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Status of selenium in soils of middle Gujarat region

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Abstract
Background: Selenium is an essential micronutrient for mammals, birds, fish and many bacteria for their growth and survival. Selenium is an ingredient in many multivitamins and other dietary supplements, including infant formula. The main source of selenium for human food or animal fodder is the soil–plant system. Although Se is not classified as a micronutrient for higher plants, numerous studies have shown that at low concentrations, Se exerts a beneficial effect on growth and stress tolerance of plants by enhancing their antioxidative capacity.
Method: The survey work was carried out during the month of May-June, 2020. The soil samples were collected particularly from forage grown field of middle Gujarat region. The total 15 soil and fodder plant samples were collected from each district of Anand, Ahmedabad, Mahisagar, Botad, Vadodara, Kheda, Dahod, Panchmahal and Chhotaudepur and nine (9) profile soil sample were also taken from different depths (0-15, 15-30, 30-45, 45-60 and 60-90 cm) from individual district.
Results: The analytical results of soil samples collected during survey work indicated that mean total Se content ranged from 0.13 to 0.42 ppm in forage grown soils of nine districts wherein, minimum value was reported in Ahmedabad district and maximum in Dahod district. The comparison of total Se with ratings, soils categorized under moderate (0.125-0.175 ppm) and high (0.175-3 ppm). The data of soil profile on total Se decreased with increasing depth in all the districts. The surveyed forage crops (135 samples) grouped as per Se content in soil and plant indicated that highest mean Se content observed in sorghum plant (0.98 ppm) and lowest in fodder cowpea (0.32 ppm). Irrespective of forage crops, the overall Se content in forage crops plant ranged from 0.17 to 1.05 with a mean of 0.50 ppm. The total Se in soils indicated that highest mean total Se content was observed in maize (DP) grown soil (0.37 ppm) while lowest in soils of lucerne (0.14 ppm). Irrespective of soils, the overall total Se content in forage grown soils ranged from 0.11 to 0.72 with a mean of 0.27 ppm.

Keywords: Selenium, forage, fodder, sorghum, Lucerne, profile, district

Introduction
Selenium is an essential micronutrient for mammals, birds, fish and many bacteria for their growth and survival (Burau, 1985) [1]. In human beings and animals, its deficiency has been shown to be associated with heart failure (Ge *et al*., 1983) [4], muscle pain (Van Rij *et al*., 1981) [12], cancer inhibitor (Ip and Ganther, 1994) [5] and many other diseases (Burk, 1994). Selenium is an ingredient in many multivitamins and other dietary supplements, including infant formula. The main source of selenium for human food or animal fodder is the soil–plant system. Its status in plants is related to the selenium content of the soil on which the plants are grown and is ultimately reflected in the livestock through plant selenium intake. According to the appropriate dietary intake limits by the livestock, different areas of the world can be characterized as selenium deficient, selenium adequate and selenium toxic. Although, Se is not classified as a micronutrient for higher plants, numerous studies have shown that at low concentrations, Se exerts a beneficial effect on growth and stress tolerance of plants by enhancing their antioxidative capacity (Kong *et al.* 2005) [6].
The global Se distribution in soils varies greatly from 0.005 mg/kg in Finland to 8,000 mg/ kg in Tuva-Russia (Chasteen and Bentley, 2003) [3]. Selenium concentration in the soil generally ranges from 0.01-2.0 mg/kg but seleniferous soils usually contain more than 5 mg/kg and these seleniferous soils have been reported in Ireland, China, India and USA (Saha *et al*., 2017) [8]. The Se concentration of soil depends on the composition of bedrock from which the soil component derives and the geochemical processes that produce the soil. The mean Se content in clay soils was 0.29 mg/kg and in coarse mineral soils 0.17 mg/kg. The highest Se concentration was measured from organic soils (0.46 mg/kg) (Mirza *et al.*, 2010) [7].

In order to meet the requirements for human nutrition, soils have been classified as deficient (<0.125 mg/kg), marginal (0.125-0.175 mg/kg), moderate to high (0.175-3 mg/kg) and excessive (>3mg/kg) based on total Se in soil. Selenium in soil varies in availability may occur in many forms (e.g. as selenites, selenates, elemental selenium, and selenide). Both the total selenium content and the chemical forms (including availability) are critical for the production of vegetation with low, high, or even toxic levels of selenium. In alkaline soils (pH > 7.5), selenium is present as water-soluble selenate and is available to plants, whereas in acidic soils it is usually bound as basic ferric selenite, with very low solubility (WHO, 1987) [13].

Although all plants can take up and metabolize selenium, the assumption about its necessity for higher plants has not been fully+ confirmed yet. As selenium is derived by plants from soils, it was thought necessary first to study the selenium status of soils. Therefore, representative surface soil samples from different districts of middle Gujarat were collected and studied on status of selenium in soils of middle Gujarat region.

Materials and Methods

The survey work was carried out during the month of May-June, 2020. To meet the objectives, fifteen (15) surface soil samples (0-20 cm) were collected from Anand, Kheda, Ahmedabad, Panchmahal, Dahod, Vadodara, Botad, ChhotaUdepur and Mahisagar districts of middle Gujarat region. Total of 135 soil samples were collected from the different fields of the region. Also, one profile soil sample (0-15, 15-30, 30-45, 45-60 and 60-90 cm depth) was collected from each district.

Soil sampling method: A representative composite samples of 0.5 kg soil was collected in a plastic bag and brought to the laboratory. A profile soil samples (0-15, 15-30, 30-45, 45-60 and 60-90 cm depth) were also taken from different districts of middle Gujarat. The samples were air dried under shade, pounded in a wooden mortar and pestle and sieved through 2 mm sieve. The samples were stored in polythene bags and labeled properly for further analysis.

Plant samples collection: Fodder plant samples were collected from each of nine districts. From each district, total 15 samples were collected at the site of soil sampling. Total 135 plant samples were collected and air dry under shade and oven dried at 65+5 ºC temperature still constant weight. Thereafter the dried samples were ground by stainless steel wiley mill and stored in paper bag to prevent from moisture. The samples were analysed for total Se as per the standard methods.

Method followed for determination of Selenium from soil: Total Se determined by a procedure described by USFDA (2015) [10]. A representative sample of 0.5 g soil was taken into PTFE tube. Added 8 mL of concentrated nitric acid, 1 mL hydrochloric acid and 1 mL hydrogen peroxide into tube and tighten well with lid cover. Shaken well and kept all these sample tubes overnight for pre digestion. Placed tubes in microwave digester and run the programme for about half an hour as described in Table 1. Filtered the samples through whatman filter paper and transferred the digested acidic liquid into accurately marked 50 mL PE tube and give frequent wash of milliQ water to PTFE tube and transfer to PE tube. Finally made up 50 mL with milliQ water and followed ICP-MS analysis (Table 2).

ICP-MS Parameter for Selenium

Inductively Coupled Plasma Mass Spectrometry (ICP-MS: AGILENT:7900)

Sample Digestion

HNO_3	:	8 mL
HCL	:	1 mL
H_2O_2	:	1.0 mL
Sample weight	:	0.5 g
Final volume	:	50 mL

Table 1: Digestion programing

Ramp	Min	Mega Watt (w)	Temperature °C	Hold time
1	5	1500	120	8
2	8	1500	150	15
3	15	1800	200	5
4	5	1800	200	30
Cooling	20			

Table 2: Instrument (ICP-MS) operation details

ICP RF Power	1550 W	Nebulizer pump	0.1 rps
Nebulizer Gas Flow	1.09 L min^{-1}	sample flow	0.2 mL min^{-1}
Carier gas Flow	1 L min^{-1}	Energy Discrimination	7.0 V
Plasma gas (Argon) Flow	15 L min^{-1}	Sampler Cone	Ni
Auxiliary Gas	0.90 L min^{-1}	Skimmer Cone	Ni
He Flow	10 mL min^{-1}		

Determination of selenium from plant

Total Se was analysed by digestion with 4 mL HNO_3 (1:1): 10 mL HCl (1:4) di-acid mixture as per the U.S.EPA procedure.

Results and Discussion

Total selenium of forage grown soils in different districts of middle Gujarat: The data on total Se in forage grown soils of middle Gujarat are given in Table 3. The mean total Se content ranged from 0.13 to 0.42 ppm in forage grown soils of nine districts, wherein the minimum value reported in Ahmedabad district and maximum in Dahod district (fig 1). Total Se were observed as low as 0.11 ppm and as high as 0.72 ppm. The lower variation (9.25%) found in Ahmedabad district among the data as compared to other districts, whereas maximum variation (53.7%) found in Mahisagar district. In general, soils containing less than 0.6 mg Se/kg are likely to produce crops with insufficient Se (<0.1 mg/kg) to protect livestock from Se deficiency.

Table 3: Total selenium content in forage grown soils of different districts of middle Gujarat (n=15)

Total Se (ppm)									
Sample detail	**Mahisagar**	**Botad**	**Dahod**	**Vadodara**	**Chhota Udepur**	**Ahmedabad**	**Panchmahal**	**Anand**	**Kheda**
Minimum	0.12	0.11	0.26	0.13	0.12	0.12	0.15	0.12	0.12
Maximum	0.58	0.47	0.63	0.22	0.72	0.15	0.63	0.18	0.20
Mean	0.25	0.30	0.42	0.17	0.38	0.13	0.41	0.15	0.15
Std. Dev.	0.14	0.12	0.12	0.03	0.20	0.01	0.15	0.02	0.02
CV%	53.7	39.8	28.9	15.8	52.6	9.25	37.5	12.4	16.4

The results related total Se in profile soil samples are presented in Table 4. The total Se for surface soil (0-15 cm) depth was found in the range of 0.11 to 0.63 ppm. The higher value of total Se (0.63 ppm) observed in Dahod district, while the lower concentration of total Se (0.11 ppm) found in Anand district. The overall results indicated that with increasing the depth of soil (from 0-15 cm and above), total se decreased in all districts might be due to un-weathered parent rocks. Based on total Se classification, soils have been classified as deficient (<0.125 mg/kg), marginal (0.125-0.175 mg/kg) and moderate to high (0.175-3 mg/kg) and excessive (>3mg/kg) as reported by Tan *et al.*, 1989 [9].

Table 4: Total Selenium content of profile sample in forage grown soils of different districts of middle Gujarat

Total Se (ppm)									
Soil depth (cm)	**Mahisagar**	**Botad**	**Dahod**	**Vadodara**	**Chhota Udepur**	**Ahmedabad**	**Panchmahal**	**Anand**	**Kheda**
0-15	0.24	0.49	0.63	0.18	0.35	0.20	0.56	0.11	0.19
15-30	0.15	0.33	0.57	0.14	0.33	0.17	0.50	0.14	0.17
30-45	0.18	0.48	0.51	0.10	0.14	0.19	0.57	0.13	0.18
45-60	0.14	0.39	0.57	0.13	0.18	0.18	0.54	0.12	0.20
60-75	0.18	0.37	0.49	0.14	0.13	0.17	0.52	0.10	0.13
75-90	0.16	0.36	0.46	0.15	0.11	0.18	0.50	0.10	0.10

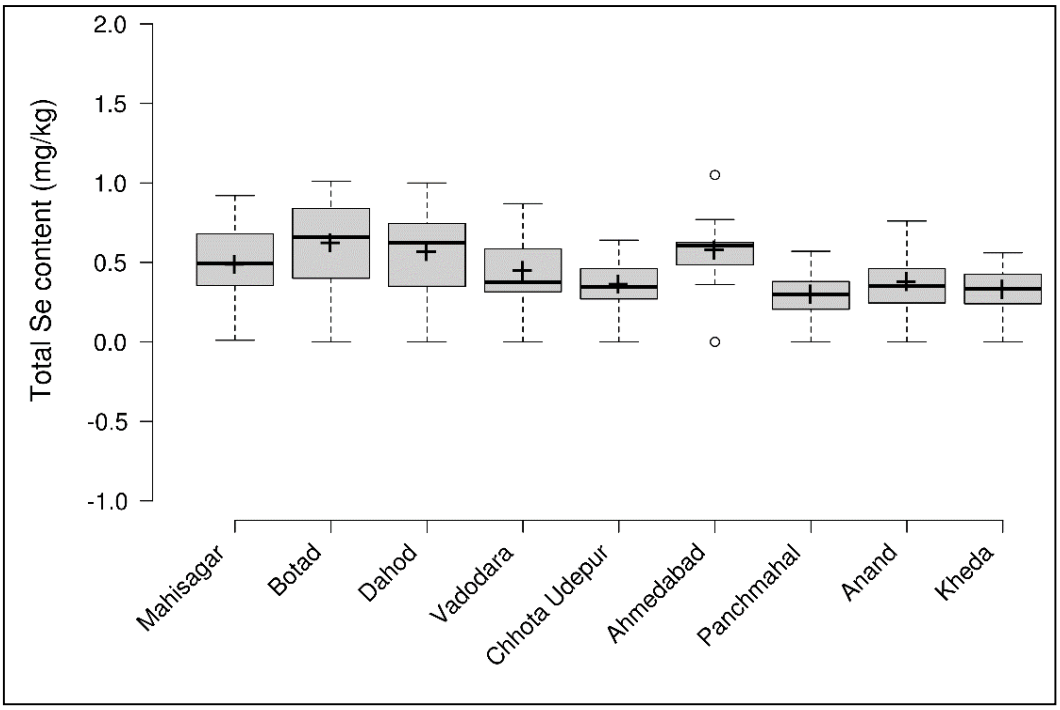

Fig 1: Box plot chart of total Se content in forage grown soils of different districts of middle Gujarat

Selenium content in forage grown plants from different districts of middle Gujarat: The result of Se content in fodder crops collected from different districts are presented in Table 5. The mean Se content was found in the range of 0.32 to 0.66% in various forage plants. The higher Se content (0.66%) was observed in Botad and the lowest content found in Panchmahal district. The coefficient variation indicated that largest variation (44.7%) observed in Vadodara and lowest variation (26.2%) reported from Ahmedabad district may be due to parent materials.

The surveyed forage crops (135 samples) grouped as per Se content in soil and plant and presented in Table 6. The Se content in forage crop plant indicated that highest mean Se content observed in sorghum plant (0.98 ppm) followed by fodder sorghum (0.55 ppm) and lowest in fodder cowpea (0.32 ppm). Irrespective of forage crops, the overall Se content in forage crops plant ranged from 0.17 to 1.05 with a mean of 0.50 ppm. In case of total Se content in forage grown soil indicated that highest mean total Se content observed in maize (DP) grown soil (0.37 ppm) followed by fodder sorghum (DC) (0.35 ppm) and lowest in soils of Lucerne (0.14 ppm). Irrespective of soils, the overall total Se content in forage grown soils ranged from 0.11 to 0.72 with a mean of 0.27 ppm.

Table 5: Selenium content in forage grown plants from different districts of middle Gujarat (n=15)

Se content (ppm)									
Sample detail	**Mahisagar**	**Botad**	**Dahod**	**Vadodara**	**Chhota Udepur**	**Ahmedabad**	**Panchmahal**	**Anand**	**Kheda**
Minimum	0.21	0.35	0.23	0.25	0.21	0.36	0.18	0.22	0.17
Maximum	0.92	1.01	1.00	0.87	0.64	1.05	0.57	0.76	0.56
Mean	0.52	0.66	0.60	0.48	0.38	0.61	0.32	0.40	0.35
Std. Dev.	0.21	0.24	0.24	0.21	0.13	0.16	0.12	0.17	0.12
CV%	39.9	35.6	38.9	44.7	33.2	26.2	36.2	42.30	33.1

Table 6: Selenium content in forage crop plants and soil from different districts of middle Gujarat

Forage crop	**Total Se in soil (ppm)**		**Se content in plant (ppm)**	
	Range	**Mean**	**Range**	**Mean**
Bajra (4)*	0.12-0.43	0.25	0.26-0.86	0.54
Bajra Napiar Hybrid (25)	0.12-0.63	0.24	0.18-1.01	0.47
Fodder Bajra (8)	0.14-0.58	0.24	0.31-0.76	0.52
Fodder Cowpea (3)	0.15-0.63	0.33	0.26-0.38	0.32
Fodder Maize (20)	0.12-0.72	0.26	0.17-0.74	0.45
Fodder Sorghum (16)	0.11-0.70	0.26	0.28-0.87	0.55
Fodder Sorghum (DC) (4)	0.14-0.56	0.35	0.24-0.96	0.53
Fodder Sorghum (MC) (12)	0.12-0.62	0.26	0.20-1.01	0.42
Lucerne (11)	0.12-0.18	0.14	0.27-0.71	0.45
Maize (DP) (18)	0.14-0.63	0.37	0.18-1.00	0.47
Oat (8)	0.14-0.59	0.24	0.21-0.77	0.47
Sorghum (2)	0.13-0.45	0.29	0.91-1.05	0.98
Sorghum (Batu) (3)	0.17-0.50	0.31	0.28-0.64	0.42
Para grass (1)	--	0.18	--	0.39
Overall (135)	0.11-0.72	0.27	0.17-1.05	0.50

*Number of soil samples

Summary and Conclusion

The comparison of mean total Se with ratings, soils categorised under moderate (0.125-0.175 ppm) to high (0.175-3 ppm). In case of overall (135 samples) total Se content in forage grown soil indicated that highest mean total Se content observed in maize (DP) grown soil followed by fodder sorghum (DC) and lowest in soils of Lucerne. Irrespective of soils, the total Se content in forage grown soils ranged from 0.11 to 0.72 with a mean of 0.27 ppm. The overall results indicated that with increasing the depth of soil (from 0-15 cm and above), total Se decreased in all districts. The surveyed forage crops (135 samples) grouped as per Se content in plant and results indicated that highest mean Se content observed in sorghum plant followed by fodder sorghum and lowest in fodder cowpea. Irrespective of forage crops, the overall Se content in forage crops plant ranged from 0.17 to 1.05 with a mean of 0.50 ppm. The total Se content in forage crops grown soils of middle Gujarat region categorized under moderate to high status.

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