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Effect of Industrial Effluents on Mineral Nutrition of Rice and Soil Health

S.M. Mehdi, G. Abbas, M. Sarfraz, [1]S.T. Abbas and G. Hassan
Soil Salinity Research Institute, Pindi Bhattian, Pakistan
[1]Crop Sciences Research Institute,
National Agricultural Research Council, Islamabad, Pakistan

Abstract: A research study was carried out to see the effect of industrial effluents on mineral nutrition of rice and soil health. For this purpose a site was selected near the bank of nullah Dek at "Shakirabad" in the Distt. Sheikhupura. The water of this nullah is contaminated by industrial effluents carrying different mineral metals. This water was applied to rice crop growing at the site. Three fine rice varieties namely Super Basmati, Shaheen Basmati and Basmati 2000 were transplanted which were grown up to maturity. The system of layout was Randomized Complete Block Design with four replications. Paddy and straw yields data were recorded. Water samples were collected before transplanting of rice and during rice season after every fifteen days interval from 3rd August to first of November which were analysed for different mineral metals contents. After the harvest of rice crop, soil, paddy and straw samples were analysed for different mineral metals. The analysis of Nullah Dek water showed that its total salts concentration was higher than the safe limit (>1 EC d Sm^{-1}). Even SAR of the nullah water is high but it has no problem of high RSC. Among mineral metals, Zn, Mn, Cd and Sr are present but these are within safe limit except Sr. Soil analysis before transplanting of rice showed that all these samples were free of salinity/sodicity hazards. Among mineral metals, the zinc ranged between deficiency limit (<0.5 mg kg^{-1}) to adequate amount (>1.0 mg kg^{-1}). Copper, Mn and Fe were present in adequate amounts at the sampled site. Strontium, Nickel and cadmium were within safe limits. After the harvest of rice crop there was a slight decrease in pH_s, EC_e and SAR at both the depths of experimental site. The decrease in pH_s was noted < 1 unit. Like pH_s and EC_e, Sodium adsorption ratio also decreased. The contents of all mineral metals i.e. Zn, Cu, Fe, Mn, Pb, Ni, Cd and Sr after harvest of rice crop were further increased. The contents of these metals were higher in upper layer than the lower horizon. The increase in Zinc contents was up to< 0.5 mg kg^{-1} soil, the increase in Copper contents was < 0.1 mg kg^{-1} soil, Iron and manganese were increased up to 1 mg kg^{-1} soil, Cadmium, Nickel and Strontium were increased < 0.1 mg kg^{-1} soil. Lead was determined after harvest of rice crop only which ranged from 2.68 to 3.33 mg kg^{-1}. There was maximum paddy and straw yield of Shaheen Basmati followed by basmati 2000 and least of super basmati. The chemical analysis of paddy and straw samples indicated that there was a sufficient accumulation of all the heavy metals in both the plant parts. The accumulation of zinc (1.60-1.68 mg kg^{-1}), copper (0.93-1.13 mg kg^{-1}), iron (3.15- 3.50 mg kg^{-1}), manganese (1.83- 1.88 mg kg^{-1}) and lead (2.89-2.95 mg kg^{-1}) were noted in paddy of different varieties. Cadmium (0.125- 0.175 mg kg^{-1}) and nickel was found in minute quantities (0.073- 0.093 mg kg^{-1}). Strontium was noted in higher quantities at the site of the study. Its concentration ranged between 26.74 to 30.73 mg kg^{-}. Rice straw was also analysed for heavy metal contents because it is used as fodder for animals in this area. It is indicated from the results that the rice straw also contains sufficient quantities of different metals. It contains zinc (27.75-30.0 mg kg^{-1}), copper (18.0 - 19.50 mg kg^{-1}), iron (274- 279 mg kg^{-1}), manganese (2.33- 2.43 mg kg^{-}1), lead (1.23-1.24 mg kg^{-}1). Cadmium (0.20- 0.35 mg kg^{-}1) and nickel was found in minute quantities (1.162 to 1.195 mg kg^{-1}. Strontium was noted in higher quantities. Its concentration ranged between 46.68 to 48.86 mg kg^{-1}.

Key words: Industrial effluents, rice crop, heavy metals and soil health

Introduction

The disposal of sewage water is a major problem of big cities. There is great concern that several toxic elements are accumulating in soils as a consequence of industrial and urban activities and/or because of the use of untreated sewage sludge (Davies and Jones, 1989). However, the use of untreated sewage water for irrigation in the surroundings of urban dwellings for growing crops is a common practice in Pakistan (Ghafoor ***et al.***, 1995). The sewage effluents are considered not only a rich source of organic matter and many other plant food nutrients (Ibrahim ***et al.***, 1998) but also contain heavy metals like Fe, Mn, Cu, Zn, Pb, Cr and Ni. However, continuous use of such effluents for crop production can result in accumulation of such metals in concentrations that may become phyto toxic (Kirkham, 1983; Ghafoor ***et al.***, 1999). Accumulation of heavy metals over prolonged time becomes hazardous to animals and human health after entering in their body systems through food chain. The concentration of individual mineral metals in living tissues is ordinarily very low. Some mineral metals are essential in low amounts, namely Co, Cu, Fe, Mn, Mo and Zn for plants; Cr, Ni and Sn for animals while Cd, Hg and Pb have not been established to be essential for either plants or animals (Misra and Mani, 1991).

Rice is an important cash crop of Pakistan. Its water requirement is very high. However, due to shortage of canal irrigation water, the farmers use underground as well as surface water. Nullah Dek starting from Kashmir passes through the biggest industrial zone of Punjab, i.e. G.T. road industrial area Muridke. While passing through this zone, it carries the industrial effluents and the human wastes because the city sewage drains from Mandi Muridke industrial area along with many small towns fall in these nullahs. In rainy seasons these nullahs inundate the surrounding cropped area. Moreover, the farmers lift this polluted water to irrigate rice fields through pumps installed on the banks or in the basins of these nullahs. Since, the use of such effluents as irrigation water may introduce some metal ions, which may accumulate in the plants, the practice may culminate into a hazard. The metal ions can induce toxic impact on the living systems if present in excessive concentrations (Nriago and Pacyna, 1988; Tiller, 1989; Nriago, 1990). The heavy metals accumulate in the plant material grown in these soils, which will ultimately go to human body through food chain directly or indirectly causing a number of physio-mental problems (Sial, 2000). Quantitative data regarding the accumulation and bioavailability of heavy metals in soils and rice plants polluted with industrial waste water are lacking in the country. Singh ***et al.*** (1991) studied the effect of sewage water and refinery effluent on yield and heavy metal concentration (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in berseem in a pot experiment. It was concluded that concentration of metals increased with increasing the amount of sewage water irrigation and/or refinery effluents. Ghafoor ***et al.*** (1994) studied the chemical composition of effluents from different industries of the Faisalabad city. It was found that quality of effluents from the Kashmir Ghee Mills and Lyallpur Chemicals Ltd. was worse to compare to those from the textile units, Nishatabad, Kohinoor and dying units and cereal grain processing industry [Flour Mill and Rafhan Maize Products]. Overall, the EC and RSC values of the main Paharang drain at Chak No. 217/ R.B. (EC 2.88 dS m^{-1}, RSC 10.05 me l^{-1}) and Madhuana drain at Chak no. 225/R.B. (EC 5.39 dS m^{-1}, RSC 11.0 me l^{-1}) were much higher than the critical limits prescribed by many organizations as reported by Muhammad and Ghafoor (1992). The concentration of Fe, Mn, Cu, Zn, Pb and Ni were below their respective safe limits prescribed by Ayers and Westcott (1985) in effluents from all the sources as well as in both the main drains. Iron was found in higher concentration in effluents from Lyallpur Chemicals Ltd. (1.80 mg l^{-1}) and Kashmir Ghee Mills (1.50 mg l^{-1}) than that in the effluents from other sources.

From the above paragraphs it can be concluded that soils accumulate heavy metals to different extent when irrigated with water containing these metals. These heavy metals are assimilated by plants and accumulate in their tissues. In general plants accumulated metals more in shoot than the roots or fruits. These metals enter the food chain of animals and human and in many cases, may cause danger to their health.

Keeping in view these considerations, the present study was conducted with the following objectives.

- To know the chemical composition of nullah at different time intervals with special reference to electrical conductivity (EC) and mineral metals (traced).
- To analyse the levels of pH_s, EC_e, O.M. and mineral metals in the soils adjacent to nullah and heavy metals accumulation in paddy and straw of rice.

Materials and Methods

A research study was carried out to see the effect of industrial effluents on mineral nutrition of rice and soil health. For this purpose a site was selected on the bank of nullah Dek at "Shakirabad" a railway station and Village on Lahore Faisalabad railway track in the Distt. Sheikhupura. Six soil samples at two depths i.e. 0-15 and 15-30 cm from three spots at the site were collected and analysed for chemical characteristics and mineral metals contents in the soil. Water samples from the nullah were collected before transplanting of rice and during rice season after every fifteen days interval from 3rd August to first of November which were analysed for chemical composition and mineral metals contents. Three fine rice varieties i.e. Super Basmati; Shaheen Basmati and Basmati 2000 were transplanted in the third week of July. The system of lay out was randomized complete block design with four replications. Recommended dose of N, P and K was applied. These varieties were grown up to maturity. Paddy and straw yields data were recorded. After the harvest of rice crop soil, paddy and straw samples were analyzed for, Zn, Cu, Fe, Mn, Ni, Cd, Pb and Sr contents. Plant samples were analysed for Zn, Cu, Fe, Mn Ni, Cd, Pb and Sr contents according to the method of AOAC (1990). All the soil analyses were done using the methods given in Hand book No. 60 (U S Salinity Lab. Staff, 1954) except Zn, Cu, Fe, Mn Ni, Cd, Pb and Sr by Soltanpour (1985) and Page ***et al.*** (1982). All the data were analysed statistically by using randomized complete block design (Steel and Torrie, 1980).

Results and Discussion

Chemical characteristics of soils

The original soil analyses (Table 1) before transplanting of rice indicated that all the soil samples have pH_s between 7.9 to 8.3 indicating the absence of sodicity hazard at this site. Soil analysis after harvest of rice crop (Table 2) showed that there was a slight decrease in pH_s at both the depths. This decrease in pH_s was noted < 1 unit. The original soil sampling site have EC_e less than 4 dS m^{-1} i.e. in normal range. Post rice harvest analyses (Table 2) indicated that there was a decrease in EC_e of soil at both the depths i.e. 0-15 and 15-30 cm. Like pH_s and EC_e, Sodium Adsorption ratio which ranged initially between 6.30 to 13.77(m.mol $l^{-1})^{1/2}$ also decreased. The decrease in pH_s, EC_e and SAR after harvest of rice crop was noted. The reason for this decrease in these parameters might be that when soils are submerged, pH_s decreased in alkaline soils and increased in acid soils, tends to become neutral i.e. 7. Similarly EC_e is decreased on flooding of fields. Because when fields are flooded continuously, there is downward movement of water to the lower horizons and soluble salts also move downward with this water, resulting in decrease of EC_e. The decrease in SAR can be explained in similar ways because it is the ratio between soluble sodium and calcium plus magnesium. When soils are flooded, soluble salts are leached down to lower horizons and their quantities decreased in the upper layers resulting in decrease of SAR. Similar explanations for decrease in these parameters were given by Patrick ***et al.*** (1985).These soil chemical characteristics indicate that although the water of Nullah Dek, is being used for many years for irrigation at this site, soil is still free from salinity/sodicity hazards. Ghafoor ***et al.*** (1996) also observed similar changes in chemical characteristics of soils while studying the soil and plant composition being irrigated with Paharang drain sewage effluents at Faisalabad.

Heavy metals contents in soils

The original soil analyses (Table 1) before transplanting of rice crop showed that Zinc concentration was variable at the sampling site. It was medium to high. Copper; Iron and Manganese were in sufficient amount at this site. Strontium was in poor range at the site while Nickel and Cadmium were in deficient range. The contents of all these heavy metals i.e. Zn, Cu, Fe, Mn, Pb, Ni, Cd and Sr after harvest of rice crop were further increased (Table 2). The contents of these metals were higher in upper layer than the lower horizons. The increase in Zinc contents was up to< 0.5 mg kg^{-1} soil, the increase in Copper contents was < 0.1 mg kg^{-1} soil,

Table 1: Soil analysis before transplanting of rice

Depth (cm)	pH_s	Ec_e d Sm^{-1}	SAR (m mol1^{-1})^{½}	Zn mg Kg^{-1}	Cu mg Kg^{-1}	Fe mg Kg^{-1}	Mn mg Kg^{-1}	Ni mg Kg^{-1}	Cd mg Kg^{-1}	Sr mg Kg^{-1}
0-15	7.9	2.24	7.81	1.8	1.4	50.2	24.0	0.08	0.010	6.0
15-30	8.3	2.28	13.77	0.8	1.2	49.0	22.0	0.06	0.008	6.0
0-15	8.0	2.27	7.35	1.0	1.2	49.8	26.0	0.08	0.012	6.0
15-30	8.2	2.11	9.88	0.8	1.2	49.4	26.0	0.08	0.016	7.6
0-15	8.1	1.69	6.30	1.0	1.4	50.0	30.0	0.10	0.010	7.0
15-30	8.1	1.79	7.62	0.8	1.2	49.4	28.0	0.08	0.014	6.8

Table 2: Soil analysis after harvest of rice

Element	Depth (cm)	Super	Sha.	Bas. 2000	Element	Depth (cm)	Super	Sha.	Bas. 2000
ECe (dS m^{-1})	0-15	2.06	1.58	2.17	Mn (mg Kg^{-1})	0-15	24.8	26.9	30.3
	15-30	1.54	1.46	1.91		15-30	21.3	21.9	29.6
pHs	0-15	7.56	7.71	7.54	Pb (mg Kg^{-1})	0-15	2.93	2.68	3.33
	15-30	7.55	7.69	7.51		15-30	2.91	2.16	3.0
SAR (m mol l^{-1})^{½}	0-15	6.13	6.39	6.05	Cd (mg Kg^{-1})	0-15	0.017	0.016	0.015
	15-30	6.07	6.16	5.95		15-30	0.016	0.015	0.012
Zn (mg Kg^{-1})	0-15	1.91	1.06	1.21	Ni (mg Kg^{-1})	0-15	0.085	0.082	0.082
	15-30	1.757	.90	1.11		15-30	0.066	0.080	0.050
Copper (mg Kg^{-1})	0-15	1.23	1.33	1.49	Sr (mg Kg^{-1})	0-15	6.1	6.2	7.1
	15-30	1.21	1.21	1.37		15-30	6.4	6.9	7.6
Iron (mg Kg^{-1})	0-15	50.8	50.6	51.3		15-30	49.6	49.5	49.65

Table 3: Heavy metals contents in paddy and straw of rice

	Paddy	Straw				
Element	Super Bas.	Sha. Bas.	Bas. 2000	Super Bas.	Sha. Bas.	Bas. 2000
Zn (mg Kg^{-1})	1.68	1.60	1.63	28AB	27.75B	30.0A
Copper (mg Kg^{-1})	0.93B	1.08A	1.13A	18.5	19.5	18.0
Iron (mg Kg^{-1})	3.15B	3.38AB	3.50A	274.0	277.0	279.0
Mn (mg Kg^{-1})	1.88	1.86	1.83	2.33	2.38	2.43
Pb (mg Kg^{-1})	2.95	2.89	2.92	1.24	1.23	1.23
Cd (mg Kg^{-1})	0.175	0.125	0.175	0.2B	0.25B	0.35A
Ni (mg Kg^{-1})	0.093	0.088	0.073	1.162	1.167	1.195
Sr (mg Kg^{-1})	26.74	29.73	30.73	46.82	46.68	48.86

Iron and Manganese were increased up to 1 mg Kg^{-1} soil, Cadmium, Nickel and Strontium were increased < 0.1 mg Kg^{-1} soil. Copper, Iron and Manganese were already in sufficient amounts at this site which were further increased. Nickel, Strontium and Cadmium were initially in deficient range which are still in deficient range. Lead was determined after harvest of rice crop only which was within the permissible limits. It was ranged from 2.68 to 3.33 (mg Kg^{-1} soil).A number of workers have also reported similar results i.e. the continuous use of polluted effluents for crop production could result in accumulation of heavy metals in concentration that may become phytotoxic (Kirkham, 1983), Ibrahim ***et al.*** (1998); Ghafoor ***et al.*** (1995, 1996 and 1999).

Water characteristics

The results (Fig. 1-11) indicate that water of nullah Dek have high EC which indicates that the industrial effluents thrown to this nullah are brackish and have high EC. Sodium adsorption ratio ranged from 2.15 to 18.61 (m mol $l^{-1})^{½}$ indicating that the water of Dek is sodic in nature.

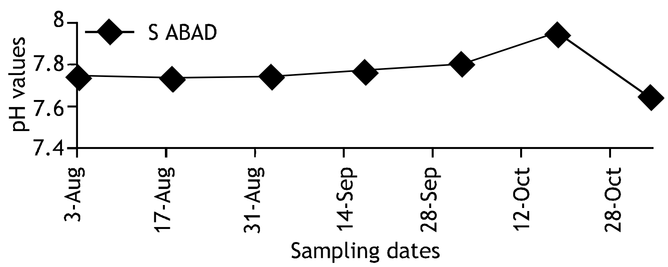

Fig. 1: Changes in pH of water

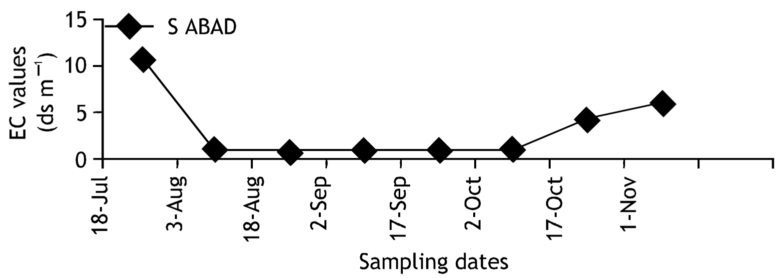

Fig. 2: Changes in EC of water

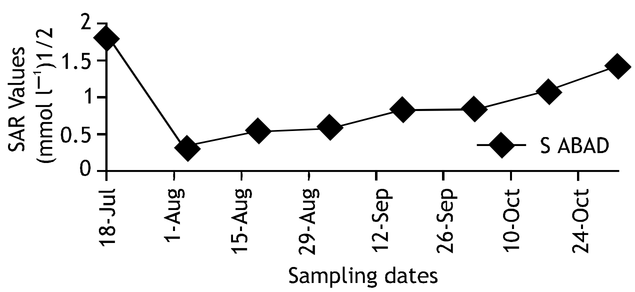

Fig. 3: Changes in SAR of water

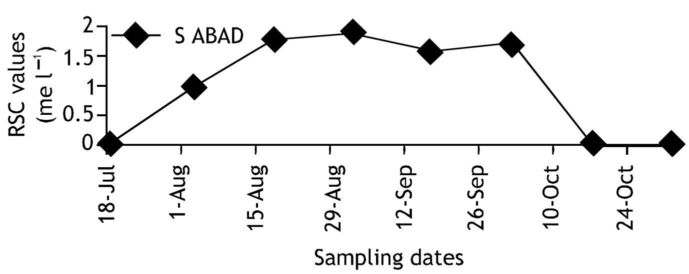

Fig. 4: Changes in RSC of water

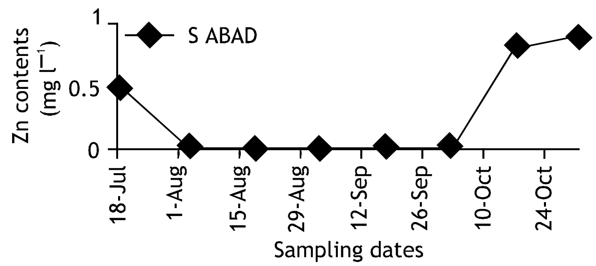

Fig. 5: Changes in Zinc contents of water

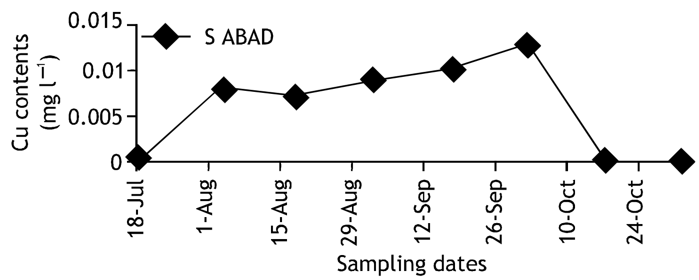

Fig. 6: Changes in copper contents of water

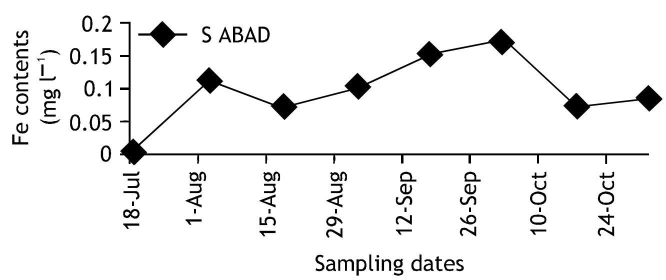

Fig. 7: Changes in iron contents of water

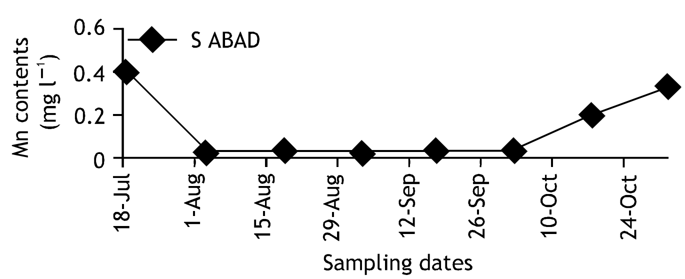

Fig. 8: Changes in manganese contents of water

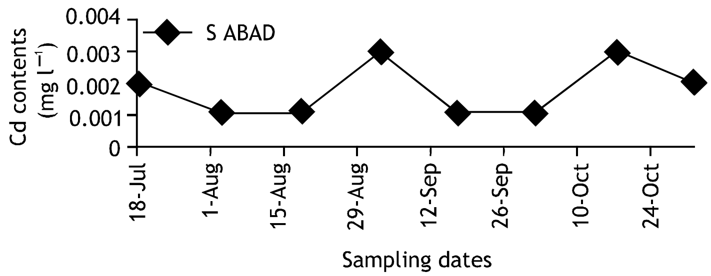

Fig. 9: Changes in cadmium contents of water

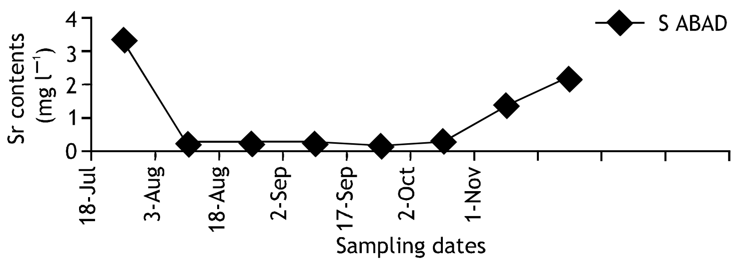

Fig. 10: Changes in strontium contents of water

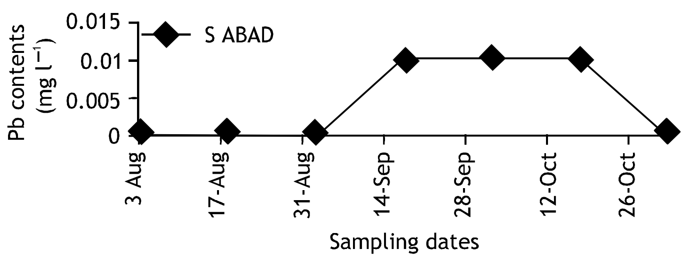

Fig. 11: Changes in lead contents of water

There was no problem of Residual Sodium Carbonate. It was further noted that the heavy metals i.e. Zn, Mn, Cd and Sr are present but these are within safe limits except Sr. Water of these nullahs is applied to rice crop and occasionally to wheat crop. The monsoon rains during this year (2002) started late due to which transplanting of rice was delayed around the banks of nullah Dek (end of July and start of August, 2002). The trial of this project was also initiated in the third week of July. The water used initially for irrigation was of tube well. The rainy water began to flow at the end of July and the farmers started to use it for irrigation purpose. This water was applied up to first week of November, 2002. The analyses of this water (Fig. 1-11) showed that pH ranged between 7.52 to 7.95 and remained variable during the application period. The EC of water became very low i.e.< 1 dS m^{-1} at the end of July during rainy season due to dilution of soluble salts indicating that water is in fit range for agricultural purposes. However there was a sharp rise in this parameter after 15th of October and water became highly brackish after this date. This situation indicates that water applied in the month of October can cause soil salinity. Otherwise this water can be used for irrigation during monsoon season. Similarly SAR, RSC, Zn, Cu, Fe, Mn, Cd, Sr and Pb are many times diluted during rainy season and were within safe limits for agricultural crops. Their values, however, also increased after 15th October on the end of monsoon. Their concentrations however, were still within permissible limits. Although the nullah water remained diluted throughout the monsoon i.e. the main rice growing time, yet minor accumulations of all the heavy metals under study were observed (Table 2). Similar findings were reported by Khan ***et al.*** (1994), Younas ***et al.*** (1999), Ibrahim ***et al.*** (1998) and Ghafoor ***et al.*** (1995, 1996 and 1999).

Paddy and straw yield

Paddy and straw yield data have been depicted in Fig. 12 and 13. The Shaheen basmati produced significantly higher yield followed by basmati 2000 and least by the super basmati. Similarly the higher straw yield was recorded of Shaheen basmati followed by basmati 2000 and least by the super basmati. The reason for higher yields of Shaheen basmati compared to the other varieties might be its relative salt tolerance and higher yield potential.

Heavy metals contents in paddy and straw of rice

Paddy and straw samples were analysed for eight heavy metals contents i.e. Zn, Cu, Fe, Mn, Pb, Cd, Ni and Sr. The data showed (Table 3) that in paddy Zn contents ranged between 1.60 to 1.68 (mg kg^{-1} paddy).There was more zinc contents in super basmati than all other varieties used in this study. Although zinc contents ranged from 1.60 to 1.68 (mg kg^{-1}) yet are within permissible limit. In case of copper, its contents ranged between 0.93 to 1.13 (mg kg^{-1}). Among varieties used there was no definite trend. Although copper contents ranged from 0.93 to 1.13 mg kg^{-1} yet are within permissible limit. Iron contents in paddy were found in very low range i.e. from 3.15 to 3.50 mg kg^{-1} paddy. Manganese concentration ranged from 1.84 to 1.88 (mg kg^{-1}. Lead contents in paddy ranged between 2.89 to 2.95 mg kg^{-1} paddy.

Cadmium contents ranged between 0.125 to 0.175 mg kg^{-1} paddy. Its concentration was within permissible limit of food grains. Nickel was found in minute quantities ranged from 0.073 to 0.093 mg kg^{-1} paddy which is like Cd within permissible limit of food grains. Strontium was noted in higher quantities at the site of the study. Its concentration ranged between 26.74 to 30.73 mg kg^{-1}. Rice straw was also analysed for heavy metal contents because it is used as fodder for animals in this area. The results showed that zinc ranged from 27.75 to 30.0 (mg kg^{-1}). Copper concentration was also quite sufficient which varied from 18.0-19.5 (mg kg^{-1}). Among varieties used there was no definite trend. Although copper contents ranged from 18.0 to 19.5 mg kg^{-1} yet do not fall in toxic bracket. Iron contents in straw were found in very high range I. e. from 274 to 279 (mg kg^{-1}). Manganese ranged between 2.33 to 2.43 (mg kg^{-1}). Lead contents in straw ranged between 12.26 to 12.37 (mg kg^{-1}).Cadmium contents ranged between 0.20 to 0.35 mg kg^{-1} straw. Its concentration was within permissible limit of fodders. Nickel was found in

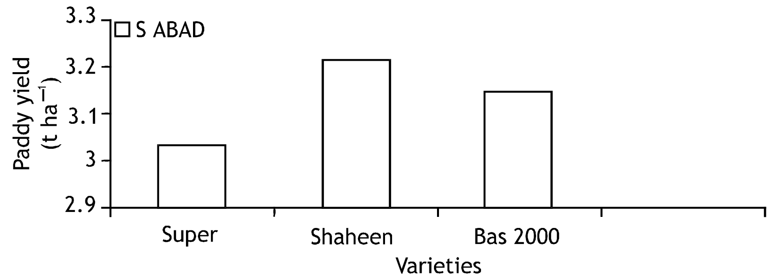

Fig. 12: Paddy yield of different varieties

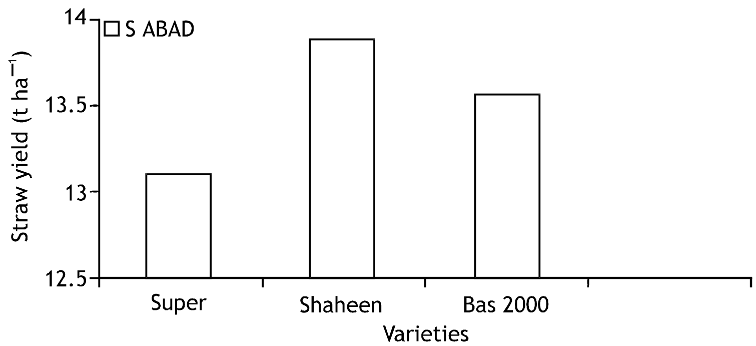

Fig. 13: Straw yield of different varieties

minute quantities ranged from 1.162 to 1.195 mg kg^{-1} straw which is like Cd within permissible limit of fodders. Strontium was noted in higher quantities at the site of the study. Its concentration ranged between 46.68 to 48.86 mg kg^{-1}.

The use of effluents for irrigation like nullah Dek water is introducing heavy metal ions, which accumulate in the plants, the practice of using this water may culminate into a hazard if this practice prolongs. These metal ions can induce toxic impact on the living systems if present in excessive concentrations as reported by Nriago and Pacyna (1988), Tiller (1989) ; Nriago (1990). These heavy metals accumulate in the plant material grown in these soils, which will ultimately go to human body through food chain directly or indirectly causing a number of physio-mental problems as reported by Sial (2000). Ghafoor ***et al.*** (1995) also studied the impact of Madhuana drain water on soils and vegetables. It was concluded that waste water discharged from different industrial works at Faisalabad was unfit, i.e. EC (5.4 d S m^{-1}), SAR (12.7 m mol l^{-1})^{½} and RSC (11.0 me l^{-1}) for irrigating the crops. In soils [pH$_s$ 8.18-8.45, EC$_e$ 4.95-5.72 dSm^{-1}), SAR 12.18-13.68 (m mol $^{-1}$)^{½}, Total N 0.11-0.20%] under cultivation of cauliflower and spinach using sewage water, heavy metals tended to accumulate (Fe, 37.06-198.30, Mn 13.8-73.55, Cu 2.16-14.00, Zn 40.94-123.85 and Pb 0.49-5.76 mg l^{-1}) which were beyond the critical levels. Only Pb and Ni concentrations were within permissible limits.

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