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Research Article

Evaluation of Soil Fertility and Maize Crop Nutrient Status in Himalayan Region Poonch, Azad Jammu and Kashmir

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Abstract: The judgment of the fertility status of agricultural soils is very substantial to determine crop sustainability and judicious nutrient management. A field survey of dominant maize growing areas of District Poonch, Azad Jammu, and Kashmir was undertaken in July-August, 2017. The twelve dominant maize growing sites, namely Char, Chak, Dothan, Banjusa, Chamber, Hajira Kelot, Kakuta, Mandhole, Madarpur, Tatrinote, Chattra Abbaspur, and Dawarandi were selected for the collection of soil and associated maize plant samples. A total of 24 composite soil samples (each representative of three individual samples) was separately collected from 0-15 and 15-30 cm depths and were analyzed for physicochemical characteristics, i.e. soil texture, pH, organic matter, soil nitrogen, available P, exchangeable K and micronutrients (Cu, Fe, Mn, and Zn). The maize ear leaves samples were also analyzed for N, P, K, and micronutrients (Cu, Fe, Mn, and Zn). To evaluate the adequacy levels of nutrients for maize growth the critical nutrient levels were used. Soils in the sampled sites were weakly acidic to neutral (pH 6.66-7.29) and had low to medium soil organic matter content (0.57-1.12%). The percent of sites with low nutrient contents were 66.7% for P and K, 8.3% for Cu, and 66.7% for Zn. The 100% sampled sites had plant N, P, and Cu deficiency while percent deficiency for plant K, Mn, and Zn was 1, 50, and 25, respectively. Soil pH had negative and organic matter had a positive significant correlation with all analyzed soil and plant nutrients. These results suggest that having integrated nutrient management strategies can enhance soil fertility and productivity in the study area.

Keywords: Macro-nutrients, Micro-nutrients, Plant nutrient, Soil fertility, Maize

1. INTRODUCTION

The understanding of the fertility status of agricultural soils is of paramount importance for rational soil management and efficient utilization of nutrient resources to achieve crop sustainability [1]. The human population of Pakistan has progressively increased by a factor of 4.5 between 1960 and 2018 (from 45 million to 201 million) whereas currently per capita land availability (0.18 ha head^{-1}) is expected to be reduced by almost 90% by 2050 [2]. Land degradation due to soil salinization, nutrient mining, waterlogging, and growing urbanization is mainly responsible for the progressive reduction in arable land [3 - 5]. Besides, the lands situated on slopes are prone to plant nutrient deficiencies, productivity stagnation, or physical, chemical, and biological deterioration mainly due to water erosion. The micronutrient deficiency at the global scale is one-third of arable soils, mainly in Zn [6] and ultimately this influences human nutrition. In developing countries half of the population is affected by micronutrient deficiencies and globally, approximately 2–3 billion people are suffering [7]. The reason is an unbalanced and lower application of N, P, and K which increases soil degradation too. The micronutrient importance is also being demonstrated [8] but still, its links to nutrition are not well known and understood. Khan *et al.* [9] reported 18.2, 13.8, and 6.7% reductions in the

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total arable land area in Pakistan due to deletion of top fertile soil layer by erosion, waterlogging, and salinity/ sodicity hazards, respectively. This ongoing declining trend in land availability has sought the attention of scientists, policy-makers, and other stakeholders in devising sustainable management strategies for restoring the productive potential of these degraded arable lands to ensure feed, food, and fiber requirements of a rapidly growing population.

To develop and adopt appropriate sustainable management strategies for soil fertility restoration and its quality, the updated knowledge on the status of existing soil fertility is very important. Therefore, the evaluation of soil fertility through soil and plant analyses is vital for soil management practices. The soil fertility assessment of an area is a key aspect of the maintenance of soil fertility and sustaining agricultural production [10].

Soil testing and plant analyses are the precise quantitative assessments of nutrients that are frequently used to predict the soil fertility status and confirm visual deficiency symptoms of limiting nutrients [11]. The fertility status of a soil can also be assessed through nutrient indexing by using organic carbon, total soil N, available P, exchangeable K, and micronutrient concentrations as a measure of soil fertility components [12]. Kihara *et al.* [13] stated that micronutrient use efficiency can be improved by applying the type and rate of fertilizers according to soil fertility status and management practices.

Maize is the third significant cereal crop of Pakistan after wheat and rice that requires high amounts of nutrients. The estimates had shown that maize removes nearly 350 kg N, 150 - 220 kg P_2O_5, and 400 - 500 kg K_2O ha^{-1} from the soil over a growing season to produce a maximum yield of 12 tones ha^{-1} [14]. On the other hand, in Pakistan average maize yield of 4.59 tones, ha^{-1} is still below the world's targets of about 5.2 tones ha^{-1} [15]. This difference in yield potential might be attributed to the deficiency of essential plant nutrients.

Keeping in view, the high nutrient demands of maize crop and lack of comprehensive knowledge of the current fertility status of soil from concerned maize growing areas, the present research was planned to evaluate the soil fertility and nutrients status of maize from selected maize growing zones of District Poonch, Azad Jammu, and Kashmir-Pakistan. This data will be valuable for making integrative nutrient management policies and plans suitable for small land-holding farmers.

2. MATERIAL AND METHODS

2.1 Description of Study Area

The study was conducted in maize growing sites of district Poonch (33.8369° N, 73.8889° E) Azad Jammu, and Kashmir-Pakistan. The twelve selected maize growing sites included Char, Chak, Dothan, Banjusa, Chambanar, Hajira-Kelot, Kakuta, Mandhole, Madarpur, Tatrinote, Chatra-Abbaspur, and Dwarandi. The study area ranges at an altitude from 803-1798 m above sea level. The entire area is rain-fed (500 - 2000 mm average annual rainfall), receiving a major portion of rainfall during monsoon and winter months. The parent materials of soils are mainly comprised of colluvial and alluvial sediment depositions. Taxonomically, the soils of the area belong to Thermic Lithic Eutrudepts and Hyperthermic Typic udifluents sub-groups of orders Inceptisols and Entisols with loam to silt loam textures. The area is prone to moderate risk of water erosion with a considerable annual loss of soil, organic matter, and essential plant nutrients. The summer maize followed by winter wheat is the existing cropping sequence traditionally practiced by the farmers in the study area with little or even no applications of recommended fertilizers. Being nutrient exhaustive, both of the crops continuously deplete soil fertility. The weather attributes, i.e. humidity, barometric pressure, air, temperature, altitude, and a heat index of selected sites were noted by using a portable weather tracker (model: Kestrel 4500) is presented in Figure 1.

2.2 Sampling, Processing, and Analyses

A total of 24 composite soil samples (each comprised of three individual samples) were collected by using a soil auger to a 0-15 and 15-30 cm depths randomly, brought to the laboratory of Soil and Environmental Sciences, and were processed for further required determinations. The determinations on soil texture [16], $pH_{1:2}$ by soil water suspension [17] organic matter [18], soil total nitrogen by Kjeldahl method of Bremmer and Mulvaney [19], available P by

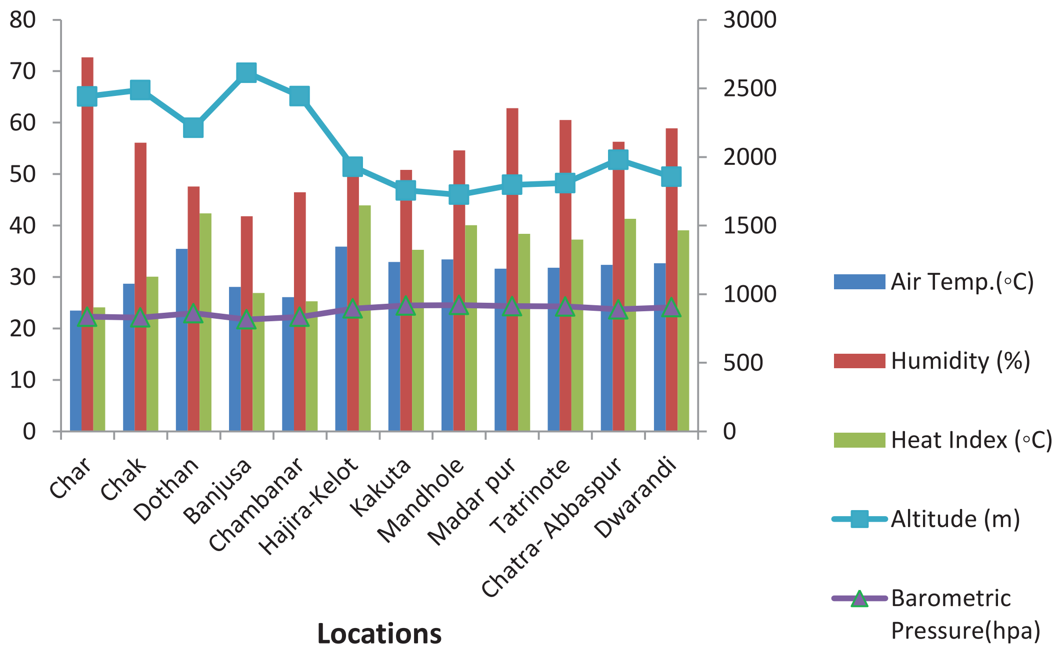

Fig. 1. Weather attributes of selected maize growing sites of District Poonch, Azad Jammu & Kashmir at the time of soil sampling.

Murphy and Riley [20] method, and extractable K [21, 22] were done. The P and K valuation in the the extract was done by spectrophotometer and flame photometer, respectively. The ammonium bicarbonate diethylene triamine penta acetic acid (AB-DTA) extractable iron, zinc, copper, and manganese were determined using the method given by Lindsay and Norvell [23] and then read by atomic absorption. The ear leaves samples of associated maize crops were also obtained from each respective site at silking. The best plant part of maize is the ear leaf and the time of sampling is initial silk [24]. The plant samples were over-dried (at 60°C), processed, and analyzed for total N by Kjeldahl's method described by Bremmer and Mulvaney [19], for P [25], and K [26]. The digestion procedure for plant micronutrients was adopted from Rashid (1986) and concentrations were determined by the atomic absorption spectrometer [27].

2.3 Data Analyses

Illustrative measurable investigations containing means, ranges, and standard deviations were done in MS Excel. Nutrients adequacy ranges (low, sufficient, and abundance) (Table 1) were utilized to bunch the sites relying upon particular adequacy levels. Parker's nutrient index [28] changed by Pathak [29], Kumar *et al.* [30], and Ravikumar and Somashekar [12] based on the percentage of samples in every one of the three classes (for example, low, medium, and high) and multiplied by 1, 2 and 3 individually, was utilized for the assessment of fertility status of soils. Pearson's correlations were also calculated in MS Excel.

3. RESULTS

3.1 Soil Physicochemical Characteristics

The soil pH ranged from 6.66 - 7.29 with an overall mean of 6.99 ± 0.2. The pH showed slightly acidic to neutral conditions (Table 2). The soil organic matter (SOM) ranged between 0.57 - 1.12% and this range is showing low to medium status. Total soil N was 0.037 - 0.06% and it was above the critical value and found in the medium range. Soil available P with the minimum concentration of 5.57 to a maximum of 7.47 mg kg^{-1} was in the low range. The extractable K ranged from 32.7 - 80.25 mg kg^{-1} with an overall mean of 52.64 ± 18.5 mg kg^{-1}. The mean showed that K contents were below a critical value. Among soil micronutrients, the Cu and Zn ranges were below the critical value to medium concentration with a mean of 0.56 to 0.78 mg kg^{-1}, respectively. The Fe and Mn were adequate in both minimum and maximum concentrations. The

Table 1. Soil and tissue nutrient critical levels of macro and micronutrients as an interpretive guide for nutrient ranking

Parameters	Soil nutrient concentration				Plant nutrient concentrations	
	Units	Low	Medium	Adequate	Units	
Soil organic matter	(%)	<0.86	0.86-1.29	>1.29	-	-
Total soil nitrogen	(%)	<0.02	0.03-0.40	>0.40	(%)	2.6-3.1
Available P	mg kg^{-1})	4-7	8-11	12-15	(%)	0.22-0.27
Extractable Potassium	(mg kg^{-1})	<60	60-120	>120	(%)	1.2-1.7
Copper	(mg kg^{-1})	<0.2	0.2-0.5	>0.5	(mg kg^{-1})	10-20
Iron	(mg kg^{-1})	<3.0	3.0-5.0	>5.0	(mg kg^{-1})	15
Manganese	(mg kg^{-1})	<0.5	0.5-1.0	>1.0	(mg kg^{-1})	50
Zinc	(mg kg^{-1})	<0.9	0.9-1.5	>1.5	(mg kg^{-1})	25

Source: Maize ear leaf critical values [55], [56] and [57]; Source: Soil critical values [58] and [59]

textural analysis showed a higher percentage of silt followed by sand and clay with means of 40.72, 37.7, and 21.7 respectively.

3.2 Ear Leaf Nutrient Contents

Ear leaf total N had a variation ranged from 0.67 - 1.77% and all sites were below the critical value with 100% deficiency (Table 3). The P concentration was also below critical values in all sites and sites below critical value were 100%. The sampled sites with K values below low were only 1% and 41. 6% were within the range of critical value. The sampled sites with Cu were 100% deficient and Fe was above critical value in all sites with wide variation ranged from 85.6 - 263.2 mg kg^{-1}. Both Mn and Zn also showed variations between the sampled sites averaging 51.61 ± 9.69 mg kg^{-1} and 37.96 ± 10.77 mg kg^{-1}, respectively. About 50% of sampled sites had Mn below a critical value and Zn deficiency was 25% in sampled sites.

3.3 Nutrient Indices for Organic Matter, N, P, K and Micronutrients of Maize

The nutrient index value (NIV) of organic matter was low, i.e. 1.50 and OM was in the low range in 50% sites and was medium again in 50% sites (Table 4). The sampled sites had 100% N in the medium range while 66.7% sites had the P and K deficiency and were in the low category with NIV of 1.33. In sampled sites, the Cu deficiency was 8.3%. The Fe and Mn were higher in all sites with and NIV of 3.00. The sampled sites with Zn were 66.7% at the low range while 33.3% sites were in high nutrient status.

3.4 Correlation between Soil Chemical Properties and Plant Nutrient Contents

The leaf ear TN, P, Mn, and Zn were highly significantly ($P \leq 0.01$) correlated to soil pH and it was a negative correlation (Table 5). A significant negative correlation was also observed between ear leaf Cu and soil pH (-0.78^{*}) and between ear leaf Fe and soil pH (-0.74^{*}). All observed ear leaf nutrients contents positively correlated with soil OM. The ear leaf N and P had a positive significant correlation with Soil N, P, K, Cu, Fe, Mn, and Zn. The ear leaf K had significant positive correlations with soil organic matter (r=0.84), soil N (r=0.81) soil P (r=0.81), soil K (r=0.85), soil Fe (r=0.78) and soil Mn content (r=0.83). The ear leaf Cu significantly correlated with soil TN, Zn, Cu, Fe, and Mn. A positive significant correlation was observed between ear leaf Fe and all analyzed soil nutrients. The ear leaf Mn was significantly and positively correlated with all analyzed soil nutrients

Table 2. Statistics (Mean, SD, Minimum and Maximum) of soil physico-chemical properties and nutrients of maize growing at farmers' fields in District Poonch, Azad Jammu & Kashmir (Data is averaged across 0-30 cm depth)

Variable	Min	Max	Mean	Std. Dev.
pH	6.66	7.29	6.99	0.20
Organic matter (%)	0.57	1.12	0.84	0.19
Total N (%)	0.037	0.06	0.05	0.01
P (mg kg^{-1})	5.57	7.47	6.54	0.73
K (mg kg^{-1})	32.7	80.25	52.64	18.51
Cu (mg kg^{-1})	0.18	1.16	0.56	0.38
Fe (mg kg^{-1})	11.37	21.53	14.10	2.84
Mn (mg kg^{-1})	3.56	10.4	6.53	2.15
Zn (mg kg^{-1})	0.36	1.43	0.78	0.33
Clay (%)	16.9	30.3	21.7	3.65
Silt (%)	33.7	50.1	40.72	4.79
Sand (%)	27.9	42.5	37.7	4.49

Table 3. Statistics (Mean, SD, Minimum and Maximum) of maize plant nutrient content at farmers' fields in District Poonch, Azad Jammu & Kashmir.

Plant nutrients	Min	Max	Mean	Std. Dev.	% sites below a critical value
Total N (%)	0.67	1.77	1.29	0.40	100
P (%)	0.04	0.08	0.06	0.01	100
K (%)	1.07	2.29	1.75	0.39	1
Cu (mg kg^{-1})	2.17	3.95	2.17	0.93	100
Fe (mg kg^{-1})	85.6	263.2	192.32	62.12	0
Mn (mg kg^{-1})	35.2	71.9	51.61	9.69	50
Zn (mg kg^{-1})	21.53	53.9	37.96	10.77	25

Table 4. Nutrient indices for organic matter, N, P, K, and micronutrients of maize growing at farmers' fields in District Poonch, Azad Jammu & Kashmir

Nutrients	No. of Samples	Rating			Nutrient Index value (NIV)
		Low	Medium	High	
Soil organic matter (%)	24	12 (50)	12 (50)	---	1.50
Total Soil Nitrogen (TSN; %)	24	---	24 (100)	---	2.00
Soil Available Phosphorus (mg kg^{-1})	24	16 (66.7)	08 (33.3)	---	1.33
Soil Exchangeable Potassium(mg kg^{-1})	24	16 (66.7)	08 (33.3)	---	1.33
Soil Copper (mg kg^{-1})	24	02 (8.3)	12 (50.0)	10 (41.7)	2.33
Soil Iron (mg kg^{-1})	24	---	---	24 (100)	3.00
Soil Manganese (mg kg^{-1})	24	---	---	24 (100)	3.00
Soil Zinc (mg kg^{-1})	24	16 (66.7)	08 (33.3)	---	1.33

Index value: Low = < 1.67; Medium = 1.67 – 2.33 and High = > 2.33

except AP while Zn was having a significant positive correlation with all analyzed soil nutrients except AP and Cu.

3.5 Interrelations of Soil Chemical Properties

Soil pH had a significant negative correlation (-0.91) with OM and all analyzed soil nutrients while OM had a significant positive correlation with all observed nutrients (Table 6). The N was positively correlated with K (0.95), Zn (0.84), Cu (0.78), Mn (0.82), and Fe (0.93). The K positively and significantly correlated with AP (0.90), Zn

Table 5. Pearson's correlations coefficients (r) between soil and plant nutrient contents of maize growing at farmers' fields in District Poonch, Azad Jammu & Kashmir

Plant nutrients	Soil nutrients								
	pH	OM	TN	AP	K	Zn	Cu	Mn	Fe
N	-0.88**	0.93**	0.85**	0.93**	0.87**	0.74*	0.72*	0.81**	0.71*
P	-0.83**	0.93**	0.91**	0.87**	0.92**	0.77*	0.72*	0.88**	0 .84**
K	-0.73*	0.84**	0.81*	0.81**	0.85**	0.68	0.70*	0.83**	0.78*
Cu	-0.78*	0.79*	0.80*	0.63	0.69	0.90**	0.91**	0.94**	0.85**
Fe	-0.74*	0.85**	0.75*	0.78*	0.79*	0.79*	0.71*	0.82**	0.74*
Mn	- 0.84**	0.84**	0.84**	0.69	0.79*	0.88**	0.83**	0.98**	0.89**
Zn	-0.82**	0.76*	0.76*	0.67	0.73*	0.93**	0.69	0.84**	0.77*

** Correlation is highly significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.01 level (2-tailed)

Table 6. Pearson's correlations coefficients (r) of soil properties at maize growing farmers' fields in District Poonch, Azad Jammu & Kashmir

nutrients	pH	OM	SN	AP	K	Zn	Cu	Mn
OM	-0.91**							
N	-0.90**	0.93**						
AP	-0.81*	0.95**	0.82*					
K	-0.84**	0.94**	0.95**	0.90**				
Zn	-0.87**	0.78*	0.84*	0.64	0.75*			
Cu	-0.80*	0.80*	0.78*	0.68	0.63	0.78*		
Mn	-0.82*	0.84**	0.82*	0.71*	0.76*	0.87**	0.87**	
Fe	-0.80*	0.82*	0.93**	0.64	0.86**	0.86**	0.73*	0.84**

** Correlation is highly significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.01 level (2-tailed)

(0.75), Mn (0.76), and Fe (0.86). The AP had a significant correlation with Mn (0.71) and Zn was significantly correlated to Cu (0.73) and Mn (0.84).

4. DISCUSSION

The sampled sites were slightly acidic to neutral with organic matter concentration from low to medium. Soils at sampled sites were Entisols and Inceptisols which were slightly weathered. The slightly acidic pH could be due to high rainfall that caused the leaching of cations. Low soil pH consequently influences the uptake of plant nutrients by affecting the microbial population and concentration of Al/Fe ions in the solution [31]. The low organic matter in sampled sites may be attributed to the previous cropping system that has depleted it. In sampled sites, the low organic matter contents could be due to exhaustive crop rotation as well. The low diversity of soil microbes, development of host-specific soil-born diseases, and imbalances of soil nutrients resulted due to growing the same crops in the same field continuously [32, 33]. Devkota *et al* [34] reported that cropping systems have an immense effect on plant nutrient dynamics in soil. The medium range of soil total N in sampled sites indicated the low rate of inorganic and organic fertilizer addition. The long-term addition of inorganic and organic fertilizers affects the nutrient concentration and soil organic matter build-up. Where the earlier cropping system has depleted soil organic matter, the soils mostly become acidic with little capability to retain macro (N, P & K) and some micronutrients. This in addition to the low inorganic and organic fertilizer use, augmented soil degradation. As reported by Bhattacharya [35], in agriculture soil degradation is primarily because of insufficient and imbalanced fertilizer application.

The low N levels in sampled sites could be a result of N leaching, less the amount of N addition, low organic matter, and high nutrient removal due to continuous farming [36]**.** Cobo *et al.* [37] described the results of 57 selected studies and revealed that due to nutrient mining, most systems had a negative balance for N and K while the percent deficiency of P was not severe.

Soil organic matter holds soil N, stops its leaching, and makes it available for plant uptake [38]. Conventional tillage practices can adversely change the soil mechanical behavior, and in turn, it affects the organic compounds, pH, N, C, and micronutrients such as Zn and Mn [39, 40]. It further aggravates water and wind erosion, which ultimately causes soil degradation [41]. The low contents of total N in plant tissue could be attributed to a medium concentration of total N in soil and consequently lesser uptake. The observed low P in the sampled soil could be associated with P leaching, P complexation, and subsequently low P in plant tissues. Phosphorus is distinctive among the anions due to its low mobility and accessibility in soils. It is hard to manage because it makes strong bonds with both soil matrix and solution [42]. In acid soils Al and Fe cause P fixation, whereas Ca compounds dominate P fixation in alkaline soils.

Soil K was found low in the sampled soil while in plant tissue the low concentration of K was only 1% and this is attributed to cation balances. The optimum K concentration in plant tissues could be due to higher mass flow movement [43] and lower soil pH. Low soil pH due to the solubility of Al could be another factor that interferes with the uptake of plant nutrients [31]. The Al becomes soluble at low soil pH and dominates the cation exchange capacity, thereby it affects the soil capacity to retain K [44].

Among micronutrients, Cu and Zn were limited in sampled soil and plant tissues also showed a deficiency. The positive relationship between tissue Cu and Zn and soil Cu and Zn content showed that these nutrients requiring corrective measures.

The protein components of numerous enzymes require Cu [45] and it is an important plant micronutrient. In soil, Cu rarely leaches as it is relatively immobile and binds strongly with OM. The accessibility of Cu to plants relies upon the pH, OM content, and soil type [46]. Copper uptake by the plant is affected by predominant chemical species, soil pH, and its concentration in soil. Zinc is also an important plant growth element and its deficiency reduces the yield [47, 48] The correlation between P and Zn was not significant in sampled sites, however, Murdock and Howe [49] reported that the higher content of soil P and higher soil pH was correlated with lower levels of Zn in the plant. The Zn deficiency is attributed to low OM contents and pH levels above 7.0.

Manganese was found high in the sampled soil, but some sampled sites showed deficiencies in plant tissues. It may be credited to low soil pH and less organic matter addition. Wang et al [33] also reported a similar dependency of Mn on soil organic carbon status. Manganese scarcity has likewise been found in profoundly fertile clayey soils [50]. The studies have demonstrated an antagonism amongst Zn and Mn, a higher content of Zn in the soil diminished the leaf Mn concentration [51]. The concentration of interchangeable metal in soil relies upon their amount in soil solutions, subsequently, soil pH impacts the replaceable Fe, Mn, Cu, and Zn likewise. Mugo *et al.* [52] reported that soil pH strongly correlated with most of the investigated both soil and tissue nutrient contents. The substantial positive association between leaf P and soil P in sampled soils is attributed to low P ions in the soil solution at the root surface. The pH is negatively correlated with P showing its effect on P uptake. The significant association between tissue K contents and soil K in sampled soils, but low K in the plant could be attributed to its negative correlation with pH.

The cropping systems and soil management practices affect soil organic matter concentration and in turn, it influences soil fertility [31]. Goshu *et al.* [53] reported that for sustainable maize production the fertilizer recommendation needs to be soil test-based because due to applied management practices and inherent soil nutrient status the heterogeneity is common in farmer's field.

The low soil nutrient contents of sampled sites caused the lower concentration of nutrients in plant tissues and a strong correlation between plant nutrients and soil nutrients indicates the need for both organic and inorganic inputs. Anthropogenic activities like cropping practices, soil management, intensive land use, and conservation measures impact soil functions [54]. Therefore, to increase productivity and fertility of maize growing areas sustainable and cost-effective measures are required.

5. CONCLUSION

This study shows that N, P, K, Cu, and Zn are restricting nutrients for maize production in significant maize growing zones of District Poonch Azad Jammu & Kasmir. The OM was also lower in sampled sites. The correlation showed the dependence of all plant nutrients on their concentration in soil. The correlation of OM was positive and highly significant with all analyzed soil nutrients. The management practices are required to build up the fertility status and productivity of study sites. The nutrients need to be provided as an integrated nutrient management program where both organic and inorganic sources should be applied.

6. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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