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SPATIAL VARIABILITY OF SOIL MICRONUTRIENTS (Cu, Fe, Zn & Mn) AND POPULATION DYNAMIC OF MYCOFLORA IN POTATO FIELDS OF CKNP REGION GILGIT-BALTISTAN PAKISTAN

Azhar Hussain[1,*], Muhammad Saeed Awan[1], Sartaj Ali[1], Sher Wali Khan[2,*], Francesco Morari[3] and Shamsher Ali[4]

[1]Department of Agriculture and Food Technology Karakoram International University Gilgit Baltistan, Pakistan;
[3]Department of Agronomy, Food, Natural Resources, Animals and Environment, Agripolis, University of Padova 16, 35020 Legnaro (Padova), Italy;
[4]Department of Chemistry, Karakoram International University Gilgit Baltistan, Pakistan.
[*]Corresponding author's e-mail: azharkiu@gmail.com, dr.sherwali@kiu.edu.pk

The main aim of current study was to explore the spatial variability of micronutrients (Cu, Fe, Zn & Mn) and mycoflora in a potato growing valleys of CKNP region, Gilgit-Baltistan, Pakistan. Ninety sixty soil samples were collected by a random sampling technique using Global Positioning System (GPS). In general, soils of survey valleys are loamy or silty loam with slightly alkaline pH and low to medium organic matter. Geographic Information System (GIS) was applied for micronutrients mapping of the analyzed data obtained from laboratory test. Results indicated that micronutrients (Cu, Fe and Mn) were found high except Zn. The Zinc concentration was low in 57.29% samples, medium in 30.20% samples and high in 12.50% samples respectively. The GIS mapping of soil micronutrients can be used in precision farming studies with the application of fertilizers and this approach is also proposed for the evaluation of sustainable soil management practices. The observed spatial variability of micronutrients helps potato growers in crop management decisions to increase productivity and improve farmer's livelihood. Knowledge and conservation of soil mycoflora is essential for sustainable agriculture development. In the current study a total number of thirteen mycoflora species were isolated from the composite soil sample of four valleys. The valley wise population per gram of soil was recorded as $24x10^{-6}$ in Bagrote, $18x10^{-6}$ in Haramosh, $15x10^{-6}$ in Hoper and $26x10^{-6}$ in Shigar valley. The most dominant among them were *Aspergillus flavus*, *Mucor species*, *Rhizopus stolonifer*, *Penicillium species* and *Alternaria alternate*.

Keywords: Micronutrients, spatial variability, mycoflora, potato fields, soil fertility.

INTRODUCTION

Soil plays a key role for sustainable crop production and food security. Fertility of soil is intrinsic ability of a soil to supply micro-macro nutrients in sufficient amounts for getting maximum crop production (Von, 1988). Soil nutritional status is key indicators of soil quality (Jansen *et al*., 1995). Soil fertility influence by land use and management practices and its quality varies either spatially or temporally from field to field or on regional scale (Sun *et al*., 2003). Regardless of the spatial and temporal changes of soil properties in small and large scales, awareness of how these changes occur for increasing profitability and sustainable agriculture management is necessary (Ayoubia *et al*., 2007). Determining soil variability is important for ecological modeling, environmental predictions, precise agriculture and management of natural resources (Hangsheng *et al*., 2005). Farmers all over the world normally take care of macronutrients rather than micronutrient application in the soils, thereby resulting increased deficiencies of micronutrients. On the other hand, micronutrients have an important role in balanced plant nutrition for the stabilization of crop yield of an area (Rattan and Sharma, 2004).

Soil micronutrient is equally important as the macro nutrient for crop growth, and often they are present in small quantities in the soil. Deficiency of micronutrients can lead to severe depression in crop growth, yield, and crop quality. Its availability in soil is depending on the parent material and pedogenic process (White and Zasoski, 1999). In the present era of precision farming, the inputs such as fertilizer, crop varieties and management practices are matched precisely with the variability in soil and climatic conditions so that inputs are applied as per the location specific requirements of the crop. Further, the monitoring of the same sites has remained a major problem due to absence of geo coded location of the sampling sites.

The advent of information technology have provided tools like Global Positioning System (GPS), Geographical Information System (GIS) which helps in collecting a systematic set of geo referenced samples and generating the spatial data about the distribution of nutrients (Sharma, 2007). The maps generated through remote sensing helps in

delineating the homogenous units to decide the sampling size and thereby saving a lot of time. This will also help to monitor the changes in micronutrient status over a period of time as geo-referenced sampling sites can be revisited with the help of GPS which is otherwise difficult in the random sampling (Sood *et al*., 2004).

Soil microorganisms play active role to increase fertility and plant growth because they are involved a number of biochemical transformation and mineralization activities. Method of cultivation and management practices found to have greater influence on the activity of soil mycoflora (McGill *et al*., 1980). Soil mycoflora plays a pivotal role in evaluation of soil conditions and in stimulating plant growth (Kiran *et al*., 1999).

Microorganisms play significant role for enhancing soil fertility as well as plant growth. They are involved in many biochemical reaction including nutrient transformation and mineralization activities in soils. Among microbioata mycoflora are an important component due its abundance. The conservation of soil mycoflora in agriculture field becomes very essential for the sustainable agriculture development (Gnanasekaran *et al*., 2015). Soil mycoflora are essential for ecosystem functioning of soil. Particularly in forest and agricultural soils, they play a key role in many necessary processes such as decomposition of organic matter and release of element by mineralization. It is important part of the soil micro biota and plays a focal role in nutrient cycling by regulating soil biological activity. The amount of organic and inorganic materials present in the soil has a direct effect on the fungal population of the soil (Warcup *et al*., 1950; Christensen, 1989; Ainsworth, 1995). The soil mycoflora naturally constitutes more biomass as compared to bacteria, depending on soil depth and nutrient conditions. The function of fungi in the soil is tremendously multifaceted one and it is fundamental to the soil ecosystem. They perform ecological services that strongly impact the quality of human life and have enormous potential for providing economic benefits. Mycoflora play a focal role in nutrient cycling by regulating soil biological activity (Arunachalam *et al.*, 1997).

This is first ever study on the spatial variability of soil micronutrients and population dynamic of mycoflora in the study area. The results of micronutrient may use in determining site specific nutrient management practices, minimize cost of cultivation and preventing environmental pollution. Whereas, diversity of soil mycoflora may provide information related to soil conservation and sustained ecological balance of the area. Keeping in view the fact, the current endeavor was aimed to assess the spatial variability of micronutrients and population dynamic in the soil of potato growing valleys of CKNP region Gilgit-Baltistan Pakistan.

MATERIALS AND METHODS

***Study area*:** Central Karakoram National Park (CKNP) covers three major districts i.e. Gilgit, Skardu and Ghanche. In 1993, Govt of Pakistan declared CKNP as a national park. Total covered area is over ten thousand km² and encompassing largest glacier; Baltoro, Hispar-Biafo and Siachen of the world outside the Polar Regions whereas the buffer zone (7,400 km²) of CKNP is home to about 97,608 people residing in 230 village settlements. Mixed mountain agriculture is main activity of the locals. In the current study a total of 96 soil samples were collected from four valleys of CKNP region Gilgit-Baltistan Pakistan at 0-20 cm depth after harvesting of potato crop. These samples were dried, ground, sieved and stored until used (Fig. 1).

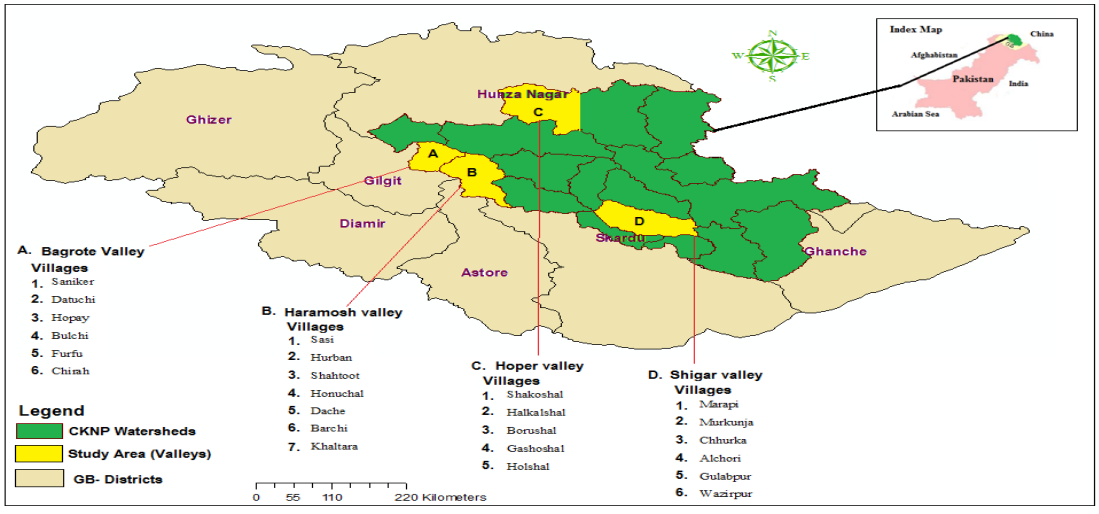

Figure 1. Map of Central Karakoram National Park, Gilgit-Baltistan, Pakistan.

Table 1. The criteria used to categorize the soil samples (O.M % and soil saturation).

Saturation %		Organic Matter %	
0 < 20	Sand or loamy sand	Low	< 0.86
20-35	Sandy loam	Medium	0.86- 1.29
35-50	Loam or silty loam	High	> 1.29
50-65	Clay loam		
65-35	Clay		

***Soil pH, organic matter and saturation percentage*:** Soil pH was determined with the help of pH meter (InoLab, WTW Germany) while organic matter (OM) was determined by the modified method of Walkely and Black reported by Nelson and Sommers (1982). Soil saturation % was determined as described by Milk *et al*. (1985).

$$\text{Saturation \%} = \frac{\text{Amount of water added(g) x 100}}{\text{Mass of air dry soil (g) x (100 − Pw)/100}}$$

The criteria used to categorize the soil organic matter and saturation percentage is given in Table 1 (Malik *et al*., 1984).

***Micronutrients*:** Ammonium bicarbonate diethylene triamine penta acetic acid (AB-DTPA) extractable Cu, Fe, Zn and Mn were determined using the method given by Soltonpour and Schawab 1977. Thematic maps were generated for each of the soil micronutrients using Inverse Distance Weighted (IDW) interpolation provided in Arc GIS 10.1 software (Kartik *et al*., 2014). Critical soil test values of AB-DTPA extractable Cu, Fe, Zn & Mn described by Soltanpour, 1985 as given below were used for comparison:

Table 2. The criteria used to categorize the soil samples for various classes of micronutrients.

Micronutrients	Nutrient Content (mg kg^{-1})		
	Low	Medium	High
Cu	<0.3	0.3-0.5	>0.5
Fe	<3.0	3.0-5.0	>5.0
Mn	<0.6	0.6-1.0	>1.0
Zn	<1.0	1.0-1.5	>1.5

***Mycoflora diversity*:** Composite soil samples were collected from four valleys (Bagrote, Haramosh, Hoper and Shigar) of potato growing region of CKNP. These samples were packed in polythene bags and used to enumerate mycoflora diversity using standard method of Warcup, (1950) by serial dilution techniques (10^{-3}, 10^{-4} and 10^{-6}) using PDA (potato dextrose agar). The medium was prepared and sterilized at 121°C (15 lbs pressure) for 15-20 minutes. Then it was supplemented with 1% streptomycin to prevent bacterial growth. The medium was poured into the sterile petri plates and allowed to solidify. Then serially diluted soil samples were directly inoculated into petri plates containing PDA medium. The inoculated plates were incubated at 28±2°C for seven days. Four replicates of each sample were maintained and experiment was repeated twice. Percentage of occurrence of mycoflora per gram of soil was calculated by using the formula:

$$\text{OP} = \frac{Tn.\ \text{CFU. I}spp}{\text{Tn. CFU. A}spp} \text{ x } 100$$

(OP = Occurrence percentage; Tn = Total number; CFU = Colony forming unit; I. *spp* = Individual species; A. *spp* = All species).

***Identification of mycoflora*:** Mycoflora were identified macroscopically by observing colony features (Colour and Texture) and microscopically by staining with lacto phenol cotton blue and observe under compound microscope. The mycoflora identified with the help of literature (Barnett, 1998; Ellis, 1993; Gilman, 2000; Nagamani *et al*., 2006).

RESULTS

***Soil pH, organic matter and Saturation percentage*:** The data regarding the pH, Organic matter and saturation % of soil is presented in Table 3. The mean±SD values recorded for pH, organic matter and saturation percentage were 7.99±0.06, 0.99±0.12 and 41.37±2.96 in Bagrote valley while 7.61±0.20, 1.02±0.13 and 39.10±2.22 was recorded in Haramosh valley. In Hoper and Shigar valley, the mean±SD values of soil pH (7.84±0.27, 7.77±0.25) organic matter (1.02±0.11, 1.0±0.12 and saturation percentage (43.35±2.99, 40.12±2.193) were noted. The overall study showed that the soil of area was loamy or silty loam with 7.23-8.30 pH range whereas organic

Table 3. Soil pH, OM (%) and Saturation (%) in the valley of CKNP region Gilgit-Baltistan (n = 96).

Valleys	pH		OM%		Sat.%	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Bagrote	7.80-8.10	7.99±0.06	0.80-1.22	0.99±0.12	37.0-48.0	41.37±2.96
Haramosh	7.23-7.98	7.61±0.20	0.75-1.26	1.02±0.13	35.0-45.0	39.10±2.22
Hoper	7.38-8.30	7.84±0.27	0.84-1.30	1.02±0.11	39.0-48.0	43.35±2.99
Shigar	7.35-8.13	7.77±0.25	0.78-1.21	1.00±0.12	36.0- 44.0	40.12±2.193

matter content of the study area was low (15.62%), medium (83.33%) and adequate (1.04%) (Table 4).

Table 4. Soil pH, OM (%) and Saturation (%) categorized in different ranges of study area.

Valley	N.S	OM %		
Soil status		Low	Medium	High
Bagrote	N= 24	6 (25.0)	18 (75.0)	0.0 (0.0)
Haramosh	N = 28	2 (7.1)	26 (92.9)	0.0 (0.0)
Hoper	N = 20	3 (15.0)	16 (80.0)	1.0 (5.0)
Shigar	N= 24	4 (16.7)	20 (83.3)	0.0 (0.0)
Mean	N = 96	15 (15.6)	80 (83.3)	1.0 (1.0)
Soil pH Range			7.23-8.30	
Saturation %			Loamy or silty loam	

***Spatial variability of micronutrients*:** Spatial variability of micronutrients (Cu, Fe, Zn and Mn) and mycoflora were assessed in twenty four villages that consist of four valleys of Central Karakoram National Park Gilgit-Baltistan. Results revealed that the mean concentration of Cu, Fe, Mn and Zn in potato growing soil of Bagrote valley was found to be 3.58, 7.43, 7.66 and 0.96 mg kg^{-1} (Table 5). All soil samples exhibited high concentration of Cu, Fe and Mn except Zn which was low in 58.3% and medium in 41.6% tested samples. Mapping of micronutrients by GIS techniques showed that above 70% area contains Cu concentration in the range of 3.33-4.22 mg kg^{-1}, 66.6% area falls in the range of 6.22-7.51 mg kg^{-1} of Fe, 75% area falls in the range of 0.92-1.12, mg kg^{-1} of Zn and 58.3% areas fall in the range of 7.80-10.06 mg kg^{-1} Mn concentration (Fig. 2). Similarly mean values of micronutrients in Haramosh valley were recorded as

Table 5. Spatial variability of micronutrients in the valley CKNP region Gilgit-Baltistan (n = 96).

Valleys	Cu (mg kg^{-1})		Fe		Zn		Mn	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Bagrote	2.44-4.33	3.58±0.48	6.22-10.12	7.43±0.93	0.73-1.12	0.96±0.09	5.44-10.08	7.66±1.28
Haramosh	2.44-4.89	3.38±0.57	4.86-12.22	8.85±1.79	0.65-1.46	0.99±0.18	6.24-11.19	8.87±1.33
Hoper	2.88-4.92	3.41±0.59	6.18-13.24	9.25±2.03	0.74-1.86	1.06±0.27	8.15-12.13	10.34±1.37
Shigar	3.18-4.66	3.54±0.34	10.46-13.55	12.53±0.3	0.62-1.22	0.96±0.15	10.12-12.08	10.81±0.49
Mean	2.73-4.70	3.47±0.49	6.93-12.28	9.51-1.26	0.68-1.41	0.99±0.17	7.48-11.37	9.42±1.12

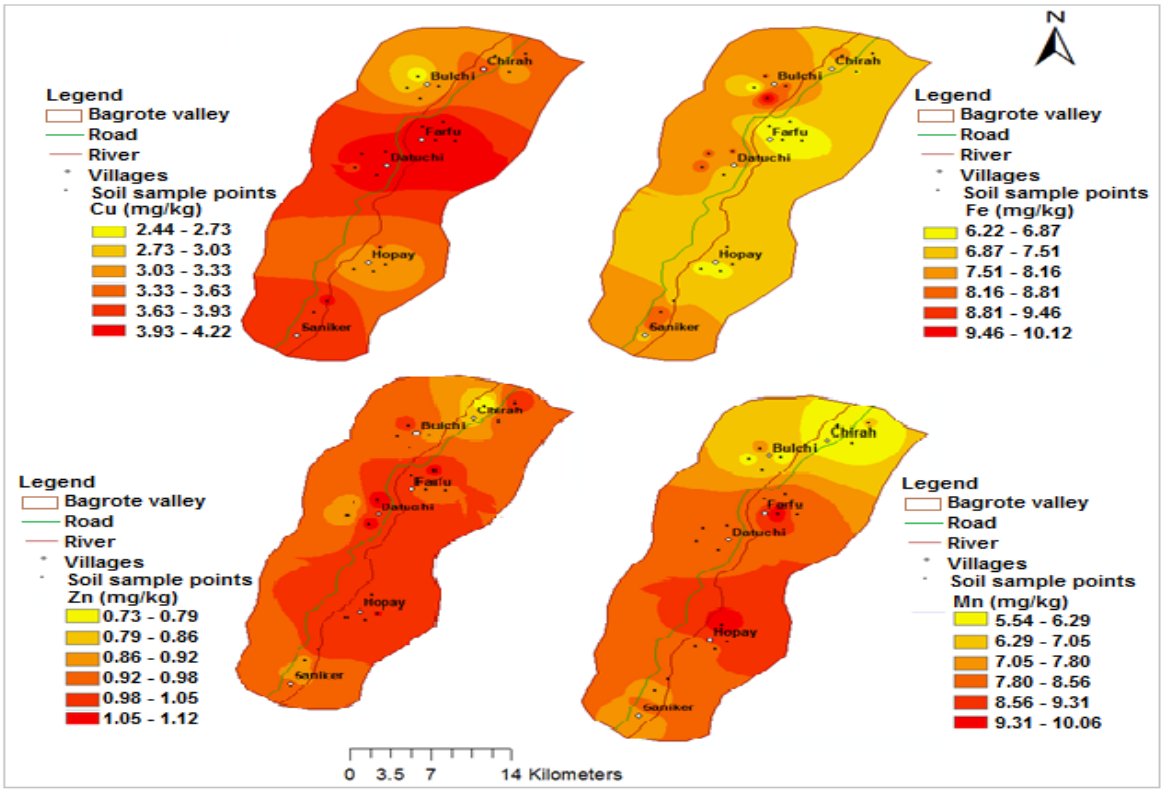

Figure 2. Mapping of micronutrient in villages of Bagrote valley.

3.38 Cu, 8.85 Fe, 0.99, Zn and 8.87 mg kg^{-1} Mn. The extractable Cu and Mn was high in all tested samples, whereas, Fe was found medium in 3.58% and high in 96.2% tested samples, furthermore, Zn was low in 6.2%, medium in 14.2% and high in 21.4% investigated samples (Table 6). Macronutrients map showed that 64.28% area contains >3.11 mg kg^{-1} Cu concentration, 78.5% area having >7.31 mg kg^{-1} concentration of Fe, 67.8% >0.91 mg kg^{-1} and 75% >7.89 mg kg^{-1} contains Zn and Mn concentrations respectively (Fig. 3). Micronutrient concentrations in Hoper valley were found to be 3.41 Cu, 9.25 Fe, 1.06 Zn and 10.34 Mn mg kg^{-1}. Result indicated that Cu, Fe and Mn were high in all soil samples except Zn which was low in 50%, Medium 35% high in 15% tested soil samples (Table 3). Map of Hoper valley showed 80% tested soil samples contain <3.89 mg kg^{-1} concentration of Cu, 60% <9.70 mg kg^{-1}, Fe 90% sample contain <1.29 mg kg^{-1} of soil (Fig. 4). In Shigar valley mean value of Cu 3.54 mg kg^{-1}, Fe 12.53 mg kg^{-1}, Zn 0.96 mg kg^{-1} and Mn 10.81 mg kg^{-1} was detected. All soil samples exhibited high concentration of Cu, Fe and Mn except Zn which was low in

Table 6. Micronutrients percent samples under different categories in the study area.

Valleys	Cu			Fe			Zn			Mn		
N=96	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Bagrote (n = 24)	00	00	24	00	00	24	13	8	3	00	00	24
	(0)	(0)	(100)	(0)	(0)	(100)	(54.2)	(33.3)	(12.5)	(0)	(0)	(100)
Haramosh (n = 28)	00	00	28	00	1	27	18	4	6	00	00	28
	(0)	(0)	(100)	(0)	(3.58)	(96.42)	(64.29)	(14.29)	(21.42)	(0)	(0)	(100)
Hoper (n = 20)	00	00	20	00	00	20	10	7	3	00	00	20
	(0)	(0)	(100)	(0)	(0)	(100)	(50.0)	(35.0)	(15.0)	(0)	(0)	(100)
Shigar (n = 24)	00	00	24	00	00	24	13	8	3	00	00	24
	(0)	(0)	(100)	(0)	(0)	(100)	(54.17)	(33.33)	(12.50)	(0)	(0)	(100)
Mean	00	00	96	00	1	95	54	27	15	00	00	96
	(0)	(0)	(100)	(0)	(0.90)	(99.10)	(56.26)	(28.12)	(15.62)	(0)	(0)	(100)

Values outside & in parenthesis denote number & percent samples respectively

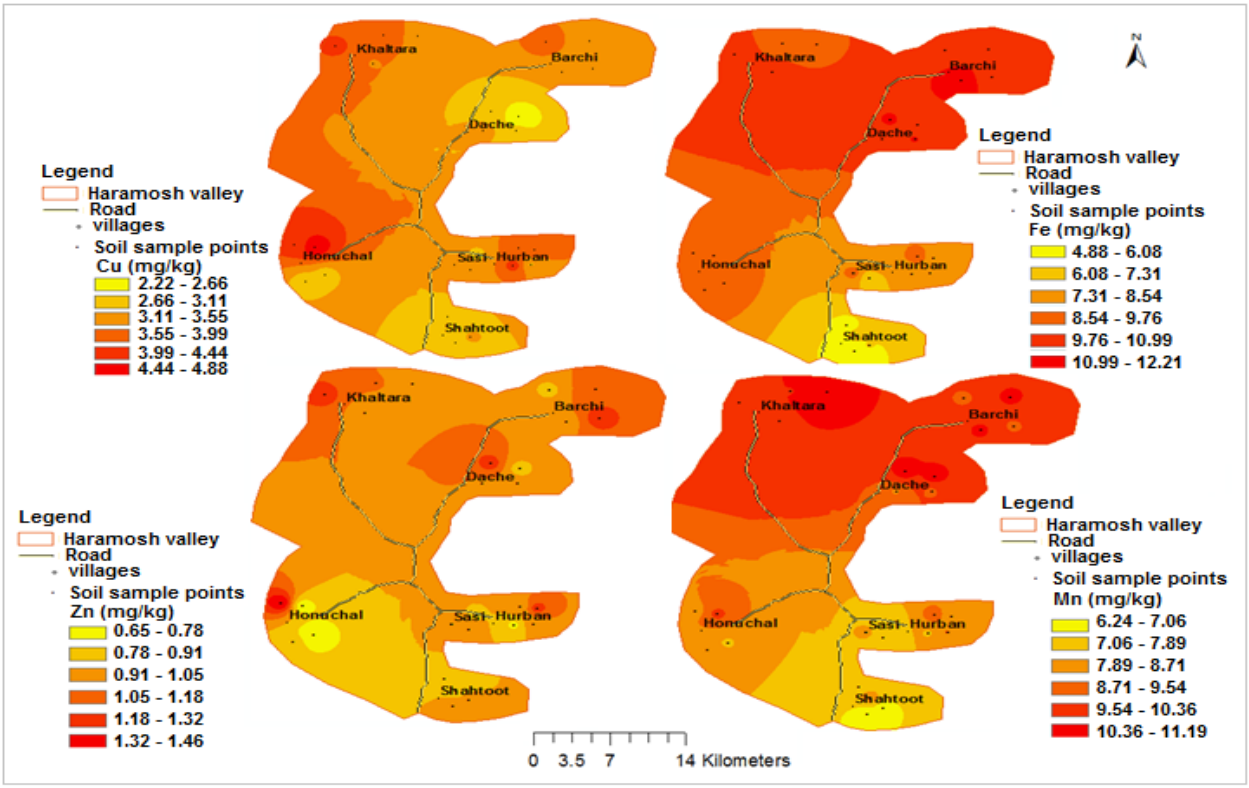

Figure 3. Mapping of micronutrient in villages of Haramosh valley.

54.1%, medium 33.3% and high 12.5% in tested soil samples (Table 7). Macronutrients map showed that 58.5%, 83.3%, 62.5% and 79.1% tested soil fall in the range of 3.42-3.91 mg kg^{-1} of Cu, 12.0-13.55 mg kg^{-1} Fe, 0.92-1.22 mg kg^{-1} Zn and 10.12-11.09 mg kg^{-1} Mn (Fig. 5).

***Soil mycoflora*:** In this part of the study, soil mycoflora was

Table 7. Mycoflora diversity and % of occurrence in soil of Bagrote valley.

Valley	Dilution	NCSD	NC/GS	Species	NC	% occurrence
Bagrote	10^{-3}	14		*Rhizopus stolonifer*	2	8.33
	10^{-4}	7	24 x 10^{-6}	*Aspergillus flavus*	4	16.67
	10^{-6}	3		*Alternaria alternata*	2	8.33
	Total	24		*Curvularia lunata*	1	4.17
				Mucor species	3	12.50
				Rhizoctonia solani	1	4.17
				Fusarium solani	2	8.33
				Trichoderma harzanium	2	8.33
				Trichoderma viride	1	4.17
				Penicillium species	2	8.33
				Aspergillus niger	2	8.33
				Helminthosporium species	1	4.17
				Fusarium oxysporum,	1	4.17

NCSD: No of colonies in serial dilution; NC/GS: No of colonies per gram of soil; NC: No of colonies

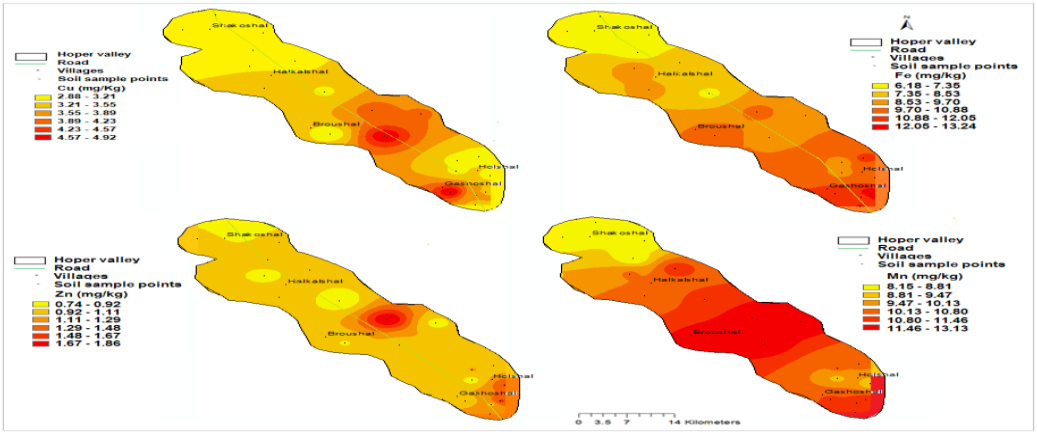

Figure 4. Mapping of micronutrient in villages of Hoper valley.

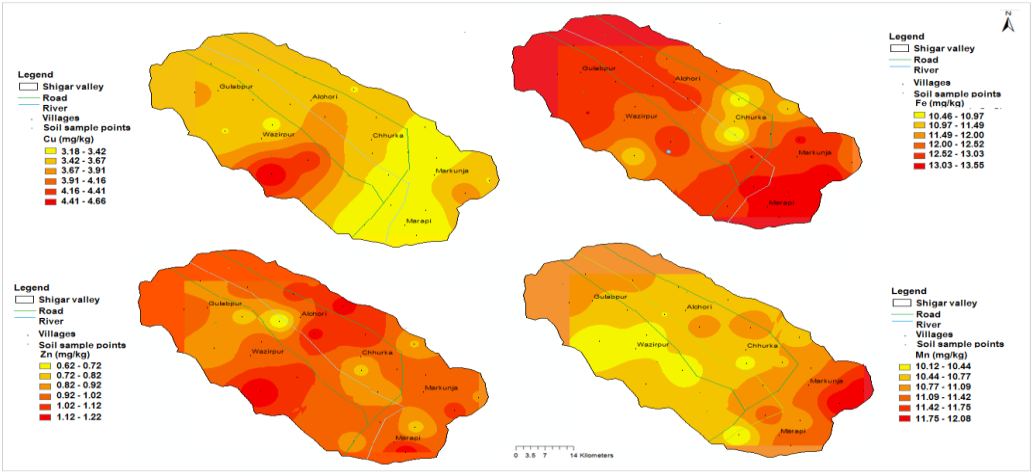

Figure 5. Mapping of micronutrient in villages of Shigar valley.

enumerated through serial dilution technique from four composite samples (one from each valley). Results showed that a total of thirteen mycoflora were identified in the tested samples. Highest population of mycoflora was found in Shigar followed by Bagrote valley. The valley wise population of mycoflora in per gram of soil was recorded as $24x10^{-6}$ in Bagrote, $18x10^{-6}$ in Haramosh, $15x10^{-6}$ in Hoper and $26x10^{-6}$ in Shigar valley. Thirteen species were isolated in Bagrote valley with the highest number of *Aspergillus flavus* and *Mucor species* (Table 7). Similarly, ten mycoflora were isolated in soil samples of Haramosh valley with highest number of *Rhizopus stolonifer* and *Penicillium species* (Table 8). Nine mycoflora species were found in Hoper and thirteen in Shigar valley. Mucor species was found with highest percentage of occurrence in Hoper valley, whereas, *Mucor* and *Penicillium* were dominant followed by *Alternaria alternata species* in Shigar valley (Table 9, 10).

Table 8. Mycoflora diversity and % of occurrence in soil of Haramosh valley.

Valley	Dilution	NCSD	NC/GS	Species	NC	% occurrence
Haramosh	10^{-3}	8		*Rhizopus stolonifer*	3	16.67
	10^{-4}	4	18×10^{-6}	*Aspergillus flavus*	2	11.11
	10^{-6}	2		*Alternaria alternata*	1	5.55
	Total	18		*Curvularia lunata*	1	5.55
				Mucor species	2	11.11
				Rhizoctonia solani	1	5.55
				Fusarium solani	2	11.11
				Trichoderma harzanium	1	5.55
				Penicillium species	3	16.67
				Aspergillus niger	2	11.11

NCSD: No of colonies in serial dilution; NC/GS: No of colonies per gram of soil; NC: No of colonies

Table 9. Mycoflora diversity and % of occurrence in soil of Hoper valley.

Valley	Dilution	NCSD	NC/GS	Species	NC	% occurrence
Hoper	10^{-3}	10		*Rhizopus stolonifer*	2	13.33
	10^{-4}	3	15×10^{-6}	*Aspergillus flavus*	1	6.67
	10^{-6}	2		*Alternaria alternata*	1	6.67
	Total	15		*Curvularia lunata*	2	13.33
				Mucor species	3	20.0
				Trichoderma harzanium	1	6.67
				Penicillium species	2	13.33
				Aspergillus niger	2	13.33
				Helminthosporium species	1	6.67

NCSD: No of colonies in serial dilution; NC/GS: No of colonies per gram of soil; NC: No of colonies

Table 10. Mycoflora diversity and % of occurrence in soil of Shigar valley.

Valley	Dilution	NCSD	NC/GS	Species	NC	% occurrence
Shigar	10^{-3}	15		*Rhizopus stolonifer*	1	3.84
	10^{-4}	7	26×10^{-6}	*Aspergillus flavus*	2	7.69
	10^{-6}	4		*Alternaria alternata*	3	11.53
	Total	26		*Curvularia lunata*	1	3.84
				Mucor species	4	15.38
				Rhizoctonia solani	1	3.84
				Fusarium solani	2	7.69
				Trichoderma harzanium	1	3.84
				Trichoderma viride	2	7.69
				Penicillium species	4	15.38
				Aspergillus niger	1	3.84
				Helminthosporium species	2	7.69
				Fusarium oxysporum,	2	7.69

NCSD: No of colonies in serial dilution; NC/GS: No of colonies per gram of soil; NC: No of colonies

DISCUSSION

***Soil pH, organic matter and Saturation percentage*:** Soil plays a foremost role in determining the sustainable productivity of agricultural crop. The sustainable agriculture development is a mainly depends upon the ability of soil to supply essential nutrients to the growing crop (Bell and Dell, 2008). The result of current study showed that pH of the study area was slightly alkaline, loamy or silty loam with low to medium organic matter contents. Similar results were obtained by (Baber *et al*., 2004; Whiteman, 1985. Soil pH is important parameter that influence physiochemical, biological and soil nutrient availability. Organic matter has a dynamic role in agricultural soil. It supplies plant nutrient to improve the soil structure, water infiltration and retention, feeds soil microflora and fauna (Johnston, 2007). The low or medium organic matter in the study area might be due to inadequate return of plant residues to the soil and environmental conditions which are conducive to rapid mineralization. Soil texture is basic to many other soil properties and helps as an indicator of water holding capacity, cation exchange capacity, aeration and organic matter content. Soil texture also controls the retention and losses of soil nutrients. In the current study saturation percentage raged from 35-50. According to Muhammad *et al.* (2015) stated that soil saturation percentage ranged from 26-46 are suitable for cultivation of all common crops.

***Micronutrients*:** The results pertaining to micronutrients of study area indicated that Cu, Fe and Mn (mg kg^{-1}) were high except Zn which showed irregular trends in the tested samples. Despite the sufficient amount of micronutrient concentrations in the soil of CKNP region, there is spatial variability between and within the villages. Several researchers reported that spatial variability of soil is due to intrinsic and extrinsic factors. Intrinsic factors are; soil formation factors, such as soil parent materials, while extrinsic factors are; soil management practices like fertilization (Mzuku *et al*., 2005; Guo-Shun *et al*., 2008; Denis *et al*., 2015). Variability is one of the intrinsic properties of soil quality and within the same ecosystem; soil characteristics may show significant spatial variations (Robinson *et al*., 2006). Main sources of micronutrients are parent material, sewage sludge, town refuse, farmyard manure (FYM) and organic matter (Wajahat *et al*., 2006). Whiteman 1985 reported that the pH of Northern Area now Gilgit-Baltistan is alkaline and found no widespread symptom of nutrient deficiency in these soils. Similar report was also contributed by Baber *et al.* 2004 in tehsil Gilgit which concluded that the tested soil samples were sufficient in Cu, Fe and Mn except Zn. This information's revealed that the study area is adequate in micronutrients which were in agreement with the current findings. It has been further reported that the agricultural systems where animal farming related practices are intensive, heavy metals can reach the soil due to application of liquid and solid manures. These practices are the main source of heavy metals and particularly Cu (Nicholson *et al*., 2003). The Zn deficiency of this region might be due to high pH and $CaCO_3$ contents that precipitate as hydroxide and carbonates as reported by Vijayasekhar *et al*. (2000) on Indian soils. Management of soil nutrients is important for meeting the food requirements of ever-increasing population of the world without adversely affecting the environment. Surveys and maps illustrating the geographic distribution of soil micronutrient availability provide guidance for proper management of nutrients in the soils. This information is further essential for a better understanding of the nature and extent of micronutrient deficiencies and toxicities in plants, livestock and humans (Jeffrey and Robert, 1999). GIS and geostatistics have been proven as an effective tool to assess the spatial variability of soil nutrients (Webster and Oliver, 2001). Spatial variability in soil nutrients of any area is necessary in order to gather information and prepare soil maps through spatial interpolation of point based measurements of soil characteristics (Santra *et al*., 2008). Micronutrient plays a significant role for growth and productivity of the crops and it contributes to ensure food security. In general, soil micronutrient status (Cu, Fe and Mn) are satisfactory except Zn, however, in near future intensive cropping may possibly reduce their concentrations, therefore, integrated nutrient management practices are recommended. Zn status of the study area was medium to deficient that needs immediate attention for mitigation. GIS is used to produce micronutrient map of an area, which helps in formulating site specific fertilizer recommendations and to understand the status of soil micronutrients spatially.

***Mycoflora diversity*:** Knowledge of mycoflora diversity and conservation in agricultural soil becomes very essential for the development of sustainable agriculture. Soil has a complex nature and dynamic environment in which the biological activities are mostly governed by microorganisms. Among the microorganisms; mycoflora are cosmopolitan in distribution and their population depends on the physico-chemical properties of soil (Gomathi, 2011). The current investigation also revealed a variety of soil mycoflora which was in agreement of the above statement. Hawksworth (2002) reported that fungi is a main part of biodiversity, important for the survival of other organisms and plays a vital role in global ecological processes. It is omnipresent and occurs in all types of habitats and happens to be one of the most adaptable organisms. The results of the current study indicated that *Aspergillus flavus* and *Penicillium species* showed high percentage of occurrence in all valleys. *Penicillium* spp. are attributed to produce antibiotics and the *Aspergillus* spp. produce different kinds of toxins such as aflotoxins and achrotoxins etc. These toxins may prevent the growth of other fungal species (Chandrashekar *et al*., 2015; Shiny Niharika *et al*., 2013). It has been further reported that

agricultural soils having diversity of fungal species are dominant by *Aspergillus* and *Penicillium spp.* (Rakesh and Raju, 2013). *Aspergillus* and *Penicillium* were dominating in all sites of the study area which was also confirmed by previous reports (Gnanasekaran *et al*., 2015; Gaddeyya *et al*., 2012; Shiny Niharika *et al*., 2013).

***Conclusion*:** It is concluded that the soil of study area was slightly alkaline, loamy or silty loam with low to medium organic matter. GIS mapping showed that spatial variability of micronutrients was found. The results may be applied for determining the site specific nutrient management practices, fertilizer use efficiency, reducing cost of cultivation and preventing environmental pollution. Furthermore, mycoflora diversity was also observed in the study. Hence, the diversity of soil mycoflora of potato fields would provide information related to soil conservation and sustained ecological balance.

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