Original Research Article

Status of Sulphur, Zinc and Boron in Onion Growing Soils of Dharwad Taluk, Karnataka

Abstract

Survey was undertaken during *rabi* 2021-22, to study the sulphur, zinc and boron status in onion growing fields in selected villages of Dharwad taluk. One hundred surface soil samples were collected from selected ten villages of Dharwad taluk using GPS. The results revealed that soils were neutral to alkaline in reaction, low in total soluble salts, low to high organic carbon content, low in available nitrogen, medium in available phosphorus, potassium and sulphur and 49.00 and 77.00 per cent of the soils were deficient in DTPA extractable zinc and hot water soluble boron, respectively.

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Key words: Onion; Sulphur; Zinc; Boron

1. INTRODUCTION

Onion (*Allium cepa* L.) belonging to the family *Alliaceae*, is one of the most important monocotyledonous, cross-pollinated and cool season vegetable crop and is an important export earning vegetable crop worldwide. Onion has it’s own distinctive flavour, used in soups, meat dishes, salads and sandwiches and is cooked alone as a vegetable. The presence of the volatile oil "*Allyl propyl disulphide*" accounts for it’s pungency. After China, India is the world's second largest producer of onion, accounting 22.60 per cent of the world production. Onion is grown on an area of 16.2 lakh hectares in India, with yearly production and productivity of 26.64 million tonnes and 16.4 million tonnes per hectare, respectively. The major onion producing states include Maharashtra, Karnataka, Madhya Pradesh, Rajasthan, Bihar, Gujarat and Odisha. The Karnataka state occupies second position in area (2.30 lakh hectare) and third in production (26.60 lakh tonnes) [1]. The major onion growing districts in the state are Chitradurga, Gadag, Vijayapura, Bagalkot, Dharwad and Haveri.

The yield and quality of crops are greatly improved by nutrients. As a result, improving onion productivity while maintaining high quality is a key goal for the local market. Among the nutrients, sulphur is regarded as the fourth most important nutrient for crops after nitrogen, phosphorus and potassium. It is necessary for the synthesis of amino acids such as cystine, cysteine and methionine (which are building blocks for protein in the plant), a component of vitamin ‘A’ and activates certain enzyme systems in plants. Sulphur is incorporated into onion flavour precursors *S-alk(en)yl-L-cysteine sulphoxides* (ACSOs) among other compounds. The volatile oil *Allyl propyl disulphide* is what gives it it’s pungent flavor. The production of *allyl propyl disulphide* is negatively impacted by severe sulphur deficit during bulb development. These sulphur compounds are produced when the onion cell is mechanically disrupted, the enzyme allinase comes into contact with flavor precursors such as *S- alk(en)yl-L-cysteine sulfoxides* (ACSOs). Apart from volatile sulphur compounds, the enzymatic break down of ACSOs also produces ammonia, pyruvic acid and ascorbic acid, all of which are linked to quality of bulbs. Sulphur application not only improves the bulb quality, but it also extends the shelf life of onion during storage. Zinc plays an important role in various enzymatic and physiological activities of the plant body. The functional role of zinc includes auxin metabolism, influence on the activity of carbonic anhydrase, dehydrogenase enzymes, cytochrome synthesis and stabilization of ribosomal fractions. Besides, it plays a significant role in chlorophyll formation. Boron plays important role in pollen germination and pollination and also it is essential for transport of carbohydrates, cell wall metabolism, the permeability and stability of cell membranes and phenol metabolism, besides having primary role in lignin synthesis.

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Excessive removal of nutrients by crops and their inadequate replenishment resulted in soil fertility deterioration which is considered to be one of the major constraints in attaining and sustaining higher productivity. As a consequence, widespread deficiencies of at least six nutrients *viz.*, nitrogen, phosphorus, potassium, sulphur, zinc and boron have been recorded in Indian soils [2].

The apparent impact of excessive and imbalanced application of inorganic fertilizers in intensive cropping system has been reflected in terms of emerging and spreading of multi-nutrient deficiencies in soil. Loss of productive soil is another concern and about 6000 to 12000 million tonnes of top soil is washed away every year which carry nearly 5.6 to 8.4 million tonnes of nutrients mainly because of faulty management of soil and water resources. More emphasis on application of major nutrients has triggered widespread deficiencies of secondary and micronutrients like sulphur (41 %), zinc (49 %) and boron (33 %) with other micronutrients [3]. The knowledge regarding the status of sulphur, zinc and boron in soils helps in proper plant nutrition. Therefore, it is necessary to increase the status of these nutrients for sustainable crop productivity. Keeping all these facts in view, an investigation was undertaken to know the "Status of sulphur, zinc and boron in onion growing soils of Dharwad taluk".

2. MATERIAL AND METHODS

An investigation was carried out to study the status of sulphur, zinc and boron in selected villages of onion growing areas in Dharwad taluk of Karnataka. The study area covered ten selected villages in Dharwad taluk of Karnataka (Fig. 1). The geographical co-ordinates of Dharwad are 15^0 26' N latitude and 75^0 07' E longitude and an altitude of 678 m above the mean sea level. Dharwad comes under Northern Transitional Zone (Zone 8) of Karnataka, which lies in between the Western heavy rainfall areas of Hilly Zone (Zone 9) and low rainfall areas of plain zone, Northern Dry Zone (Zone 3) of Karnataka. The soil types in these study area are shallow to medium black. The major crops grown are maize, sorghum, soybean, groundnut, *etc*.

A survey was conducted during *rabi* 2021-22 season in onion growing areas of Dharwad taluk. One hundred surface soil (0-15 cm) were collected from the respective onion growing fields of the farmers from selected 10 villages in Dharwad taluk and sampling locations were marked by GPS. The soil samples were dried under shade, powdered using wooden pestle and mortar and passed through 2 mm sieve and preserved in polyethylene bags for further analysis. The 0.2 mm sieved soil samples were used for estimation of organic carbon [4]. The collected soil samples were analysed for chemical properties (pH, EC and OC), major (N, P and K), secondary (Ca, Mg and S) and micro nutrients (Fe, Zn, Cu, Mn and B). The details of methods followed for each parameter is presented in Table 1.

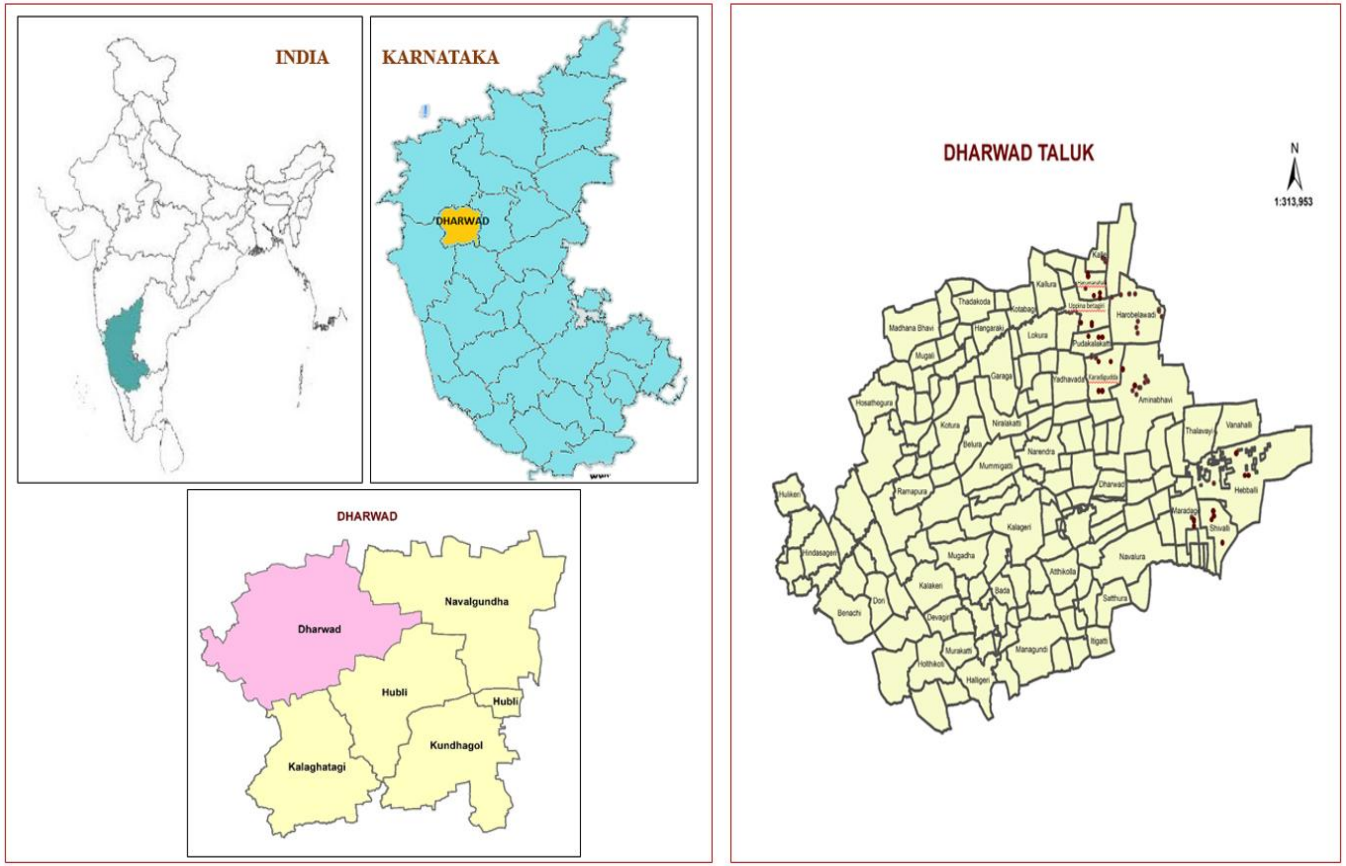

Fig. 1: Map of Dharwad taluk showing locations of sample collection

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Table 1. Methods followed for soil and plant analysis

Sl. No.	Properties	Method	Reference
1	Partical size analysis	Hydrometer method	[5]
2	Soil pH (1:2.5 soil water suspension)	Potentiometric method	[5]
3	Electrical conductivity (dS m^{-1}) (1:2.5 soil water extract)	Conductometric method	[5]
4	Organic carbon (g kg^{-1})	Walkley and Black's wet oxidation method	[4]
5	Available nitrogen (kg ha^{-1})	Alkaline potassium permanganate method	[6]
6	Available phosphorus (kg ha^{-1})	Olsen's extraction followed by spectrophotometric method	[7]
7	Available potassium (kg ha^{-1})	Neutral normal ammonium acetate extraction followed by flamephotometric method	[7]
8	Exchangeable calcium and magnesium [cmol (p^+) kg^{-1}]	Neutral normal ammonium acetate extraction followed by versenate titration method	[8]
9	Available sulphur (kg ha^{-1})	$CaCl_2$. $2H_2O$ extraction followed by turbidimetric method	[8]
10	DTPA extractable- Cu, Fe, Mn and Zn (mg kg^{-1})	DTPA extraction followed by Atomic Absorption Spectrophotometer method	[9]
11	Available boron (mg kg^{-1})	Hot water extraction followed by Azometheine-H method	[10]

3. RESULTS AND DISCUSSION

3.1 Chemical properties

The data presented in Table 2 revealed that soils of selected villages in Dharwad taluk were neutral to alkaline in reaction and the pH values ranged from 6.67 to 8.80 with an average of 7.91. Distribution of pH was negatively skewed indicating that there were some extreme high values in this area and positively kurtotic indicating a peaked distribution. The electrical conductivity values of these soils ranged from 0.16 to 0.67 dS m^{-1} with a mean of 0.38 dS m^{-1} and the soils were non-saline in nature. Distribution of EC was positively skewed indicating that there were some extreme low values in this area and negatively kurtotic indicating a flattened distribution. Organic carbon content was low to high and the values varied between 1.50 and 9.60 g kg^{-1} with an average of 6.00 g kg^{-1} and distribution of organic carbon was negatively skewed and positively kurtotic.

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3.2 Available macro nutrients (N, P, K, Ca, Mg and S)

Available nitrogen, phosphorus and potassium contents ranged from 120.56 to 562.82, 12.54 to 85.88 and 110.76 to 497.28 with mean values of 286.36, 41.29 and 286.97 kg ha^{-1}, respectively (Table 2). Distribution of available nitrogen and phosphorus was positively skewed and kurtotic whereas in case of potassium, distribution was positively skewed and negatively kurtotic. Among 100 samples, 42 per cent soil samples were low in available nitrogen, while 57 and one per cent of samples were in medium and high category, respectively. The wide variation in the available nitrogen status in the study area might be due to the higher dynamicity of the soil nitrogen and varied management practices followed by the farmers in different crops and cropping systems and also due to different soil types. Patil *et al.* [11] and Nagaraju *et al.* [12] also reported similar reasons for greater variation in available nitrogen status of red and black soils. Further, Pulakeshi *et al.* [13] observed that temperature, rainfall and altitude greatly influence the available nitrogen content of soils. For available phosphorus, nine per cent of the soil samples were under low category while 71 and 20 per cent of samples were in medium and high categories, respectively. The lower available phosphorus status of these soils in the area under study might be attributed to low clay content and hence lower ion exchange capacity as revealed by Mamaledesai *et al.* [14]. Dasog and Patil [15] reported that the soils in Zone-3 in North Karnataka were medium in available phosphorus content. In case of available potassium, 11 and 21 per cent samples were in low and high categories, respectively and 68 per cent of

Table 2. Chemical properties and available nutrients' status in onion growing fields of Dharwad taluk

Descriptive statistics	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})	N	P_2O_5	K_2O	Ca	Mg	S (mg kg^{-1})	Fe	Mn	Cu	Zn	B
				(kg ha^{-1})			[cmol (p$^+$) kg^{-1}]			(mg kg^{-1})				
Mean	7.91	0.38	6.00	286.36	41.29	286.97	20.68	8.87	15.23	5.23	5.07	0.42	0.60	0.43
Min	6.67	0.16	1.50	120.56	12.54	110.76	10.10	3.36	6.06	3.02	2.03	0.19	0.35	0.20
Max	8.80	0.67	9.60	562.82	85.88	497.28	35.24	16.44	23.53	8.48	9.54	0.81	0.91	0.72
SD	0.44	0.11	1.61	76.51	14.83	93.17	4.66	3.33	4.02	1.31	1.52	0.18	0.13	0.12
CV (%)	5.60	29.35	26.91	26.72	35.93	32.47	22.51	37.53	26.41	25.10	29.91	43.09	21.41	28.75
Skewness	-0.67	0.54	-0.22	0.22	0.77	0.11	0.78	0.81	-0.05	0.41	0.60	0.47	0.09	0.48
Kurtosis	0.20	-0.29	0.06	0.69	0.34	-0.53	0.41	-0.31	-0.69	-0.51	0.12	-0.98	-0.60	-0.50

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samples were in medium category. Medium available potassium content in some of the soils under study area might be due to coarser texture of the soil which might have led to greater leaching losses of potassium. The higher potassium content in the surface soils of the study area might be attributed to the genesis of these soils from the potassium rich parent material like micaceous and feldspar minerals. Similar observation was made by Ravikumar *et al*. [16] in Malaprabha right bank command area.

Similarly, for secondary nutrients the values of exchangeable calcium, magnesium ranged from 10.10 to 35.24, 3.36 to 16.44, with mean values of 20.68, 8.87 cmol (p+) kg^{-1}, respectively and available sulphur ranged from and 6.06 to 23.53 kg ha^{-1} with mean value of 15.23 kg ha^{-1}. Distribution of sulphur was negatively skewed and kurtotic and 14, 72 and 14 per cent samples were in low, medium and high categories, respectively (Fig.2). The lower available status of the sulphur in some of the soils might be attributed to application of major nutrient fertilizers devoid of sulphur and little or no addition of organic matter including organic manures causing continuous mining of sulphur by crops [11]. Seventy two per cent of the soil samples in the area under study tested were medium in available sulphur and this might be due to gypsiferous nature of black calcareous soils and higher organic matter content in soil. Similar results were also reported by Bidari [17] and Srikanth *et al*. [18].

3.3 Micronutrients (Fe, Mn, Cu, Zn and B)

The DTPA- extractable Fe, Mn, Cu and Zn contents ranged from 3.02 to 8.48, 2.03 to 9.54, 0.19 to 0.81 and 0.35 to 0.91 mg kg^{-1}, respectively with the corresponding mean values of 5.23, 5.07, 0.42 and 0.60 mg kg^{-1} (Table 2). Fourty nine per cent of samples were deficient in DTPA- extractable zinc (Fig.3 & 5). The lower availability of DTPA-extractable zinc status in the soils of the study area was due to the poor organic carbon content [19] and depletion by continuous cropping without addition of these nutrients [20]. The results of the study area are comparable to the reports of Sahrawat *et al*. [21] and Chander *et al*. [22]. Similar findings were also reported by Basavaraja *et al*. [23] who observed that 55.44 per cent of the soil samples analyzed were deficient in DTPA-extractable Zn in Alfisols of southern Karnataka and the values ranged from 0.08 to 6.70 mg kg^{-1}. Similarly, Jagdev *et al.* [24] reported that DTPA-extractable zinc content in Alfisosls of Jalandhar district ranged from 0.20 to 9.76 mg kg^{-1}. The lower availability of these micronutrients in some soils might also be due to higher pH. These results are similar to the observations made by Shukla *et al*. [25] and Basavaraja *et al*. [23].

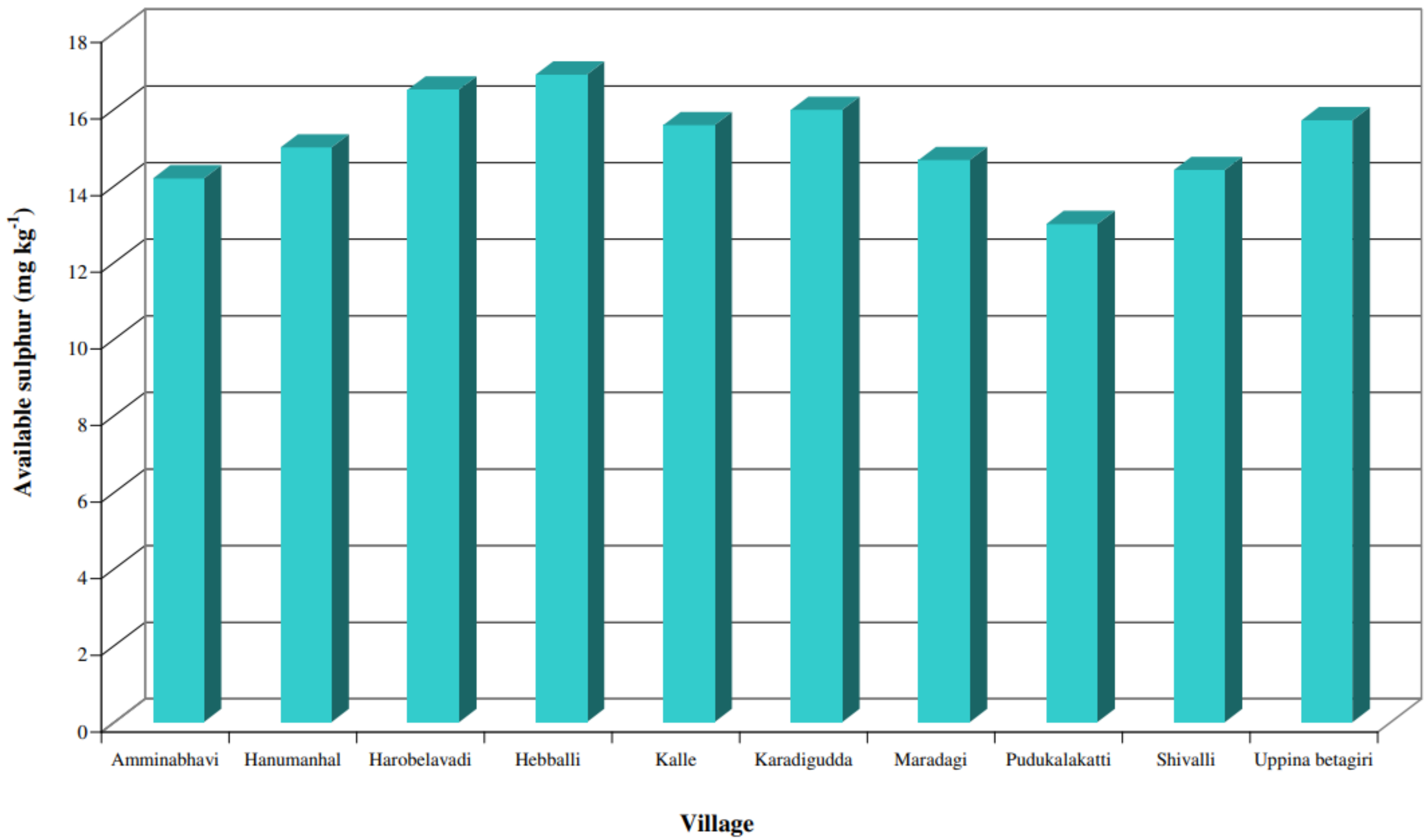

Fig. 2. Available sulphur status in onion growing fields in selected villages of Dharwad taluk

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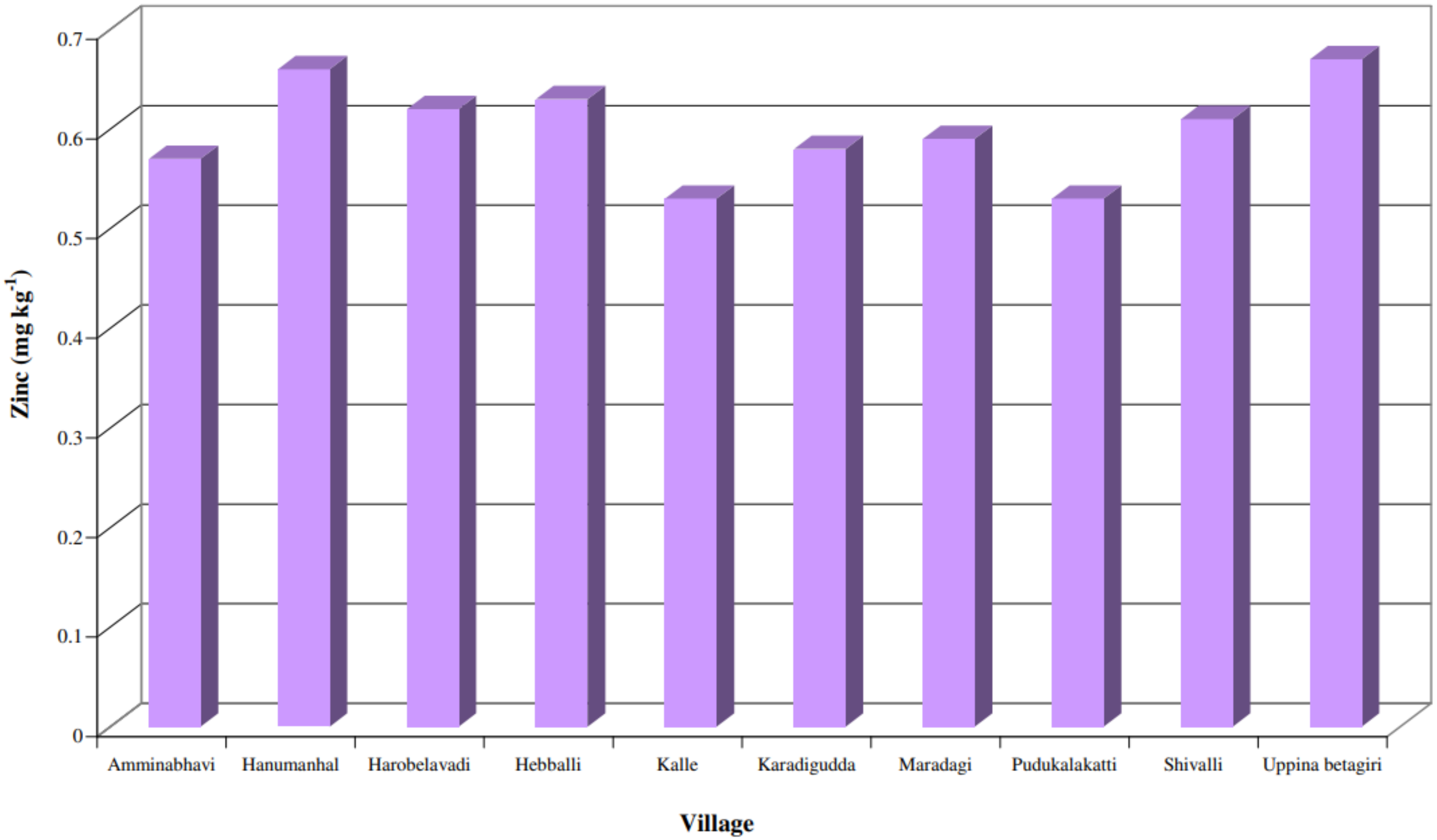

Fig. 3. DTPA extractable-zinc content in onion growing fields in selected villages of Dharwad taluk

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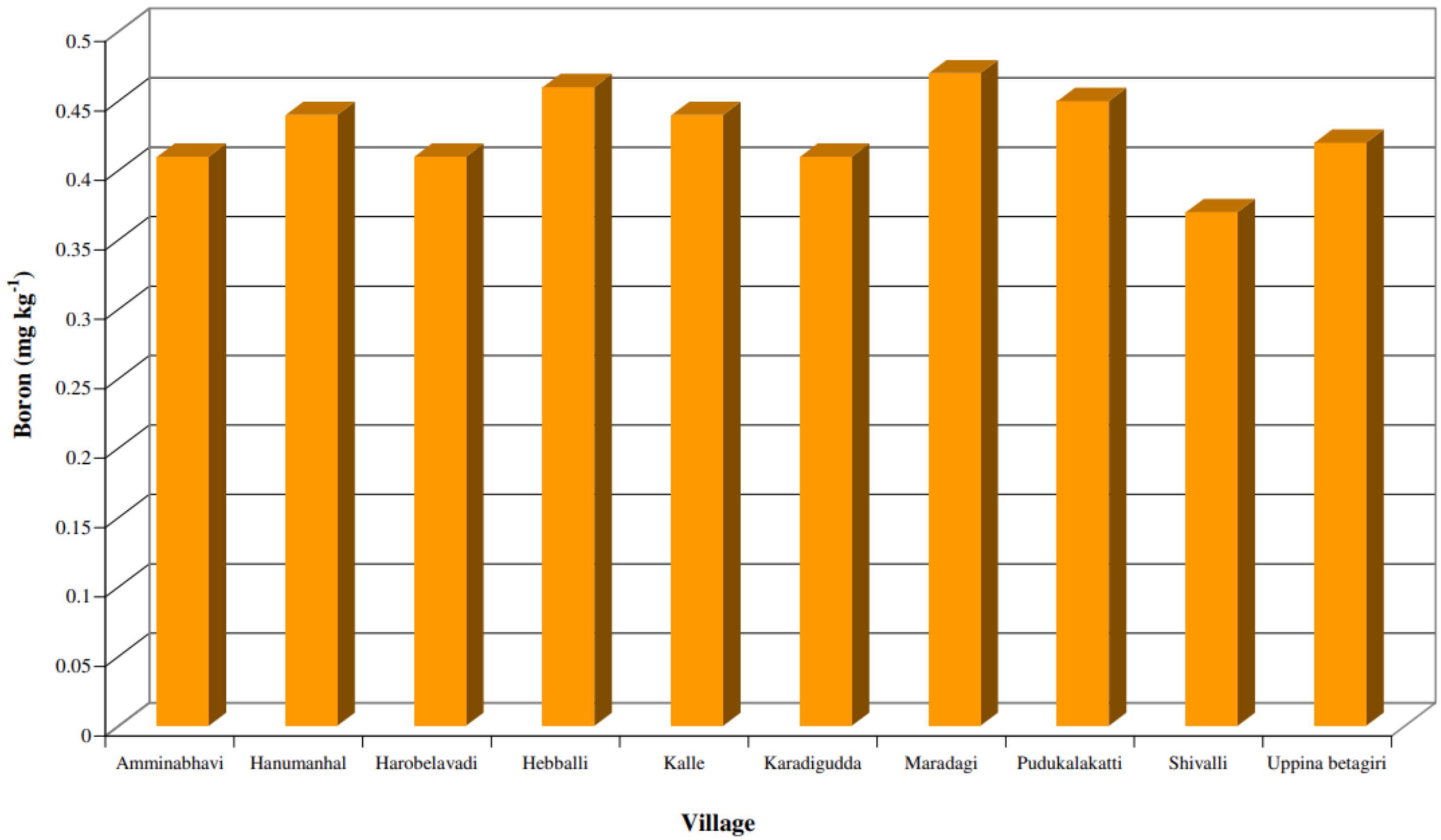

Fig. 4. Hot water soluble boron status in onion growing fields in selected villages of Dharwad taluk

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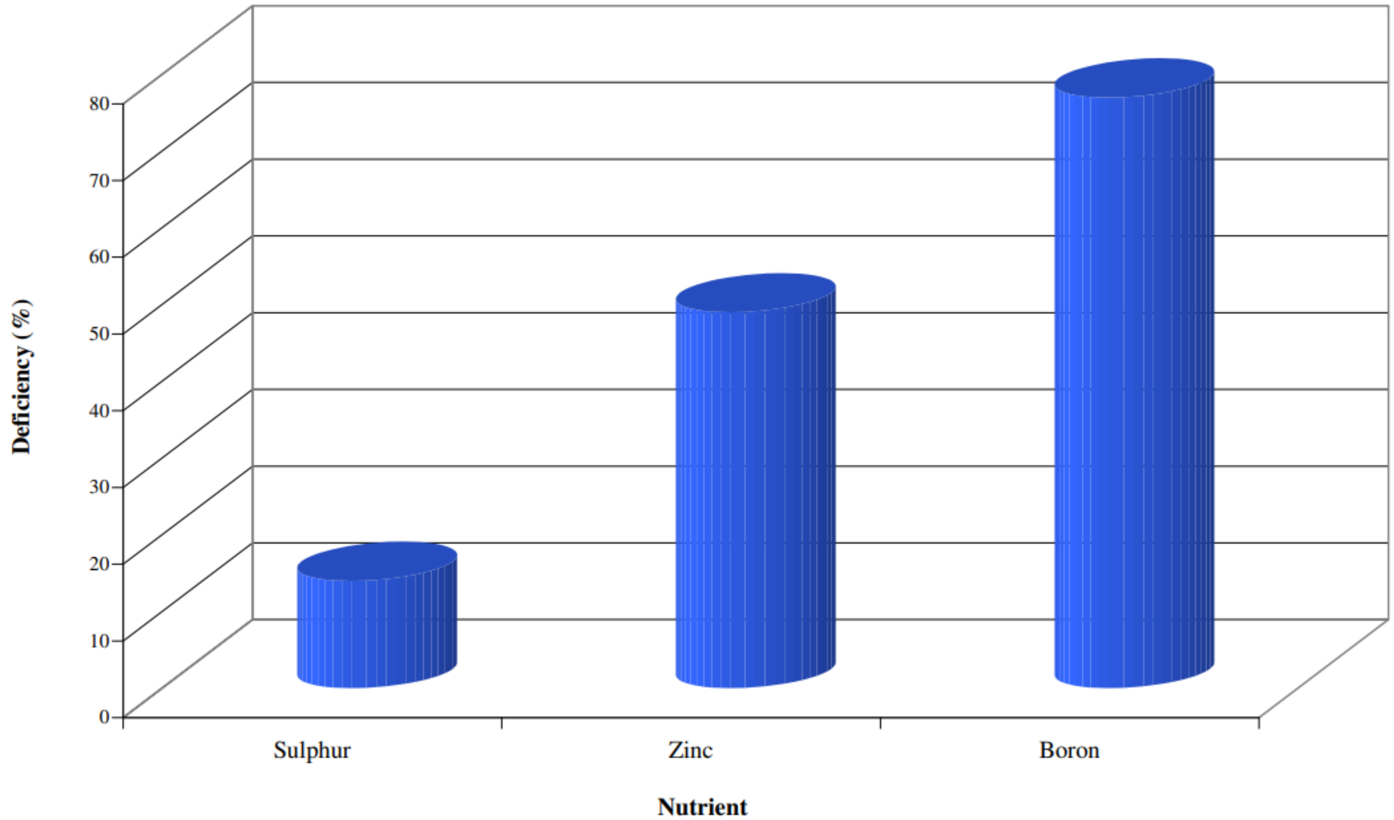

Fig. 5. Per cent soil samples deficient in available sulphur, DTPA-zinc and hot water soluble boron in in onion growing fields in selected villages of Dharwad taluk

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The available boron content in surface soil samples of farmers' field of Dharwad taluk varied between 0.20 to 0.72 mg kg^{-1} with the mean value of 0.43 mg kg^{-1}(Table 2). Distribution of Fe, Cu, Zn and B was positively skewed and negatively kurtotic. The available boron content in surface soil samples of farmers' field of Dharwad taluk varied between 0.20 to 0.72 mg kg^{-1} with the mean value of 0.43 mg kg^{-1}. Seventy seven per cent of samples were deficient in hot water soluble boron (Fig.4). The lower hot water soluble boron content was attributed to the lower organic carbon content in these soils since available boron content is increases with increase in organic carbon content. These results are similar to the observations made by Sanjib *et al*. [26], Kumari *et al*. [27], Sonamani *et al*. [28] and Mane and Anuse [29]. Pujari *et al*. [30] reported lower hot soluble boron (0.12 to 1.19 mg kg^{-1}) content in the soils of Kotur micro- watershed in the Northern Transition Zone of Karnataka and 58 per cent of the soil samples were found deficient and was attributed to the lower organic matter content in the soils. The lower availability of boron in soils in some areas might also be due to the conversion of available form of boron to non-available form at high soil pH (> 8.1). Boron being an anion, high rainfall in the study area might have also caused leaching losses from surface soil lowering its availability. Similar findings were reported by Pulakeshi *et al*. [13] for soils of Northern Karnataka.

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Categorization of soils based on soil fertility status and nutrient index (NI) for onion growing fields in selected villages of Dharwad taluk

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Based on the soil nutrient status, soils were classified as low, medium and high category using standard soil test rating for each nutrient. The nutrient index value for the percentage of soils in the low, medium and high categories of available nutrients was calculated. According to Ramamoorthy and Bajaj [31], NI value less than 1.67 indicated as low fertility status, between 1.67 to 2.33 as medium and more than 2.33 was rated as high. The percentage of soil samples falling in low, medium and high categories for different nutrients and the calculated values of nutrient indices are presented in Table 3. It is apparent from the data that out of 100 samples, 42 per cent samples were low in available nitrogen, while 57 and one per cent of samples were in medium and high category, respectively. For available phosphorus, nine per cent samples were under low category while 71 and 20 per cent of samples were in medium and high category, respectively. In case of available potassium, 11 and 21 per cent samples were in low and high categories, respectively and 68 per cent of samples were in medium category. For available sulphur, 14, 72 and 14 per cent samples were in low, medium and high categories,

Table 3: Classification of soils based on available nutrients' ratings and nutrients index in the study area

Nutrients	Low	Medium	High	Nutrient index
Nitrogen	42 (42)	57 (57)	1 (1)	1.59 (L)
Phosphorus	9 (9)	71 (71)	20 (20)	2.11 (M)
Potassium	11 (11)	68 (68)	21 (21)	2.10 (M)
Sulphur	14 (14)	72 (72)	14 (14)	2.00 (M)
Zinc	49 (49)	51 (51)	-	1.51 (L)
Boron	77 (77)	23 (23)	-	1.23 (L)

Note: Values in paranthesis indicate per cent samples falling in low (L), medium (M) and high (H) categories respectively. In case of DTPA- extractable Zn, 49 and 51 per cent of samples were in low and medium categories, respectively but for hot water soluble boron 77 and 23 per cent of samples were in low and medium categories, respectively. Based on the calculated values of nutrient indices, soils of the study area were low in available nitrogen, medium in available phosphorus, potassium and sulphur. In case of micronutrients zinc and boron were low in onion grown areas.

4. CONCLUSION

The surface soil samples from the farmers' fields in different villages of Dharwad taluk were medium in available sulphur and 49 and 77 per cent of the soils were deficient in DTPA extractable zinc and hot water soluble boron, respectively.

Comment [C13]: Mention state

REFERENCES

1. Anonymous. Indiastat, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi; 2021.
2. Dwivedi BS. The 41st Dr. R.V. Tamhane memorial lecture on Revisiting soil testing and fertilizer use research. *Journal of the Indian Society of Soil Science*. 2014;62 (Supplement): 40-55.
3. Singh A. Development, conservation and utilization of soil resource – random thoughts. Newsletter. 2009;1: 26.
4. Jackson ML. Soil Chemical Analysis, Prentice Hall of India, Pvt. Ltd., New Delhi; 1973.
5. Piper CS. Soil and Plant Analysis. Hans Publishers, Bombay, India; 2002.
6. Subbaiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. *Current Science*. 1956;25: 259-260.
7. Sparks. Methods of Soil Analysis Part-3: Chemical Methods. *The Soil Science Society of America Journal*, USA; 1996.
8. Jaiswal PC. Soil, Plant and Water Analysis, Kalyani Publishers, Ludhiyana (Panjab); 2013.
9. Lindsay WL, Norvell WA. Development of DTPA soil test for Fe, Mn, Zn and Cu. *The Soil Science Society of America Journal*. 1978;42 (3): 421-428.
10. Tandon HLS. Methods of Analysis of Soils, Plants, Water and Fertilizers. Fertilizer

Development and Consultation Organization. 1998;31: 9-16.

11. Patil PL, Pulakeshi HBP, Dasog GS. Identification of soil fertility constraints by geographic information system (GIS) technique and response of crops to identified nutrient constraints in northern transitional zone of Karnataka. Proceedings of AIP conference; 2012.
12. Nagaraju MSS, Reddy GP, Maji AK, Srivastava R, Raja P, Barthwal K. Soil loss mapping for sustainable development and management of land resources in warora tehsil of Chandrapur district of Maharashtra: An integrated approach using remote sensing and GIS. *Journal of the Indian Society of Remote Sensing*. 2011;39(1): 51-61.
13. Pulakeshi HBP, Patil PL, Dasog GS. Characterization and classification of soil resources derived from chlorite schist in northern transition zone of Karnataka. *Karnataka Journal of Agricultural Sciences*. 2014;27 (1): 14-21.
14. Mamaledesai NR, Patil PL, Chandrashekar CP, Potdar MP, Astaputre SA, Desai SR, Swamy H. Assessment of nutrients status in cotton growing area of Haveri district in northern transitional zone of Karnataka and response of cotton to applied nutrients at different yield targets. *Agro-Informatics Precision Agriculture,* India, 2012; pp. 42-46.
15. Dasog GS, Patil PL. Genesis and classification of black, red and lateritic soils of North Karnataka. In: *Soil Science Research in North Karnataka*, Dharwad Chapter of ISSS (Ed.), 76th annual convention of ISSS, 2011; pp. 1-10.
16. Ravikumar MA, Patil PL, Dasog GS. Soil resource characterization, classification and mapping of 48A distributary of Malaprabha right bank command, Karnataka for land use planning. *Karnataka Journal of Agricultural Sciences*. 2009; 22(1): 81-88.
17. Bidari BI. Studies on yield and quality of Byadgi chilli (*Capsicum annuum* L.) in relation to soil properties in transitional zone and part of dry zone of North Karnataka, *Ph. D. Thesis,* University of Agricultural Sciences, Dharwad, Karnataka, India; 2000.
18. Srikanth KS, Patil PL, Dasog GS, Gali SK. Mapping of available major nutrients of a micro-watershed in northern dry zone of Karnataka. *Karnataka Journal of Agricultural Sciences*. 2008;21 (3): 391-395.
19. Srinivasarao C, Vittal KPR, Ravindra CG, Gajbhiye PN, Venkateswarlu B. Characterization of available major nutrients in dominant soils of rainfed crop production systems of India. *Indian Journal of Dryland Agricultural Research and Development*. 2006;21: 105-113.

20. Rego TJ, Sahrawat KL, Wani SP, Pardhasaradhi G. Wide spread deficiencies of sulfur, boron and zinc in Indian semi-arid tropical Soils: On-farm crop responses. *Journal of Plant Nutrition*. 2007;30: 1569-1583.
21. Sahrawat KL, Rego TJ, Wani SP, Pardhasaradhi G, Murthy KVS. Diagnosis of secondary and micronutrient deficiencies and their management in rainfed agroecosystems. *Communication in Soil Science and Plant Analysis*. 2010;41: 346-360.
22. Chander SP, Sahrawata KL, Sreenath D, Venkateswarlu B, Rajesha CP, Narsimh RP, Pardhasaradhia G. Soil test-based nutrient balancing improved crop productivity and rural livelihoods: case study from rainfed semi-arid tropics in Andhra Pradesh, India. *Archives of Agronomy and Soil Science*. 2014;60(8): 1051-1066.
23. Basavaraja PK, Dey P, Mohamed SH, Yogendra ND. Geo-reference based soil fertility status in Hassan district of Karnataka, India for development of the nutrient plan. *Indian Journal of Soil Conservation*. 2017;45(2): 141-147.
24. Jagdev S, Prince K, Dua VK, Vineeta S, Deepak K, Sushil K, Sanjay R, Khan MA. Status of micronutrients in intensively cultivated potato growing soils of Punjab. *Potato Journal*. 2017;44(1): 196-204.
25. Shukla AK, Tiwari PK, Chandra. Micronutrients deficiencies *vis-a-vis* food and nutritional security of India. *Indian Journal of Fertilizers*. 2015;10(12): 94-112.
26. Sanjib KB, Arvind KB, Mahavir S, Brahma SD. Extractable boron in some acid soils of India: Status, spatial variability and relationship with soil properties. *Journal of the Indian Society of Soil Science*. 2016;64(2): 183-192.
27. Kumari K, Nazir G, Singh A, Kumar K. Studies on boron fractions with different physico-chemical properties of cultivated soils of Himachal Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*. 2017;6(6): 1547-1555.
28. Sonamani SK, Haribhushan A, Singh. Soil macro- and micro- nutrient status of Chandel district, Manipur, India. *International Journal of Agricultural Science*. 2018;9(15): 4107- 4109.
29. Mane NA, Anuse MA. Studies on the status of micronutrients in the soil of Appachiwadi of thasil chikkodi in Belgaum district. *National conference on sustainable agriculture*. 2019; pp. 212-217.

30. Pujari KL, Patil PL, Dasog GS, Hebsur NS, Manjunath MV, Alagundagi SC. Identification of soil fertility constraints by geographic information system technique in Kotur micro-watershed, *Journal of Farm Sciences*.2016;29: 32-36.
31. Ramamoorthy B, Bajaj C. Available N, P and K status of Indian soils. *Fertilizer News*. 1969;14 (8): 24-26.