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Evaluation of Nutrient Status in the Rice Growing Areas of the Punjab

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Abstract: The study was carried out to assess the macro and micro nutrients status and their relation with pH, organic matter, clay contents and calcium carbonate ($CaCO_3$) in the rice growing areas (Kallar track). Soil samples from 0-15 cm depth were collected from 45-50 sites located in this area. The soil samples were processed and analyzed for macro and micronutrients. Results indicated that 40% soil samples were deficient in total N, 17.77% P, 4.41% SO_4, 60% Zn, 4.5% Cu and 13.33% Mn. The K, Ca+Mg, Fe and B were not deficient. About 15.15% were low in total N, 33.33 in P, 6.66% in SO_4^{2-}-S and 22.22% in Zn and no one in K, Ca+Mg, Cu, Fe, Mn and B. Soil pH, organic matter, clay and $CaCO_3$ contents were correlated with macro and DTPA (diethyletriaminepenta-acetic acid) extractable available micronutrients. Organic matter showed positive correlation with N (0.969**), whereas pH_s correlated negative with Mn (-0.316*). Clay contents showed significant positive correlation with K (0.325*), Cu (0.372*) and B (0.269*). Similarly, significant positive correlation of $CaCO_3$ was recorded with Cu (0.415*) and Mn (0.360*).

Key words: Macro and micro nutrient evaluation, correlation with organic matter, pH, clay

Introduction

At present rice is being grown on approximately 2 M ha million hectares of land the second largest area under any kharif crop. The introduction of short saturated, fertilizer responsive and high yield varieties, along with the adaptation of improved management practices have resulted an increase in the yield, hence greater economic return. Although these initial gains are impressive, but unfortunately the average yield remained static, rather decline during the past few years, inspite of all efforts such as the use of fertilizers, selection of good crop varieties and control of pest and diseases. For instance, the average yield of Basmati verities is 1129 kg ha^{-1} in the country (Anonymous, 2000-2001), which is very low as compared to other rice growing countries in the world. This situation is discouraging the farmers to grow fine quality Basmati rice, as its yield is generally lower than that of coarse varieties.

Due to the continuous nutrient mining through the intensive cropping pattern and growing of high yielding crop varieties, most of the soils have become depleted of one or more plant nutrients. Deficiency of NPK has been well established but their excessive application, particularly of N has disturbed the balance of other macro and micronutrients in the soil. Improper fertilizer management thus has further aggravated the problem due to which the crops yield has become stagnant or even decreasing in spite that fertilizer consumption is increasing each year in the country. According to Mathiew (1979), a major constraint for low yield is the imbalanced use of fertilizers.

Most of the rice fields are alkaline in reaction and remain submerged during the growing season of the rice crop. Under this specific situation, the availability of nutrients is affected with lime content, organic matter, pH, clay content and various oxidation-reduction reactions. Moreover, with the intensive fertilization of the soil, it is likely that some physiological nutritional imbalance in plants may also arise due to lower uptake of indigenous nutrients or their reduced translocation within the plant. Under these circumstances, a deficiency of one or more nutrients may be expected in the paddy fields of the Punjab.

This study indicates solution of the problem in getting potential paddy yield. It will be very helpful in formulating the balanced fertilizer programme, as the study has been extended from the traditional investigation of NPK and Zn to a range of about all the macro and micronutrients required for maximum yield of rice. Higher crops yield, multiple cropping and an increase in the productivity of marginal lands is not possible without balanced fertilization. Moreover, modern crop varieties cannot achieve their genetic potential unless good soil fertility is maintained. Balanced nutrient ratio besides increasing yield may improve the quality of many crops (Saleem *et al*., 1986). This work is therefore, planned to assess the nutrient status of the rice growing areas of the Punjab. In addition, an attempt has also been made to study the relationship of nutrient contents with physical and chemical properties of the soils.

Materials and Methods

Selecting 45-50 sites located in the district of Gujranwala, Sheikhupura, Sialkot and Narowal collected soil samples from a depth of 0-15 cm. Insitu, soil pH and EC of standing water was also measured. Soil samples were brought to laboratory, Department of Soil Science, University of Agriculture, Faisalablad during 1992. The samples were air-dried, ground with a wooden pestle and mortar and passed through a 2 mm sieve.

The EC_e, pH_s, $CaCO_3$, available K, soluble Ca+Mg were determined (Table 1) by following standard methods outlined by Anonymous (1954). Other determinants like particle size analysis and organic matter (Moodie *et al.*, 1959), total nitrogen (Jakson, 1962), available phosphorus (Watanable and Olsen, 1965), sulphate-sulphur (Bardsley and Lancaster, 1965) and boron (John *et al.*, 1975).

Micronutrients (Zn, Cu, Fe and Mn) in the soils were determined after extraction with DTPA (Lindsay and Norvell, 1978). The extractant consisted of 0.005 M DTPA, 0.01M TEA (triethanolamine) + 0.01 M $CaCl_2$. Ten grams of soil were shaken with 20 ml of extractants for 2 h and filtered through Whatman No. 42 filter paper. Concentration of Zn, Cu, Fe and Mn in the filtrate was determined with atomic absorption spectrophotometer. The correlation (Steel and Torrie, 1980) between pH, organic matter, clay contents and $CaCO_3$ and the soil nutrient elements, i.e. N, P, K, Ca+Mg, SO_4^{-2}-S, Zn, Cu, Fe, Mn and B were determined.

Table 1: Soil properties and available macro and micronutrients in the paddy soils of the Punjab

Soil attributes				Macronutrients					Available micronutrients				
	OM	Clay	$CaCO_3$	Total N	Avail.P	Extrt.K	Sol.Ca+Mg	SO_4^{-2}-S	Zn	Cu	Fe	Mn	B
pH	------%------			(%)	(ppm)	(ppm)	me l^{-1}	(ppm)	------ppm------				
8.52	0.52	24	2.09	0.020	11.1	262	5.0	23.08	0.22	4.3	5.6	0.7	3.1
7.83	1.13	50	1.67	0.062	7.7	580	6.0	28.00	0.32	3.3	25.2	21.2	2.0
8.32	0.21	39	1.82	0.010	2.6	280	7.0	40.08	0.04	1.19	12.8	3.52	3.4
8.22	1.03	30	2.13	0.041	3.5	290	4.0	26.76	0.57	2.6	7.0	0.80	1.5
8.25	0.83	38	1.56	0.041	11.8	240	7.0	09.26	0.54	0.7	7.0	1.60	1.6
8.18	0.21	13	2.36	0.014	2.0	262	6.0	02.50	0.98	6.5	9.8	0.40	1.2
8.14	0.22	39	1.86	0.011	4.5	280	6.0	22.24	0.60	5.3	19.68	15.2	2.7
8.00	0.62	22	2.70	0.031	0.3	210	4.0	22.70	0.20	7.1	12.8	2.8	2.0
8.09	0.52	50	1.82	0.036	2.3	330	7.0	23.00	0.21	1.0	5.6	3.0	3.2
7.19	0.55	49	3.57	0.027	5.4	250	7.0	10.20	1.32	3.6	8.4	62.4	3.7
8.23	1.03	49	3.65	0.051	1.9	330	4.0	09.20	1.09	7.6	28.0	25.8	3.7
8.10	1.06	34	1.98	0.049	6.2	330	8.0	13.50	0.18	2.2	9.8	15.0	4.9
7.86	0.42	25	1.56	0.021	1.9	230	6.0	24.80	1.54	1.5	11.4	0.3	2.1
7.83	1.45	39	1.52	0.072	3.8	290	9.0	32.00	1.52	2.0	16.8	8.6	3.6
8.03	1.24	44	1.33	0.052	4.2	481	7.0	23.70	1.46	1.94	28.2	1.6	1.5
7.98	1.24	42	1.33	0.062	4.2	300	4.0	14.57	1.28	0.90	23.8	1.6	2.0
8.24	0.83	34	1.71	0.041	3.2	272	6.0	11.22	1.22	4.3	28.2	8.2	1.5
8.03	0.62	25	1.98	0.036	4.6	221	8.0	27.80	1.26	3.4	14.0	1.2	2.5
7.98	1.03	37	1.44	0.051	4.2	340	7.0	37.00	0.24	4.8	4.0	12.0	2.5
7.97	0.83	31	3.19	0.041	3.3	362	5.0	29.80	0.52	1.5	11.2	0.2	1.4
8.10	0.62	39	2.16	0.031	3.6	221	7.0	20.50	0.20	2.8	11.4	0.4	1.6
8.07	0.42	35	2.74	0.021	3.2	221	6.0	23.90	0.14	2.2	15.4	4.8	1.6
8.01	0.44	31	3.50	0.027	3.0	362	11.0	25.40	0.18	6.4	21.0	7.4	1.7
8.04	0.21	16	1.52	0.010	11.5	262	8.0	15.00	0.28	1.1	30.8	3.6	1.7
8.20	1.03	26	3.42	0.051	2.7	310	7.0	21.90	1.84	0.1	28.0	17.4	2.2
8.08	0.52	27	2.40	0.026	2.8	450	8.0	23.20	0.38	2.6	21.0	17.4	3.0
8.42	0.57	35	3.83	0.038	5.8	400	9.0	18.56	0.34	1.5	41.0	19.8	2.6
8.12	0.46	26	2.24	0.023	9.7	210	6.0	10.02	0.80	7.2	22.4	20.4	2.6
8.30	0.62	40	1.60	0.031	3.0	200	7.0	17.12	0.32	1.7	04.0	9.68	1.7
8.20	0.83	35	2.47	0.041	9.2	300	10.0	08.00	0.12	2.7	12.6	6.60	1.8
8.42	0.80	28	2.96	0.043	5.8	280	9.0	14.48	0.72	3.2	11.2	10.48	2.1
8.25	0.42	35	2.58	0.021	9.1	272	6.0	09.20	0.23	1.9	14.0	12.40	1.9
7.85	1.43	31	1.63	0.061	9.6	322	5.0	17.40	0.56	2.3	12.6	40.80	3.3
8.29	1.35	30	3.72	0.067	7.7	221	7.0	12.97	0.40	4.4	14.4	2.80	2.1
8.00	1.25	40	3.61	0.062	12.6	271	6.0	15.00	0.38	7.0	14.0	19.80	2.5
8.40	0.93	49	3.95	0.046	11.9	490	4.0	14.09	0.28	4.6	07.0	17.40	2.7
8.35	0.62	23	3.12	0.028	3.2	262	7.0	21.50	0.19	4.6	11.2	14.40	2.1
8.10	1.25	22	1.06	0.062	8.3	272	6.0	17.00	0.18	0.1	12.6	2.00	1.7
8.30	0.21	30	1.56	0.010	8.8	340	5.0	06.00	0.22	1.4	08.4	4.40	2.0
8.40	0.83	27	3.00	0.051	10.1	350	7.0	29.00	0.22	2.8	20.0	3.60	2.7
8.25	0.82	20	2.58	0.04	5.8	221	8.0	12.00	0.76	1.1	20.0	5.40	3.1
8.20	0.83	42	2.62	0.041	4.4	340	6.0	21.07	0.06	2.7	15.4	5.40	2.7
8.10	0.52	31	1.52	0.030	2.3	300	7.0	14.40	5.54	3.9	20.0	1.60	2.1
8.40	0.85	37	2.43	0.041	6.5	300	8.0	20.70	0.14	4.9	28.0	15.20	2.7
8.50	0.42	42	3.84	0.017	8.9	330	10.0	30.80	0.16	5.6	41.0	17.40	2.0

Results and Discussion

Nutrient Contents

Macro (N, P, K, Ca+Mg, SO_4^{2-}-S) nutrients: Total nitrogen and available phosphorus ranged from 0.01 to 0.072% (average 0.04%) and 0.3 to 12.6 mg kg^{-1} with an average of 5.89 mg kg^{-1} soil, respectively. This difference might be due to difference in natural fertility of the paddy soils. The cultural practices like sowing of berseem in some fields might also have affected their nitrogen contents. According to the standards suggested by Gunning and Hubbard's (Jackson, 1962) for soil nitrogen (Table 2), about 40% of the soil samples were deficient in total N, 15.55% had low, only 17.77% were satisfactory and 26.66% were high in total N contents for normal rice plant growth. Nitrogen deficiency in paddy soils may also be due to the chemical reactions occurring under reduced conditions, i.e. denitrification, ammonia volatilization, clay fixation, losses in run-off water and deep percolation (Patrick *et al*., 1985). On the basis of standards laid down by Watanable and Olsen (1965), about 17.77% samples were deficient, 33.33% low, 17.77% satisfactory and only 31.11% had high P contents (Table 2). The main reason for this low available P content in gley paddy soils was their low P release rate, high P fixation capacity and leaching of P under long-term submergence (Xiao, 1988). Results indicated that P is generally deficient in rice growing areas because it forms insoluble compounds with Ca like Ca-phosphate, dicalcium and tricalcium phosphate due to alkaline and calcium nature of the soil.

The extractable K ranged from 200 to 580 mg kg^{-1} soil with an average of 303 mg kg^{-1} soil in the paddy fields. According to the quantitative standards proposed by Ge and Su (1986), none of the soil samples indicated deficiency of K i.e. 100% samples had sufficient extractable K required for the normal plant growth. Due to dominance of clay minerals like hydrous mica or illite, canal irrigation system, K is not deficient in Pakistan's soils. It is evident that the range of soluble Ca+Mg range in the paddy fields is 4 to 11 me l^{-1} with an average of 6.73 me l^{-1} (Table 2). All the values obtained were in satisfactory range according to the standards suggested by Harding and Chapman (1950).

The sulphate-sulphur level of paddy soils indicated that rice fields differed in soil S contents in the rice-growing track of the Punjab. The sulphate-sulphur of these paddy soils varied from 2.8 to 40.08 mg kg^{-1} with an average of 19.26 mg kg^{-1} soil (Table 2).

Out of the 45 analyzed paddy soil samples 4.44% were deficient, 6.66% had marginal status and rests of all the samples were adequate in sulphate-sulphor (Bansal *et al*., 1979). Sulphur deficiency is not widespread in rice and sulphur fertilization was not common as N, P, K and Zn fertilization (Patrick *et al*., 1985). In general, sulphur in paddy soils was favourable due to the use of SSP and SOP as a source of P and K and sulphate based NPK fertilizers.

Micro (Zn, Cu, Fe, Mn, B) nutrients: The paddy soils differed with regard to their average contents of DTPA extractable Zn in soil (Table 2). The available Zn in the paddy soil ranged from 0.04 to 1.84 mg kg^{-1} with an average value of 0.53 mg kg^{-1} soil. According to the quantitative standards proposed by Lindsay and Norvell (1978), out of the 45 analyzed soil samples, 60% were deficient, 22.22% marginal and 17.77% were adequate in available Zn contents. The CO_3, HCO_3 relationships, organic fermentation products, sulphide formation, interaction and antagonisms such as Zn-N, Zn-Fe, Zn-P and Zn-Cu were considered the main factors associated with the Zn deficiency in submerged paddy soils (Patrick *et al*., 1985). The DTPA extractable Cu in paddy soils ranged from 0.1 to 7.6 mg kg^{-1} with an average value of 3.22 mg kg^{-1} soil (Table 2). According to the standards (Lindsay and Norvell, 1978), out of the 45 analyzed paddy soil samples, only 4.5% were deficient in available Cu while about 95% were adequate. Results indicated that there was no iron deficiency in the paddy soils according to the standards outlined by Lindsay and Norvell (1978). The DTPA extractable Fe in paddy soils ranged from 5.6 to 41.0 mg kg^{-1} with an average of 16.01 mg kg^{-1} soil. Iron deficiencies are not common in flooded rice, because flooding enhanced the reduction and solubility of soil iron (Patrick *et al*., 1985). Ranjha *et al*. (1987) observed the similar results and reported no iron deficiency in Thikriwala project area of Faisalabad district.

It is apparent that DTPA extractable Mn contents of paddy soils ranged from 0.2 to 62.4 mg kg^{-1} with an average of 10.36 mg kg^{-1} soil (Table 2). Results indicated that out of 45 analyzed paddy soil samples, 13.33% were deficient while the rest were in adequate range according to the standards reported by Lindsay and Norvell (1978). This higher amount of Mn in the paddy soils might be due to its higher solubility caused by reduction of Mn following flooding. The available B ranged from 1.2 to 4.9

Table 2: Ranges and means of physical, chemical and nutritional properties of soils collected from the paddy soils of the Punjab

Properties	Unit	Range	Mean
pH	-	7.1-8.5	8.12
Organic matter	%	0.21-1.45	0.75
Clay	%	13-50	33.53
Calcium carbonate	%	1.06-3.95	2.39
Total N	%	0.01-0.072	0.04
Available P	ppm	0.30-12.6	5.89
Extractable K	ppm	200-580	303.00
Soluble Ca+Mg	me l^{-1}	4-11	6.73
Sulphate-sulphar	ppm	2.8-40.08	19.26
DTPA-TEA extractable Zn	ppm	0.04-1.84	0.53
Copper	"	0.10-7.60	3.22
Iron	"	5.60-41.00	16.01
Manganese	"	0.20-62.40	10.36
Boron	"	1.20-4.90	2.36

Table 3: Correlation co-efficient between soil attributes and available nutrient status in the paddy soils of the Punjab

Soil attributes	N	P	K	Ca+Mg	S	Zn	Cu	Fe	Mn	B
pH	-0.132	0.258	0.114	0.051	-0.072	-0.259	0.139	0.236	-0.316*	-0.213
Organic matter	0.969**	0.116	0.015	-0.146	0.054	0.272	-0.113	-0.034	0.132	0.158
Clay	0.272	-0.007	0.325*	-0.082	0.014	0.029	0.037	0.009	0.372*	0.269
Calcium carbonate	0.010	0.038	0.103	0.146	-0.084	-0.081	0.415*	0.300	0.360*	0.098

* = Significant at 5% level of probability ** = Significant at 1% level of probability

mg kg^{-1} with an average of 2.36 mg kg^{-1} soil (Table 2). According to the quantitative standards proposed by Reisenaure *et al*. (1973), almost all the 45 soil samples were in the normal range of available B content in the paddy soils.

Effect of soil properties on the nutrient availability:
Soil reaction (pH_s): Results depicted that a negative but non-significant correlation of pH with N and SO_4-S, while positive and non-significant with P, K and Ca+Mg contents of the soils (Table 3). Cheema and Arora (1984) observed the similar results and reported that available SO_4-S negatively correlated with pH of the Ludhiana district. At high pH, sulphate combine with Na and for sodium sulphate (Na_2SO_4), which is a mild neutral salt and is leach able. So sulphur with sodium leach down due to which the sulphur availability decreases at high pH.

Soil pH showed a negative correlation with DTPA-Zn and significant negative correlation with DTPA-Mn (-0.316*) contents of the soil (Table 3). It is evident that positive but non-significant correlation was noted between pH, DTPA-Cu and Fe contents of the soil. A decrease in Zn and Mn availability with an increase in pH has been reported by many workers (Kausar *et al.,* 1979; Qureshi and Anjum, 1977; Patel and Dangarwala, 1984). The decreased availability of Zn with an increase in soil pH was attributed to the formation of insoluble Zn-hydroxide (Seatz and Jurinak, 1957). The low availability of Mn at high pH might be due to the conversion of divalent form of manganese into trivalent form (Truog, 1946).

Organic matter: The organic matter content of the paddy soils ranged from 0.21 to 1.45%. Organic matter showed significant and positive correlation (0.969**) with N, while non-significant and positive correlation with P, K, SO^{-2}_4-S, Zn, Cu, Mn and B contents of the soil. It is evident that negative but non-significant correlation was noted with Ca+Mg, Cu and Fe contents (Table 3). Positive correlation indicated that organic matter increases the availability of most of the nutrient elements (N, P, K, SO_4^{-2}-S, Zn, Cu, Mn, B). Organic matter contains most of the plant essential elements. Upon decomposition these becomes available to the plants. The presence of organic matter may promote the availability of certain elements, presumably by supplying soluble complexing agent that interferes with their fixation in the soil. Decomposition of organic matter produces certain organic acids, which lower the pH of the soil (Bandyopadhya and Adhikari, 1968), which ultimately increased the availability of nutrient elements. Kausar *et al.* (1979) and Qureshi and Anjum (1977) reported that organic matter increased the availability of most of the micronutrients.

Clay and calcium carbonate ($CaCO_3$) contents: Clay contents showed significant and positive correlation of 0.325* with K and 0.372* with Mn (Table 3). It showed non-significant correlation with N, P, Ca+Mg, Zn, Fe, etc (Table 3). Depending upon the critical limit of 1.00 ppm DTPA-Mn as suggested by Lindsay and Norvell (1978), it appeared that Mn was present in sufficient amounts in the soil. Calcium carbonate showed significant positive correlation (0.415*) with Cu and 0.360* with Mn but non-significant negative correlation with SO_4-S and Zn (Table 3). Results indicated that non-significant correlation with N, P, K, Ca+Mg, Fe and B contents of the paddy soils was noted in the present investigations.

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