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Soil Fertility Mapping of Chilli Growing Areas of Taluka Kunri, Sindh, Pakistan

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Abstract: Soil fertility evaluation is an important tool for site-specific fertilization for sustainable crop production. Regular monitoring of soil fertility status provides basis for the precious soil resource management. TalukaKunri is the most important chilli growing tract of Pakistan and is the largest chilli market of Asia. However, no any study reports its status of physicochemical properties and fertility of soil. We mapped selected physicochemical properties and nutrient status of talukaKunri, Sindh, Pakistan. A total of 50 soil samples were collected from major chili growing tract of six union councils of talukaKunri, from 0-20 cm depth and their coordinates were recorded. The results revealed that 80% soils were heavy in texture while 20% soils were medium-textured loams. Electrical conductivity (dS m^{-1}) ranged from 0.3-7.2 (avg: 1.6, mode: 1.3). Majority (68%) of soil samples were non-saline (EC: <2.0 dS m^{-1}) followed by very slightly saline (28%) soils (EC: 2-4 dS m^{-1}). SoilpH ranged from 7.7-8.5 (avg: 8.1, mode: 8.2). Most (70%) of the soil samples were medium alkaline in nature (pH: 7.6-8.2) while remaining (30%) were strongly alkaline (pH: 8.3-8.5). Lime content ranged from 0.4-29.4% (avg: 11.9%, mode: 4.8%). Majority of soils were strongly (46%) or moderately (40%) calcareous ($CaCO_3$: >15% and 3-15%, respectively). Organic matter ranged from 0.4-1.17% (avg: 0.8%, mode: 1.04%). No soil sample was found to have adequate (>1.29%) organic matter. The organic matter for 56% soils was found to be deficient (<0.86%) while for 44% soils it was medium (86-1.29%). Soil ABDTPA-P (mg kg^{-1}) ranged from 0.9-7.1 (avg: 3.4, mode: 2.4). Half of the soils had low P content, whereas, 48% soils had medium P content. Only a negligible portion of soils (2%) were found to have adequate P. Soil ABDTPA-K (mg kg^{-1}) ranged from 40-620 (avg: 124.6, mode: 100 mg kg^{-1}). Majority of soil samples (64%) were found to have medium K content while 12% soils had low K content. K content of only 24% soils was found adequate. We recommend site-specific balanced fertilization and use of organic amendments for the soils of chili growing areas of talukaKunri for sustainable chili production.

Keywords: Mapping, soil, phosphorus, potassium, chilies, Kunri, Sindh, Pakistan, Asia

1. INTRODUCTION

Chilli (*Capasum annum* L.) is one of the most important condiment crops of Pakistan, grown as a cash crop. According to recent agricultural Statistics of Pakistan (2013-14), Sindh contributes ~83% of chilies growing area with ~89% of the total production of chilies in Pakistan. However, a 22% decrease in chilies production was noted during 2013-14 as against 2009-10 due to a 10% decrease in the area under chilies production. It is noteworthy to mention that the yield of chilies in Pakistan remained highly stagnant since last many years (from 2000-01 to 2013-14) with an average yield of 2.0 tons ha^{-1} (ranged from 1.5 to 2.7 ha^{-1}) (GoP, 2015).

Kunri is the largest chili market of Asia. However, no recent study is reported in the literature focusing up on the status of soil properties and nutrient content of this most important chili growing tract of Asia. Soil fertility evaluation is an important tool for site-specific fertilization for sustainable crop production. Regular monitoring of soil fertility status provides basis for the precious soil resource management.

It is estimated that about 90% of Pakistani soils are deficient in their phosphorus (P) content, i.e.<10 mg kg^{1}Olsen P (Memon *et al*., 1992). P is an essential macronutrient, required by plants in relatively large quantity i.e., 0.2 to 0.8% (Mills and Jones, 1996). It is essential for early vegetative plant growth since it enhances tillering and development of roots (Slaton *et al*., 2002). However, poor farming community face difficulty in using P-fertilizers since they are becoming very costly due to the rapid mining of non-renewable P reserves which are reported to be vanished within next 6-8 decades (Metzger, 1995).

Potassium (K) deficient soils are rapidly increasing in Pakistan and about 40% soils are being reported K-deficient (Zia-ul-hassan *et al*., 2008). This is due to the unaffordable cost of K-fertilizers in Pakistan and the misconception about the adequacy of K in Pakistani soils (Zia-ul-hassan *et al*., 2014). Pakistani soils though mostly contain large amounts of K as part of relatively insoluble minerals, nonetheless, very negligible amount is available for the use of plants (Bajwa and Rehman, 1996). K is required in chili crop in more amounts as compared to other crops (Alabi, 2006). Suresh (2000) observed that, total extractable K content of chili significantly increased by increasing K dose. Talpur (2002) found that the soils of chili growing areas of

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Kunri are sufficient in K. K, as an essential macronutrient, used by plants in huge quantities. It is an important enzyme activator and is essential for many important growth (Fageria*et al*., 2011) physiological and biochemical attributes of plants, besides its pertinent roles in enhancing plant tolerance against biotic and abiotic stresses (Amtmann *et al*., 2006; Maschmann *et al*., 2010) and improving crop yield and quality (Fageria *et al*., 2011).

Due to these factors, the regular monitoring of chili growing areas for their nutrient status in order to ensure sustainable chili growing. However, except a very old study on the subject (Talpur, 2002), no current study reports the status of soil properties and nutrient content of this important chili growing tract of Pakistan. This study was, therefore, planned to map the soils of chili growing areas of taluka Kunri, Sindh, Pakistan for their current status of physicochemical properties and nutrient content.

2. MATERIALS AND METHODS

A total of 50 soil samples were collected from major chili growing tract of all six union councils of taluka Kunri, i.e. Chajro, Bustan, NabiSar, Sher Khan Chandio, Kunri Memon and Talhi. Soil sampling (0-20 cm depth) was done as suggested by Ryan *et al*. (2001).The details of sampling sites is given in (**Table 1** and mapped in **Fig. 1A).**

Table 1. Details of Sampling Sites and Status of Selected Soil Properties and Macronutrient Content of Chillies Growing Areas of Taluka Kunri

Site No.	UC/Deh	Lat.	Long.	EC (dS/m)	pH	CaCO3 (%)	O.M. (%)	P (mg/kg)	K (mg/kg)
	UC Chajro								
1	Chajro	25.20664º	69.53623º	0.74	8.2	10.2	0.48	2.9	110
2	Chajro	25.20995º	69.53435º	0.89	8.4	18.4	0.65	1.9	80
3	Dhadhro	25.20890º	69.54502º	2.08	8.3	20.1	0.67	4.3	70
4	Dhadhro	25.21592º	69.54502º	2.19	7.9	16.5	1.07	5.1	80
5	Morjango	25.22541º	69.55401º	2.07	7.9	7.5	1.04	4.2	60
6	Morjango	25.22709º	69.54177º	1.33	8.3	16.8	0.84	4.8	60
7	Chajro	25.21690º	69.54586º	5.09	8.1	27.8	0.77	0.9	60
8	Goraho	25.16722º	69.62235º	1.58	8.3	4.8	1.02	6.3	70
9	Goraho	25.16283º	69.62439º	0.94	8.3	21.5	0.89	4.7	100
10	Goraho	25.21218º	69.59784º	1.15	8.2	19.0	1.01	4.5	80
11	Dhadhro	25.21199º	69.59390º	0.35	8.4	10.0	0.49	7.1	70
	UC KunriMemon								
12	Kunri	25.21210º	69.59784º	0.45	8.1	25.8	0.53	4.8	50
13	Kunri	25.21394º	69.52372º	1.39	8.2	24.6	1.04	5.0	70
14	Khamnon	25.11909º	69.60103º	0.59	8.4	28.0	1.04	4.8	80
15	Khamnon	25.13432º	69.58388º	7.19	7.7	6.0	1.18	4.6	140
16	Malhansar	25.21719º	69.58388º	1.92	8.2	9.0	0.95	5.7	100
17	Malhansar	25.31216º	69.56271º	3.19	8.0	16.2	1.05	4.3	110
18	Mayadars	25.22083º	69.58150º	2.11	8.1	14.0	0.96	5.5	110
19	Mayadars	25.22377º	69.58396º	2.87	8.1	25.0	0.74	3.8	110
20	Barani	25.17888º	69.53669º	3.41	8.2	20.0	0.48	3.5	70
21	Kharchelo	25.18042º	69.54348º	0.83	8.2	17.0	0.79	4.6	70
	UC Bustan								
22	Bustan	25.19720º	69.53782º	0.51	8.1	28.0	0.88	5.7	40
23	Khamnon	25.17920º	69.51328º	0.32	8.0	29.0	0.49	2.4	100
24	Char	25.21640º	69.49220º	0.75	7.9	24.4	0.92	3.4	100
25	Mojan	25.20240º	69.52173º	0.6	7.8	4.8	0.82	5.0	100
26	Jhinjhi	25.19081º	69.52322º	0.81	7.8	4.8	0.80	4.7	90
27	Manjhakar	25.14664º	69.48419º	0.53	8.3	2.4	1.05	2,7	80
28	Seerkhi	25.13410º	69.46482º	0.44	8.2	3.6	0.76	2.3	70
29	Seerkhi	25.12900º	69.45053º	1.03	8.5	2.0	0.60	2.9	50
30	Char	25.13528º	69.44680º	0.43	8.1	2.0	0.78	3.2	80

	UC Sher Khan Chandio								
31	Rindki	25.11540º	69.56317º	1.5	7.8	8.2	0.96	4.5	100
32	FatehDhandh	25.11130º	69.56775º	1.79	7.95	3.8	1.08	4.5	80
33	ShakhDarelo	25.13469º	69.56218º	1.65	8.1	3.2	0.96	3.9	100
34	Kuria	25.12258º	69.60987º	2.4	7.9	4.8	0.87	2.7	170
35	Saidki	25.16219º	69.53406º	0.6	8.1	5.0	0.62	3.6	110
36	GharaKaranga	25.15449º	69.58396º	0.61	8.25	0.4	0.88	2.4	110
37	Darelo	25.12882º	69.53188º	1.09	8.1	8.5	0.92	1.9	170
38	Kandiari	25.17264º	69.50975º	1.63	8.0	1.5	0.90	4.0	360
	UC NabiSar								
39	Sanwari	25.13063º	69.50726º	1.22	8.05	2.2	0.54	3.40	170
40	Sanwari	25.16230º	69.51211º	1.25	7.8	13.0	0.81	4.70	280
41	Maluk Shah	25.99420º	69.47606º	3.57	7.9	4.1	0.89	2.80	620
42	NabiSar Part.1	24.09393º	69.43616º	3.14	7.8	29.4	0.80	3.50	220
43	Ranwai	24.09243º	69.42718º	0.71	8.3	4.8	0.78	4.20	200
44	Rajpari Pat	24.05674º	69.44211º	0.46	8.3	2.5	0.86	2.40	130
	UC Talhi								
45	Danbharlo	24.06446º	69.44.496º	0.65	8.1	1.5	0.78	3.70	200
46	Mundhwai	25.23416º	69.51248º	2.94	8.4	22.4	0.65	3.40	100
47	K.B Chandio	25.23416º	69.52816º	3.97	8.3	4.5	0.75	4.00	120
48	NaseerChandio	25.21634º	69.52124º	2.74	8.5	0.7	0.81	4.30	100
49	Talhi	25.20432º	69.51132º	1.24	8.2	12.1	1.10	2.40	260
50	Hydio	25.19212º	69.49118º	2.18	8.2	1.5	0.84	2.80	170
	Minimum			**0.32**	**7.70**	**0.4**	**0.48**	**0.90**	**40**
	Maximum			**7.19**	**8.50**	**29.4**	**1.18**	**7.14**	**620**
	Mean			**1.66**	**8.12**	**11.9**	**0.83**	**3.92**	**125**
	Mode			**0.60**	**8.20**	**4.8**	**1.04**	**2.40**	**100**
	STD			**1.35**	**0.20**	**9.4**	**0.18**	**1.23**	**95**

The coordinates for various sites were recorded with the RMaps® software v.0.9.4, run on an android platform (Credit: Robert, 2009, Developer Osmdroid by Nicolas Gramlich). Soil samples were analyzed in two replicates to determine soil texture, EC, pH, organic matter, $CaCO_3$ and ABDTPA-extractable P and K (Ryan *et al*., 2001). Taluka level descriptive statistics (minimum, maximum, mean, mode, standard deviation and coefficient of variation) was performed through spread sheet software MS-Excel® (Microsoft, 2010). For this purpose individual values of various soil properties of all 50 sites of six union councils were utilized.Mapping of various soil properties and nutrient content of chili growing areas of six union councils of talukaKunri was done by using Google earth® and by utilizing the coordinates recorded through RMaps® software at the time of soil sampling. Moreover, Corel DRAW Graphics Suite X7 (www.coreldraw.com) was utilized to develop various maps.Union council wise average values of various soil properties and nutrient contents were utilized for this purpose.

3. RESULTS

Soil texture: The results **(Fig. 1B)** revealed that soils of chili growing areas of taluka Kunri varied from fine or heavy textured clays (80%) to different types of medium to moderately textured loams (20%), including silt loam (14%), clay loam, sandy loam and sandy clay loam (2% each). The union council Kunri Memon had a variety of soil textures, i.e. clay, silt loam and clay loam. Similarly, some areas of union council Chajro had sandy loam and union council Nabisar had sandy clay loam textures, nonetheless, heavy clays dominated both these union councils. All other union councils had clayey texture.

Electrical Conductivity: The electrical conductivity (EC) of chilies growing areas of talukaKunri ranged from 0.32-7.19 dS m^{-1} with an average of 1.66 dS m^{-1} and the most frequent value of 0.60 dS m^{-1}**(Table 1)**. The soil samples were grouped according to Jackson (1962) utilizing the data given in **Table 1**. The grouping revealed that 40% of the soils of chili growing areas

oftalukaKunri were moderately saline (EC: 4-8 dS m^{-1}), 32% soils were very slightly saline (EC: 2-4 dS m^{-1}), 20% soils were non-saline (EC: <2.0 dS m^{-1}) while the leftover (8%) soil samples were strongly saline (EC: 8-16 dS m^{-1}). The mapping of soils revealed that five union councils were free from salinity hazard while the union council KunriMemon had slightly saline soils **(Fig. 1C).**

pH: SoilpH of chilies growing areas of talukaKunri ranged from 7.7-8.5 with an average of 8.1 and most frequent value of 8.2 **(Table 1).** The soils were grouped according to Ankerman and Richard (1989) using the soil pH values given in **Table 1**. The ranking indicated that 70% soils of chili growing areas of talukaKunri had medium alkaline (pH 7.6 to 8.2) while the remaining (30%) soils were strongly alkaline (pH 8.3- 9.0). The mapping of soils depicted that five union councils had medium alkaline soils while union council Talhi had strongly alkaline soils **(Fig. 1D).**

Organic matter: Organic matter content of chilies growing areas of taluka Kunri was observed in the range of 0.5 to 1.2% with an average value of 0.8% while the most frequent value was found to be 1.0% (**Table 1**). The soil samples were grouped according to FAO (1986) taking individual soil samples into account (**Table 1**). Accordingly, 54% soils were deficient (<0.86%) and 46% soils were medium (0.86-1.29%) in organic matter content. As depicted in **Figure 2A**, two union councils, Sher Khan Chandio and KunriMemon, had medium organic matter while the soils of remaining four union councils were low in organic matter content.

Lime content: Lime contentof chilies growing areas of taluka Kunri ranged from 0.4-29.4% with an average of 11.9% and most frequent value of 4.8% **(Table 1)**. The soils were grouped according to Reconnaissance Soil Survey (1972) on the basis of $CaCO_3$ values of individual soils **(Table 1)**. It was found that 40% soils were moderately calcareous in reaction (3-15% $CaCO_3$), 46% soils were strongly calcareous (>15% $CaCO_3$), 10% soils were slightly calcareous (1-3% CaCO3) while only 4% soils were non-calcareous (<1.0% $CaCO_3$). The mapping of soils indicated that two union councils, Chajro and Kunri Memon, were strongly calcareous while remaining four union councils had moderately calcareous soils **(Fig. 2B).**

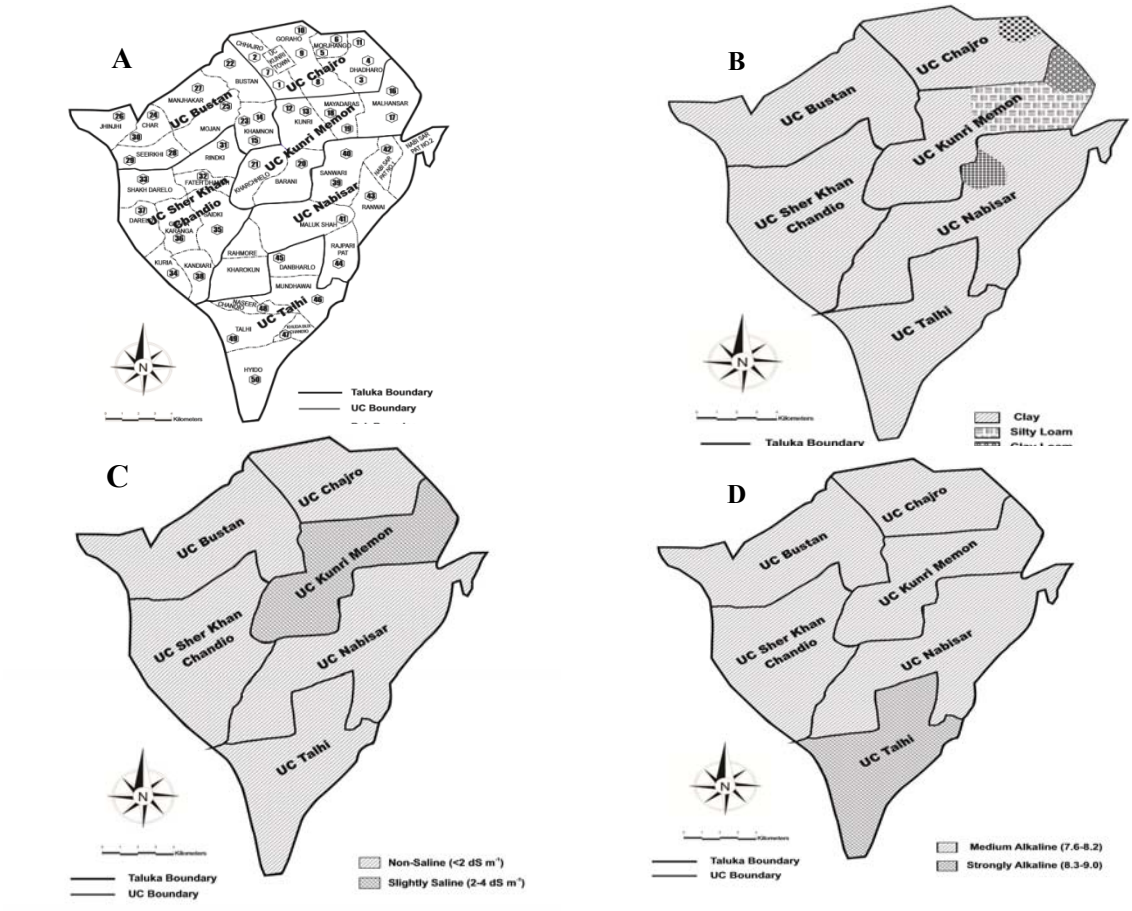

Fig. 1. Maps of chilli growing areas of taluka Kunri showing sampling sites (A), categorization of soil texture (B) electrical conductivity (C) and pH (D)

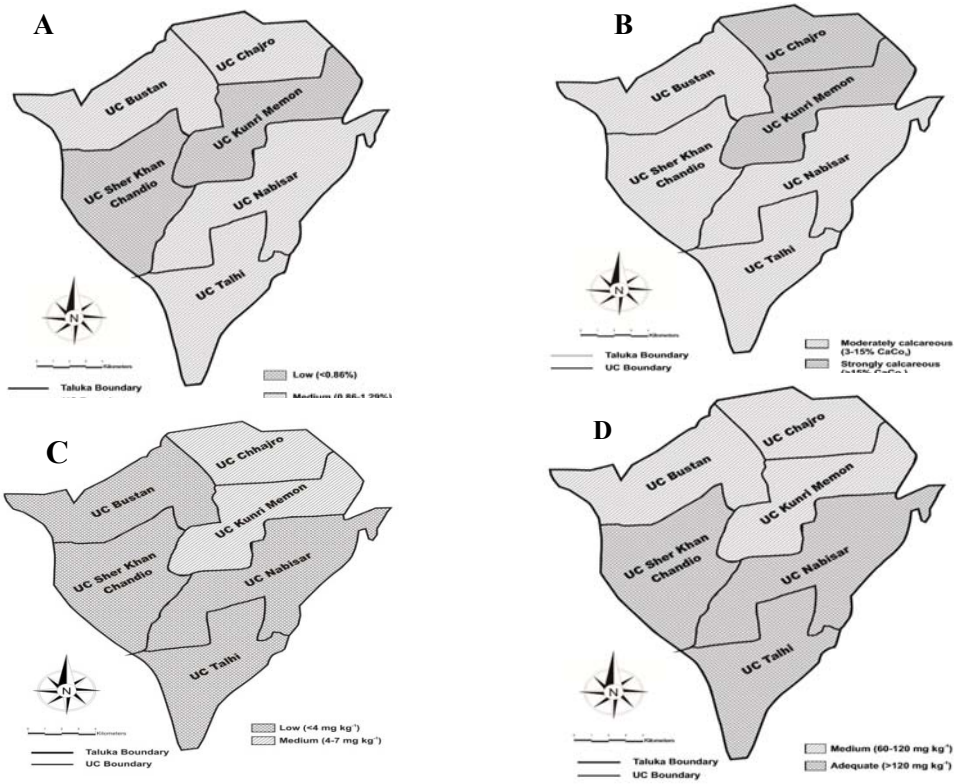

Fig. 2. Maps of chilli growing areas of taluka Kunri showing Lime content % (A), Organic matter % (B), Potassium (C) and Phosphorus (D)

ABDTPA-P: The ABDTPA-P of chilies growing areas of taluka Kunri ranged from 0.9-7.1 mg kg^{-1} with an average value of 3.9 mg kg^{-1} and the most frequent value noted for ABDTPA-P was 2.4 mg kg^{-1}**(Table 1)**. The soils were grouped according to Sultanpur and Schwab (1977) using the data for individual soils **(Table 1)**. About half (52%) soils were low in ABDTPA-P (<4.0 mg kg^{-1}), 48% soils were medium (4-7 mg kg^{-1})while only 2% soils were adequate (>7.0 mg kg^{-1}). The mapping of soils revealed that two union councils, Chajro and Kunri Memon, had medium amount of P whereas four union councils were found had low P content **(Fig. 2C).**

ABDTPA-K: The ABDTPA K content of chilies growing areas of taluka Kunri ranged from 40-620 mg kg^{-1} with an average value of 124.6 mg kg^{-1}. The most frequent value noted for ABDTPA-K was 100 mg kg^{-1}**(Table 1)**. The individual soil samples were grouped on whole taluka basis following Sultanpur and Schwab (1977). It was noted that ABDTPA-K content of 12% soils was deficient (<60 mg kg^{-1}), 64% soils was medium (60-120 mg kg^{-1}) while only 24% soils was adequate (60-120 mg kg^{-1}). Soil mapping illustrated that three union councils, Bustan, Chajro and Kunri Memon had medium K content while the leftover union councils had adequate soil K **(Fig. 2D).**

4. DISCUSSION

Soil fertility evaluation is an important tool for site-specific fertilization for sustainable crop production. Regular monitoring of soil fertility status provides basis for the precious soil resource management. Taluka Kunri is the most important chili growing area of Pakistan having the biggest chili market of Asia. However, very little is known about the physico-chemical properties and nutrient status of this very important chili growing tract of Pakistan, except one study conducted more than a decade earlier (Talpur, 2002). To the best of our knowledge, the present study is the first ever study conducted on soil mapping of chili growing areas of taluka Kunri. The results of this study revealed that majority (80%) of the soils of area under study were heavy clays. Almost similar results were reported earlier by Talpur (2002) who found that 60% of the soils were clayey in texture. This study further highlighted that majority (68%) of soils were free from salinity and endorsed earlier results of Talpur (2002) which also revealed that most (70%) of the soils of taluka Kunri were either non-saline or had very slight salinity levels. The results of present study were also in agreement with the earlier findings (Talpur, 2002) that these soils were medium alkaline in majority (70%) of cases. Earlier, Rashid (1996) also reported that most of the Pakistani soils are medium to strongly alkaline. Our

results showed that almost half of the soils (46%) were medium in organic matter content, while earlier reports (Talpur, 2002) revealed that only 30% soils of taluka Kunri were medium in their organic matter content. However, it is believed that organic matter content of Pakistani soils is <1% (Rashid, 1996). Hence, it can be concluded that organic matter content of chili growing areas of taluka Kunri is improved with the passage of time might be due to the regular use of organic amendments. Lime content results of the present study showed that 40% soils were calcareous and 46% soils were strongly calcareous in nature. The results are in line with the earlier findings which reported that most Pakistani soils are calcareous in nature. The present study also attempted to map the soil P and K contents. P is an essential macronutrient, required by plants for their proper growth and yield (Mills and Jones, 1996). About 90% soils of Pakistan are deficient in P (Memon *et al*., 1992). Previous study (Talpur, 2002) on the subject concluded that the soils of chili growing areas of taluka Kunri were very low (60%) to low (25%). Moreover, 15% soils were also reported medium in their P content.

Our results showed that 50% soils were low in P content while 48% soils had medium content of P. These results suggest that P status of soils improved with time due to the balanced P fertilization. K is required by plants for better yield and quality. It is required in chili crop in more amounts as compared to other crops (Alabi, 2006). It is earlier reported that 40% soils of Pakistan are K-deficient (Zia-ul-hassan *et al*., 2008). Contrary to the above findings, the present study showed that 75% soils of taluka Kunri had inadequate K content. The negligible use of K for crop production in Pakistan (Zia-ul-hassan *et al*., 2014), which is also true for chili growing areas of taluka Kunri, may be the main reason for this low K content of these soils.

5. CONCLUSION

We recommend site-specific balanced fertilization and use of organic amendments for the soils of chili growing areas of taluka Kunri for sustainable chili production.

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