	11.27±2.94	2.05±1.19	18.6±4.55
Bell Pepper	30.5±32.9	13.08±7.16	1.96±2.57	22.6-10.1
Green Chilies	22.4±9.71	10.95±4.31	0.67±0.83	14.2±4.74
Fenugreek	34.4±3.15	16.25±9.00	8.43±1.49	33.3±11.1
Coriander	22.4±4.46	8.91±2.14	12.81±2.33	57.3±4.77
Hybrid Brinjal	27.7±3.36	10.04±0.93	0.48±0.30	16.9±5.87

B. NUTRIENT USE EFFICIENCY

10. SURVEY OF SOIL SULPHUR (S) CONTENTS IN OILSEED GROWING AREAS

Severe deficiency of S has been reported in some oil seed crops. It may be due to low S in soil or no application of S containing fertilizer. To assess the S contents of soils of oilseed growing areas, this study was planned. Soil samples were collected from Mianwali, Multan and Lahore Districts. The result(Table 10) showed that soil of these districts is sufficient in soil sulphur.

Table 10; (%) Sulphur contents.

Districts	Samples	Range	Average	SD	Safe Limit (ppm)
Lahore	**Plant**	0.04-0.1	0.06	0.02	**0.15-0.4**
Multan		0.14-1.2	0.77	0.43	
Lahore	**Soil**	11.3-62	22.3	9.5	**5.0-20.0**
Multan		10.6-20.4	13.4	2.7	
Mianwali		10.9-86.3	28	33.3	

11. MAIZE ROOT GROWTH AND YIELD IN RESPONSE TO SOIL POROSITY CHANGES UNDER DIFFERENT IRRIGATION REGIMES

This study was conducted to assess the relationships among soil porosity, nutrient uptake, and root growth for irrigation water optimization. Three irrigation treatments with 3 replications were tested as follows;

Treatments:

T1: 8 Irrigations @ 3 inch (Control)

T2: 8 Irrigations @ 2 inch

T3: 8 Irrigations (1st 4 irrigations @ 2 inch and next 4 irrigations @ 3 inch)

The results (Table 11) showed that maximum maize grain yield (6.55 $^{t\ ha-1}$) was observed in T3 receiving Irrigations at different depths, followed by T1 where 8 Irrigations were applied @ 3 inch. Maximum root weigh (0.74 mg/cm^3) and highest soil porosity (0.51cm^3/cm^3) was also observed in T3.

Table 11; Maize root growth and yield in response to soil porosity changes under different irrigation regimes

Treatments	Grain yield (t ha^{-1})	Root weight density (mg/cm^3)	Soil porosity (cm^3/cm^3)
T1: 8 Irrigations @ 3 inch (Control)	6.24 a	0.59 b	0.44 b
T2: 8 Irrigations @ 2 inch	5.45 b	0.65 ab	0.51 a
T3: 1st 4 Irrigations @ 2 inch and next 4 Irrigations @ 3 inch	6.55 a	0.71 a	0.49 a
LSD	0.51	0.07	0.04
Soil Analysis:	**pH= 8.06, ECe = 1.36 dS/m, O.M = 0.69 %, P= 8.55 mg/kg, K= 190 mg/kg**		

12. EVALUATION OF BIO SOLIDS AS AN ORGANIC SOURCE FOR MAIZE CROP

The disposal of bio-solids is a potential threat to the environment, therefore, this study was planned to check the possible use of bio-solids as an alternative of farm manure as well as to monitor the heavy metal accumulation in the soil. Five treatments were used as;

TREATMENTS

T1: Control

T2: NPK

T3: NPK + 5 t ha^{-1} bio-solids

T4: ½ N from chemical fertilizer + ½ N from bio-solids

T5: NPK + 10 t ha^{-1} bio-solids

The results (Table 12) indicated that maximum grain yield of maize (6.66 t ha^{-1}) was obtained in T5 where NPK + 10 t ha^{-1} bio-solids were applied while minimum yield of maize (3.5 t ha^{-1}) was obtained in control. The Pb, Cd, Ni and Cr concentrations in maize grains were well below the prescribed safe limits of WHO. The soil chemical analysis showed that bio-solids did not pose any threat to the soil environment after application, but it may cause heavy metal accumulation with permanent use of bio-solids.

Table 12; Evaluation of bio solids as an organic source for maize crop

Treatments	**Grain yield (t ha^{-1})**
T1: Control	3.5 D
T2: RD NPK	5.56 C
T3: NPK + 5 $^{t\ ha-1}$ bio solids	6.37 AB
T4: Full PK + Half N from chemical fertilizer + Half N from bio solids	5.93 BC
T5: NPK + 10 $^{t\ ha-1}$ bio solids	6.66 A
LSD	0.65

13. TO STUDY THE NUTRIENT USE EFFICIENCY UNDER BURNT AND RETAINED CROP RESIDUE IN RICE WHEAT CROPPING SYSTEM

Burning of wheat and rice straw is a common practice in rice tract. This study was planned to evaluate the efficiency of NPK under burnt and retained crop residue situation. This study was conducted at Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute Faisalabad. The four different treatments were tested by using Split Plot design with three replications.

Treatments (sub plot):

T1: Control

T2: 50% of recommended dose of NPK

T3: 75% of recommended dose of NPK

T4: 100% of recommended dose of NPK

The three main plots were:

1: Traditional plot

2: Burnt plot

3: Rotavated plot

Recommended dose of NPK (Rice) = 150-90-60 kg ha^{-1}

Recommended dose of NPK (wheat) = 120-90-60 kg ha^{-1}

Rice Crop:

The rice crop was transplanted on 13-07-2016. The composite soil samples (0-15 and 15-30 cm depth) were taken before the start of the experiment and analyzed (Table 13.1).

Table 13.1; Pre-Sowing Soil Analysis (Pre-Sowing).

Depth (cm)	pH	ECe (dS/m)	Organic matter (%)	Av. P (mg/kg)	Av. K (mg/kg)	Texture
0-15	8.18	1.11	0.76	7.69	201	Sandy clay loam
15-30	8.10	1.01	0.62	7.62	170	

The soil analysis (Table 13.1) showed that the field was free from salinity and sodicity hazard, deficient in O.M., moderate in available P and sufficient in K. After taking the post-harvest soil samples from 0-15 and 15-30 cm, the straw of previous crop (wheat) was added after burning to the burnt plot and in the rotavated plots straw was incorporated. The treatments were applied at random in all the three sub plots in three replications. The rice was harvested on 08-11-2016. The data regarding paddy yield is presented in Table 13.2.

Table 13.2; Effect of different residue management practices and treatments on the paddy yield (t ha^{-1}).

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	3.8 GH	3.6 H	4.62 DE	4.0 D
T2: 50% of RD dose of NPK	4.40 EF	4.0 FGH	4.7 CDE	4.3 C
T3: 75% of RD dose of NPK	5.10 BCD	4.28 EFG	5.05 BCD	4.8 B
T4: 100% of RD dose of NPK	5.20 ABC	5.4 AB	5.6 A	5.4 A
Mean	4.6 B	4.3 B	5.01 A	
LSD of Group= 0.31, LSD of treatments= 0.29				

The results showed that paddy yield was maximum (5.6 t ha^{-1}) in the rotavated, sub plots where 100% RD fertilizer was applied. Comparing all the three main plots it was observed that rotavated plots gave maximum paddy yield (5.01 t ha^{-1}). The burnt and traditional plots gave similar yield (4.3 and 4.6 t ha^{-1} respectively). All the sub plots were significantly different from each other. Treatment in which 100% RD fertilizer was applied gave maximum yield (5.4 t ha^{-1}) while minimum yield was observed in the treatment where no fertilizer was added.

The soil samples were collected after harvesting of rice crop and were analyzed for OM, P and K content. The data for OM, P and K are presented in Table 13.3, 13.4 and 13.5, respectively. The results indicated that phosphorus and OM content of the soil samples in the burnt plots decreased comparing with the traditional and rotavated plots while potassium in burnt plot was more than traditional.

Table 13.3; Effect of different residue management practices and treatments on the OM (%) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.46 DE	0.40 E	0.63 C	0.52 C
T2: 50% of RD dose of NPK	0.54 D	0.47 DE	0.74 AB	0.56 C
T3: 75% of RD dose of NPK	0.64 C	0.53 D	0.77 A	0.65 B
T4: 100% of RD dose of NPK	0.66 BC	0.63 C	0.81 A	0.70 A
Mean	0.58 B	0.51 C	0.74 A	
LSD of plots=0.09, LSD of treatments= 0.15				

The analysis showed that rotavation of straw proved better for increasing soil fertility either alone or combined with 100% RD of NPK application resulted in high O.M while minimum O.M was found in control where residues were burnt.

Table 13.4; Effect of different residue management practices and treatments on the phosphorus (mg kg^{-1}) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	6.6 CD	6.2 D	6.2 D	6.6 CD
T2: 50% of RD dose of NPK	8.4 C	6.8 CD	11.0 B	8.4 C
T3: 75% of RD dose of NPK	12.6 AB	5.8 D	11.8 AB	12.6 AB
T4: 100% of RD dose of NPK	13.6 A	12.3 AB	13.6 A	13.6 A
Mean	10.3 A	7.8 B	10.6 A	10.3 A
LSD of Group=0.88 , LSD of treatments =1.15				

Table 13.5; Effect of different residue management practices and treatments on the potassium (mg kg^{-1}) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	224.0 D	224.0 D	210.6 D	219.5 C
T2: 50% of RD dose of NPK	277.3 BC	244.0 CD	270.6 BC	252.8 B
T3: 75% of RD dose of NPK	244.0 CD	244.0 CD	290.6 B	264.0 B
T4: 100% of RD dose of NPK	290.6 AB	290.6 AB	324.0 A	306.2 A
Mean	250.6 B	254.0 B	277.3 A	
LSD of Group=21.7, LSD of treatments= 20.8				

The paddy samples were collected after threshing and analyzed for N, P and K contents. The data regarding N, P and K are presented in Table 13.6, 13.7 and 13.8. The results indicated that all the treatments gave significantly different results. The treatment where 100% RD of NPK was applied gave highest N, P and K contents in Subplot.

Table 13.6; Effect of different residue management practices and treatments on the nitrogen (%) content of paddy

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.51F	0.72 DE	0.58 EF	0.60 C
T2: 50% of RD dose of NPK	0.77 CDE	0.91 BC	0.75 CDE	0.81 B
T3: 75% of RD dose of NPK	0.88 BCD	0.88 BC	0.86 CD	0.87 B
T4: 100% of RD dose of NPK	1.03 AB	1.19 A	1.02 AB	1.12 A
Mean	0.83 A	0.92 A	0.80 A	
LSD of Group=0.173 , LSD of treatments= 0.071				

Table 13.7; Effect of different residue management practices and treatments on the phosphorus (%) content of paddy

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.25 C	0.22 C	0.27 BC	0.25 B
T2: 50% of RD dose of NPK	0.28 BC	0.19 C	0.40 A	0.29 B
T3: 75% of RD dose of NPK	0.37 AB	0.39 A	0.43 A	0.40 A
T4: 100% of RD dose of NPK	0.43 A	0.41 A	0.46 A	0.43 A
Mean	0.33 AB	0.30 B	0.39 A	
LSD of Group=0.062 , LSD of treatments= 0.054				

Table 13.8; Effect of different residue management practices and treatments on the potassium (%) content of paddy

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.27 FG	0.27 G	0.30 EFG	0.28 C
T2: 50% of RD dose of NPK	0.32 DE	0.31 DEF	0.34 BCD	0.32 B
T3: 75% of RD dose of NPK	0.34 CDE	0.31 DEF	0.37 ABC	0.34 B
T4: 100% of RD dose of NPK	0.38 AB	0.32 DE	0.40 A	0.37 A
Mean	0.33 AB	0.30 B	0.35 A	
LSD of plots=0.020 , LSD of treatments= 0.027				

Wheat Crop:

In the same layout wheat was sown on 18-11-2016. All the treatments were applied according to the treatment plan. Crop was harvested on 26-04-2017 and yield data was recorded. The wheat yield data is presented in Table 13.9.

Table 13.9; Effect of different residue management practices and treatments on the yield of wheat (t ha^{-1})

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	1.32 F	1.56 F	3.10 DE	1.99 D
T2: 50% of RD dose of NPK	2.64 E	3.46 D	4.26 B	3.45 C
T3: 75% of RD dose of NPK	3.60 CD	4.26 B	4.23 B	4.03 B
T4: 100% of RD dose of NPK	4.40 AB	3.86 BC	4.83 A	4.36 A
Mean	2.99 B	3.29 B	4.10 A	
LSD of plots= 0.74, LSD of treatments= 0.21				

The results showed that wheat grain yield was maximum (4.1 t ha^{-1}) in rotavated plot while in

Table 13.10; Effect of different residue management practices and treatments on the potassium (%) content of wheat grain

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.36ABC	0.33 BCD	0.31 D	0.33 AB
T2: 50% of RD dose of NPK	0.31 D	0.33 BCD	0.33 BCD	0.32 B
T3: 75% of RD dose of NPK	0.37 A	0.32 CD	0.36 ABC	0.38 A
T4: 100% of RD dose of NPK	0.37 Ab	0.34 ABCD	0.33 BCD	0.35 A
Mean	0.35 A	0.33 A	0.33 A	
LSD of Group=0.34 , LSD of treatments= 0.24				

Table 13.11; Effect of different residue management practices and treatments on the phosphorus (%) content of wheat grain

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.28 CDE	0.26 EFG	0.23 FG	0.26 B
T2: 50% of RD dose of NPK	0.30 BCD	0.27 DEF	0.22 G	0.26 B
T3: 75% of RD dose of NPK	0.33 AB	0.31 BC	0.23 FG	0.29 A
T4: 100% of RD dose of NPK	0.35 A	0.31 BC	0.25 EFG	0.31 A
Mean	0.3183 A	0.29 B	0.23 C	
LSD of Group=0.027 , LSD of treatments= 0.0174				

burnt and traditional plots the yield was 3.29 and 2.99 t ha^{-1} respectively. All the treatments were significantly different and the treatment with NPK @ 75 and 100% gave better results. The wheat grain samples were collected after threshing and analyzed for N, P and K contents. The data regarding P and K is presented in Table 13.10 and 13.11. The results indicated that all the treatments gave significantly different results. The treatment where 100% RD was applied gave maximum P and K content in all three sub plots. The soil samples were collected after harvesting of wheat crop and were analyzed for OM, P and K content. The data for OM, P and K were presented in Table 13.12, 13.13 and 13.14, respectively. The results indicated that OM contents of soil samples differ significantly in main plots. Rotavated plot having full recommended fertilizer showed maximum organic matter % (0.90) while minimum (0.34%) was observed in traditional plot where no fertilizer was added. Available P was significantly higher (20.9 ppm) in traditional plot where 100 % fertilizer was applied. While available K contents were found maximum (260 ppm) in Rotavated plot where maximum fertilizer was applied.

Table 13.12; Effect of different residue management practices and treatments on the OM (%) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	0.34 G	0.63 E	0.66 CDE	0.54 D
T2: 50% of RD dose of NPK	0.66 DE	0.77 BC	0.80 B	0.74 B
T3: 75% of RD dose of NPK	0.52 F	0.63 E	0.80 B	0.65 C
T4: 100% of RD dose of NPK	0.74 BCD	0.82 AB	0.90 A	0.82 A
Mean	0.56 C	0.71 B	0.79 A	
LSD of Group=0.07, LSD of treatments= 0.06				

Table 13.13; Effect of different residue management practices and treatments on the phosphorus (mg kg^{-1}) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	9.81 G	11.5 EFG	10.2 FG	10.5 C
T2: 50% of RD dose of NPK	15.1 BCD	10.2 FG	12.6 DEFG	12.6 B
T3: 75% of RD dose of NPK	17.6 AB	12.7 DEFG	13.3 CDEF	14.6 B
T4: 100% of RD dose of NPK	20.9 A	16.4 BC	14.9 BCDE	17.4 A
Mean	15.8 A	12.7 B	12.8 B	
LSD of Group=1.86 , LSD of treatments=2.00				

Table 13.14; Effect of different residue management practices and treatments on the potassium (mg kg^{-1}) content of soil (0-15 cm)

Treatments	Traditional Plots	Burnt Plots	Rotavated Plots	Mean
T1: Control	180.0 D	246.6 AB	253.3 A	226.6 B
T2: 50% of RD dose of NPK	206.6 CD	273.3 A	266.6 A	248.8 A
T3: 75% of RD dose of NPK	206.6 CD	253.3 A	260.0 A	240.0 AB
T4: 100% of RD dose of NPK	220.0 BC	273.3 A	260.0 A	251.1 A
Mean	203.3 B	261.6 A	260.0 A	
LSD of Group=12.24, LSD of treatments= 19.25				

14. EFFECT OF FOLIAR PHOSPHOURS APPLICATION ON THE YIELD OF RICE/ WHEAT

The use of chemical fertilizer is indispensable for maximum crop production as population increased manifold to meet the food requirement chemical fertilizer applied. Phosphorus is an essential element classified as a macronutrient because relatively large quantity of Phosphorous required by the plant. Huge expense comes over the import of phosphatic fertilizers because phosphorous is immobile element in soil and huge quantity is not available to the plants due to fixation Phosphorous is indispensable for better root proliferation required by the plants and phosphorous availability is a permanent problem therefore, this project was planned to evaluate the response of foliar application to rice.

Treatments;

T1: Control

T2: RD of NPK

T3: RD of NK

T4: RD of NK + 75 % P (soil) + 2 spray (2% P)

T5: RD of NK + 50 % P (soil) + 3spray (2% P)

T6: RD of NK + 25 % P (soil) + 4 spray (2% P)

Prior to sowing, the composite soil samples from 0-15 and 15-30 cm depths were collected and analyzed. Pre-Sowing Soil Analysis showed that the field was free from salinity and sodicity hazards with low organic matter status, moderate in available P and adequate in available K (Table 14.1).

Table 14.1; Pre-Sowing Soil Analysis

Soil depth (cm)	pH_s	EC_e (dS m^{-1})	Av. P (ppm)	Av. K (ppm)	O.M (%)	Texture
0-15	8.0	1.42	7.5	180	0.67	Sandy clay loam

RICE:

Rice (Basmati super) was transplanted on 14th July, 2016 and harvested on 1st November, 2016. All the fertilizers were applied according to the plan. Potassium was applied before transplanting while nitrogen was broadcasted in three increments. The result related to the paddy yield and straw (Table 14.2) showed that maximum paddy and straw yield (3.40 and 4.99 $^{t\ ha-1}$ respectively) was obtained in T2 whereas minimum paddy and straw yield (1.26 and 2.63 t ha^{-1}) was observed in T1 (control).

Table 14.2; Effect of foliar application of P on rice paddy and straw yield on macronutrients (NPK) Concentration in paddy

Treatments	Paddy yield (t ha^{-1})	Straw yield (t ha^{-1})	N (%)	P (%)	K (%)
T1: Control	1.26 d	2.63 d	1.4 b	0.25	0.3
T2: RD of NPK	3.40 a	4.99 a	1.8 ab	0.32	0.39
T3: RD of NK	2.67 c	3.53 c	1.6 b	0.26	0.33
T4: RD of NK + 75 % P (soil) + 2 spray (2% P)	3.09 a	4.47 ab	2.2 a	0.34	0.41
T5: RD of NK + 50 % P (soil) + 3spray (2% P)	2.74 b	4.01 bc	1.9 ab	0.28	0.35
T6: RD of NK + 25 % P (soil) + 4 spray (2% P)	2.69 c	3.73 c	1.6 b	0.27	0.31
LSD	0.35	0.47	0.4	NS	NS

Paddy chemical analysis showed the maximum nitrogen contents in T4 (RD of NK+ 75% P (soil)+ 2 spray (2% P)) on the other hand phosphorous and potassium contents of paddy were non-significant among the all treatments in (Table 14.2). On the other hand, P and K were found maximum in RD of NK of + 75% p (soil) + 2 sprays (2% P) treatment that depicted maximum yield.

WHEAT:

Wheat variety (Galaxy 2013) was sown on 20-11-2016 and harvested on 15-04-2017. Fertilizers applied as per following treatment plan;

Treatments

T1: Control

T2: RD of NPK (120-90-60)

T3: RD of NK

T4: RD of NK + 75 % P (soil) + 2 spray (2% P) at tillering and booting stage

T5: RD of NK + 50 % P (soil) + 3spray (2% P) booting and grain forming stage

T6: RD of NK + 25 % P (soil) + 4 spray (2% P) at two leaves, tillering, booting and grain formation

T7: RD of NPK+ 4 water spray at two leaves, tillering, booting and grain formation stage.

The experiment was conducted in RCBD design with 3 replications at Soil Chemistry Section ISCES Faisalabad. The composite soil samples were collected before sowing of the crop and analyzed for basic soil characteristics. Wheat was sown on 20-11-2016 and recommended dose of NPK @ 120-90-60 kg/ha was applied.

Table 14.3; Pre-Sowing Soil Analysis

Soil depth	pH_s	EC_e	O.M	Av. P	Av. K
(Cm)	**-**	**(dSm^{-1})**	**(%)**	**(ppm)**	
0-15	8.2	1.57	0.61	8.2	195
15-30	8.0	1.59	0.59	7.9	180

The analysis of the field showed that the soil was free from salinity and sodicity, low in organic matter and phosphorus while potash was medium. Wheat was harvested on (18-04-2017) and grain and straw yield data were recorded. The data regarding grain yield (Table 14.4) showed that maximum grain yield of 4.32 was obtained in T2.

Table 14.4; Effect of Foliar phosphorus application on wheat grain and straw yield (t ha^{-1})

Treatments	Grain yield	Straw yield	N	P	K
	(t ha^{-1})		**(%)**	**(%)**	**(%)**
T1: Control	2.46 c	4.03 d	2.8 c	0.17 c	3.10 c
T2: RD of NPK (120-90-60)	4.32 a	7.55 ab	3.3 a	0.26 a	3.30 a
T3: RD Of NK	3.43 b	6.36 c	3.2 b	0.22 b	3.25 a
T4: RD of NK + 75 % P (soil) + 2 spray (2% P) at tillering and booting stage	4.16 a	7.65 a	3.2 b	0.26 a	3.28 a
T5: RD of NK + 50 % P (soil) + 3spray (2% P) booting and grain forming stage	4.06 ab	6.97 bc	3.3 a	0.24 ab	3.27 a
T6: RD of NK + 25 % P (soil) + 4 spray (2% P) at two leaves, tillering, booting and grain forming stage	3.55 b	7.06 b	3.1 a	0.24 ab	3.18 b
T7: RD of NPK+ 4 water spray at two leaves, tillering, booting and grain formation stage.	4.02 a	7.11 b	3.3 a	0.25 ab	3.25 a
LSD	0.55	0.69	0.07	0.03	0.06

Maximum grain yield (4.32 t ha^{-1}) was obtained in T2 while lowest (2.46 t ha^{-1}) was observed in T1 where no fertilized was added. Maximum straw yield (7.65 t ha^{-1}) was obtained in T4 while minimum (4.03 t ha^{-1}) was observed in control. The data regarding grain NPK contents (Table

14.4) showed that maximum nitrogen (3.3%) were found in T5 and T7 while maximum Phosphorus (0.26%) contents were found in T2 and T4.

15. NUTRIENT REMOVAL BY DIFFERENT CROPS

Crops are good source of carbohydrates, proteins, vitamins and minerals but very little information is available about their nutrient removal from soil. Therefore, this study was planned to determine the removal of nutrients i.e., N, P, K, Zn, Cu, Fe and Mn from soil by Okra and Maize crop. The Okra crop was grown at the farm area of Vegetable Research Institute and Maize crop was grown on the farm of Soil Chemistry Section, Institute of Soil and Environmental Sciences. Fertilizers were applied according to the recommendations. The yield data of the crops were recorded and plant samples were collected for N, P, K, Zn, Cu, Fe and Mn analysis. Nutrients removed by both crops are presented in Table 15.

Table 15: Dry matter yield and nutrients removed by okra and maize

Crop	Dry matter yield	N	P	K	Zn	Cu	Fe	Mn
	(kg/ha)				(g/ha)			
Okra	5951	118.1	13.2	154.1	764.6	24.4	43.7	181.2
Maize	1040	87.3	6.9	15.3	26.99	7.56	76.35	277.79

Results indicated (Table 15) that dry matter yield of 5951 kg/ha of Okra removed 118.1 kg N, 13.2 kg P, 154.1 kg K, 764.6 g Zn, 24.4 g Cu, 43.7 g Fe and 181.2 g Mn /ha. The results also revealed that dry maize of 1040 kg/ha removed 87.3 kg N, 6.9 kg P, 15.3 kg K, 26.99 g Zn, 7.56 g Cu, 76.35 g Fe and 277.79 g Mn/ha.

16. EVALUATION OF DIFFERENT MODELS OF FERTILIZER REQUIREMENT FOR YIELD PREDICTION OF MAIZE/WHEAT

This study was planned to verify various models for maize/wheat yield prediction. The experiment was conducted at Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Faisalabad.

Treatments

T1: Control (no fertilizer)
T2: Farmer practice
T3: Departmental recommendation (NPK :: 275-125-75 kg/ha)
T4: Fertilizer according to prediction model of UAF
T5: Fertilizer according to prediction model of FFC

Maize:

UAF model was based on soil organic matter, soil P and location, and FFC model was based on soil organic matter, soil P and K. Pre-Sowing Soil Analysis indicated no salinity and sodicity hazard however; it was moderate in soil P and sufficient in soil K contents. Soil organic matter contents were also deficient at research area (Table 16.1).

Table 16.1; Pre-Sowing Soil Analysis

Soil Depth (cm)	pH	ECe (dS/m)	OM (%)	Available P (mg/kg)	Available K (mg/kg)
0-15	8.12	1.96	0.63	8.42	200
15-30	8.12	1.81	0.62	8.16	195

The results (Table 16.2) indicated that maximum maize yield (6.10 t ha^{-1}) was obtained with departmental recommendation (T3) followed by UAF model (T4) while minimum maize yield was obtained in T1 (3.83 t ha^{-1}). On the other hand farmer practice T2 gave minimum yield

(4.78 t ha^{-1}) because of imbalance use of nitrogen and no application of phosphorous and potassium. Both UAF and FFC models showed 3% and 5% decrease respectively when compared with departmental recommendation.

Table 16.2; Evaluation of different models of fertilizer requirement for yield prediction of Maize

Treatments	**Yield (t ha^{-1})**
T1: Control (no fertilizer)	3.83 d
T2: Farmer practice	4.78 c
T3: Departmental recommendation (NPK :: 275-125-75 kg/ha)	6.10 a
T4: Fertilizer according to prediction model of UAF	5.91 ab
T5: Fertilizer according to prediction model of FFC	5.82 b
LSD	0.25

Wheat:

The trial was conducted at research area of Soil Chemistry section, ISCES, Faisalabad with following treatments using RCBD with three repeats. Wheat was sown on 18-11-2016 and harvested on 14-04-2017. All the agronomic practices were followed according to the recommendation.

Table 16.3; Pre-Sowing Soil Analysis

Soil Depth	**pH**	**ECe**	**OM**	**Available P**	**Available K**
(cm)	**-**	**(dS/m)**	**(%)**	**(mg/kg)**	
0-15 cm	8.1	1.76	0.75	6.1	161
15-30 cm	8.0	1.63	0.70	5.8	155

The results indicated (16.4) that maximum grain yield (4.01 t ha^{-1}) and maximum straw yield (7.26 $^{\text{t ha-1}}$) was obtained with departmental recommendation treatment and minimum grain yield was obtained in control (1.59 t ha^{-1}). The models UAF, FFC and farm practice treatment

Table 16.4; Evaluation of different models of fertilizer requirement for wheat yield

Treatments	**Grain Yield**	**Straw Yield**
	(t ha^{-1})	
T1: Control (no fertilizer)	1.59 c	2.70 d
T2: Farmer practice	2.84 b	5.21 c
T3: Departmental recommendation (NPK :: 275-125-75 kg/ha)	4.01 a	7.65 a
T4: Fertilizer according to prediction model of UAF	3.22 b	6.08 b
T5: Fertilizer according to prediction model of FFC	3.41 b	7.26 a
LSD	0.58	0.81

depicted non-significant results of wheat grain yield. In both models, there is over dosing of nitrogen, however, phosphorous application was less in UAF model and higher in FFC model compared with departmental recommendation treatment. This imbalanced nutrition in both models resulted in significantly lower yield compared with departmental recommendation that was found better in terms of higher yield and optimum balanced nutrition between nitrogen and phosphorous.

17. YIELD AND POTASSIUM UPTAKE OF MAIZE/ WHEAT USING DIFFERENT SOURCES OF NITROGEN

With the introduction of high yielding varieties in our cropping system, the removal of nutrients from the soils has increased many folds where as high nitrogen losses by ammonia volatilization are predictable when urea is used as the source of N which is mainly due to high pH of alkaline calcareous soils of Pakistan. In current senario ammonia and Oxides of nitrogen are potential source of climate change. Ammonium ions being monovalent reduce the potassium ions uptake in plants. To avoid nitrogen losses in the form of ammonia and to increase nitrogen use efficiency, a field study was initiated using calcium ammonium nitrate (CAN) and urea as sources of nitrogen along with half and full dozes of potassium in wheat. Nitrogen was spllited according to the treatments plan while phosphorus @ 125 kg/ha was applied in all plots except control.

Treatments

T1: Control (no fertilizer)
T2: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 0 kg/ha
T3: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 38 kg/ha
T4: RD of N (1st ½ as CAN + 2nd ½ as CAN) + K @ 38 kg/ha
T5: RD of N (1st ½ as urea + 2nd ½ as CAN) + K @ 38 kg/ha
T6: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 75 kg/ha
T7: RD of N (1st ½ as CAN + 2nd ½ as CAN) + K @ 75 kg/ha
T8: RD of N (1st ½ as urea + 2nd ½ as CAN) + @ 75 kg/ha

Maize:

The experiment was conducted in RCBD design with 3 replications at Soil Chemistry Section ISCES Faisalabad. The composite soil samples were collected before sowing of the crop and analyzed for basic soil characteristics. Maize crop was sown on 17-08-2016 and recommended dose of NPK @ 275-125-75 kg/ha was applied as per treatment plan. The analysis of the field (Table 17.1) which was used for the sowing of wheat crop showed that the soil was free from salinity and sodicity, low in organic matter and phosphorus while potash was medium. Maize was harvested on 23-11-2016 and grain and straw yield data was recorded. The data regarding grain yield (Table 17.2) showed Maximum grain yield of 6.80 t ha^{-1} was obtained in T8 where fist ½ nitrogen applied in the form of Urea and 2nd dose as CAN along with full rate of potassium was used while lowest straw yield 3.63 t ha^{-1} in control treatment.

Table 17.1; Pre-Sowing Soil Analysis

Soil depth	pH_s	EC_e	O.M	Av. P	Av. K	Texture
(Cm)		(dSm^{-1})	(%)	(ppm)		
0-15	7.82	1.35	0.68	7.90	170	Sandy Clay loam
15-30	7.96	1.43	0.51	4.89	142	

Table 17.2; Effect of different sources of nitrogen and varying rates of potassium on maize grain, N, P and K contents

Treatments	Grain yield	Concentration (%)			Uptake (kg/ha)	
	(t ha^{-1})	N	P	K	N	K
T1: Control (no fertilizer)	3.63 c	0.97 b	0.21b	0.36 b	79	49
T2: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 0 kg/ha	5.52 b	1.32 a	0.23 ab	0.40 ab	122	71
T3: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 38 kg/ha	6.15 ab	1.34 a	0.28 ab	0.42 ab	130	76
T4: RD of N (1st ½ as CAN + 2nd ½ as	6.34 ab	1.33 a	0.29ab	0.43 ab	133	**81**

CAN) + K @ 38 kg/ha						
T5: RD of N (1st ½ as urea + 2nd ½ as CAN) + K @ 38 kg/ha	6.46 ab	1.37 a	0.26 ab	0.42 ab	129	68
T6: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 75 kg/ha	6.57 a	1.32 a	0.26ab	0.42 ab	131	70
T7: RD of N (1st ½ as CAN + 2nd ½ as CAN) + K @ 75 kg/ha	6.62 a	1.40 a	0.24ab	0.47ab	137	75
T8: RD of N (1st ½ as urea + 2nd ½ as CAN) + @ 75 kg/ha	6.80 a	1.39 a	0.30 a	0.49a	**145**	**81**
LSD	0.97	0.11	0.09	0.11	NS	

The data regarding grain NPK contents (Table 17.2) showed that maximum nitrogen and potassium contents of 1.40 and 0.47 % respectively were found where half dose of nitrogen from CAN and 2nd half from CAN along with half dose of potassium was used, however these concentration were non-significant with all other treatments except control. Phosphorus concentration on the other hand was showed non-significant in all treatments. The results reveled that, highest nitrogen uptake (145 kg/ha) was noted in T8 where 1st half as urea and 2nd half CAN as source of nitrogen along with full doze of potassium was used. While the highest Potassium uptake (81 kg/ha) was found where half nitrogen from urea and half from CAN along with full doze of potassium was used.

Wheat:

The experiment was conducted in RCBD design with 3 replications at Soil Chemistry Section ISCES Faisalabad. The composite soil samples were collected before sowing of the crop and analyzed for basic soil characteristics. Wheat crop was sown on 25-11-2016 and was harvested on 24-04-2017. Fertilizers were applied as per treatment plan.

Table 17.3; Pre-Sowing Soil Analysis

Soil depth	**pH_s**	**EC_e**	**O.M**	**Av. P**	**Av. K**	**Texture**
(Cm)		**(dSm^{-1})**	**(%)**	**(ppm)**		
0-15	7.95	1.35	0.63	7.3	192	Sandy Clay loam
15-30	7.90	1.43	0.50	5.9	139	

The analysis of the field (Table 17.3) showed that the soil was free from salinity and sodicity, low in organic matter and phosphorus while potash contents were medium. Wheat was harvested on 23-04-2018 and grain and straw yield data was recorded.

The data regarding grain yield (Table 17.4) showed that maximum grain (4.1 t ha^{-1}) and straw yield (7.40 t ha^{-1}) was obtained in T7 where fist ½ nitrogen applied in the form of CAN and 2nd dose also as CAN along with full rate of potassium was used. While lowest straw yield 4.20 t ha^{-1} was observed in control treatment.

Table 17.4; Effect of different sources of nitrogen and varying rates of potassium on wheat grain and straw yield (t ha^{-1}), N, P and K concentration and N and K uptake

Treatments	Grain yield	Straw yield	Concentration (%)			Uptake (kg/ha)	
	(t ha^{-1})		N	P	K	N	K
T1: Control (no fertilizer)	2.0 d	4.20 d	1.9	0.17	0.45 b	48	74
T2: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 0 kg/ha	3.20 d	6.23 bc	2.19	0.19	0.52 ab	120	138
T3: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 38 kg/ha	3.60 bc	6.80 abc	2.24	0.18	0.53 ab	129	154
T4: RD of N (1st ½ as CAN + 2nd ½ as CAN) + K @ 38 kg/ha	4.o ab	6.96 abc	2.22	0.22	0.55 a	128	183
T5: RD of N (1st ½ as urea + 2nd ½ as CAN) + K @ 38 kg/ha	3.51 bc	6.20 c	2.28	0.19	0.57 a	125	149
T6: RD of N (1st ½ as urea + 2nd ½ as urea) + K @ 75 kg/ha	3.7 abc	6.73 abc	2.21	0.21	0.55a	135	153
T7: RD of N (1st ½ as CAN + 2nd ½ as CAN) + K @ 75 kg/ha	4.1a	7.40 a	2.17	0.19	0.54a	130	169
T8: RD of N (1st ½ as urea + 2nd ½ as CAN) + @ 75 kg/ha	3.8 ab	7.20 ab	2.26	0.20	0.56a	136	168
LSD	0.48	0.98	0.19	NS	0.21	NS	

The data regarding grain NPK contents (Table 17.4) showed that maximum nitrogen and potassium contents of 2.28 and 0.57 % respectively were found where half dose of nitrogen from urea and 2nd half from CAN along with half dose of potassium was used, however these concentration were non-significant with all other treatments except control. Phosphorus concentration on the other hand was non-significant in all treatments. Similarly, highest nitrogen uptake of 136 kg/ha was also noted where in T8. In case of Potassium uptake, the highest uptake of 183 kg/ha was found in T4 where half nitrogen from urea and half from CAN along with full doze of potassium was used.

C. NUTRIENT DYNAMICS IN SOIL

18. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF HYBRID MAIZE/WHEAT

Integrated Nutrient Management (INM) is to assimilate the use of natural as well as the man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. With increasing population the demand of food has also been increased. With the introduction of hybrid and high yielding varieties in our cropping system, the removal of nutrients from the soils has increased many folds. So this study was planned to assess the effects of integrated use of organic and inorganic fertilizers on fertilizer use efficiency, growth and yield of hybrid maize and wheat.

Treatments
T1: Control (no fertilizer)
T2: 100% RD of NPK
T3: 75% of RD of NPK + FYM @ 5 t ha^{-1}
T4: 75% of RD of NPK + 2% foliar spray of NPK (30 and 45 DAS)
T5: 75% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)
T6: 100% of RD of NPK + FYM @ 5 t ha^{-1}
T7: 100 % of RD of NPK + 2% foliar spray of NPK (30 and 45 DAS)
T8: 100% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)

To check soil fertility status Pre-Sowing Soil Analysis was conducted. Maize grain yield data was recorded and grain samples were analyzed for NPK.

Maize:

The experiment was conducted in RCBD design with 3 replications at Soil Chemistry Section ISCES Faisalabad. The composite soil samples were collected before sowing of the crop and analyzed for basic soil characteristics. Maize crop was sown on 20-08-2016 and recommended dose of NPK @ 275-125-75 kg/ha was applied as per treatment plan. The analysis of the field (Table 18.1) which was used for the sowing of wheat crop showed that the soil was free from salinity and sodicity, low in organic matter and phosphorus while potash was medium.

Table 18.1; Pre-Sowing Soil Analysis

Soil Depth (cm)	pH	ECe (dS/m)	OM (%)	Available P (mg/kg)	Available K (mg/kg)
0-15	7.12	1.76	0.68	8.82	210
15-30	7.92	1.41	0.59	7.16	195

Maize was harvested on 20-11-2016 and grain and straw yield data was recorded. The data regarding grain yield (Table 18.2) showed Maximum grain yield of 6.80 t ha^{-1} was obtained in T8 where fist ½ nitrogen applied in the form of Urea and 2nd dose as CAN along with full rate of potassium was used while lowest straw yield 3.63 t ha^{-1} in control treatment.

Table 18.2; Effect of integrated nutrient management on maize grain yield and soil health

Treatments	Grain yield	Grain Concentration		
		N	P	K
	(t ha^{-1})	(%)		
T1: Control (no fertilizer)	3.34 c	1.03 d	0.15 b	0.41
T2: 100% RD of NPK	6.41 ab	1.35 abc	0.21 a	0.48
T3: 75% of RD of NPK + FYM @ 5 t ha^{-1}	6.55 ab	1.34 abc	0.24 a	0.46
T4: 75% of RD of NPK + 2% foliar spray of NPK (30 and 45 DAS)	6.12 b	1.30 c	0.22 a	0.45
T5: 75% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)	6.67 ab	1.38 abc	0.20 a	0.51
T6: 100% of RD of NPK + FYM @ 5 t ha^{-1}	6.90 ab	1.32 bc	0.20 a	0.50
T7: 100 % of RD of NPK + 2% foliar spray of	6.74 ab	1.40 ab	0.25 a	0.48

NPK (30 and 45 DAS)				
T8: 100% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)	7.21 a	1.43 a	0.24 a	0.48
LSD	0.80	0.09	0.05	NS

The results revealed that maximum maize grain yields (7.21 t ha^{-1}) was obtained in T8 where 100% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS) followed by T6 100% RD + FYM @ 5 t ha^{-1}, 100% RD + 2% foliar spray of NPK and 75% of RD of NPK+ FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (Table 18.2). This best treatment also resulted in higher concentrations of N, P and K (1.43, 0.24 and 0.48% respectively) in maize grain compared to control (Table 18.2). The integrated use of organic, inorganic and foliar also improved the soil health.

Wheat Crop:

Wheat is a cereal grain, which is a worldwide staple food. Keeping in view the importance of this subject a field experiment was conducted in Rabi season 2016-17 at soil chemistry section, AARI, Faisalabad to assess the effects of INM under alkaline calcareous soils by using wheat as a test crop to meet the Quality and quantity demand of food for ever increasing population Before sowing of wheat crop the composite soil samples (0-15 and 15-30 cm depth) were taken and analyzed for soil physic chemical properties (Table 18.2)

Table 18.3; Effect of integrated nutrient management on grain and straw yield of Wheat and grain macronutrients contents

Treatments	**Grain Yield**		**Grain Concentration**		
	Grain	**Straw**	**N**	**P**	**K**
	(t ha^{-1})		**%**		
T1: Control (no fertilizer)	2.1 e	4.1 c	1.98 b	0.17 b	0.46 b
T2: 100% RD of NPK	3.2 d	6.3 ab	2.11 ab	0.24 a	0.54 a
T3: 75% of RD of NPK + FYM @ 5 t ha^{-1}	3.3 cd	6.1 ab	2.21 a	0.23 a	0.54 a
T4: 75% of RD of NPK + 2% foliar spray of NPK (30 and 45 DAS)	3.2 d	5.7 b	2.14 ab	0.21 ab	0.53 ab
T5: 75% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)	3.5 bcd	6.1 ab	2.19 a	0.20 ab	0.54 a
T6: 100% of RD of NPK + FYM @ 5 t ha^{-1}	3.9 ab	6.6 ab	2.22 a	0.22 ab	0.56 a
T7: 100 % of RD of NPK + 2% foliar spray of NPK (30 and 45 DAS)	3.8 abc	6.1 ab	2.19 a	0.22 ab	0.57 a
T8: 100% of RD of NPK + FYM @ 5 t ha^{-1} + 2% foliar spray of NPK (30 and 45 DAS)	4.1 a	6.7 a	2.26 a	0.25 a	0.55 a
LSD	0.53	1.0	0.17	0.05	0.07
Soil Analysis: pH= 8.0, ECe = 1.4 dS/m, O.M = 0.61 %, P= 7.6 mg/kg, K= 160 mg/kg					

The soil analysis showed that the field was free from salinity and sodicity hazard and moderate in fertility. The results (Table 18.3) showed that the highest wheat grain yield (4.1 t ha^{-1}) was observed in the T8 with the integration of 100% RD of NPK, FYM and foliar application of fertilizers. Integrated application of nutrients improved the nutrient contents in wheat grain. Highest contents of N, P and K were also observed in the T8 with the integration of organic, inorganic and foliar application. Integrated nutrient management not only improved the crop yield but also improved the nutrient contents of grain and soil health.

19. TEMPORAL AND DIFFERENTIAL APPLICATION OF NITROGEN AND POTASH ON GROWTH, YIELD AND QUALITY OF MAIZE/WHEAT

To get maximum production; the fertilizer requirement and time/method of application is important. This study was conducted at Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute Faisalabad to appraise the response of hybrid maize and wheat to nitrogen and potassium fertilizer management through soil and foliar application at different time.

Recommended doses of NPK (maize) = 275-125-75 kg/ha

Recommended doses of NPK (wheat) = 120-90-60 kg/ha

T1: Control (RD NPK)

T2: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + RD of K

T3: N + K (½ K at sowing + ½ at 30 DAS)

T4: N + K (½ K at sowing + 2 % Spray at 30 & 45 DAS)

T5: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + K (½ K at sowing + ½ at 30 DAS)

T6: N (½ at sowing +2%Spray at 30 & 45 DAS) + K (½ at sowing +2 % Spray at 30 & 45 DAS)

Maize Crop:

The maize crop was sown on 28-07-2016 and harvested on 12-11-16. The composite soil samples (0-15 and 15-30 cm depth) was taken before sowing and analyzed (Table 19.1)

Table 19.1 ; Pre-Sowing Soil Analysis

Depth (cm)	pH	ECe (dS/m)	Organic matter (%)	Av.P (mg/kg)	Av.K (mg/kg)	Texture
0-15	8.10	1.2	0.80	7.60	215	Sandy clay loam

The soil analysis showed that the field was free from salinity and sodicity hazard, inadequate in O.M, moderate in available P and sufficient in K. The data regarding yield, N, P and K concentration in maize grain is presented in Table 19.2. The obtained results showed that maximum grain N (1.33 %) was obtained in T3 and T6 where recommended N applied while K was applied half at sowing and half at 30 DAS as soil application and also where half N and K applied at sowing and 2 % spray at 30 & 45 DAS. The minimum N (1.27 %) was obtained in control (RD NPK-fertilizer). There is non-significant difference between the treatments in yield and K in maize grain.

Table 19.2; Effect of soil and foliar application of N & K on N, P and K in maize grain

Treatments	Yield	N	P	K	Crude protein	Crude Fiber
	(t ha^{-1})	(%)				
T1: Control (RD NPK)	3.66	1.27 ab	0.23 c	0.75	7.96	1.99
T2: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + RD of K	3.7	1.27 ab	0.55 b	0.75	7.91	1.96
T3: N + K (½ K at sowing + ½ at 30 DAS)	3.13	1.33 a	0.22 c	0.74	8.22	1.86
T4: N + K (½ K at sowing + 2 % Spray at 30 & 45 DAS)	3.21	1.30 ab	0.83 a	0.71	8.23	2.66
T5: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + K (½ K at sowing +	3.23	1.2 b	0.46 bc	0.74	7.99	2.01

½ at 30 DAS)						
T6: N (½ at sowing +2%Spray at 30 & 45 DAS) + K (½ at sowing +2 % Spray at 30 & 45 DAS)	2.87	1.33 a	0.57 ab	0.74	7.85	1.92
LSD	ns	0.11	0.26	ns	ns	ns

The data regarding quality parameters of maize grain is presented in Table 19.2. It showed that there is non-significant difference between treatments.

Wheat Crop:

The wheat crop was sown on 21-11-2016 and was harvested on 26-04-16. The composite soil samples (0-15 and 15-30 cm depth) was taken before sowing and analyzed (Table 19.3)

Table 19.3; Pre-Sowing Soil Analysis

Depth (cm)	pH	ECe (dS/m)	Organic matter (%)	Av.P (mg/kg)	Av.K (mg/kg)	Texture
0-15	7.8	1.6	0.78	6.8	151	Sandy clay loam

The soil analysis showed that the field was free from salinity and sodicity hazard, inadequate in O.M., moderate in available P and sufficient in K. The data regarding yield of wheat, P and K concentration in wheat grain is presented in Table 19.4. The obtained results showed that maximum grain yield (4.14 t ha^{-1}) was obtained in T4 where recommended N applied and K was applied half at sowing as soil application and 2 % spray at 30 & 45 days after sowing. The minimum grain yield (2.70 $^{t\ ha-1}$) was obtained in T2, where recommended dose of K applied at sowing while half N applied at sowing and 2 % spray of N applied at 30 and 45 DAS.

Table 19.4; Effect of soil and foliar application of N & K on wheat yield, P and K in grain

Treatments	Yield (t ha^{-1})	P (%)	K (%)
T1: Control (RD NPK)	3.68 ab	0.28 b	0.58
T2: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + RD of K	2.70 ab	0.33 ab	0.59 bc
T3: N + K (½ K at sowing + ½ at 30 DAS)	3.65 ab	0.32 ab	0.62 b
T4: N + K (½ K at sowing + 2 % Spray at 30 & 45 DAS)	4.14 a	0.32 ab	0.60 bc
T5: N (½ at sowing + 2 % Spray at 30 & 45 DAS) + K (½ K at sowing + ½ at 30 DAS)	3.63 ab	0.31 b	0.71 a
T6: N (½ at sowing +2%Spray at 30 & 45 DAS) + K (½ at sowing +2 % Spray at 30 & 45 DAS)	3.42 b	0.36 a	0.59 c
LSD		0.05	0.28

20. INFLUENCE OF SULPHUR ON THE OIL QUALITY OF OILSEED CROPS (MAIZE AND CANOLA)

Sulphur is secondary element, along with Mg and Ca, but it is sometimes called "the 4th major nutrient". Some crops can take up as much S as P. Sulfur has found to be an important limiting nutrient in crop production. This study was planned to find the effect of suplhur on the quality of oil seed crops.

Maize Crop:

The maize crop was sown on 19-08-2016 at research area of Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute Faisalabad and was harvested on 30-11-16. Soil of experimental site was analyzed for Sulphur contents. The field selected was deficient in Sulphur. Ammonium sulphate was applied to the soil as a source of sulphur. The composite soil samples (0-15 and 15-30 cm depth) were taken before the application of Sulphur and analyzed (Table20.1)

Table 20.1; Pre-Sowing Soil Analysis.

Depth (cm)	pH	ECe (dS/m)	Organic matter (%)	Av. P (mg/kg)	Av. K (mg/kg)	Av. S (mg/kg)	Texture
0-15	8.21	1.31	0.77	7.53	230	10	Sandy clay loam
15-30	7.09	1.12	0.71	7.24	200	20	

The soil analysis showed that the field was free from salinity and sodicity hazard, inadequate in OM, adequate in available phosphorus and potassium and deficient in sulphur.

Treatments;

T1: Control

T2: Rd NPK

T3: Rd NPK+ S (5 kg/ha)

T4: Rd NPK+ S (10kg/ha)

T5: Rd NPK+ S (15 kg/ha)

The data regarding yield of maize and oil contents is presented in table 20.2. The results showed that maximum grain yield (5.9 t ha^{-1}) was obtained where 15 kg S was applied along with recommended fertilizer. The minimum grain yield (4.2 t ha^{-1}) was obtained in control. Maximum oil contents (6.49 %) were also observed in T5 while minimum oil contents (5.19 %) were found in control.

Table 20.2: Effect of Sulphur on grain yield and oil contents

Treatment	Grain Yield (t ha^{-1})	Oil (grain) %
T1: Control	4.2 B	5.19 C
T2: Rd NPK	5.2 AB	5.37 BC
T3: Rd NPK+ S (5 kg/ha)	5.2 AB	5.57 BC
T4: Rd NPK+ S (10kg/ha)	5.3 A	5.84 B
T5: Rd NPK+ S (15 kg/ha)	5.9 A	6.49 A
LSD	1.01	0.547

Canola

Canola crop was sown on 31-10-16 research area of Soil Chemistry Section, ISCES, AARI, FSD and harvested on 04-04-2017. The composite soil samples (0-15 and 15-30 cm depth) were taken before sowing and analyzed (Table 20.3)

Table 20.3: Pre-Sowing Soil Analysis.

Depth (cm)	pH	ECe (dS/m)	Organic matter (%)	Av. P (mg/kg)	Av. K (mg/kg)	Av. S (mg/kg)	Texture
0-15	8.21	1.31	0.77	7.53	230	10	Sandy clay loam
15-30	7.9	1.12	0.71	7.24	200	12	

The soil analysis showed that the field was free from salinity and sodicity hazard, inadequate in O.M., adequate in available phosphorus and potassium and deficient in sulphur. The data regarding yield and oil contents of canola is presented in Table20.4. The results showed that maximum grain yield (1.83 $^{t\ ha-1}$) was obtained in the treatment where 15 kg/ha S was applied with recommended fertilizer. The minimum grain yield (1.40 $^{t\ ha-1}$) was obtained in control.

Table 20.4: Effect of Sulphur on grain yield, nitrogen and protein contents

Treatment	Grain Yield (t ha^{-1})	Oil (%)
Control	1.40 C	35.7 C
Rd NPK	1.43 C	36.8 BC
Rd NPK+ S (5 kg/ha)	1.80 A	37.5 B
Rd NPK+ S (10kg/ha)	1.69 B	40.0 A
Rd NPK+ S (15 kg/ha)	1.83 A	37.7 B
LSD	0.072	1.5541

The data reveled that maximum oil %age (40.0 %) was obtained in the treatment where 10 kg S was applied Sulphur was applied.

21. EFFECT OF PHOSPHORUS AND ZINC APPLICATION AT TWO DIFFERENT GROWTH STAGES ON PHYTIN CONTENTS IN RICE/WHEAT GRAIN

Phosphorus is an essential element classified as a macronutrient because relatively large amounts of P are required by plants. Most of the applied phosphates in wheat convert to phytic acid (Phytate) which is not digestible to humans or non-ruminant animals. This study was planned to determine the best combination and time of phosphorus and zinc application to reduce phytin contents and improve Zn in rice/wheat grain.

RICE:

Prior to sowing, the composite soil samples from 0-15 and 15-30 cm depth were collected and analyzed. Pre-Sowing Soil Analysis (Table 21.1) showed that the field was free from salinity and sodicity hazards with low organic matter status, moderate in available P and adequate in available K in table 21.1.

Table 21.1; Pre-Sowing Soil Analysis

Soil depth (cm)	pH_s	EC_e (dS m^{-1})	Av. P (ppm)	Av. K (ppm)	O.M (%)	Texture
0-15	8.1	1.31	7.6	196	0.78	Sandy clay loam
15-30	7.9	1.19	7.1	161	0.71	

Treatments

T_1: Control

T_2: P @ 60 kg/ha + Zn@ 5 kg/ha

T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha

T_4: P @ 120 kg/ha + Zn @ 5 kg/ha

T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha

T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha

T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha

The recommended rate of NPK for wheat was 150-90-60 kg/ha.

The data reveled (Table 21.2) indicated that the maximum paddy yield (4.43 t/ha) was obtained in the treatment where P @ 60 kg/ha+ Zn @ 10 kg/ha was applied which was significantly more effective than all other treatment combinations. It was also observed that Zn application at tillering and booting stage showed no effect on yield of rice.

Table 21.2; Rice paddy yield (t/ha) after the application of Zn at two different growth stages.

Treatments	Paddy Yield		
	Tillering	Booting	Mean
T_1: Control	3.73 C	4.60 AB	4.17
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	4.10 ABC	4.20 ABC	4.15
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	4.50 AB	4.70 A	4.60
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	3.80 BC	4.70 A	4.25
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	4.13 ABC	4.73 A	4.43
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	4.27 ABC	4.50 ABC	4.38
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	3.97 ABC	4.70 A	4.33
MEAN	4.07 A	4.59 A	NS
LSD TRT	0.65		
LSD GROUP	0.46		

Data presented in table 21.3 indicates that maximum P (0.57 ppm) was found inT4 treatment P @ 120 kg/ha+ Zn @ 10 kg/ha, while its mean value is non-significant in all the treatments for tillering and booting.

Table 21.3; Phosphorus in Rice paddy (ppm) after the application of Zn at two different growth stages

Treatments	Phosphorus in Rice paddy (ppm)		
	Tillering	Booting	Mean
T_1: Control	0.52 AB	0.52 AB	0.52
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	0.46 AB	0.55 A	0.51
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	0.49 AB	0.54 AB	0.52
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	0.41 B	0.57 A	0.49
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	0.47 AB	0.55 AB	0.51
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	0.49 AB	0.55 A	0.52
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	0.50 AB	0.55 AB	0.53
MEAN	0.4790 A	0.54 A	NS
LSD TRT	0.839		
LSD GROUP	0.1186		

Table 21.4 shows data regarding Zn concentration in rice paddy. Maximum concentration of Zn (13.6 ppm) is present in treatment with P @ 60 kg/ha+ Zn @ 10 kg/ha while control has minimum amount of Zn (4.3 ppm) in rice paddy.

Table 21.4; Zinc in Rice paddy (ppm) after the application of Zn at two different growth stages

Treatments	Zinc in Rice paddy (ppm)		
	Tillering	Booting	Mean
T_1: Control	3.8 F	4.8 F	4.3 E
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	8.9 E	9.1 E	8.9 D
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	12.3CD	9.7 E	11.0 C
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	15.0 A	12.2 CD	13.6 A
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	13.9AB	12.6 BC	13.2 A

T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	13.0 BC	11.4 CD	12.2 B
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	11.9 CD	11.3 D	11.6 BC
MEAN	11.2 A	10.1 A	
LSD TRT	0.8378		
LSD GROUP	1.184		

Table 21.5. shows the phytin content in rice paddy. Minimum Phytin content (1.06 %) was seen in P @ 60 kg/ha+ Zn @ 10 kg/ha, while control has Phytin content (1.21 %)

Table 21.5; Phytin content in Rice paddy (%) after the application of Zn at two different growth stages

Treatments	Phytin content in Rice paddy (%)		
	Tillering	**Booting**	**Mean**
T_1: Control	1.26 ABC	1.15 ABC	1.20 AB
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	1.41 A	1.21 ABC	1.31 AB
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	1.32 AB	1.46 A	1.39 AB
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	1.58 A	1.57 A	1.57 A
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	1.41 A	0.71 C	1.06 B
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	1.68 A	0.7 BC	1.21AB
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	1.57 A	1.4 A	1.49 A
MEAN	1.4624 A	1.1786 B	
LSD TRT	0.42		
LSD GROUP	0.62		
Safe limit of Phytic acid in rice	0.06-1.08		

WHEAT

Wheat crop was sown on 16.11.2016 and was harvested on 24.04.2016. Prior to sowing the composite soil samples from 0-15 cm depth, were collected and analyzed. Pre-Sowing Soil Analysis showed that the field was free from salinity and sodicity hazards with low organic matter status and was marginal in available P and adequate in available K in table 21.6.

Table 21.6; Pre-Sowing Soil Analysis

Soil depth (cm)	pH_s	EC_e (dS m^{-1})	Av. P (ppm)	Av. K (ppm)	O.M (%)	Texture
0-15	8.5	1.45	7.5	200	0.71	Sandy clay loam
15-30	8.2	1.15	7.1	186	0.67	

Treatments

T_1: Control

T_2: P @ 60 kg/ha + Zn@ 5 kg/ha

T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha

T_4: P @ 120 kg/ha + Zn @ 5 kg/ha

T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha

T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha

T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha

The recommended rate of NPK for wheat was 120-90-60 kg/ha.

The data presented in Table 21.7. indicated that the maximum grain yield (4.33 t/ha) was obtained in the treatment where P @ 120 kg/ha + Zn @ 5 kg/ha was applied which was significantly more effective than all other treatment combinations. It was also observed that Zn application at tillering and booting stage showed no effect on yield of wheat.

Table 21.7; Wheat yield (t/ha) after the application of Zn at two different growth stages

Treatments	Wheat Yield		
	Tillering	Booting	Mean
T_1: Control	3.75 EF	3.91 D	3.83 C
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	3.03 H	3.17 H	3.10 E
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	3.87 DE	4.13 BC	4.00 B
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	4.21 B	4.45 A	4.33 A
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	3.01 H	3.44 G	3.22 D
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	3.71 F	4.02 CD	3.86 C
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	3.99 CD	4.51 A	4.25 A
MEAN	3.65 B	3.95 A	
LSD TRT	0.0985		
LSD GROUP	0.1393		

The data presented in Table 21.8 indicated that the maximum phosphorus (0.29 ppm) was obtained in the treatment where P @ 60 kg/ha + Zn@ 5 kg/ha was applied which was significantly more effective than all other treatment combinations. It was also observed that Zn application at tillering and booting stage showed no effect on P concentration in wheat.

Table 21.8; Phosphorus (ppm) in Wheat after the application of Zn at two different growth Stages

Treatments	Phosphorus (ppm) in Wheat		
	Tillering	Booting	Mean
T_1: Control	0.20 AB	0.19 B	0.19 B
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	0.25 AB	0.35 A	0.29 A
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	0.25 AB	0.27 AB	0.26 AB
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	0.26 AB	0.25 AB	0.25 AB
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	0.27 AB	0.29 AB	0.28 A
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	0.29AB	0.27 AB	0.28 A
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	0.23 AB	0.22 AB	0.22 AB
MEAN	0.26 A	0.26 A	
LSD TRT	0.0821		
LSD GROUP	0.1343		

Table 21.9 shows data regarding Zn concentration in wheat. Maximum conc. of Zn (29.77 ppm) is present in treatment with P @ 90 kg/ha+ Zn @ 10 kg/ha while control has minimum amount of Zn (24.35 ppm) in rice paddy. Mean values of Zinc at tillering and booting showed variation.

Table 21.9; Zinc (ppm) in Wheat after the application of Zn at two different growth stages

Treatments	Zinc (ppm) in Wheat		
	Tillering	**Booting**	**Mean**
T_1: Control	23.50 H	25.20 F	24.35 F
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	27.13 D	29.43 B	28.28 C
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	27.17 D	28.47 C	27.82 D
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	24.57 G	26.40 E	25.48 E
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	28.67 C	30.33 A	29.50 A
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	28.77 C	30.77 A	29.77 A
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	28.40 C	29.37 B	28.88 B
MEAN	26.88 B	28.57 A	
LSD TRT	0.375		
LSD GROUP	0.5304		

Table 21.10 shows the phytin content in wheat. Minimum Phytin content (0.28 %) was seen in P control, while rest of all treatments has higher phytin content trend. Mean values of Phytin content at tillering and booting showed variation.

Table 21.10; Phytin content (%) in wheat after the application of Zn at two different growth Stages

Treatments	Phytin content (%) in wheat		
	Tillering	**Booting**	**Mean**
T_1: Control	0.27 E	0.29 DE	0.28 D
T_2: P @ 60 kg/ha + Zn@ 5 kg/ha	0.31 CD	0.34 ABC	0.32 BC
T_3: P @ 90 kg/ha+ Zn @ 5 kg/ha	0.34 CD	0.33 ABC	0.34 AB
T_4: P @ 120 kg/ha + Zn @ 5 kg/ha	0.36 A	0.31 CD	0.34 ABC
T_5: P @ 60 kg/ha+ Zn @ 10 kg/ha	0.29 DE	0.33 ABC	0.31 C
T_6: P @ 90 kg/ha+ Zn @ 10 kg/ha	0.32 BCD	0.37 A	0.34 AB
T_7: P @ 120 kg/ha+ Zn @ 10 kg/ha	0.35 AB	0.36 A	0.36 A
MEAN	0.32 B	0.33 A	
LSD TRT	0.0245		
LSD GROUP	0.0346		
Safe Limit of Phytic acid in wheat	0.39-1.35		

D. FERTILIZERS AND SOIL HEALTH

22. EFFECT OF GREEN MANURING ON SOIL PHYSICO-CHEMICAL PROPERTIES UNDER RICE-BERSEEM CROPPING PATTERN

Green manuring is recognized as additive of organic matter thereby improving aeration and water holding capacity of soil. It also enriches soil with organic matter and nitrogen hence improving crop production. Barseem (Trifolium elexandrium) is such a green manuring crop which also serves as a fodder. So, incorporation of barseem as Rabi crop in our cropping patterns may improve physico-chemical properties of soil. Therefore, this study was planned to assess the effect of green manuring on soil physico-chemical properties under rice-barseem cropping pattern. For this purpose, following five treatments were tested in rice and barseem:

Treatments

T1: Control

T2: Recommended NPK

T3: Recommended NPK + green manuring

T4: 75 % of recommended NPK + green manuring

T5: 50 % of recommended NPK + green manuring

Treatments were replicated three times in Randomized Complete Block Design. Prior to experimentation, composite soil samples were analyzed for various physical and chemical characteristics as given in Table 22.1.

Table 22.1; Pre-Sowing Soil Analysis

Depth (cm)	Texture	Bulk density ($g\ cm^{-3}$)	Porosity (%)
0-15	Sandy clay loam	1.66	42.4
15-30	Sandy clay loam	1.59	44.2

Pre-Sowing Soil Analysis (Table 22.2) indicated that experimental site had sandy clay loam texture and free of salinity and sodicity problem, deficient in available phosphorous and organic matter while sufficient in available potassium.

Table 22.2; Chemical Characteristics of Experimental Soil

Depth	pH	ECe	CEC	Organic carbon	Organic matter	Available P ($mg\ kg^{-1}$)	Available K ($mg\ kg^{-1}$)
(cm)		($dS\ m^{-1}$)	$Cmol_c\ kg^{-1}$	($g\ kg^{-1}$)	(%)	($mg\ kg^{-1}$)	
0-15	7.67	1.43	5.50	0.8	0.67	5.70	156.3
15-30	7.62	2.42	5.32	0.8	0.55	5.00	152.1

Rice:

Rice (Basmati super) was transplanted on 14th July, 2016 and harvested on 31th October, 2017. All the fertilizers were applied according to the plan. All phosphorous and potassium was` applied before transplanting while nitrogen was broadcasted in two splits. Crop was irrigated as per requirement to ensure water stand. Pendimethalin, Cypermetharin, and Furadon were applied to control pests. The results given in Table 22.3 indicated that the maximum rice paddy yield (3.4 t ha^{-1}) was obtained in treatment where 100% of the recommended dose of fertilizer NPK i.e. 150-90-60 Kg $ha^{-1}$was applied along with green manuring (T_4), while minimum paddy yield (2.2 t ha^{-1}) was obtained in control (T_1).

The results also showed maximum rice straw yield (9.3 t ha^{-1}) was obtained in treatment where

Table 22.3; Effect of Green Manuring on Rice Paddy and Straw yield

Treatments	Paddy Yield	Straw Yield
	($t\ ha^{-1}$)	
T1: Control	2.2 c	6.3 b
T2: Recommended NPK	2.9 b	8.4 a
T3: Recommended NPK + green manuring	3.4 a	9.3 a
T4: 75 % of recommended NPK + green manuring	3.3 a	8.8 a
T5: 50 % of recommended NPK + green manuring	2.6 b	8.0 b
LSD	0.31	1.55

100% of the recommended dose of NPK was applied along with green manuring (T_3), while minimum straw yield (6.3 t ha^{-1}) was obtained in control (T_1). Treatment with 75% of recommended NPK + green manuring (T_4) followed T_3 100% of recommended NPK + green manuring in producing paddy and straw yield i.e. 3.3 and 3.4 t ha^{-1} and 8.8 and 9.3 t ha^{-1} respectively.

Barseem:

Post-harvest soil analysis was performed after rice crop before sowing of barseem. The results revealed that soil was deficient in organic matter and phosphorous while potassium contents were sufficient (Table 22.4).

Barseem was sown on November 07, 2016. After taking four cuttings, the barseem on attaining full vegetative growth was incorporated into the soil according to the treatment plan on May 6, 2017. All the fertilizers were applied according to the plan. All the nitrogen and phosphorous was applied at the time of seed bed preparation in the respective plots. The results shown in Table 4 indicated that maximum barseem biomass (96.2 t ha^{-1}) was obtained in T_3 while minimum barseem biomass (68.5 t ha^{-1}) was obtained in control (T_1).

Table 22.4; Soil analysis before sowing of Barseem from 0-15 cm depth.

Treatments	O.M	P	K	Zn	Fe	Mn	Cu
	(%)	(ppm)					
T1: Control	0.63	5.96	141	1.05	1.99	7.8	0.33
T2: Recommended NPK	0.68	6.28	153	1.24	2.15	7.2	0.5
T3: Recommended NPK + green manuring	0.88	8.12	192	1.7	3.75	8.8	0.55
T4: 75 % of recommended NPK + green manuring	0.79	7.86	188	1.45	3.81	7.7	0.58
T5: 50 % of recommended NPK + green manuring	0.75	7.27	181	1.32	3.1	7.9	0.53

Table 22.5; Effect of Green Manuring on Barseem yield.

Treatments	Berseem Yield (t ha^{-1})
T1: Control	68.5 c
T2: Recommended NPK	85.8 b
T3: Recommended NPK + green manuring	96.2 a
T4: 75 % of recommended NPK + green manuring	92.9 a
T5: 50 % of recommended NPK + green manuring	86.1 b
LSD	9.9

23. LONG-TERM EFFECT OF FERTILIZER USE ON SOIL PROPERTIES

The use of chemical fertilizer is indispensable for maximum crop production but it was perceived by the farmers that continuous use of chemical fertilizers would deteriorate the soil health and ultimately reduce the crop yields. This study was started in 1978 on a permanent lay out to assess the long-term effect of fertilizer use on the physical and chemical properties of the soil in intensive cropping system. During 2015-16 maize fodder-wheat crop rotation was followed. This long term study is being conducted at research area of Soil Chemistry Section, ISCES, Faisalabad.

Maize Fodder:

Crop was sown on 01-08-2016 and harvested on 25-09-2016 before sowing; soil samples were collected from 0-15 cm depth for analysis. NPK Fertilizers were applied @ 136-57-57 kg/ha according to the plan. FYM (calculated on nitrogen basis), was applied in the plots according to the permanent layout. Maize fodder yield and pre-sowing soil analysis is given in Table 23.1.

Table 23.1: Maize fodder yield and Pre-sowing soil analysis (0-15 cm)

Sr#	Treatments	Yield	pHs	ECe	O.M	Av. P	Ex. K
		(t ha^{-1})		(dS m^{-1})	(%)	(ppm)	
1.	Control	23.0	8.12	1.98	0.43	7.9	180
2.	N	40.0	8.08	2.01	0.56	8.2	200
3.	NP	57.0	8.11	2.15	0.65	13.8	220
4.	NPK	62.0	8.00	1.99	0.72	14.4	240
5.	All N from FYM	39.0	8.10	2.03	1.06	15.7	260
6.	½ N from urea + ½ N from FYM	48.0	8.24	2.08	0.92	12.1	240
7.	½ NP	50.0	8.16	1.94	0.69	12.9	220

The pre-sowing soil analysis showed that addition of chemical fertilizer had no adverse effect rather it improved the soil health and fertility status of soil. Fodder yield data showed that use of chemical fertilizer NPK proved better to get higher yields (62 t ha^{-1}). Maize fodder yield was in the order of NPK >NP>1/2NP>½ N from urea + ½ N from FYM >N > FYM>control.

Wheat Crop:

After harvesting of maize crop, wheat variety Punjab-2011 was sown in same permanent layout on 12-11-2016. The chemical fertilizers and FYM were applied according to the plan. All agronomic practices were followed according to the recommendations. The recommended dose of NPK 120-90-60 kg/ha was applied. The crop was harvested on 21-04-2016. Wheat grain yield data and pre sowing soil analysis is presented in the following Table 23.2.

Table 23.2: Pre-sowing soil analysis (0-15 cm) and wheat grain yield.

Sr#	Treatments	Wheat grain Yield (t ha^{-1})	pHs	ECe (dS m^{-1})	O.M (%)	Av. P (ppm)	Ex. K (ppm)
1.	Control	0.93	8.0	1.87	0.50	6.5	160
2.	N	1.97	7.9	2.0	0.66	7.1	260
3.	NP	3.13	7.9	1.98	0.69	7.1	190
4.	NPK	3.33	7.8	1.90	0.80	6.8	200
5.	All N from FYM	1.08	7.8	2.0	0.92	6.8	190
6.	½ N from urea + ½ N from FYM	3.13	7.8	2.0	1.01	6.8	200
7.	½ NP	1.79	8.0	2.0	0.72	7.2	180

The pre sowing soil analysis indicated that plots receiving various nutrients alone or in combination with each other or even application of FYM alone or in combination with urea showed an increased fertility status as compared with control. P status decreased in all treatments from maize fodder to wheat crop. Grain yield data of wheat was taken and the order of decrease in grain yield was NPK>NP and ½ N from urea ½ N from FYM. However, maximum wheat grain yield was found in treatment where NPK was applied.

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