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Compositional Nutrient Diagnosis (CND) Norms and Indices for Potato (*Solanum tuberosum* L.)

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ABSTRACT

A survey was conducted in potato fields for collection of leaf samples to establish nutrient concentration yield data bank. The data bank was used for developing multivariate compositional nutrient diagnosis (CND) norms for assessing the nutritional status of selected centres of potato growing fields. The mean N, P and K concentrations were 2.09, 0.25 and 4.16 %, respectively. The mean Ca (1.11%) concentration was twice higher compared to Mg (0.63 %) concentration. The mean values of Zn, Cu, Fe, Mn and B were 43.69, 31.24, 986.71, 192.76 and 59.98 ppm, respectively. The CND norms for V_N, V_P and V_K were 3.04, 0.94 and 3.73, respectively. The norm for Ca (V_{Ca}=2.45) and Mg (V_{Mg}=1.78) were much narrower compared to the absolute nutrient concentration. The norm for V_{Zn}, V_{Cu}, V_{Fe}, V_{Mn} and V_B were -3.24, -3.60, -0.23, -1.98 and -2.89respectively. The multivariate CND norms developed for ten nutrients proved to be an important tool for diagnosis of nutrient imbalance in potato. The nutrient indices developed indicated that Zn was the most common yield-limiting nutrient. The CND norms and the indices developed can be used for identifying the hidden hunger of various nutrients in potato for evolving nutrient management strategies.

Keywords: CND norms, Nutrients and Potato

INTRODUCTION

Potato (*Solanum tuberosum L.*) is the world's fourth most important food crop after wheat, rice and maize because of its great yield potential and high nutritive value. It constitutes nearly half of the world's annual output of all root and tuber crops, with an annual world production of about 388 m t (FAO, 2019). India produces 48.23m t of potatoes from an area of 2.15 m ha (Anon., 2017) with a productivityof 2.24 t ha^{-1}. Potatois a crop of temperate climates. Optimum soil temperature for normal tuber growth is 15 to 18°C.Potato requires a well-drained, well-aerated, porous soil with pH of 5.0 to 6.0. As well as providing starch, an essential component of the diet, potatoes are rich in vitamin C, minerals, high in potassium and an excellent source of fibre.

The potato crop requires substantial amounts of nutrient sources for maximum yield and quality. Fertilizer management could be guided in part by plant analysis. Reliable nutrient norms for obtaining adequate nutrient balance with minimum application of fertilizers are required (Parent *et al*., 1994). Nutrient status in plants is currently diagnosed using nutrient concentration or dual ratios in selected tissues (Walworth and Sumner, 1987). Elemental concentrations vary vastly with time and the critical level of one element can shift widely if another element can substitute or interfere with the uptake of the first element planttissues possess a multivariate character with respect to elemental composition that could be interpreted for diagnostic purposes. Mineral composition of plant tissues, expressed as concentrations or relative (ratio) values forms the basic numerical information for diagnosing nutrient status in plants (Parent and Dafir, 1992).

Several approaches are adopted for identification of nutrient imbalances, a one being the compositional nutrient diagnosis (CND). It provides a correction factor for any nutrient, given all the nutrients under analysis (i.e. multinutrient ratios). In addition, CND generates new variables and it is amendable to multivariate analysis of tissue compositional data (Parent and Dafir, 1992). It recognizes that, given a change in certain nutrient proportions in the foliage, other proportions must be altered since plant composition is constrained to 100 per cent the dry matter content. Thus, nutrient diagnosis is generally conducted at a particular growth stage for which norms were derived (Parent *et al*., 1994).

The CND norms are multivariate norms that give due weightage to all the elements, including unmeasured factors and therefore, have higher diagnostic sensitivity (Anjaneyulu *et al*., 2008).

The present investigation was carried out with the main objective to develop multivariate diagnostic norms for potato leaves collected from different centres of All India Coordinated Research Project (AICRP) on potato using CND to improve diagnostic precision and to understand interaction among different nutrients governing yield and quality of the potato crop.

MATERIALS AND METHODS

The leaf samples of potato were collected from different centres of AICRP on potato under Indian Council of Agricultural Research (ICAR) *viz*., Sardar Krishinagar (Gujarat), Bidhan Chandra Krishi Vishwavidyalaya (West Bengal), Indira Gandhi Agricultural University, Raipur (Chhattisgarh), G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), Assam Agricultural University, Jorhat (Assam), Rajendra Agricultural University (Bihar) and ChaudharyCharan Singh Haryana Agricultural University, Hisar (Haryana) to establish nutrient concentration versus yield data bank for developing diagnostic norms. A total of 78 leaf samples were collected by selecting the 3rd to 6th leaf from growing tip were collected just before bloom stage, which provides the index leaf in potato. About 25 to 30 samples were collected from each plot from different centres of AICRP on potato. The leaf samples were decontaminated by washing in a sequentially with tap water, 0.2 per cent detergent solution, 0.1 N HCl and finally with double distilled water. Leaf samples were dried at 65 to 70^{0}C for 48 h. The samples were then powdered in a cyclotec mill and analysed for different nutrients by digesting 1g tissue in diacid mixture (9:4 ratio of nitric acid and perchloric acid) using standard analytical methods (Jackson, 1973). The samples were analysed for major (N, P and K), secondary (Ca, Mg and S) and micronutrients (Zn, Cu, Fe, Mn and B) by standard method (Piper, 1966; Jackson, 1973 and Jones and Case, 1990). Thus, nutrient concentration vs yield data bank (based on standard procedure, below 30 t ha^{-1} and above 30 t ha^{-1} are considered as low yield and high yield) was established for developing nutrient diagnostic norms.

The CND norms (mean and standard deviation (SD) of the analysed leaf samples) were developed by adopting the procedure outlined by Parent and Dafir (1992). This was accomplished by following the steps proposed by Khiari *et al.* (2001) as follows.

Ist step: To convert all the plant nutrient concentrations to percentage (%).

IInd step: Sum all the plant nutrient concentration i.e.

Total = $\sum$ (N+P+K+Ca+Mg+Zn+Cu+Fe+Mn+B)

IIIrd step: Calculate residue (R_d)

R_d = 100-$\sum$ (N+P+K+Ca+Mg+Zn+Cu+Fe+Mn+B)

Where,

Rd = it is the filling value between 100 and the sum of the nutrient proportions.

IVth step: Calculate Geometric mean (G)

$G= (N*P*K*Ca*Mg*Zn*Cu*Fe*Mn*B)^{1/n}$

Where,

n = no. of nutrient elements taken for calculation.

Vth step: row centred log ratios of the nutrient proportions (V_x) were calculated using the equation.

$V_N = \ln (N/G)$, $V_P = \ln (P/G)$, $V_K = \ln (K/G)$,
$V_{Ca} = \ln (Ca/G)$, $V_{Mg} = \ln (Mg/G)$,
$V_{Zn} = \ln (Zn/G)$, $V_{Cu} = \ln (Cu/G)$, $V_{Fe} = \ln (Fe/G)$,
$V_{Mn} = \ln (Mn/G)$ and $V_B = \ln (B/G)$

VIth step: CND norms are computed using means and SD corresponding to the row centred log ratios V_X of the nutrients for high yielding populations.

$V^*_N, V^*_P, V^*_K, ...V^*_B$ i.e mean = average $(V_{X1}+ V_{X2}+ V_{X3}+ ....+V_{Xn})$

Where,

V_x = average of no. of row centred log ratios of all the nutrients proportions.

$SD^*_N, SD^*_P, SD^*_K, ...SD^*_B$ i.e SD = stdev $(V_{X1}+ V_{X2}+ V_{X3}+ ....+V_{Xn})$

Where,

V_x = SD of no. of row centred log ratios of all the nutrients proportions.

VII[th] step: the standardized variables $(V_N - V^*_N)/SD^*_N$ to $(V_B - V^*_B) / SD^*_B$ are CND nutrient indices for low yielding population.

$I_N = (V_N - V^*_N) / SD^*_N$, $I_P = (V_P - V^*_P)/ SD^*_P$, ... $I_B = (V_B - V^*_B)/ SD^*_B$.

Independent values for V_N to $V_B$were introduced in the equation for diagnostic purpose. Once CND norms and indices have been developed, an independent database can validate them. The validations of CND norms and indices have been reported by Parent and Dafir (1992), Parent *et al.* (1994) and Khiari *et al.* (2001).

RESULTS AND DISCUSSION

Nutrient concentration range

The mean concentrations of N, P, K, Ca, Mg, Zn, Cu, Fe, Mn and B in leaf of potato are presented in Table 1. The mean N concentration was 2.09 % and ranged from 0.40 to 3.68 %. Maximum yield in potato was reported when N concentration in leaf ranged from 1.19 to 1.30 % (Vijaykumar, 2010). The mean P concentration was 0.25 % and varied from 0.42 to 0.46 %. The K concentration varied widely from 1.80 to 7.95 % with a mean of 4.16 %. The increased content of primary nutrients (N, P and K) might be attributed to the better crop growth because of increased availability of nutrients due to application of fertilizers. Besides, application of nutrients in proper balance generally results in better utilization of added nutrients (Vijaykumar, 2010).

Similarly, Ca concentration showed a wide variation ranging from 0.60 to 1.57 %. The mean Ca (1.11 %) was twice higher to Mg (0.63 %), which was comparable to the values reported by Anjaneyulu *et al,* (2008) in guava and Anjaneyulu and Raghupathi (2010) in papaya. The mean leaf concentration of Zn, Cu, Fe, Mn and B were 43.69, 31.24, 986.71, 192.76 and 59.28 ppm, respectively. The optimum range varied from 10.60-104.98, 20.08-76.40, 205.53-5721.60, 4.85-448.00 and 20.86-104.99 ppm for Zn, Cu, Fe, Mn and B respectively (Jones, 1991 and Tisdale *et al.,* 1997). This was attributed to increased availability of these nutrients due to the supply of these nutrients through micronutrient fertilizers (Vijaykumar, 2010). Gopalakrishnan (2007) reported that the micronutrients for early flower set and helps in production of growth hormones for their good growth and development for the crops.

Compositional Nutrient Diagnosis (CND) norms

The CND norms for N (V_N), P (V_P) and K (V_K) for leaf of potato were 3.04, 0.94 and 3.73 respectively (**Table 2**). The norms derived indicated higher requirement of K compared to N that might be due to continuous flowering in potato. Similarly, high CND norm for K was reported in banana (Raghupathi*et al.,* 2002) indicating higher K requirement. The norm for Ca (V_{ca}= 2.45) was higher compared to that of Mg (V_{Mg}= 1.78) norm. The higher norm value noticed for Ca was mainly due to the presence of high free calcium carbonate in soils, which might have overwhelming influence on calcium uptake. This finding corroborates with the results observed by Anjaneyulu and Raghupathi (2010). Among the micronutrients, Fe requirement was much higher compared to Mn, Zn. Cu and B with a norm value of V_{Fe} = – 0.23. CND norms are multivariate norms with due weightage to all the other elements, including the unmeasured factor. Sum of the tissue components is 100 % and therefore the sum of row centred log ratios (including filling value) is zero. CND norm values developed were difficult to comprehend compared to nutrient concentrations, expressed as per cent or ppm (Anjaneyulu *et al.,* 2008). Therefore, the CND norms are having higher diagnostic precision (Parent and Dafir, 1992) compared to the bivariate diagnosis and recommendation integrated system (Walworth and Sumner, 1987).

Compositional Nutrient diagnosis (CND) indices

Independent values were introduced from low yielding potato crops for the purpose of diagnosis of a nutrient that limits the yield. The CND indices identified Zn, Ca and K as the most common yield limiting nutrients (Table 3). Among the 44 selected low yielding potato fields, both Zn and K were common yield limiting nutrients. Similarly, the results are in conformity with the findings of Anjaneyulu (2007) in which Zn and K were identified as common yield limiting nutrients in papaya diagnosis and recommendation integrated system (DRIS) technique. Boron and Manganese were also found to be low in some potato fields as reflected through indices (Anjaneyulu and Raghupathi, 2010). However, no single nutrient was found solely responsible for low yield (Anjaneyulu *et al.,* 2008). The concentration of N when below the critical level manifested visual symptoms of nutritional imbalance, which exhibited negative indices. Thus, the yield limiting nutrients were differing from field to field though some of the nutrients were more prominent. The order in which nutrients were limiting the yield indicated that most often more than one nutrient was limiting the yield. Among different nutrient elements, B showed a significant positive relationship (Table 4) with both Ca and Mg, whereas K whose requirement is very high for crops like potato showed negative relationship with B.

Multivariate technique (compositional nutrient diagnosis) was proved to be an important tool for interpretation of complex interaction pattern among nutrients concentration in rapidly growing potato plants. The norms derived indicated higher requirement of K compared to N. Among different nutrients, the CND indices identified Zn, Ca and K as the most common yield limiting nutrients in potato.

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Table 1: Mean and range of nutrients concentration for Potato (High yielding Potato)

Nutrient	Unit	Mean	Minimum	Maximum
N	%	2.09	0.40	3.68
P	%	0.25	0.42	0.46
K	%	4.16	1.80	7.95
Ca	%	1.11	0.60	1.57
Mg	%	0.63	0.12	1.01
Zn	ppm	43.69	10.60	104.98
Cu	ppm	31.24	20.08	76.40
Fe	ppm	986.71	205.53	5721.60
Mn	ppm	192.76	4.85	448.00
B	ppm	59.98	20.86	104.99

Table 2: Compositional nutrient diagnosis (CND) norms for Potato

CND variate	CND norms	SD
V_N	3.04	0.43
V_P	0.94	0.36
V_K	3.73	0.37
V_{Ca}	2.45	0.36
V_{Mg}	1.78	0.63
V_{Zn}	-3.24	0.52
V_{Cu}	-3.60	0.55
V_{Fe}	-0.23	0.63
V_{Mn}	-1.98	0.92
V_B	-2.89	0.69
V_R	6.89	0.24

Table 3: CND indices for selected low yielding fields of potato

N	P	K	Ca	Mg	Zn	Cu	Fe	Mn	B	R
2.01	2.75	0.86	0.41	0.31	-1.41	-0.93	-0.71	-0.22	-0.90	0.16
2.20	2.71	0.66	-0.31	0.19	-1.06	-1.01	-0.68	-0.14	-0.74	0.27
2.09	2.64	0.88	0.08	0.06	-1.12	-1.05	-0.81	-0.23	-0.52	0.21
2.16	2.67	0.92	0.05	0.16	-1.24	-0.99	-0.71	-0.33	-0.60	0.34
2.17	2.64	1.09	0.31	0.23	-1.01	-0.90	-1.23	-0.29	-0.70	0.27
1.72	0.52	0.77	-0.47	-0.16	-0.58	-0.37	0.39	-0.14	-0.79	-0.45
1.79	0.67	0.69	-0.06	-0.17	-0.70	-0.49	0.33	0.01	-1.02	-0.65
1.88	0.67	1.31	-0.12	-0.10	-0.67	-0.61	0.23	-0.23	-0.97	-0.44
1.96	0.73	0.48	-0.15	-0.18	-0.96	-0.43	0.51	-0.24	-0.69	-0.68
1.71	0.95	-0.16	-0.58	-0.31	-0.57	-0.58	0.58	0.13	-0.70	-0.73
-0.15	0.40	-0.09	-0.16	0.55	-0.65	0.67	1.36	-0.64	-0.90	-0.60
0.25	-0.10	0.19	0.15	0.67	-1.00	0.44	-0.03	-0.26	-0.11	-0.24
0.55	0.19	-0.27	0.33	0.39	-0.72	0.80	-0.09	-0.09	-0.71	-0.23
0.33	0.48	0.65	0.06	0.76	-0.76	0.81	-0.30	-0.54	-0.60	-0.86
0.62	0.54	0.80	0.05	0.77	-0.81	0.63	-0.32	-1.09	0.05	-0.61
2.02	1.43	-0.04	0.04	0.70	-1.46	-0.41	-1.38	-0.27	0.41	0.23
1.54	2.11	-0.34	-0.09	0.55	-1.48	-0.38	-1.46	-0.28	0.79	-0.11
1.98	0.34	0.11	0.01	0.83	-1.57	-0.26	-1.67	-0.26	1.05	0.58
1.30	1.59	0.02	-0.10	0.86	-1.37	-0.36	-1.47	-0.57	1.04	0.67
2.30	1.34	-0.13	1.07	1.35	-1.18	-0.66	-1.78	-1.66	1.41	2.09
-2.25	1.88	-2.85	-0.23	-0.39	-0.01	0.92	0.74	0.56	0.28	-1.08
-0.73	2.18	-3.10	-0.60	-0.65	-0.24	0.71	0.65	0.70	-0.01	-1.52
0.06	3.22	-0.78	0.71	0.46	-1.40	-0.23	0.24	-0.24	-0.74	0.05
-0.80	2.25	-0.48	0.36	0.24	-1.16	0.02	0.22	0.10	-0.30	-0.72
-0.80	2.30	0.34	0.45	0.32	-0.63	1.33	-1.52	-0.58	0.17	0.25
1.90	3.67	1.02	-0.72	0.17	-1.08	-0.70	-0.74	-0.26	-1.04	0.14
2.12	3.68	0.74	-0.09	0.22	-1.15	-0.61	-0.89	-0.42	-1.07	-0.13
2.06	2.47	1.87	-0.12	0.23	-1.25	-0.89	-0.88	-0.37	-0.79	-0.18
2.13	2.71	1.24	-0.42	0.13	-1.13	-0.47	-0.77	-0.32	-0.95	0.14
2.17	2.71	0.65	-0.20	0.21	-1.25	-0.67	-0.68	-0.26	-0.76	-0.05
1.74	1.04	0.08	-0.30	-0.31	-0.61	-0.41	0.47	-0.02	-0.85	-0.48
2.04	0.83	0.13	-0.54	-0.40	-0.53	-0.41	0.50	0.05	-0.92	-0.48
1.63	0.10	0.25	-0.30	-0.35	-0.47	-0.34	0.56	0.09	-0.73	-0.29
-0.96	-0.11	-1.02	-0.44	0.07	0.19	-0.18	1.60	-0.07	0.01	-1.09
-1.24	0.02	-1.05	-0.36	0.06	0.30	-0.03	1.48	-0.09	0.02	-1.15
-0.54	0.32	-2.00	-0.65	0.01	0.67	-0.44	1.53	0.04	-0.03	-1.28
-0.52	0.17	-1.32	-0.86	-0.13	0.40	0.19	1.42	-0.05	-0.17	-1.44
-0.61	0.12	-1.33	-0.20	-0.04	0.48	-0.54	1.55	0.01	-0.18	-1.26
0.44	0.05	-3.16	-0.43	0.36	-0.56	0.70	0.53	0.04	0.64	-0.87
0.81	-0.17	-0.63	-0.69	0.21	-1.08	0.63	0.35	0.29	-0.30	-1.25
1.19	-0.15	-1.10	-0.22	0.50	-0.86	0.63	0.60	0.17	-1.02	-0.77
1.54	-0.40	-1.19	0.09	0.36	-0.99	0.16	0.65	0.05	-0.51	-0.48
1.64	0.94	-2.05	-0.24	0.41	-0.97	0.39	0.70	-0.04	-0.80	-0.41
0.89	0.52	1.93	0.27	1.26	-1.73	-0.59	-1.42	-0.52	0.62	0.68

R = Residue

Table 4: Correlation coefficient among the indices for the low yielding population

-	N	P	K	Ca	Mg	Zn	Cu	Fe	Mn	B	R
N	1										
P	0.132	1									
K	0.711	0.077	1								
Ca	-0.119	0.022	0.035	1							
Mg	0.09	-0.11	0.231	0.639	1						
Zn	-0.52	-0.357	-0.444	-0.384	-0.625	1					
Cu	-0.853	-0.415	-0.538	0.091	0.072	0.54	1				
Fe	-0.417	-0.361	-0.355	-0.387	-0.623	0.699	0.307	1			
Mn	-0.306	0.083	-0.481	-0.545	-0.802	0.42	0.077	0.514	1		
B	-0.193	-0.185	-0.397	0.367	0.569	-0.245	0.233	-0.525	-0.328	1	
R	0.498	0.241	0.363	0.542	0.667	-0.649	-0.438	-0.782	-0.687	0.44	1

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