Effect of Micronutrients on Production of Maize (*Zea Mays L.*) in the Acid Soils of Chitwan Valley

D.P. Sherchan[1], R. Upreti[2] and S.L. Maskey[2]
[1]National Maize Research Programme, Rampur, Nepal
[2]Soil Science Division, NARC, Kathmandu, Nepal

Abstract

Field experiments were held during the summer and winter seasons of 2003 and 2004 respectively in the acid soils of the National Maize Research Programme's (NMRP) farm. The objectives of the study were to identify which micronutrients were deficient in the soils and the effect on grain production, and to recommend micronutrients that would improve the quality and quantity of the produce. No significant yield advantage was found between the recommended amounts of major plant nutrients nitrogen (N), phosphorous (P_2O_5) and potash (K_2O) at a rate of 120:60:40 kg per hectare and the various combinations of micronutrients: sulphur (S), boron (B), zinc (Zn), molybdenum (Mo), iron (Fe), and copper (Cu). The same was found for stover yield and thousand grain weight of maize. The productivity of maize was found to be somewhat higher in winter than in summer with the same treatment and variety of maize. Response to micronutrients was not consistent in the two seasons. In the summer season all micronutrients demonstrated a response except for sulphur. The crop yield decreased in the absence of B, but there was no significant difference from the treatment without micronutrients. In the winter season, there was an indication of deficiency of S only and there was no response to other micronutrients. Nitrogen (N) and potassium (K) uptakes by maize grains were higher with the application of major and micronutrients but there was no significant difference except with the control plot. The treatment without sulphur also gave a significantly lower uptake of N and K, but phosphorous (P) uptake was not significant compared to the control plot. Nitrogen was recorded as deficient in leaf samples in the summer season, whereas P and K were adequate. During the winter season N, P, and K were adequate in the leaf samples. Diethylene triamine penta acetic acid (DTPA) extractable Zn was found to be below the critical level while Fe and manganese (Mn) were adequate. Zinc content in maize leaf was deficient, whereas Cu and Mn were in the normal range and Fe was in excess. A significant relationship was found between Zn and Mn content in the leaf and soil test, but not for Fe.

Introduction

The importance of essential micronutrients in Nepal was realised about two decades ago when wheat sterility problems were encountered in the eastern part of the country. At that time the micronutrient identified was boron. In areas where intensive agriculture is practised application of zinc has become a regular feature. In addition, the problem of micronutrients has been observed especially in the context of horticultural crops such as fresh vegetables and citrus fruits. Boron and magnesium are the most constraining nutrients for cauliflower from a quality perspective (Baral et al. 1986; Khatri-Chhetri and Karki 1979). Khatri-Chhetri and Schulte (1984) found B and Zn were the most limiting nutrients for the soils of the Chitwan Valley. Further, Khatri-Chhetri and Schulte (1985) reported that maize responded to the application of N and P, secondary nutrients, and micronutrients. There has been a tendency to ignore the quality aspect. But gradually it has been realised that agricultural produce must contain adequate levels of essential macro and micronutrients because of their important role in human nutrition (Darrell 1991).

The soil of the Rampur agricultural farm has the typical composition of soils in the Chitwan Valley, which are also found in the upper piedmont of the Terai region; these have been recognised as young alluvium soils. The soils are strongly acidic and very light textured. The clay content is less than 12%. The effective soil depth is very shallow. The cation exchange capacity (CEC) of soils is in the range of 1 to 2 m.e./100g of soil. Since the establishment of the farm, mono-cropping (maize only) has been practiced. In 1981, sulphur was identified as an essential micronutrient for the farm (Dr SP Pandey personal communication 2003). A few years ago, efforts were introduced to improve the soil quality by growing green manure crops and applying compost. In addition, borax and zinc sulphate are applied regularly. Following this, there was an improvement in crop productivity. However, application of micronutrients is very expensive, and indiscriminate application could cause toxicity in the soil in the long run. Usually, farmers do not grow green manure crops on upland to enrich the soil. Decline in productivity is widespread among similar types of soils in the valley and elsewhere where maize and vegetables are grown in a rotation. In this context, an experiment was designed to identify the limiting micronutrients and their effect on maize production and to recommend the micronutrients that could improve the productivity and quality of maize.

Materials and Methods

Field experiments were carried out during the summer and winter seasons of 2003 and 2004 in a randomised complete block design (RCBD) with four replications. The experimental plot size was 4.5 X 5.0m. The net harvest area for yield estimation was 15m^2. The row to row and plant to plant spacings were 75 and 25 cm respectively. The maize variety used in the experiment in both seasons was Rampur Composite. The seed rate was 20 kg/ha. For the summer season, maize was sown on 28 May 2003 and the crop harvested on 4 September 2003; for the winter season, maize was sown on 25 September 2003 and harvested on 26 February 2004.

Ten treatments of various combinations of chemical fertilisers containing zinc, iron, boron, molybdenum, sulphur, copper, and manganese were given as summarised below.

T1 = Control without organic manure or chemical fertiliser
T2 = 120:60:40 kg N:P_2O_5:K_2O/ha
T3 = T2+ B (5 kg/ha), Zn (5 kg/ha), Mo (0.5 kg/ha), S (20 kg/ha), Mn (12 kg/ha), Cu (5 kg/ha), and Fe (12 kg/ha)
T4 = Similar to T3 except B not applied
T5 = Similar to T3 except Zn not applied
T6 = Similar to T3 except S not applied
T7 = Similar to T3 except Mn not applied
T8 = Similar to T3 except Fe not applied
T9 = Similar to T3 except Cu not applied
T10 = Similar to T3 except Mo not applied

The sources of fertilisers were urea, di-ammonium phosphate (DAP), muriate of potash (MOP), ammonium molybdenum, zinc sulphate, borax, copper sulphate, cupric oxide, iron sulphate and iron oxide, manganese oxide, iron oxide, and zinc chloride. All the required micronutrients, phosphorous, and potash were applied according to the treatments as a basal application. However, nitrogen (N) was split into two applications with half applied as basal and the remaining half side dressed when the maize crop was at knee height.

Plant samples were taken at random from six plants from an experimental plot when the crop was at maximum vegetative stage. After crop harvest, grains were analysed for N, P, and K contents. Soil samples were taken before planting and after crop harvest and analysed for DTPA extractable Zn, Mn, Cu, and Fe. Standard methods were followed to analyse soil and plant samples at the Soil Science Division (SSD), Khumaltar.

Results and Discussion

Thousand-grain weight, grain, and stover yields

There was no significant effect of treatment on thousand-grain weight in either season, the only difference was that the seeds were heavier during the winter than in the summer season (Table 1). There was no significant effect of the treatments on the grain and stover yield in the summer season but there was a highly significant effect in the winter; the yield difference was significant only between the control plot and the rest of the treatments (Table 1), but not among treatments. Boron deficiency had been suspected since Khatri-Chhetri and Karki (1979) reported a high response of cauliflower to borax application at a rate of 10 kg/ha. However, no response to B application was recorded in the maize in either season. Khatri-Chhetri and Schulte (1985) found an increase in the yield of maize due to application of Cu, S, and Mg in a multi-locational trial. In this experiment, omission of S, B, or Cu did not affect the yield. The relationship between thousand-grain weight and grain yield in the summer season was not significant; but during the winter a significant result was obtained with R^2 = 0.591. In both seasons a significant relationship was demonstrated between the stover and grain yields of maize (Figure 1).

Higher productivity from the September planting

The productivity of maize from the September planting was five to six times higher than for the summer maize (or April/May) planting with the same variety of maize (Rampur composite). The reason could be greater efficiency of nutrient uptake by crops in that season and the longer growing period. Schmidt et al. (1978) reported similar results; but they found no difference in productivity among local varieties between summer and winter seasons. They further reported that during the summer infestation with insects and diseases was greater than in winter.

N, P, and K content in maize leaves

There was a substantial difference in N and P content in the ear leaves of maize between the seasons. The N and P contents in the leaf samples were greater during the winter season. Little difference was found in K content between seasons (Table 2). The concentrations of P and K in the plant tissue were higher than the critical value in both seasons, showing that P and K are not a problem in the Rampur farm soil. The critical values of N, P, and K are 2.75, 0.24 and 1.74% respectively, as cited by Khatri-Chhetri and Schulte (1984), thus the concentration of N was below the critical value in the summer season, but above the critical value in the winter season. The productivity of maize irrespective of the treatment corresponded to the concentration (Figure 2). The results show that efficiency of applied nutrients is high during the winter and low in the summer. The main reason could be the loss

Table 1: Thousand-grain weight (THW), grain weight (GRW) at 12 % moisture and stover yield (STV) of maize (sun dried)						
Treatment	Summer season 2003			Winter season 2003/04		
	THW (g)	GRW (kg/ha)	STV (t/ha)	THW (g)	GRW (kg/ha)	STV (t/ha)
T1 control	313.1	794	4.74	424.5	3875	5.99
T2 NPK only	325.2	1616	6.69	465.8	6615	9.35
T3 NPK+all MTs	333.5	1422	6.63	451.1	6845	10.06
T4 (T3-B)	312.9	1264	5.78	480.9	7576	9.98
T5 (T3-Zn)	253.4	1404	6.32	485.8	6898	10.91
T6 (T3-S)	327.2	1841	7.06	476.2	6212	9.36
T7 (T3-Mn)	324.3	1451	6.24	481.2	6992	10.09
T8 (T3-Fe)	335.9	1446	5.98	454.0	7007	9.75
T9 (T3-Cu)	322.8	1308	5.47	478.8	7118	10.73
T10 (T3-Mo)	314.3	1571	5.90	487.2	6966	10.22
F test	NS	NS	*	NS	**	**
SED	34.1	344.7	0.67	23.46	482.3	0.92
LSD	–	707.4	1.37	48.14	989.7	1.88
CV %	5.3	34.5	15.5	7.1	10.3	13.4

THW = thousand grain weight; GRW = grain weight; STV = stover yield; F test or F -ratio = ratio of variance; SED = standard error deviation; LSD = least square deviation; CV = coefficient of variation ; NS = not significant

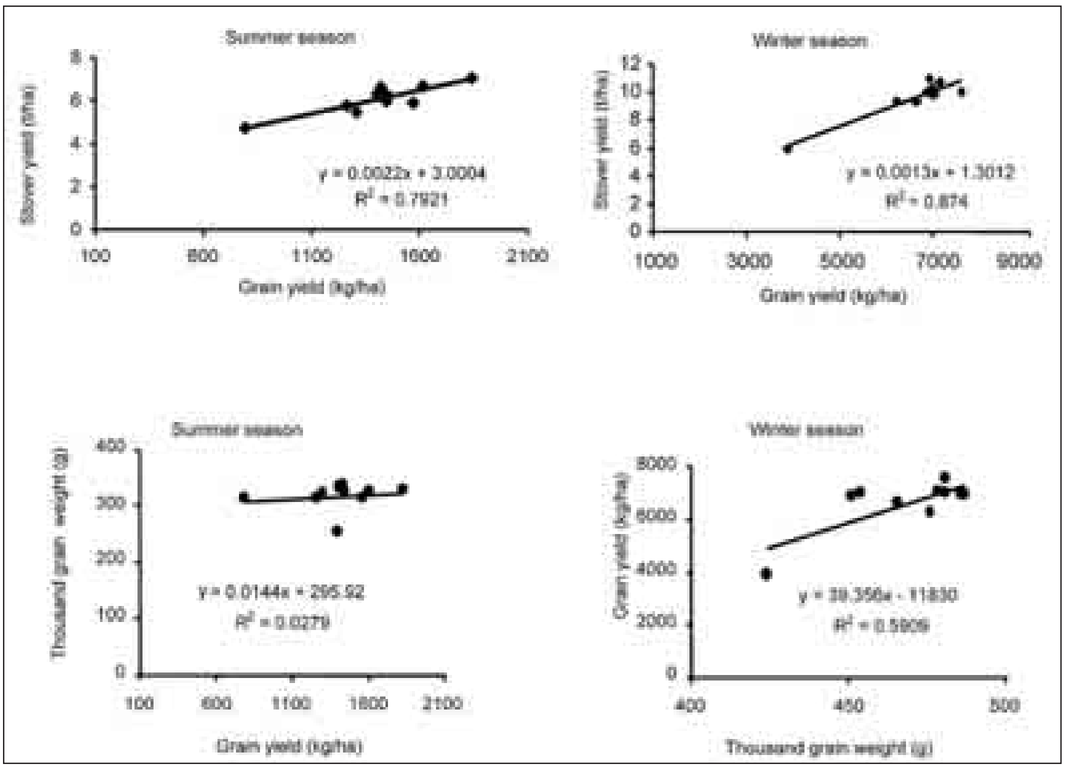

Figure 1: **Relationship between thousand-grain weight, stover yield, and grain yield of maize in the summer and winter seasons**

Table 2: **N, P, and K content in maize leaves at the tasselling stage**

Treatment	Summer season (2003) (leaves)			Winter season (2003/04) (leaves)		
	N%	P%	K%	N%	P%	K%
T1 control	1.42	0.473	2.406	2.33	0.92	2.55
T2 NPK only	1.87	0.434	2.727	3.07	0.90	2.93
T3 NPK+all micro	1.29	0.367	2.748	3.17	0.97	2.82
T4 (T3-B)	1.59	0.543	2.538	3.23	0.91	3.13
T5 (T3-Zn)	1.90	0.406	2.550	3.14	0.79	2.77
T6 (T3-S)	1.79	0.440	2.760	3.14	1.09	2.93
T7 (T3-Mn)	1.93	0.337	2.573	2.70	1.05	3.02
T8 (T3-Fe)	1.80	0.404	2.631	3.22	1.06	3.11
T9 (T3-Cu)	1.73	0.472	2.573	3.06	0.85	3.13
T10 (T3-Mo)	1.69	0.169	2.583	3.15	0.76	3.24
F test	*	NS	NS	NS	NS	NS
SED	0.195	0.1158	0.212	0.3026	0.1481	0.1967
LSD	0.3997	0.2373	0.4346	0.620	0.3036	0.4032
CV%	16.3	40.5	11.5	14.1	22.5	9.4

F test or F-ratio = ratio of variance; S ED = standard error deviation; LSD = least square deviation;
CV = coefficient of variation ; NS = not significant

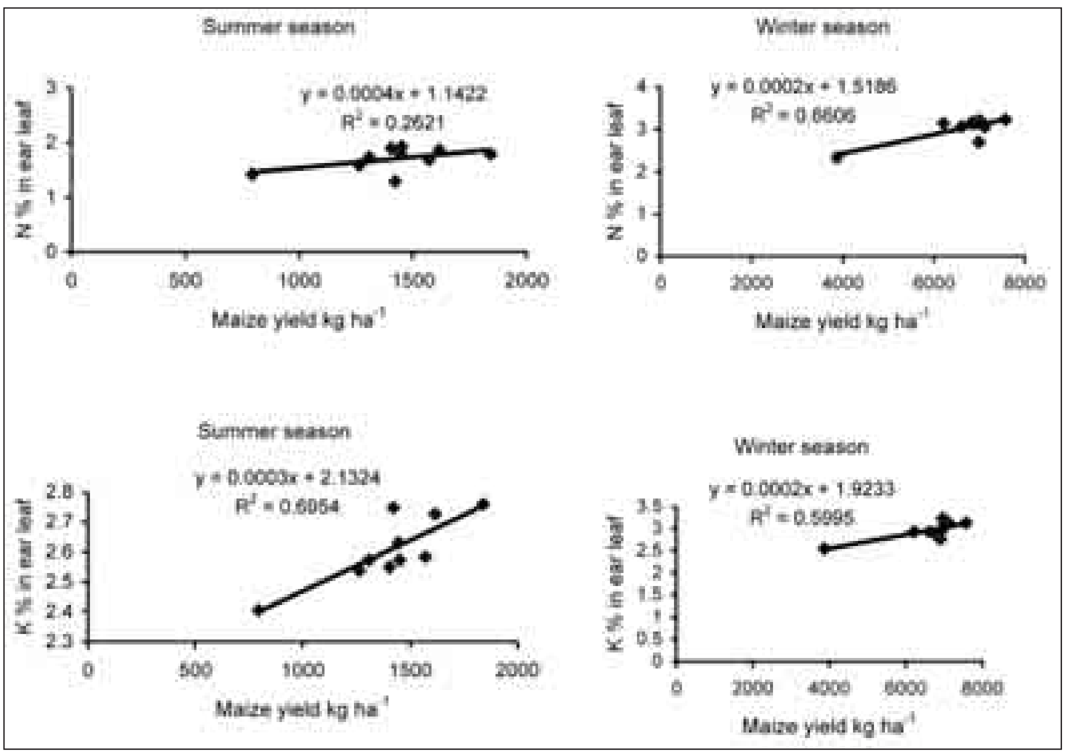

Figure 2: **Relationship between maize yield and nutrient (N&P) content in the ear leaf**

of N in the form of nitrate through leaching in summer, since the Rampur soils are light textured and quite porous.

A significant relationship was observed between the maize yield and N content of the ear leaves in winter, but in the summer, the relationship was not significant. The relationship between the K content and the maize yield in both seasons was significant, whereas no relationship was observed between the P content in the ear leaf and the maize yield in either season (Figure 2). This shows that N and K contributed strongly to the maize yield.

Uptake of N, P, and K by grains

P uptake by grain was not affected by the application of micronutrients in the winter season. However, the mean uptake decreased to 10.81 kg/ha in the absence of Mn, which was the lowest value in any plot. The lowest values for N uptake by grain (65.3 kg/ha) was found in the control plot. N uptake was not affected by application of specific micronutrients (Table 3). However, there was an indication that N uptake might be affected if S is not applied. A similar trend was observed for K. The lowest uptake of K was in the control plot (16.74 kg/ha), and there was no significant difference between the rest of the treatments, except for the treatment in which S was not applied. After the control plot, the treatment without S showed the second lowest K uptake (23.3 kg/ha).

DTPA Extractable micronutrients

The levels of DTPA extractable micronutrients in soil after the winter harvest are shown in Table 4 together with some other soil fertility attributes. DTPA extractable Zn was below the critical limit, whereas Fe and Mn were adequate and above the critical values cited by Pandey and Bhandari (1984). Das (2000) also cited that the critical level of Zn in soils for maize crops is in the range of 0.38 to 1.0 mg/kg. Since there is an antagonistic effect between P and Zn, the availability of Zn is restricted despite the soil being acidic. The maize did not

Table 3: **N, P, and K content in grain and uptake in 2003/04 winter season**

Treatment	N,P, and K content in grains			N, P, and K uptake (kg/ha)		
	N%	P%	K%	N	P	K
T1 control	1.64	0.399	0.420	65.3	15.31	16.74
T2 NPK	1.52	0.265	0.456	101.2	18.36	30.13
T3 NPK+all micro	1.45	0.417	0.410	99.35	28.6	28.15
T4 (T3-B)	1.56	0.338	0.410	118.34	25.79	31.17
T5 (T3-Zn)	1.60	0.392	0.410	109.94	27.36	28.48
T6 (T3-S)	1.56	0.367	0.375	97.01	22.53	23.30
T7 (T3-Mn)	1.69	0.152	0.423	118.54	10.81	29.62
T8 (T3-Fe)	1.62	0.398	0.423	113.42	27.86	29.74
T9 (T3-Cu)	1.47	0.260	0.443	105.28	17.68	31.53
T10(T3-Mo)	1.56	0.325	0.410	108.86	22.29	28.73
F test	NS	NS	NS	**	NS	**
SED	0.1156	0.1723	0.0321	12.03	10.86	3.345
LSD				24.66	22.26	6.86
CV%	10.4	73	10.9	16.4	71	17.0

F test or F-ratio = ratio of variance; S ED = standard error deviation; LSD = least square deviation;
CV = coefficient of variation ; NS = not significant

Table 4: Soil pH, SOM, P, and DTPA extractable micronutrients after the crop harvest in the 2003/4 winter season						
Treatment	DTPA extractable (ppm)			Some soil fertility attributes		
	Zinc (Zn)	Iron (Fe)	Manganese (Mn)	pH	SOM %	Avl. P kg/ha
T1 control	0.154	111.6	29.52	4.8	1.89	156.1
T2 NPK only	0.332	109.0	30.40	4.87	1.90	124.8
T3 NPK+all micro	1.090	108.1	31.20	4.52	2.01	165.2
T4 (T3-B)	0.506	106.8	31.42	4.72	1.98	86.1
T5 (T3-Zn)	0.564	112.7	31.04	4.82	2.27	165.7
T6 ((T3-S)	0.534	113.3	30.98	4.52	2.19	134.8
T7 (T3-Mn)	0.518	112.9	31.10	4.62	2.03	222.6
T8 (T3-Fe)	0.748	112.1	31.88	4.60	1.96	104.8
T9 (T3-Cu)	0.732	112.6	32.76	4.70	2.25	124.3
T10 (T3-Mo)	0.544	111.8	32.80	4.75	2.44	94.3
F test	**	NS	**	NS		
SED	0.1732	4.402	0.520	0.112		
LSD	0.3552	9.030	1.168	0.2306		
CV%	42.9	5.6	2.4	3.4		

F test or F-ratio = ratio of variance; SED = standard error deviation; LSD = least square deviation;
CV = coefficient of variation ; NS = not significant; SOM = soil organic matter

respond to Zn despite low availability in the soil. This shows that the critical value for maize is not well correlated in the Rampur farm soils and environment. The analysis of the remaining nutrients is in progress, as a result, conclusive recommendations cannot be given in this paper. Since the soils are acidic, availability of molybdenum (Mo) was one factor considered, but no significant response was observed. High P availability has a synergetic effect on Mo, and this could be a reason for the lack of response to Mo application (Das 2000). DTPA Zn and maize yield were correlated exponentially and found to be significant (Figure 3). Similarly, a significant relationship was observed between DTPA Mn and crop yield. However, the relationship was not significant in the case of Fe.

Leaf content of micronutrients (Zn, Cu, Mn, and Fe)

Zinc content in the leaf samples of maize at the tasselling stage was in the deficient range (Table 5). However, zinc content in the leaves receiving those treatments in which zinc was supplied was in the normal range apart from the treatment without sulphur whose results indicated Zn as deficient. The difference in Zn content among the treatments was not significant (Table 5). Manganese was in the range from normal to excess. The control plot showed a significant difference from other treatments in Mn content. However, leaves from the plot to which Mn was not supplied, but to which other micronutrients were supplied were found to have significantly greater Mn content (Table 5). Copper was in the normal range (Table 5) and significantly lower than the rest of the treatments, except for T1, T2, and T6. But again the treatment without Cu but with other micronutrients was found to be greater in Cu content. Iron was excessive in all the treatments (Table 5).

There was a significant relationship between micronutrient content in the ear leaves of maize at the tasselling stage, and DTPA extractable Zn and Mn (Figure 4). There was no relationship, however, between the Fe in soils and plant samples. Because of the significant correlation, DTPA could be applied to improve the micronutrients in soils.

No significant relationship was found between the maize grain yield and content in grain of Zn, Fe, and Mn (Figure 5).

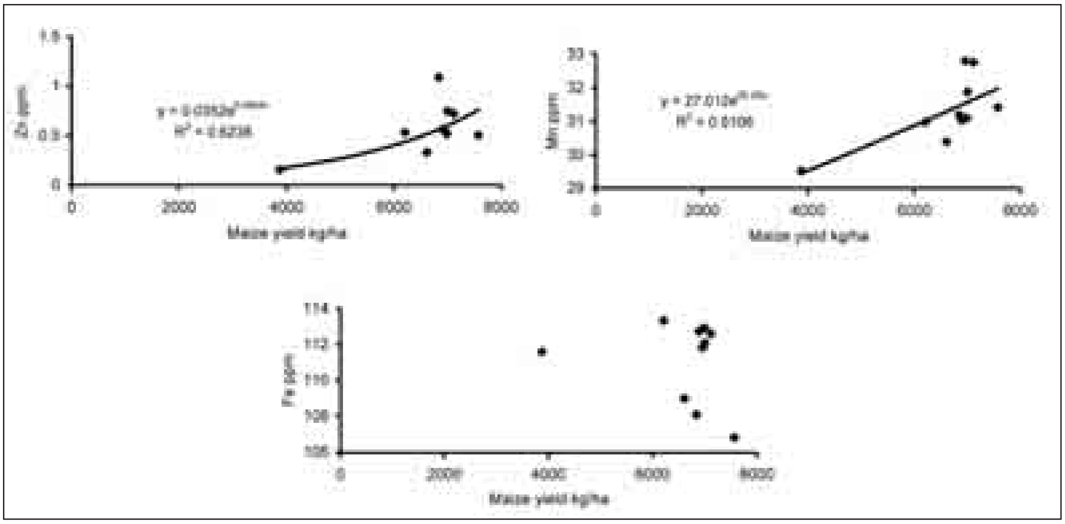

Figure 3: **Relationship between DTPA extractable Zn, Mn, and Fe and maize yield in the winter of 2004**

Table 5: Zn, Mn, Cu, and Fe content in the ear leaves and maize grains (ppm)

Treatments	Micronutrients in the ear leaves at tasselling stage (ppm)				Micronutrients in maize grains after harvest (ppm)			
	Zn	Mn	Cu	Fe	Zn	Mn	Cu	Fe
T1 control	14.2	151	7.9	9387	15.2	532	10.7	26768
T2 NPK only	10.9	205	8.3	10121	14.4	535	11.2	26951
T3 NPK+all micro	30.7	271	9.8	10495	20.0	538	10.5	27126
T4 (T3-B)	27.4	263	11.0	10831	18.6	542	11.1	27490
T5 (T3-Zn)	13.4	277	10.1	11166	18.8	547	11.4	27523
T6 ((T3-S)	16.6	265	9.3	11177	18.9	548	11.6	27704
T7 (T3-Mn)	20.5	263	10.1	11812	21.3	552	11.5	27908
T8 (T3-Fe)	23.4	280	9.3	12021	22.4	556	11.7	27913
T9 (T3-Cu)	27.2	324	11.5	12371	16.0	563	11.4	28018
T10 (T3-Mo)	30.3	331	10.8	12547	22.1	561	12.5	28233
F test	NS	**	*	**	NS	**	NS	**
SED	8.26	33.8	1.03	421.2	3.35	4.461	0.69	109.1
LSD	16.92	69.22	2.12	862.5	6.8	9.14	1.41	219.2
CV%	52	12	14.8	5.3	24	1.2	8.5	0.5

F test or F-ratio = ratio of variance; SED = standard error deviation; LSD = least square deviation;
CV = coefficient of variation; NS = not significant

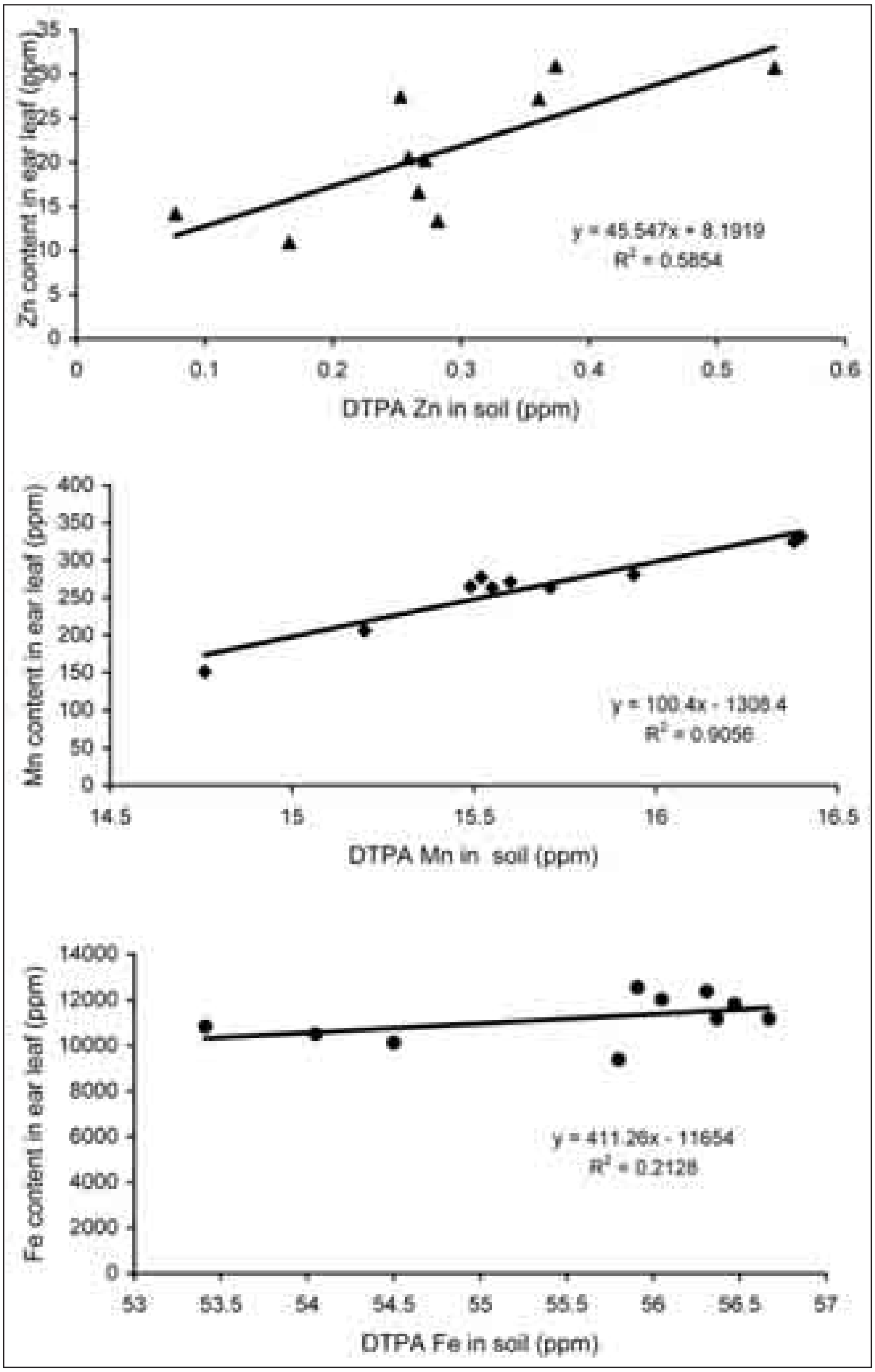

Figure 4: **Relationship between DTPA extractable Zn, Mn, and Fe in soils and content in ear leaves of maize**

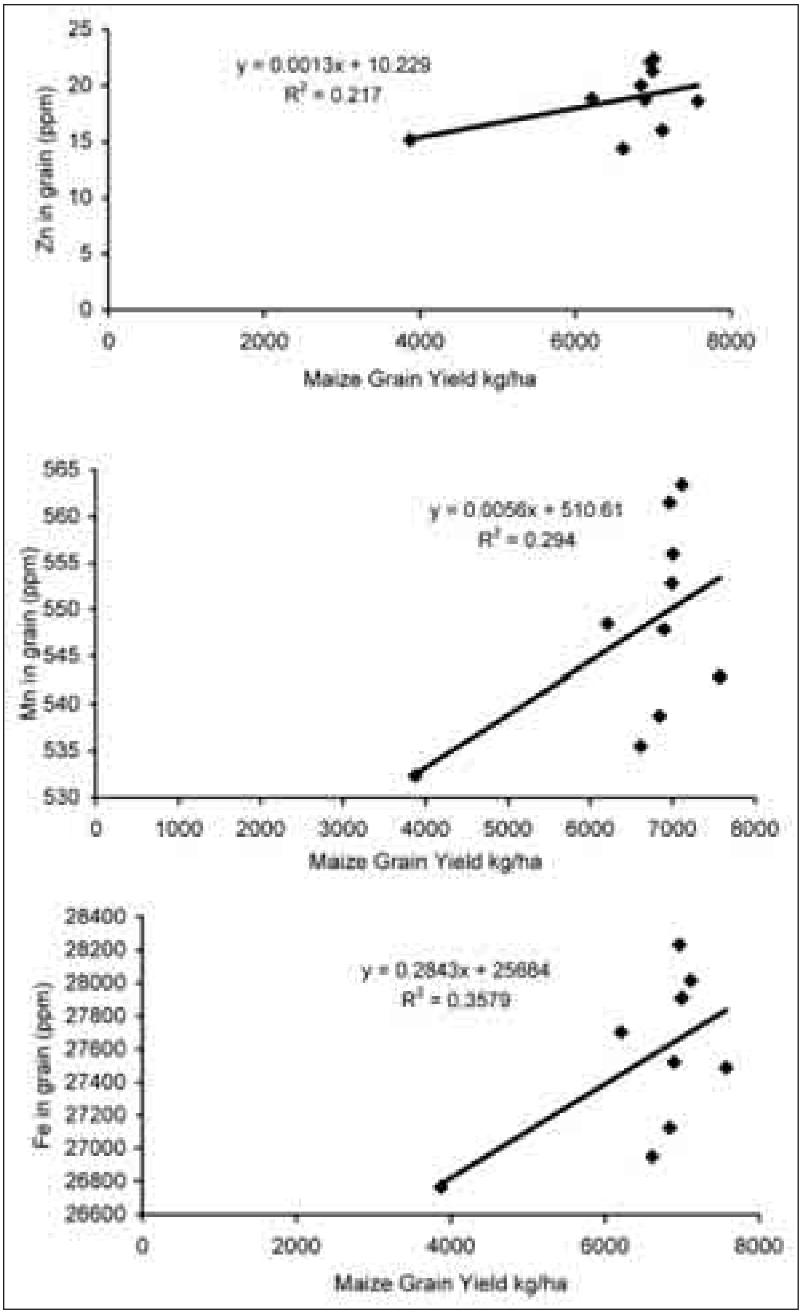

Figure 5: **Relationship between the maize grain yield and micronutrient content in grains**

Conclusions

Maize demonstrated no statistically significant response to micronutrients applied to soils in either the summer or winter seasons. The productivity of maize was more responsive to the planting season. The same level of nutrients from various fertilisers was applied to soils in both seasons, but crop production was higher in September planted maize. Although there was an indication of response to micronutrients, the results were inconsistent. No significant relationship was found between N and K content in leaf samples and grain yield. No relationship was found for P content; uptake of P by maize grains was not affected by the treatments. N and K uptakes were lowest in the control plot. K uptake was second lowest when S was not supplied. Similarly, there was an indication of a lower N uptake by grains. DTPA Zn and Mn in soil samples had a significant relationship with maize yield. No relationship was found with Fe. Similarly, there was no relationship between DTPA Fe and Fe content in the leaves. However, a significant relationship was seen between nutrient content in leaves and the DTPA soil tests for Zn and Mn.

Not all micronutrient tests could be carried out due to the lack of facilities in Nepal. In future more attention should be given to laboratory tests and field experiments, and these should be looked at from both the productivity and nutritional point of view.

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