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Diagnostic soil nutrient standards and identification of yield limiting nutrients in onion (*Allium cepa*) using DRIS

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ABSTRACT

Soil samples collected from a survey of fifty onion growing fields in Karnataka were analyzed for various macro and micronutrients for establishing a data bank to develop soil nutrient norms. By using Diagnosis and Recommendation Integrated System (DRIS), the whole population was divided into two sub-groups namely, low and high yielding and selected nutrient expressions that have shown higher variance and lower coefficient of variation as diagnostic norms, viz K/N (1.229), S/N (0.238), Ca/N (20.62), P/Zn (37.41), Mg/K (0.6.859), Fe/Mg (0.004), Fe/Zn (5.736) etc. In addition, five nutrient ranges have been derived using mean and standard deviation as low, deficient, optimum, high and excess for each nutrient to serve as a guide for diagnostic purpose. The optimum organic carbon ranged from 7.1 to 11.0 g kg^{-1}, N from 115 to 178 mg kg^{-1}, P from 26 to 38 mg kg^{-1} , K from 163 to 217 mg kg^{-1} ,Ca from 2199 to 3398 mg kg^{-1} , Mg from 802 to 1167 mg kg^{-1} and S from 34 to 43 mg kg^{-1}. Among DTPA extractable micronutrients, the optimum iron ranged from 3.40 to 4.34 mg kg^{-1}, manganese from 5.84 to 6.66 mg kg^{-1}, zinc from 0.67 to 1.01 mg kg^{-1} and copper from 1.70 to 2.11 mg kg^{-1} for onion. The diagnosis of nutrient imbalance identified through DRIS indices indicated that organic carbon, phosphorus and zinc were the most common yield limiting nutrients in onion.

Key words: Nutrients, norms, DRIS indices, onion

INTRODUCTION

Onion (*Allium cepa*) is the most important commercial vegetable crop produced in India for both domestic consumption and export. India accounts for 16% of the world's area and occupies the second position after China in production with a share of around 14%. Karnataka contributes a major area in South India (84,800 ha) and produces 4,86,130 t of onion annually. Productivity, however, is much lower in India than the world average. In order to increase the production and quality, its nutrient requirements have to be carefully monitored through soil analysis for efficient fertilizer management programme. As no established standards are available, it was planned to develop soil nutrient standards for onion using diagnosis and recommendation integrated system (DRIS), which provides a means of simultaneously identifying imbalances, deficiencies and excesses in crop nutrients and ranking them in the order of importance (Beaufils, 1973). Beaufils and Sumner (1976) developed DRIS norms for P, K, Ca, and Mg to be applied to sugarcane culture on South African soils. Similarly, this methodology has been used to interpret the results of soil analysis for fruit crops such as mango and pomegranate (Raghupathi and Bhargava, 1997) in India. However, there are a few reports in the literature on the use of DRIS for developing soil nutrient standards for crops like onion. Therefore, an investigation was carried out to develop soil nutrient standards for onion using DRIS.

MATERIAL AND METHODS

A survey was conducted in major onion growing districts of Karnataka (Bellary and Chitradurga) and soil samples were collected from fifty fields during the year 2000-01. At each site, ten sub-samples were drawn and pooled. A composite sample was used for measurement of pH, EC, organic carbon, macro and micronutrients for developing nutrient standards. The samples were air dried, processed through 2 mm sieve and analyzed for different nutrients by using standard analytical methods (Jackson, 1973). Soil pH and EC were measured in 1:2.5 soil:water suspension. Organic carbon was estimated by wet oxidation method while P was analyzed colorimetrically after extracting in 0.5M $NaHCO_3$ (pH 8.5) solution. The exchangeable K, Ca and Mg were estimated after extracting in 1N neutral ammonium acetate. Micronutrients were analyzed after extracting in DTPA solution using atomic absorption spectrophotometer (Jackson, 1973). Thus, the data bank was established for the whole population. By using DRIS, the whole population was divided into two sub-groups namely low and high yielding (Beaufils, 1973) based on the yield performance of the fields. From the experience of the growers, 20 t/ha was considered as the cut off yield between low and high performing fields. The cut off yield was positioned in such a way that the high yielding sub-population reflects conditions that are deemed desirable (Beaufils, 1973). However, Letzsch and Sumner (1984) have shown that the actual cut off value used has little effect on the norms developed as long as it is not too low. Each parameter was expressed in as many forms as possible, e.g. N/P, P/N, NxP etc. Mean, variance and standard deviations were calculated for all forms of expressions together with the coefficient of variation. Among different forms of expressions, the one showing higher variance ratio (Variance of low yielding / variance of high yielding) was selected as norm (Walworth and Sumner, 1987). The DRIS indices were calculated by using the formula described elsewhere (Anjaneyulu, 2006). Five soil nutrient guides/ranges were derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient. The optimum nutrient range is the value derived from "mean - 4/3SD (standard deviation) to mean + 4/3SD". The range "low" was obtained by calculating "mean - 4/3 SD to mean - 8/3SD" and the value below "mean - 8/3 SD" was considered as deficient. The value from "mean + 4/3 SD to mean + 8/3 SD" was taken as high and the value above "mean + 8/3 SD" was taken as excessive (Bhargava and Chadha, 1993).

RESULTS AND DISCUSSION

Soil Nutrient concentration range

The soil pH for the entire population (Table 1) ranged from 7.25 to 8.81, where onion is being grown successfully. The EC ranged from 0.12 to 0.54 dSm^{-1} and thus, the fields were in the safe range. However, the organic carbon level varied much between 3.3 to 16.8 g kg^{-1} indicating that the content was low in many of the low yielding fields compared to the optimum value. The available P varied from 4.4 to 160.2 mg kg^{-1} showing a wide variation among the fields. The exchangeable calcium and

Table 1. Mean and S.D. of nutrients in the onion growing soils

Soil Property	Unit	Mean	S.D.
pH	-	8.36	0.2287
EC	dSm-1	0.29	0.1391
OC	g kg^{-1}	11.0	0.2962
N	mg kg^{-1}	178.53	47.9996
P	mg kg^{-1}	38.88	9.9077
K	mg kg^{-1}	217.64	41.0786
Ca	mg kg^{-1}	3398.53	899.8555
Mg	mg kg^{-1}	1167.03	274.5240
S	mg kg^{-1}	43.46	7.3134
Fe	mg kg^{-1}	4.34	0.7575
Mn	mg kg^{-1}	6.66	0.6235
Zn	mg kg^{-1}	1.01	0.2645
Cu	mg kg^{-1}	2.61	0.8846

magnesium varied from 1658 to 4062 mg kg^{-1-} and 453 to 1797 mg kg^{-1} respectively due to calcareous nature of the soil. Among the micronutrients, Fe ranged from 3.02 to 6.60 mg kg^{-1-} and manganese from 3.30 to 37.50 mg kg^{-1-} (Table-1) indicating a wide variation in manganese compared to iron content.

DRIS norms, indices and Nutritional Balance Index (NBI)

A particular nutrient expression should have a high variance and low coefficient of variation to be chosen as norm for greater diagnostic precision (Walworth and Sumner, 1987). Among the nutrient expressions, certain diagnostic norms viz. K/N (1.229), S/N (0.238), Ca/N (20.62), P/Zn (37.41), Mg/K (0.6.859), Fe/Mg (0.004), Fe/Zn (5.736) etc., have shown higher variance ratios compared to others and may have greater physiological rationale. In addition, maintaining the ratios of some expressions at the optimum when coefficient of variation was large was much less critical for the performance of the crop (Raghupathi *et al.* 2004). The nutrient imbalance in plants was diagnosed through DRIS indices that are given in Table 3 for selected low yielding orchards. As the value of each ratio function was added to one index sub-total and subtracted from another prior to averaging, all indices were balanced around zero. Thus, the nutrient indices sum to zero indicated an optimum level, negative values a relative deficiency and positive values a relative excess of that nutrient (Walworth and Sumner, 1987). The absolute sum values of the nutrient indices generate an additional index called nutritional balance index (NBI). The overall imbalance of the nutrient was assessed based on sum of the indices irrespective of sign (Table 3). Higher the sum value (2644), larger is the plant nutritional imbalance and, therefore, the lower will be the yield. However, the yield cannot be predicted from sum of the indices irrespective of the sign alone, because

Table 2. DRIS ratio norms for onion growing soils

Selected Ratios	Norms	CV%	Selected Ratios	Norms	CV%
P/N	0.202	46	Cu/K	0.016	48
K/N	1.229	22	Mg/Ca	0.336	30
Ca/N	20.62	29	S/Ca	0.014	68
Mg/N	7.087	35	Fe/Ca	0.001	25
S/N	0.237	30	Mn/Ca	0.002	63
Fe/N	0.026	30	Ca/Zn	4673	52
Mn/N	0.041	70	Cu/Ca	0.001	33
N/Zn	233.6	42	Mg/S	37.45	52
Cu/N	0.016	52	Fe/Mg	0.004	29
K/P	10.45	68	Mn/Mg	0.006	50
Ca/P	189.1	67	Mg/Zn	1626	71
Mg/P	74.69	63	Cu/Mg	0.002	38
S/P	1.869	51	Fe/S	0.139	64
Fe/P	0.232	62	Mn/S	0.208	70
Mn/P	0.491	64	S/Zn	55.66	64
P/Zn	37.41	27	Cu/S	0.094	61
Cu/P	0.157	63	Mn/Fe	1.455	67
Ca/K	20.91	43	Fe/Zn	5.736	25
Mg/K	6.859	30	Cu/Fe	0.598	32
S/K	0.223	52	Mn/Zn	8.556	70
Fe/K	0.025	33	Mn/Cu	2.456	52
Mn/K	0.037	40	Cu/Zn	3.592	56
K/Zn	274.1	43	—	—	—

Table 3. DRIS Indices for selected Onion growing fields

F.No	pH	EC	OC	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	NBI(Sum)
1	52	5	-90	15	-66	31	25	14	74	-6	103	-75	-82	638
2	-1	99	-160	-175	-137	163	204	68	28	46	58	-53	-140	1332
3	150	36	-26	34	-2	-127	206	204	105	-146	111	-241	-304	1692
4	106	28	-101	21	-128	26	104	50	65	41	152	-29	-335	1186
5	62	52	-153	41	-111	-113	195	135	90	-2	26	-2	-220	1202
6	107	-143	-267	203	-347	-347	216	114	262	108	169	143	-218	2644

of the influence of unmeasured factors that affect the yield (Sumner, 1977). The yield limiting nutrients were differing from field to field though some of the nutrients were more prominent. The order in which the nutrients were limiting the yield indicated that most often more than one nutrient was limiting the yield. However, the diagnosis of nutrient imbalance in the soils of onion growing tracts of Karnataka indicated that the most common yield limiting nutrients are organic carbon, nitrogen and phosphorus among the macronutrients and copper and zinc among the micronutrients.

Optimum soil nutrients' guide

Nutrients guide/ranges have been derived using mean and standard deviation as deficient, low, optimum, high and excess for each nutrient and presented (Table 4). The optimum EC ranged from 0.11 to 0.29dSm^{-1} indicating a safe limit for the crop. All the low yielding gardens represented low organic carbon content compared to optimum, which ranged from 7.1 to 11.0 g kg^{-1} in the soil. The optimum P ranged from 26 to 38 mg kg^{-1} and the low yielding fields were deficient in P as indicated by DRIS indices in table-3. Thus, majority of the soils representing low yielding fields were low in organic carbon and available phosphorus indicating their requirement. In onion the requirement of potassium is higher than nitrogen as it is involved not only in the production but also in improving the quality. Ninety per cent of the orchards surveyed were at optimum (163 to 217 mg kg^{-1}) level for available potassium. Similarly, many fields recorded optimum to higher calcium, magnesium and sulphur contents in the soil indicating that these nutrients were not yield limiting in onion. Among the micronutrients, zinc and copper were found to be low in most of the low yielding fields followed by iron. The optimum zinc concentration ranged from 0.67 to 1.01 mg kg^{-1} whereas copper ranged from 1.70 to 2.61mg kg^{-1}. However, 87% of the fields recorded optimum levels of manganese indicating that manganese is not a yield-limiting factor. Thus, the possibility of making a successful diagnosis based on soil nutritional status increases as the

Table 4. Soil nutrient standards for onion

Nutrient	Unit	Deficient	Low	Optimum	High	Excess
Org. Carbon	g kg^{-1}	<3.1	3.1-7.0	7.1-11.0	11.1-15.0	>15.1
Nitrogen	mg kg-l	<50	51-114	115-178	179 -242	>243
Phosphorous	mg kg-l	<12	13-25	26-38	39 -52	>53
Potassium	mg kg-l	<108	109-162	163-217	218-272	>273
Calcium	mg kg-l	<998	999-2198	2199-3398	3399-4598	>4599
Magnesium	mg kg-l	<434	435-801	802-1167	1168-1533	>1534
Sulphur	mg kg-l	<23	24-33	34-43	44 -53	>54
Iron	mg kg-l	<2.32	2.32-3.33	3.40-4.34	4.35-5.35	>5.36
Manganese	mg kg-l	<5.00	5.00-5.83	5.84-6.66	6.67-7.49	>7.50
Zinc	mg kg-l	<0.31	0.31-0.66	0.67-1.01	1.02-1.36	>1.37
Copper	mg kg-l	<0.77	0.77-1.69	1.70-2.61	2.62-3.52	>3.53

number of nutrient-related yield limiting factors that are due to nutrition is increased. As with foliar diagnosis, the use of DRIS with soil data also provides the advantage of taking into account nutrient balance and ranking nutrients in terms of abundance relative to optimal levels.

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