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Spatial Variability of P/Zn Ratios on Calcareous Soil Under the Wheat Plants (*Triticum aestivum*)

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One of the main reasons of available Zn deficiency of the soils is excessive application of phosphorus (P) fertilizers. However, the ratio of P/Zn in the field soil is essential for optimal Zn use by the crops; there is little information concerning this ratio depending on varied soil and plant conditions. In this study, topsoil (0–20 cm), subsoil (20–40 cm) and plant samples were collected from the plots based on a 25 × 25 m grid under the wheat plants. The coefficient of variance (C.V.), kurtosis and skewness values revealed that a great spatial variability occurred in available P, Zn and P/Zn ratio for topsoil. Contour map of site-specific Zn contents indicated that the experimental topsoil had mainly sufficient amounts of available Zn (average 0.85 mg kg^{-1}), whereas, three dimensional map of Zn concentrations of wheat plants indicated that about 98% of the plants on these soils had a low level of Zn (11–20 mg kg^{-1}). Significant correlation, $r = 0.48$ and $P < 0.01$, was also found between the site-specific P/Zn ratios in the topsoils and P/Zn ratios in the wheat plants. The findings clearly show that the site-specific P/Zn ratio in the field soil was an important factor for maximum Zn utilization by the wheat plants. Hence, fertilization programme based on site specific P and Zn demands of the wheats will increase Zn use efficiency of the plants with proper P/Zn ratios. Contour maps based on proper site-specific samplings will provide more accurate information for balancing P/Zn ratios.

Key Words: Spatial variability, Phosphorus, Zinc, Calcareous soil, Wheat.

INTRODUCTION

It is generally known that the total zinc (Zn) content in the field soils does not reflect the availability of this micronutrient for crop growth. Many soil and climatical conditions together with farmer managements can affect the availability of Zn in the fields. For example, it has been revealed that about 50% of cultivated areas in Turkey had a potential Zn deficit[1]. One of the main reasons of available Zn deficiency of the soils is an excessive application of phosphatic fertilizers.

In a study carried out on the sunflower and wheat fields containing high level of accumulated P, the soil Zn contents were found at highly insufficient levels[2] of 76%.

The utilization of P fertilizers by crops is generally low (10–20%) in the year of application[3]. Thus, site-specific P accumulations in the field soils reduce the uptake of some other nutrients such as Zn and Fe[4, 5]. Hence, the ratio of nutrients in the soil solution is also an important factor for maximum availability of other nutrients for crops[6]. On the other hand, nutrient ratios in the wheat genotypes were affected by Zn application differently and P/Zn ratio decreased due to increase of Zn concentration[7]. The P/Zn ratio both in grain and straw of barley also decreased significantly with increasing levels of Zn application[8]. Therefore, site-specific P/Zn ratios should be carefully considered for more effective fertilizer recommendations. On the other hand, many workers have used P/Zn ratios for the diagnosis of Zn deficiency. But they have not been widely applicable, because the P/Zn ratios may vary depending on varied plant species and experimental conditions[9].

Spatial variability of soil properties can make valuable contributions to the beneficial use of soil resources[10]. Contour maps based on spatial variability of non-mobile nutrients, such as P and Zn, will provide more accurate information for balancing P/Zn ratios. Hence, more realistic P fertilizer rates will apply to the field units having varied soil properties using precision farming[11], whereas conventional soil sampling methods estimate only average soil P levels in the field. The convensional soil sampling methods based on average samplings will also result in average P/Zn ratio in the field soils. It is difficult to overcome the problems of uniform distribution of these nutrients in fields. Franzen and Cihacek[12] have emphasized that non-mobile nutrient levels, such as P, K, Zn, were of primary importance for choosing grid sampling over a directed sampling approach. On the other hand, it should not be forgotton that the performance of site-specific fertilizer management systems depends on the quality of soil property maps developing for variable-rate fertilizer recommendations[13]. Thus, alternative methods should be evaluated for map quality with further studies.

EXPERIMENTAL

The study was carried out to determine spatial variability of site-specific P and Zn relationships on a wheat field having calcareous soil during the year 2005. Geographic Information System (GIS) position of the sampling area is 40-12-983-N and 035-39-990-E for first plot. Sadova wheat variety (*Triticum aestivum*) was planted to the sampling field. Starter fertilizer of 20-20-0 at the level of 150 kg ha^{-1} had been applied before the study based on convensional (uniform) management to the sampling field in December 2004. Nitrogen fertilizer as ammonium nitrate had been applied before the study at the level of 70 kg ha^{-1} in March 2005. Soil and plant samples were collected on May 2005. Topsoil (0–20 cm) and subsoil (20–40 cm) samples were taken based on 25 × 25 m grids. The air dried soils were secreened to pass through a 2 mm mesh. Plant samples were also collected from the same plots together with soil samplings.

The analysis for P and Zn concentration in the top of plant samples was made by ICP spectrometry[14]. In the experimental soil, DTPA-extractable Fe, Cu, Zn, Mn were determined by the method of Lindsay and Norvell[15]. The textural analysis was made by the method of Bouyoucos hydrometer[16] and organic matter content was made by the method of Walkey-Black. Determinations were also made of the available P analysis[17], exchangeable potassium[18], cation exchange capacity, pH[19] and $CaCO_3$.[20] Experimental data were subjected to statistical analysis using Stat Most package program[21]. Three-dimensional map for site-specific plant Zn values was also designed using MINITAB program.

In the experimental topsoils, average sand, silt and clay contents were 38.20%, 22.65% and 39.15%, respectively. Average value of $CaCO_3$ was 156.30 g kg^{-1}, pH was 8.88, organic matter content was 1.58% and cation exchange capacity was 35.58 me $100g^{-1}$. In the subsoils, average sand, silt and clay contents were 37.24%, 20.36% and 42.40%, respectively. Average value of $CaCO_3$ was 160.50 g kg^{-1}, pH was 8.88; organic matter content was 1.36% and cation exchange capacity was 34.11 me $100g^{-1}$. There was no salt problem in the experimental soils.

RESULTS AND DISCUSSION

Spatial variability of site-specific P and Zn values for topsoils, subsoils and plants on the wheat field were presented in Tables-1 and 2, respectively.

TABLE-1
SPATIAL VARIABILITY OF SITE-SPECIFIC P AND Zn VALUES (mg kg^{-1}) FOR TOPSOILS AND SUBSOILS ON THE WHEAT FIELD

Parameters	Min.	Max.	Mean	C.V. (%)	Kurtosis	Skewness
Topsoil:						
P	17.55	120.60	61.80	40.59	0.4648	0.8983
Zn	0.24	4.09	0.85	83.42	20.4970	4.3109
P/Zn	18.15	204.18	90.20	50.17	0.3583	0.7812
Subsoil:						
P	18.90	70.40	44.57	30.98	-0.8730	-0.0818
Zn	0.25	1.06	0.63	33.90	-0.5668	0.3758
P/Zn	25.46	243.87	81.23	54.39	6.9343	2.2183

TABLE 2
SPATIAL VARIABILITY OF SITE-SPECIFIC P AND Zn VALUES (mg kg^{-1}) FOR WHEAT PLANTS ON THE FIELD

Parameters	Min.	Max.	Mean	C.V. (%)	Kurtosis	Skewness
P	15.68	28.51	20.58	18.83	–0.8161	0.6237
Zn	8.61	20.47	12.68	20.55	2.2173	1.1662
P/Zn	90.8	223.4	165.7	18.79	0.1527	–0.0917

The coefficient of variance (C.V.), kurtosis and skewness values reveal that a great spatial variability occurrs for site-specific available P, Zn and P/Zn values in the field topsoil. Wilding classified the C.V. values as 0–15 (low), 16–35 (medium) and 36 (high) variable, respectively. Thus, C.V. values of 40.59, 83.42 and 50.17 determined for P, Zn and P/Zn were at high levels. The C.V. values of P, Zn and P/Zn for subsoil were less than those of topsoil. The available P contents for topsoil varied from 17.55 to 120.60 mg kg^{-1} and average P value was 61.80 mg kg^{-1}. In general, experimental topsoil has high and very high levels of site- specific available P amounts, meaning that available P is highly accumulated in topsoil. Karaman *et al.*[22] also showed that P values were more variable in topsoils than in subsoils since the topsoils have been frequently mixed with plowing activities and P fertilizer has been applied[23].

The coefficient of variance (C.V.), kurtosis and skewness values showed that a medium variability occurred for site-specific P, Zn and P/Zn values of the wheat plants. The C.V. values of 18.83, 20.55 and 18.79 were determined for P, Zn and P/Zn in the plants, whereas very highly P/Zn ratio of 223.4 was determined for the plants. It has also been emphasized that optimal P/Zn ratio should be at the levels of 100–150 for corn plant[24] and at the level of 140 for wheat plant[25] for balanced P and Zn nutrition. Erdal[7] has also revealed that P/Zn ratios of wheat genotypes varied between 93–132 under the +Zn condition, whereas the ratios varied between 250–310 under the -Zn condition. In the –Zn condition, Zn concentrations of the plants were detected between 10–12 mg kg^{-1} (very low level). Thus, high P/Zn ratios lead to significant Zn deficiency for plants.

Contour map of site-specific Zn contents for topsoil of the wheat field indicated that the experimental topsoil had mainly sufficient amounts of available Zn (Fig. 1). The available Zn contents varied from 0.24 to 4.09 mg kg^{-1}, and average Zn value was 0.85 mg kg^{-1}, whereas three-dimensional map of Zn concentrations for wheat

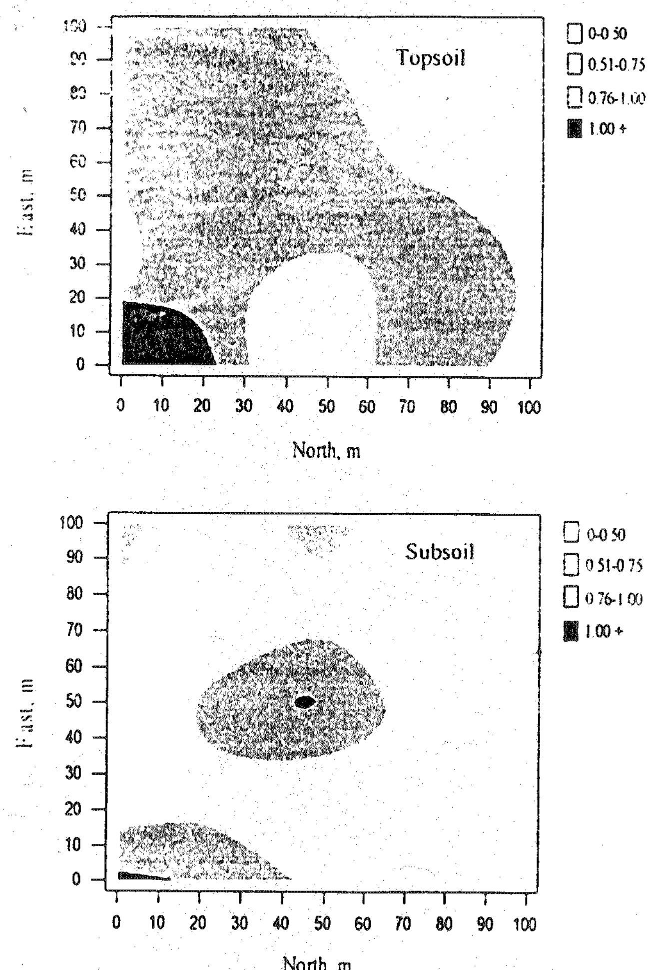

Fig. 1. Contour maps of available Zn for topsoil and subsoil; low = 0.50 mg kg^{-1}, sufficient = 0.50–1.00 mg kg^{-1} and high = 1.00 mg kg^{-1} according to Follett and Lindsay[29]

plants indicated that there was significant site–specific Zn deficiency in the wheat plants (Fig. 2.). The site-specific Zn concentrations of the plants varied from 8.61 to

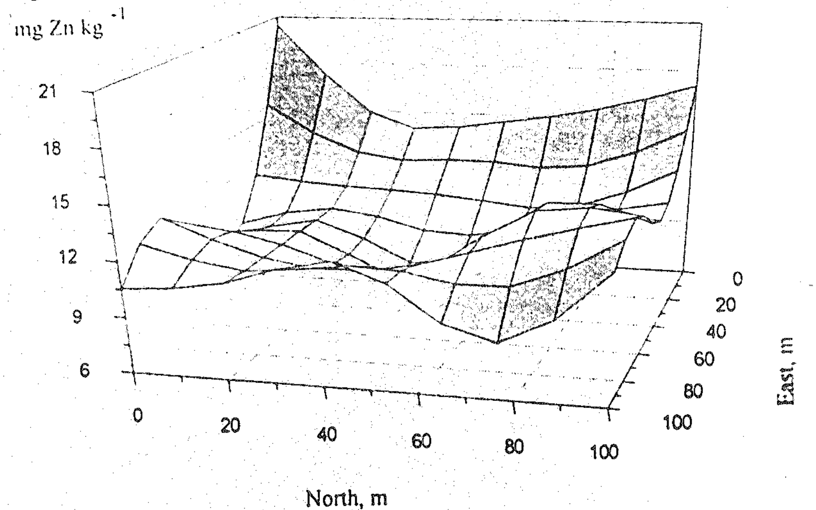

Fig.2. Three-dimensional map of Zn concentrations in the wheat plants, low = 11–20 mg kg^{-1}, sufficient = 21–70 mg kg^{-1} and high = 71–151 mg kg^{-1} according to Jones *et al.*[26]

20.47 mg kg^{-1}. About 98% of the plant samplings had a low level of Zn (11–20 mg kg^{-1})[26]. Thus, the findings clearly showed that the P/Zn ratio in the field soil was a very important factor for maximum utilization of Zn by the plants. As a matter of fact, significant correlation, r = 0.48 and $P < 0.01$, was found between the site specific P/Zn ratios for topsoils and P/Zn ratios for wheat plants on these soils (Fig.3.). It has also been emphasized for corn fields that optimal P/Zn ratio in the soil should be at the levels of 4–7.5 for balanced nutrition of the crops[24]. It also means that the site-specific P/Zn ratio of plants have a higher spatial dependency of P/Zn ratio of the topsoil. Site-specific P accumulations in the topsoil considerably reduced the Zn concentrations of the wheat[27]. Thus, because of the high variability observed for available P accumulations in the topsoil, the site-specific P/Zn ratio was also varied greatly among the wheat plants, whereas the relationships for P/Zn

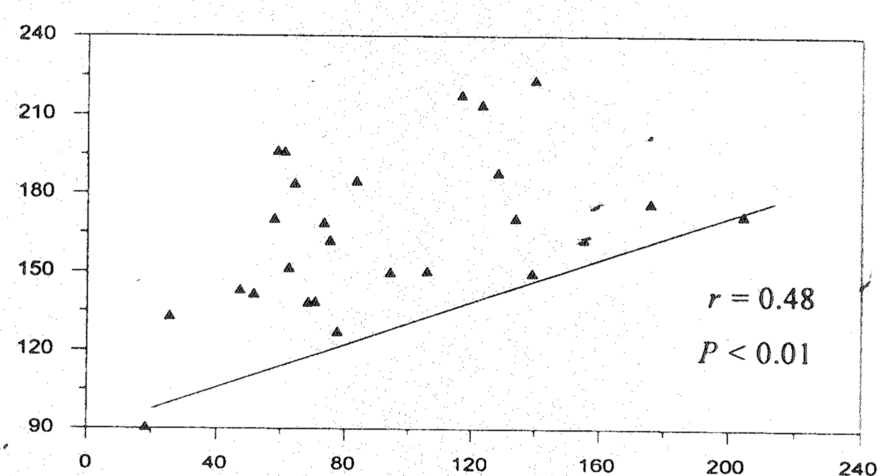

Fig.3. Relationship between the site–specific P/Zn ratios for topsoils and P/Zn ratios for wheat plants on these soils

ratios were found not significant for subsoil. On the other hand, it has also been emphasized that combining plant analysis with soil analysis will provide more realistic assessment of micronutrient status of both plants and soils[28].

Conclusion

The C.V., kurtosis and skewness values revealed that uniform P fertilizer applications before the samplings resulted in unequal soil P distribution and unbalanced P/Zn ratios. Adapting the site–specific parameters of C.V., kurtosis and skewness values will be beneficial to quickly estimate optimal P/Zn ratios and the unit P and Zn requirements of the wheat plants. Hence, fields should be divided into smaller units based on spatial analysis results. On the other hand, contour map of site–specific Zn contents indicated that the experimental topsoil had mainly sufficient amounts of available Zn, whereas three-dimensional map of wheat Zn concentrations indicated that most of the plants on these soils had a low level of Zn. As a matter of fact, significant correlation was found among the site–specific P/Zn ratios. The findings clearly showed that the site–specific P/Zn ratio was an important factor for maximum Zn utilization by the wheat plants. Hence, fertilization programme based on site–specific P and Zn demands of the wheat plants will increase Zn use efficiency of the plants with proper P/Zn ratios. In the further studies, evaluation of contour maps based on proper site–specific samplings will provide more accurate information for balancing of P/Zn ratios for varied soil and plant conditions.

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