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Zinc, Copper, Iron and Manganese in Soils and Plants at Different Canal and Water Course Sections in Rice-Wheat Cropping Zone

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ABSTRACT

Under agro-climatic and agro-ecological conditions of Pakistan, soils are calcareous with alkaline pH, and both of these could antagonize the availability of micronutrients to plants resulting in yield loss. The present study was undertaken to characterize soils and tubewell waters in the head (H), middle (M) and tail (T) sections of a canal (C)/water courses (WC) and determine zinc, copper, iron and manganese concentration in soils, plants and correlate them with soil properties. The pH_s ranged from 7.3 to 8.5 at the upper two soil depths of the three canal sections except three sites where it was as high as 10.4 at 15–30 cm soil depths. The pH_s was higher in the CT than that in the CH or CM sections. All the soil samples have $EC_e < 4.1$ dS m^{-1}, being the highest at CT followed by CM and CH. About 58, 93, and 100% tubewells are pumping hazardous water at CH, CM and CT, respectively, and the corresponding values were 82, 76 and 88% at WCH, WCM and WCT. The ammonium acetate-EDTA extractable Zn in the 0–15 cm decreased from that in the 15–30 cm soil depths consistently in the CH and WCH towards the respective middle or tail sections indicating role of irrigation water sediment for sustaining higher nutrient concentration in the former sections. About 22, 34 and 34% soil samples were found deficient in Zn at CH, CM and CT, respectively at 0–15 cm soil layer and corresponding values were 44, 23 and 33% for WC sections. None of the plant samples was found deficient in these micronutrients. The pH_s correlated significantly and negatively with Fe and Mn at CM and CT, with Zn at WCH, with Fe and Mn at WCT, while non-significantly with Cu. The EC_e showed significant and negative correlation with Fe at CM, with Cu at WCH and non- significant with Zn or Mn. Soil lime correlated negatively with Zn at CT and WCH, with Cu at WCH, and with Mn at CT sections.

Key Words: Canal/water course sections; Sediments; Soils; Wheat; Micronutrients; Correlation

INTRODUCTION

The canal commanded area (CCA) of Pakistan falls within arid to semi-arid zone receiving annual precipitation of 200 to 500 mm. For this reason, most of the crops have to be artificially irrigated. Pakistan has about 21 mha land under cultivation and irrigated agriculture is practised round the year on about 17 mha which is 78% of the CCA (Mirza & Ahmad, 1998). The gravity flow irrigation system comprises of the Indus River and its tributaries (Jehlum, Chenab, Ravi & Satluj), three major storage reservoirs, 19 barrages, 12 link canals and 43 canal commands covering about 95,000 water course commands.

It is a reality that crop yields are stagnant and yield are lower at tail of canals/water courses than that at their respective middle or head sections (Ghafoor *et al.*, 1999a & b). Mostly it is assumed that irrigation water availability at farm-gate from the gravity flow canals decreases towards tail ends (PERI, 1988). This shortage of canal water is being supplemented by pumping 46 MAF ground water in Pakistan, and of which mostly (up to 75% in Punjab) is hazardous (Malik & Hassan, 1987) and could induce soil salination/sodication. Under this situation, the micronutrients availability could be one of the major yield limiting factors. Hence the present study was undertaken with the objectives to (a) characterize soils and tubewell waters in the head, middle and tail sections of a canal and its water courses, and (b) determine micronutrients (Zn, Cu, Fe, Mn) concentration in soils/plants and correlate them with soil pH_s, EC_e and lime.

MATERIALS AND METHODS

Mananwala canal (C) was selected for the present studies which provides irrigation water to Farooqabad and Mananwala areas. It is about 45 km long and has 74 water courses/Moghas (WC). This canal was divided into three equal lengths and section towards headwork was designated as head (H), next middle (M) and the third towards exterior as tail (T). From each canal section, 11 watercourses were marked for the studies. Each watercourse, like canal, was divided into three equal lengths, near to canal was head, next middle and the last tail. One acre of wheat crop in each section of the watercourses was randomly marked. From these fields, wheat grain yield was recorded by harvesting $1 m^2$ area. Then composite soil samples were drawn with soil auger at 0–15 and 15–30 cm depths for analyses (Page *et al.*, 1982). Micronutrients were extracted with ammonium acetate-EDTA (AA-EDTA) from soils while whole wheat plants were digested in di-acid (Jones & Case, 1990) and then measured by using Atomic Absorption Spectrophotometer. Tubewell water samples with which the selected wheat fields used to receive irrigation were collected and analyzed for irrigation quality (U.S. Salinity Lab. Staff, 1954). The data collected were computed for standard deviation and correlation coefficients (Chaudhry, 1984).

RESULTS AND DISCUSSION

Soils. Soil chemical properties, like pH_s, EC_e, SAR, lime and texture are considered the most important for sustainable plant food nutrient availability and thus crop yields. The pH_s ranged from 7.3 to 8.5 at the upper two soil depths of the three canal sections except three sites where it was as high as 10.4 at 15–30 cm soil depths. Overall, the pHs values were higher in the tail section of canal and were the lowest for its head section. All the soil samples have EC_e < 4.1 dS m^{-1}. The EC_e was the highest at CT followed by CM and CH, although for all the sections the values were much below the tolerance threshold of wheat. Ayers and Westcot (1989) reported that up to EC_e 6 dS m^{-1}, wheat grain yield is not affected which is reduced to 50% at EC_e 13–15 dS m^{-1}. The SAR values were < 13 for all the soil samples except four samples where SAR was > 15 with minor differences between C or WC sections. On an average, SAR was the highest for CT and the lowest at CH at all the soil depths. For details of soil characterics, see Ghafoor *et al.* (1999 a).

Tubewell water quality. There were 59 tubewells in operation in the study area. The mean EC, RSC and SAR generally increased from head towards the tail of canal or watercourses. About 58, 93 and 100% tubewells are pumping hazardous water at CH, CM and CT, respectively based on the classification of the U.S. Salinity Lab. Staff (19954). While these values were 82, 76 and 88% at WCH, WCM and WCT, respectively. This statistics clearly lead to opine that the problems should be more severe towards the tail reaches. This is true for CT but not for WCT and thus it has to be assumed that the observed picture is mainly because of the management factor and that seepage from canal has improved the ground water quality at head sections. Detail of results pertaining to soils, water quality and wheat yields is presented by Ghafoor *et al.*, 1999a)

Micronutrients in soils. The AA-EDTA extractable Zn concentration in 0–15 cm soil decreased consistently from CH and WCH towards the respective tail sections (Table I) but in all the cases remained higher than respective 15–30 cm soil depths. The flood/irrigation coating (Ali, 1971) due to sediment inflow through the gravity flow irrigation water (Brinkman, 1971) was more in CH, WCH and plough layer than the other sections or lower soil depth. The flood coating material is mainly composed of silt with some admixture of very fine sand/clay (Brinkman & Rafiq, 1971) which is transported onto fields of the WCH while settles down in WC at the time irrigating tail and middle sections. This freshly deposited material contains Zn in insoluble forms but upon in-situ weathering could release it to sustain its availability in soils. Main source of micronutrients in soil-water system is considered soil parent materials (Deverel & Fujii, 1990) and fresh sediments, like the irrigation coating, has to be useful to sustain the nutrient concentration. Rahmatullah *et al.* (1988a) reported that about one third of the total Zn was associated with silt fraction in four soils series developed in loess plains of Pakistan. The Zn concentration was higher in the surface 0–15 cm soil in which flood coating are mainly accumulated which upon *in situ* weathering released it.

Considering the limits set by Cottenie *et al.* (1979) and Zn in 0–15 cm soil layer, about 22, 34 and 34% soil samples were found deficient in Zn at CH, CM and CT, respectively. The corresponding values were 44, 23 and 33% for WC sections. High cropping intensity as well as better crop growth at head sections of canal (Ghafoor *et al.*, 1999 a) help add organic matter in the form of more crop residues into the surface soil layer. The organic matter is one of the

Table I. The AA-EDTA extractable micronutrients in soils (mg kg^{-1}) at C/WC sections (Ave. of 33 values)

Section	Depth (cm)	Canal				Water Course			
		Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
Head	00-15	2.6	3.1	285	106	2.5	3.3	295	107
	15-30	1.9	2.6	217	84	2.0	3.0	230	98
Middle	00-15	2.3	4.3	298	107	2.4	4.0	297	117
	15-30	2.1	3.6	279	98	2.1	3.4	255	114
Tail	00-30	2.0	3.4	262	120	2.1	3.5	253	108
	15-30	1.9	3.3	228	110	1.7	3.0	238	81

major soil component to chelate and retain micronutrients in soils against leaching (Stevenson & Ardakani, 1972; Rahmatullah *et al.*, 1988a). All these factors combined to sustain higher availability of micronutrients in surface soil layer. The Zn concentration was even higher in the head reaches of WC or C than the other parts of the study area.

The pattern of Cu, Fe and Mn distribution with respect to soil depth was similar to that of Zn. However, the results pertaining to the concentration of Cu, Fe and Mn distribution in different C or WC sections were a little inconsistent. Like Zn, concentration of these nutrients was also higher in the surface soil layer than that in the lower depth mainly because of the reasons explained above. Rahmatullah *et al.*, (1988b) found that some 31.50% Cu resided in silt fraction of several soils of Pakistan. Generally these three nutrients were higher at both the soil depths in the middle than the other two sections of the C or WC. Overall, Cu was deficient in 11 and 23% soil samples drawn at 0–15 cm depth in the CH and CT reaches, respectively while 11% samples were deficient in WCH, WCM and WCT parts. At tail section, the higher soil pH_s and SAR than that of the other two parts could also be partially responsible for lower micronutrient concentration (Mengel & Kirkby, 1987; Rahmatullah *et al.* 1988a & b). The concentration of Fe and Mn was sufficient in all the sections of C and WC, rather in some sections were much higher expectedly antagonistic for other micronutrients regarding their availability and assimilation by plants.

Micronutrients in wheat plants. None of the plant samples was found deficient regarding the investigated micronutrients (Table II) considering the criteria of Reuter and Robinson (1986). The growth reduction (Maas, 1987) reflected by the economic wheat yield (Ghafoor *et al.*, 1999a & b) due to canal water shortage (PERI, 1988), and use of low quality ground water and poor soil quality (Ghafoor *et al.*, 1999a) could be other reasons for the observed nutrient concentration pattern in plants. Other possibility appears the low quantity of these micronutrients extracted by the AA-EDTA from the alkaline calcareous soils (Rahmatullah *et al.*, 1988 a & b; Page and Chang, 1990). It is interesting to note that a good number of soil samples were found deficient but plant analysis did not show deficiency of any nutrient. This aspect needs studies to determine critical levels of nutrients under our conditions.

Table II. Di-acid extracted micronutrients in whole wheat plants (mg kg^{-1}) at C/WC sections (Av. of 33 values)

Section	Canal			Water Course		
	Zn	Fe	Mn	Zn	Fe	Mn
Head	27	578	56	28	567	66
Middle	26	567	50	29	627	62
Tail	33	593	75	29	544	53

Relationship between soil properties and micronutrients. The pH_s correlated significantly and negatively with Fe and Mn at CM and CT, with Zn at WCH, with Fe and Mn at WCT, while there was non-significant correlation with Cu (Table III). The soil EC_e showed significant and negative correlation with Fe at CM, with Cu at WCH and non significant correlation was observed between Zn or Mn. Soil lime correlated negatively with Zn at CT and WCH, with Cu at WCH, and with Mn at CT reaches.

Table III. Correlation coefficients between soil properties and micronutrients (0-15 cm soil) at different sections of canal/water courses

Soil	Head				Middle				Tail			
	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
						Canal						
pH_s	-0.862**	-0.336	-0.268	-0.710	-0.864	-0.666	-0.578	-0.432	-0.030	-0.709	-0.680	-0.797
EC_e	0.444	0.071	0.322	-0.036	-0.003	-0.541	-0.700	-0.625	-0.628	-0.348	-0.507	-0.256
Lime	-0.872**	-0.157	0.010	-0.536	0.114	-0.611	-0.303	-0.812**	-0.519	-0.728*	-0.790**	-0.480
						Water Course						
pH_s	-0.636	-0.715**	-0.470	-0.549	-0.447	-0.670*	-0.504	-0.303	0.271	-0.501	-0.792**	-0.038
EC_e	-0.569	-0.580	-0.628	-0.326	-0.462	0.087	0.146	-0.109	-0.261	-0.145	-0.207	-0.638
Lime	-0.739*	-0.673*	-0.619	-0.368	-0.218	-0.313	-0.139	-0.535	0.337	-0.385	-0.438	-0.324

* and ** Significant at 5 and 1% level of probability, respectively. Number of observations is 33 for each correlation coefficient.

CONCLUSIONS

It is concluded that under the gravity flow irrigation system of Pakistan, sediment added onto soils do help to maintain the availability of Zn, Cu, Fe and Mn. Thus it is recommended to make use of such sediments in soil management instead of using it as a filling material in building construction. Ground water quality, canal water availability and wheat yield, in general, are better in the head sections than the tail reaches of canal watercourses. The micronutrient extractant, ammonium acetate-EDTA, from soils as well as their critical levels in soils for plant growth needs validation under farm soils of Pakistan since concentration of Zn, Mn, and Fe in whole wheat plants was adequate even grown on soils indicating defficiency of these nutrients with this extractant.

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