Advance Journal of Food Science and Technology 7(4): 266-273, 2015
DOI:10.19026/ajfst.7.1306
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: July 18, 2014 Accepted: September 20, 2014 Published: February 10, 2015

Research Article

Nutritional Diagnosis for Apple by DRIS, CND and DOP

Min Xu, Jianing Zhang, Faqi Wu and Xudong Wang
College of Resource and Environment, Northwest A&F University, No. 3 Taicheng Road, Shaanxi, Yangling 712100, China

Abstract: This study derived and compared norms for apple, using the Diagnosis and Recommendation Integrated System (DRIS), Compositional Nutrient Diagnosis (CND) and deviation form optimum percentage (DOP) diagnose methods in the Weibei Loess Plateau, Shaanxi Province, China. A total of 68 leaf samples were collected from apple trees grown in Huangshan soils. The nutritional status was diagnosed by the DRIS, CND and DOP methods. The CND norms expressed as row-centered log ratios (mean±standard deviation) for *d* = 5 nutrients for the high-yield subpopulation (producing more than 46.67 t/ha) were: V_N^*= 0.998±0.066, V_P^* = -1.499±0.124, V_K^* = -0.189±0.283, V_{Ca}^* = 0.217±0.213, V_{Mg}^* = -1.035±0.267, V_{R5}^* = 1.508±0.144. The optimum ranges for leaf nutrient concentrations were: N = 27.23±1.79 g/kg, P = 2.26±0.32 g/kg, K = 8.63±2.50 g/kg, Ca = 12.73±2.66 g/kg, Mg = 3.71±1.12 g/kg, R_5 = 45.44±3.95 g/kg. The regression relating CND to DRIS and DOP indices were significant linear. There was a multinomial regression equation between CND r^2 and DRIS NBI, also between CND r^2 and ∑DOP. This study showed that the differences in CND, DRIS and DOP approaches did not lead to large differences in identified deficiencies. So, CND may in practice still be the preferred approach since multivariate methods could be further explored to assess nutrient status in plants, but people can choose any approach they want use since they had the similar evaluation result.

Keywords: Apple, CND, DOP, DRIS, leaf diagnosis, weibei loess plateau

INTRODUCTION

China apple production and export volume rank the first in the world (FAO, 2010). Almost 4.7 million hectares of apple are grown around the world and about 44% of those areas are located in China (FAO, 2010). The Wei-bei Loess Plateau, with advantaged apple producing conditions, is an important apple production area in China. Apple is grown extensively in this area with an average 601,520 ha in production and annual yield reaches nearly 8.6 million ton (SPBS (Shaanxi Provence Bureau of Statistic), 2010). In this area, improper use of fertilizers is likely to be the major factors contributing to declining yield and quality, though no local nutrition guidelines are available.

The correlation between soil and plant nutrient status is often poor (Hanson, 1987), so the foliar analysis has frequently been used to be an important tool to monitor the nutrient status of plants. There were several approaches can be used to diagnose foliar nutrient status, i.e., Critical Value Approach (CVA) (Bates, 1971), Diagnosis and Recommendation Integrated System (DRIS) (Beaufils, 1973), Compositional Nutrient Diagnosis (CND) (Parent and Dafir, 1992), Deviation form Optimum Percentage (DOP) (Montañésa *et al*., 1993).

The DRIS is a bivariate diagnosis method; and the CND expands the DRIS concept from a bivariate to a multivariable method. DRIS is based on dual ratios of nutrients, while CND is based on row-centered log ratios. Both DRIS and CND take nutrient interactions into consideration. Different from DRIS and CND, the DOP is a unary analysis method which quantifies the difference between a single nutrient concentration and its reference value using a percentage expression (Montañésa *et al*., 1993).

The Diagnosis and Recommendation Integrated System (DRIS) firstly developed for Hevea brasiliensis by Beaufils (1956, 1973). Many researchers considered DRIS was claimed to have certain advantages over other conventional interpretation tools (Beverly, 1987; Malavolta *et al*., 1993; Srivastava and Singh, 2008). DRIS norms have been used successfully to interpret the results of leaf analyses for both annual crops and perennial crops, such as tomato (Caron and Parent, 1989; Hartz *et al*., 1998; Mayfield *et al*., 2002), apple (Goh and Malakouti, 1992; Singh *et al*., 2000) and mango (Schaffer *et al*., 1988; Raghupathi and Bhargava, 1999; Raj and Rao, 2006). The CND has been developed for Potato (Parent *et al*., 1994; Khiari *et al*., 2001b), banana (Raghupathi *et al*., 2002) and curcuma longa (Kumar *et al*., 2003). However, the

Corresponding Author: Xudong Wang, College of Resource and Environment, Northwest A&F University, No. 3 Taicheng Road, Shaanxi, Yangling 712100, China

DOP method is not widely used; the useful references are deficiency.

The objective of this study was to derive and compare DRIS, CND and DOP Norms for apple, in the Wei-bei Loess Plateau of the northwestern China.

METHODS AND MATERIALS

Experimental data: The research was carried out in the Wei-bei Loess Plateau which is one of the main apple producing areas in China. The Wei-bei Loess Plateau is located in between 34°36' and 36°20' North latitude, 106°20' and 110°40' East longitude and the altitude from 800 to 1200 m. The Wei-bei Loess Plateau belongs to Warm and semi-humid continental monsoon climate. The annual rainfall varies between 525 and 730 mm. Mean maximum temperatures range from 34 to 40°C and mean minimum temperatures from -16 to -25°C. The sunshine duration is between 2,300 to 2,500 h. The frost-free period is 170 D.

According to fruit leaf sample standard in China (Gangli *et al*., 1987), the collection of leaves was accomplished between July and August. Each orchard 25 plants were random selected for their uniformity. A total of 68 leaf samples were collected from apple trees grown in Huangshan soils.

Leaf samples were washed with deionized water, dried at 65°C weighed, milled to 20 mesh for mineral analysis. Total nitrogen (N) was analyzed by the Nessler procedure (Chapman and Pratt, 1961). Phosphorus (P) was analyzed by the molybdenum yellow method. Potassium (K) was measured by the flame photometer. Calcium (Ca) and magnesium (Mg) were measured by atomic absorption spectrophotometer.

Analytical approach: According to Beaufils (1973) and Walworth and Sumner (1986), the DRIS norms selection is made along the following priorities:

- Yield and leaf nutrient concentrations built a databank, which is divided into high- (>45 t/ha) and low-yielding (<45 t/ha) subpopulations
- Calculate the mean, standard deviation and variance for each leaf nutrient concentration for the two subpopulations
- Calculate a variance ratio (V_{low} for low-yielding sub-population/V_{high} for high-yielding sub-population) for each nutrient concentration and of two ratios involving each pair of nutrients
- Select nutrient expressions for which the variance ratios (V_{low}/V_{high}) are relatively large
- Select equal numbers of expressions for each of the n elements (A, B, C, …… and X) to meet an absolute (orthogonal) requirement of the mathematical model. The following equations are developed for the calculation of DRIS indexes based on leaf analysis:

$$\text{X index} = \frac{f(X/A)+f(X/B)+\cdots\cdots-f(E/X)-f(F/X)-\cdots\cdots}{n-1} \quad (1)$$

where,

$$f(X/A) = \left(\frac{X/A}{x/a}-1\right)\times\frac{1000}{CV} \quad \text{when } X/A > x/a \quad (2)$$

Or,

$$f(X/A) = \left(1-\frac{X/A}{x/a}\right)\times\frac{1000}{CV} \quad \text{when } X/A < x/a \quad (3)$$

where, X/A is the actual value of the ratio of X and A in the plant under diagnosis, x/a the value of the norm (the mean value of this ratio for a high-yielding orchards) and CV the coefficient of variation of this ratio for population of high-yielding orchards.

It was considered that plants present nutritional balance for a given nutrient when the values of the indices, defined for the DRIS methods, are close to zero (Walworth and Sumner, 1986). When nutrients are in a state of imbalance, the negative DRIS index values mean that are undersupplied and positive DRIS index values mean that are oversupplied. The greater negative DRIS index values of the indices the greater the nutrient undersupply and the greater positive DRIS index values of the indices the greater the nutrient oversupply. The absolute sum values of the nutrient indices generate an additional index called Nutritional Balance Index (NBI). The greater the NBI values the greater the nutrient imbalance:

$$NBI = |A\ index| + |B\ index| + |C\ index| + \ldots\ldots + |X\ index| \quad (4)$$

According to Khiari *et al*. (2001a), Compositional Nutrient Diagnosis (CND) method was developed by the following equations. Plant tissue composition forms a d-dimensional nutrient arrangement; i.e., simplex (S^d) made of *d*+1 nutrient proportions including d nutrients and a filling value (R_d) defined as (Parent and Dafir, 1992):

$$S^d = \begin{bmatrix} (N,P,K,\cdots\cdots,R_d): \\ N>0,P>0,K>0,\cdots\cdots,R_d>0, \\ N+P+K+\cdots\cdots+R_d=100 \end{bmatrix} \quad (5)$$

where,

100 = The dry matter concentration (%)
N, P, K,... = Nutrient proportions (%)
R_d = The filling value computed as

$$R_d = 100-(N+P+K+)\cdots\cdots \quad (6)$$

A Geometric mean (G) is computed as:

$$G = (N\times P\times K\times\cdots\cdots\times R_d)^{\frac{1}{d+1}} \quad (7)$$

Row-centered log ratio is computed as:

$$V_x = \ln\left(\frac{X}{G}\right) \tag{8}$$

$$V_N + V_P + V_K + \cdots\cdots + V_{R_d} = 0 \tag{9}$$

where, V_x is the CND row-centered log ratio expression for nutrient X.

The observations are sequenced in a decreasing yield order, after the observations are divided into two subpopulations using the Cate-Nelson procedure (Khiari *et al*., 2001a). In the first partition, the two highest yield values constitute one group (c) and the remainder of the yield values constitute another group (group Low); thereafter, the three highest yield values constitute group High and the remainder of the yield values constitute the group Low. This process is repeated until the two lowest yield values constitute group Low and the remainder of the yield values constitute group High. Each iteration, the numbers of observations were n_1 and n_2 for the group High and group Low (n_1+n_2 = n, n is the number of whole observations). For the two subpopulations obtained in iteration, the variances of the row-centered log ratios were computed. The variance ratio of component X was then computed as:

$$fi(V_x) = \frac{\text{Variance of } V_x n_1 \text{ observations}}{\text{Variance of } V_x n_2 \text{ observations}} \tag{10}$$

where, $fi(V_x)$ is the ratio function between two subpopulations for nutrient X at the *i*th iteration; V_x is the CND row-centered log ratio expression for nutrient X. The cumulative variance ratio function, which is the sum of the variance ratios at the *i*th iteration from the top, is computed as follows:

$$F_i^c(V_x) = \frac{\sum_{i=1}^{n_1-1} fi(V_x)}{\sum_{i=1}^{n-3} fi(V_x)} \times 100 \tag{11}$$

The relationship between the cumulative function and yield (Y) is showed as:

$$F_i^c(V_x) = aY^3 + bY^2 + cY + \mathrm{h} \tag{12}$$

The inflection point is obtained by equating the second derivative of Eq. (12) to zero. Therefore, the yield cutoff value is -b/3a. CND norms are computed using means and standard deviations corresponding to the row-centered log ratios V_X of *d* nutrients for high-yield subpopulation, that is, V_x^* and SD_x^*. The CND indices, denoted as I_x, are calculated as:

$$I_x = \frac{V_x - V_x^*}{SD_x^*} \tag{13}$$

The nutrient imbalance index of a diagnosed specimen, namely CND r^2, is calculated as:

$$r^2 = I_N^2 + I_P^2 + I_K^2 + \cdots\cdots + I_{R_d}^2 \tag{14}$$

Deviation form Optimum Percentage (DOP) (Montañésa *et al*., 1993) index is defined as the percentage deviation of the concentration of an element with respect to the optimum content taken as the reference value. The DOP index is calculated as:

$$\mathrm{DOP} = [(C \times 100)/Cref] - 100 \tag{15}$$

where, C is the concentration of a given nutrient; and Cref is the optimal nutrient concentration. Like the DRIS index, the DOP index can be positive, zero, or negative, the negative DOP index values mean that are undersupplied and positive DOP index values mean that are oversupplied. The sum of the absolute values of the DOP indexes (ΣDOP) is just like the NBI. If the sample is near to an adequate nutritional status, the ΣDOP will be near zero (Montañes *et al*., 1993).

RESULTS

The S^5, i.e., six-dimensional (*d*+1) apple simplex comprised the five nutrients N, P, K, Ca and Mg and the filling value R_5. R_5 values were calculated by Eq. (6). Summary statistics for the apple yield and leaf nutrient concentration data available from the apple orchard survey are listed in Table 1. The leaf nutrient concentration for N, P, K, Ca, Mg and R_5 ranged from 23.28 to 31.49, 1.65 to 3.40, 4.08 to 16.62, 6.71 to 40.44, 1.78 to 8.15 and 11.56 to 59.18 g/kg, respectively. The mean leaf nutrient concentrations of N, P, K, Ca, Mg and R_5 were 26.59, 2.41, 9.34, 14.25, 3.78 and 43.62 g/kg, respectively. Yield ranged from 9.9 to 100.4 t/ha and mean was 37.07 t/ha.

CND row-centered log ratios V_N, V_P, V_K, V_{Ca}, V_{Mg} and V_{R5} were compute using Eq. (7-9). The cumulative variance ratio function was estimated by Eq. (10) and Eq. (11). According to Eq. (12), the relationship between the cumulative function and apple yield (Y)

Table 1: Summary statistics for leaf nutrition of apple in Weibei Loess Platea (n = 68)

Items	Min	Max	Mean	S.D.	CV (%)
N (g/kg)	23.28	31.49	26.59	1.70	6.38
P (g/kg)	1.65	3.40	2.41	0.33	13.80
K (g/kg)	4.08	16.62	9.34	2.88	30.80
Ca (g/kg)	6.71	40.44	14.25	5.31	37.24
Mg (g/kg)	1.78	8.15	3.78	1.24	32.85
R_5 (g/kg)	11.56	59.18	43.62	7.26	16.63
Yield (t/ha)	9.9	100.4	37.07	20.49	55.26

CV and SD stand for coefficient of variation and standard deviation, respectively

Table 2: Relationship between the cumulative variance function $F_i^c(V_x)$ and apple yield in S^5 and yield at point of inflection

	$Fi^c (V_X) = aY^3+bY^2+cY+d$	R^2	Yield at inflection point (-b/3a)
V_N	$y = -0.0002x^3+0.0419x^2-3.4116x+95.865$	0.9976	69.83
V_P	$y = 0.0002x^3-0.028x^2-0.3305x+99.879$	0.9994	46.67
V_K	$y = -0.0002x^3+0.0233x^2-2.2483x+101.01$	0.9988	38.83
V_{Ca}	$y = -0.0002x^3+0.0309x^2-2.6174x+100.33$	0.9968	51.50
V_{Mg}	$y = 0.0001x^3-0.0188x^2-0.8626x+99.323$	0.9994	62.67
V_{R5}	$y = -0.0004x^3+0.066x^2- 4.1116x+93.048$	0.9847	55.00

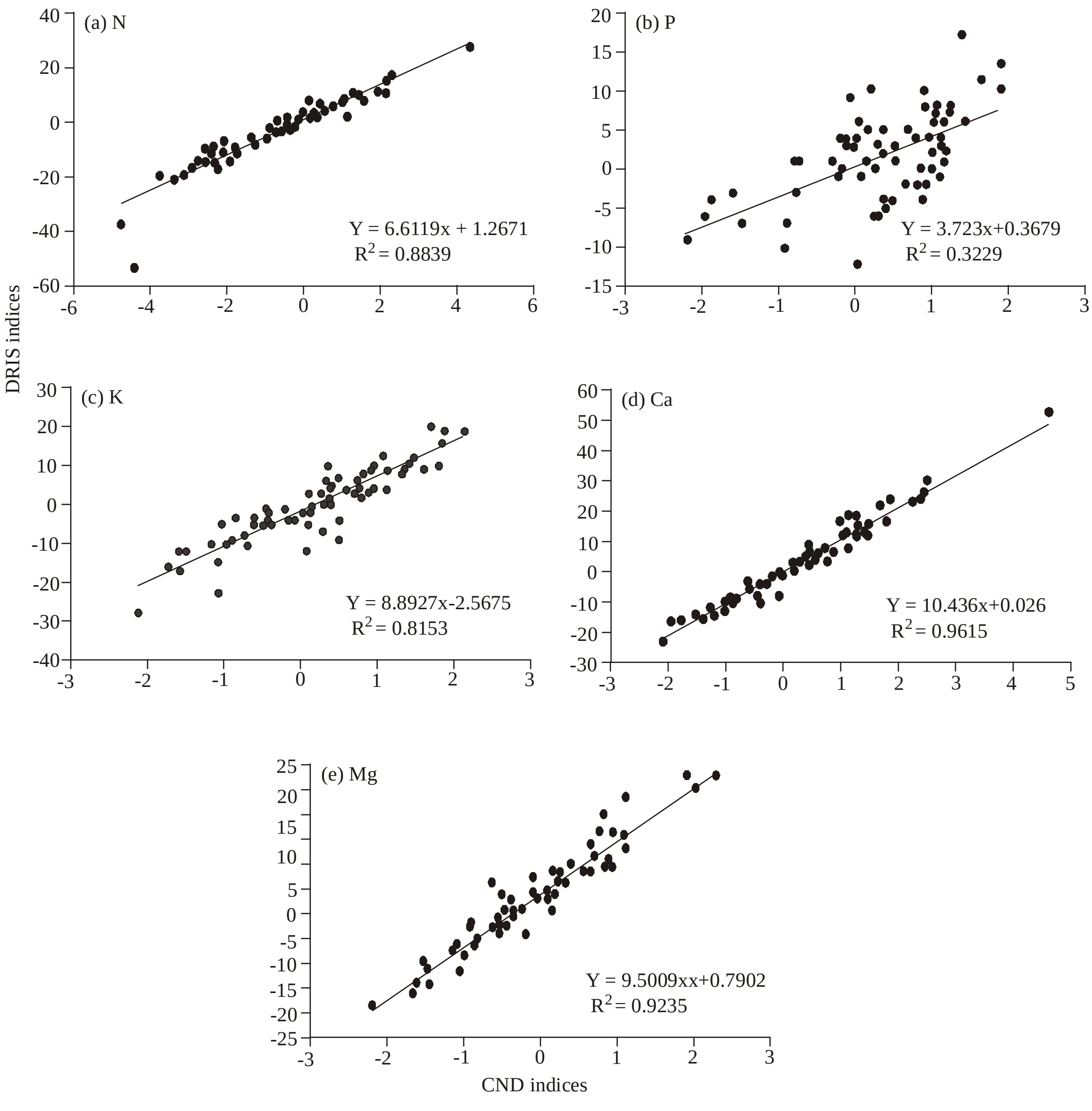

Fig. 1: Relationship between CND and DRIS indices

was showed in Table 2. Yield cutoff values (inflection points at -b/3a) were 69.83 t/ha for, 46.67 for, 38.83 for, 51.50 for, 62.67 for and 55.00 for. All six relationships showed a cubic pattern (Fig. 1). The theory of the CND approach recommends that the highest yield cutoff value must be used to partition the low-yielding subpopulation from the high-yielding subpopulation. However, in apple production in China, 45 t/ha was used to divide the high-yielding subpopulation and low-yielding subpopulation. In this study, 46.67 t/ha was chosen to define the high-yielding subpopulation. This result implied that 23.5% of the population was considered as the high-yielding subpopulation (Fig. 2).

The CND norms, as means and standard deviations (V_x^* and SD_x^*) of the CND row-centered log ratios for the high-yield subpopulation (producing more than 46.67 t/ha) were: $V_N^* = 0.998\pm0.066$, $V_P^* = -1.499\pm0.124$, $V_K^* = -0.189\pm0.283$, $V_{Ca}^* =$

Table 3: The CND norms for d = 5 nutrients in a high-yielding subpopulation producing more than 46.67 t/ha of apple and their corresponding optimum ranges of leaf nutrient concentrations

V_X^*	Mean	S.D.	Nutrient	S.D.	Mean
V_N^*	0.998	0.066	N (g/kg)	27.23	1.79
V_P^*	-1.499	0.124	P (g/kg)	2.26	0.32
V_K^*	-0.189	0.283	K (g/kg)	8.63	2.50
V_{Ca}^*	0.217	0.213	Ca (g/kg)	12.73	2.66
V_{Mg}^*	-1.035	0.267	Mg (g/kg)	3.71	1.12
V_{R5}^*	1.508	0.144	R_5 (g/kg)	45.44	3.95

SD stands for standard deviation

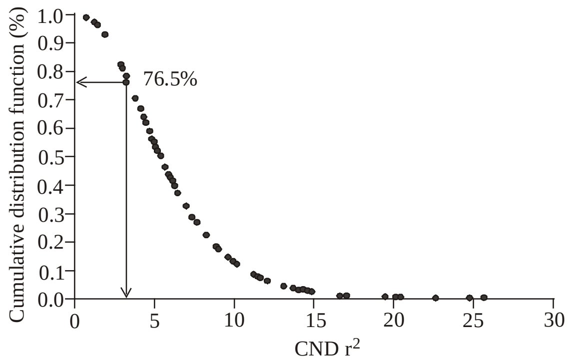

Fig. 2: The χ^2 cumulative distribution function with 6 df for obtaining theoretical threshold CND r^2 value (3.2) in S^5 for yield cutoff at 76.5% of low-yield subpopulations

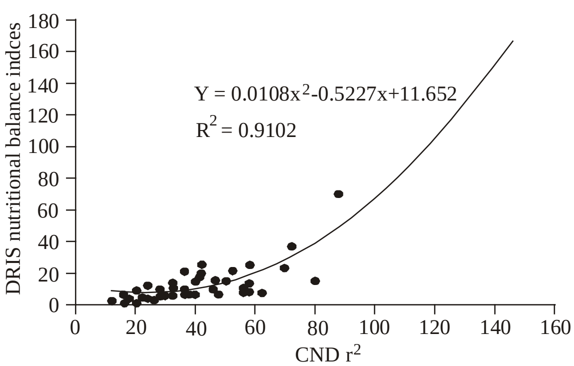

Fig. 3: Relationship between CND r^2 and DRIS NBI (nutritional balance index)

0.217±0.213, V_{Mg}^*= -1.035±0.267, V_{R5}^* = 1.508±0.144 (Table 3). These CND norms were used to calculate the CND indices I_N, I_P, I_K, I_{Ca}, I_{Mg} and I_{R5} by Eq. (13). The CND indices I_N, I_P, I_K, I_{Ca}, I_{Mg} and I_{R5} were used to compute CND r^2 values by Eq. (14). The CND r^2 values were distributed like χ^2 values (Fig. 2). 76.5% of the observations were below the yield cutoff of 46.67t ha^{-1} and the corresponding χ^2 value was 3.2 (Fig. 2).

The optimum ranges for leaf nutrient concentrations were also showed in Table 3. They were the means and standard deviations of the high-yielding subpopulation (producing more than 46.67 t/ha). These foliar ranges were N = 27.23±1.79 g/kg, P = 2.26±0.32 g/kg, K = 8.63±2.50 g/kg, Ca = 12.73±2.66 g/kg, Mg = 3.71±1.12 g/kg, R_5 = 45.44±3.95 g/kg.

Table 4: DRIS norms, mean values and Coefficient of Variation (CV) for selected nutrient ratio expressions in apple

DRIS Norms	Mean	CV (%)
P/N	0.08	13.57
K/N	0.32	29.18
Ca/N	0.47	22.30
Mg/N	0.14	27.71
K/P	3.88	30.86
P/Ca	0.19	24.21
P/Mg	0.66	34.13
K/Ca	0.72	38.63
K/Mg	2.60	48.00
Ca/Mg	3.72	36.56

CV stands for variable coefficient

The DRIS norms, as well as mean values and Coefficient of Variation (CV) were showed in Table 4. These DRIS norms were used to calculate the DRIS indices for N, P, K, Ca, Mg and R_5 Nutritional Balance Index (NBI) by Eq. (1-4). Relationship between CND and DRIS indices were showed in Fig. 1. The regression relating CND to DRIS indices for N, K, Ca and Mg were significant linear and the R^2 were 0.8839, 0.8153, 0.9615 and 0.9235, respectively. The regression relating CND to DRIS indices for P was significant linear, the R^2 was only 0.3229. There was a multinomial regression equation between CND r^2 and DRIS NBI with R^2 of 0.9102 (Fig. 3).

The Deviation form Optimum Percentage (DOP) indices were computed by Eq. (15). Relationship between CND and DOP indices were showed in Fig. 4. The regression relating CND to DOP indices for K, Ca and Mg were significant linear and the R^2 were 0.8993, 0.8885 and 0.875, respectively. The regression relating CND to DRIS indices for N and P were not significant linear, the R^2 were both less than 0.5. here was a multinomial regression equation between CND r^2 and ∑DOP with R^2 of 0.9091 (Fig. 5).

DISCUSSION

According to Gangli *et al*. (1987), the standard of apple leaf nutrient concentrations for whole China was: N 20~26 g/kg, P 1.5~2.3 g/kg, K 10~ 20 g/kg, Ca 10~ 20 g/kg and Mg 2.2~3.5 g/kg. The standard for apple leaf nutrient concentrations in Shaanxi province was N 23.1~25 kg^{-1}, P 1.38~1.66 kg^{-1}, K 7.3~9.8 kg^{-1}, Ca 17.3~22.4 kg^{-1} and Mg 3.7~4.3 kg^{-1} (An, 2004). Compare with them, this research had the same optimum leaf nutrient concentrations ranges for K, Ca and Mg which were computed by CND, N and P were

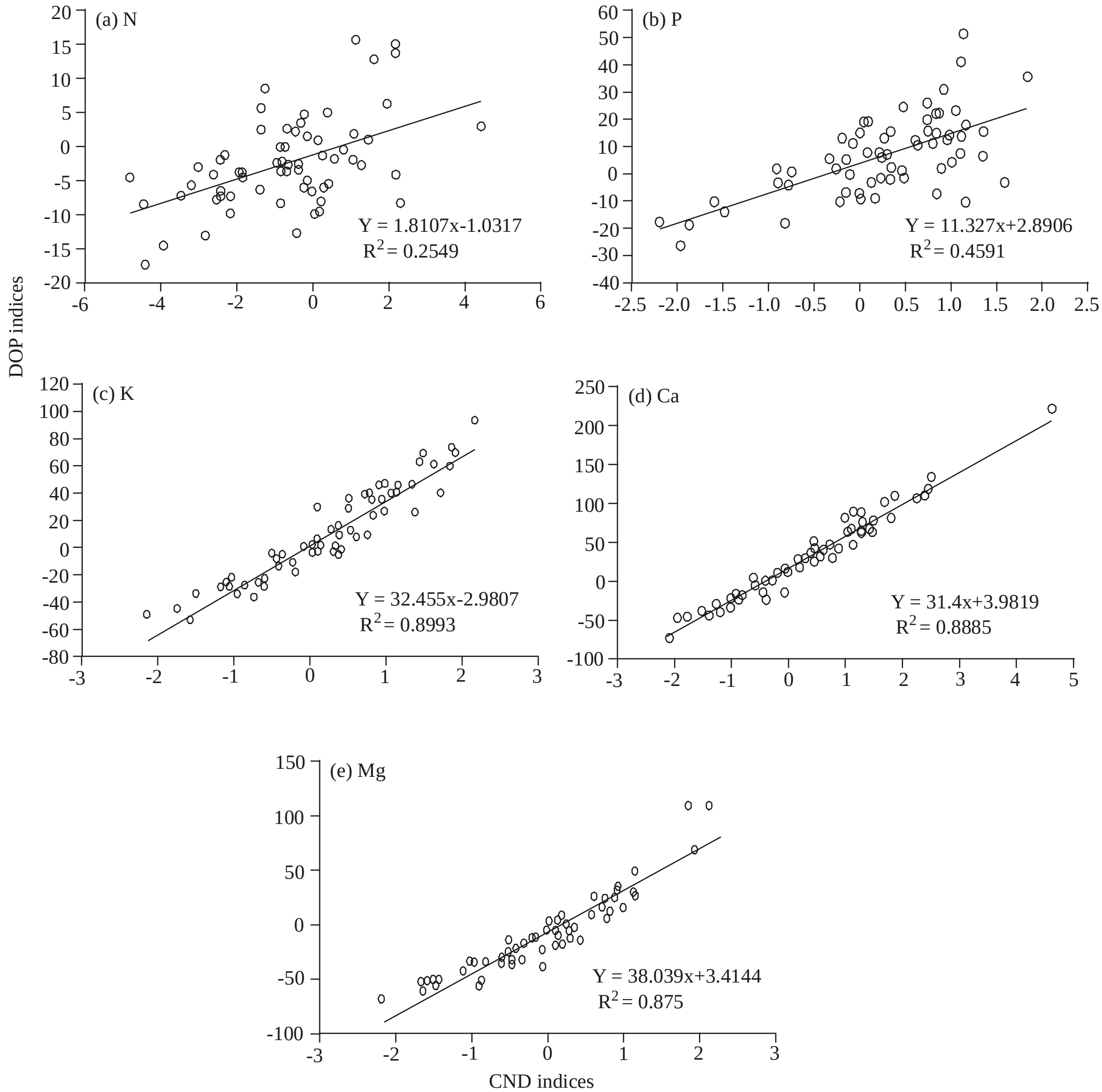

Fig. 4: Relationship between CND and DRIS indices

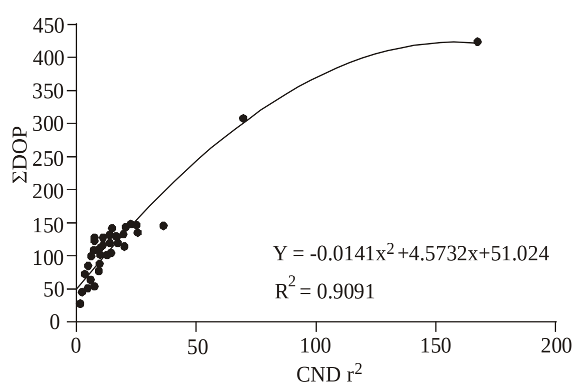

Fig. 5: Relationship between CND r^2 and $\sum$DOP

higher. Because the study showed that the applying of N and P fertilizer increased every year (Zeng, 2011).

The fact that CND and DRIS norms were closely related was in line in earlier studies (Parent *et al*., 1993; Parent *et al*., 1994; Khiari *et al*., 2001c). In this study the regressions relating CND to DRIS had high R^2 for all nutrients except P and showed similar trends (Fig. 1). The regression relating CND to DOP indices for K, Ca and Mg were significant linear and the R^2 were 0.8993, 0.8885 and 0.875, respectively (Fig. 4). Some orders of imbalances were showed in Table 5. Although the order differed between DRIS, CND and DOP, all methods identified the same most deficient nutrient and the least deficient nutrient. This suggests that the differences among the methods may be minimal. This is further supported by the fact that all three approaches did not seem to differ in categorizing of observations as either deficient or excess (Fig. 1 and 4).

The closeness in relationships between CND to DRIS or DOP suggests that both DRIS and DOP

Table 5: DRIS, CND and DOP indices for apple in 5 orchards

Case		N	P	K	Ca	Mg	Order of requirement
Sanzhuowa Orchard	DRIS	-3	2	-2	12	-9	Mg>N>K>P>Ca
	CND	-0.441	0.967	-0.254	1.404	-1.112	Mg>N>K>P>Ca
	DOP	-4	11	-11	31	-29	Mg>K>N>P>Ca
Nanwuzhong Orchard	DRIS	28	8	-18	-13	-5	K>Ca>Mg>P>N
	CND	4.386	1.193	-1.587	-1.053	-0.894	K>Ca>Mg>P>N
	DOP	3	-12	-53	-40	-42	K>Mg>Ca>P>N
Ding Orchard	DRIS	-19	0	6	15	-2	N>Mg>P>K>Ca
	CND	-3.204	0.947	0.477	1.293	0.185	N>Mg>K>P>Ca
	DOP	-6	30	29	50	18	N>Mg>K>P>Ca
Liangjiazhuang Orchard	DRIS	2	0	-10	3	5	K>P>N>Ca>Mg
	CND	-0.166	0.237	-0.913	0.155	0.295	K>N>Ca>P>Mg
	DOP	-5	-2	-29	-3	0	K>N>Ca>P>Mg
Fangjing Orchard	DRIS	-3	-10	-16	7	22	K>P>N>Ca>Mg
	CND	-0.670	-0.905	-1.105	0.440	1.934	K>P>N>Ca>Mg
	DOP	3	-5	-24	15	73	K>P>N>Ca>Mg

methods give similar diagnosis. On the other hand, the fact that the R^2 relationship between DRIS and CND r^2 had a slightly higher adjusted R^2 (0.9102) compared to the relationship between CND r^2 and DOP (0.9091) (Fig. 3 and 5) suggests that the DRIS may be superior. Nonetheless, the DRIS is a bivariate diagnosis method; the CND is a multivariable method; both of them are more complex calculations than DOP. This study showed that the differences in CND, DRIS and DOP approaches did not lead to large differences in identified deficiencies. So, CND may in practice still be the preferred approach since multivariate methods could be further explored to assess nutrient status in plants, but people can choose any approach they want use since they had the similar evaluation result.

CONCLUSION

The CND norms expressed as row-centered log ratios (mean±standard deviation) for d = 5 nutrients for the high-yield subpopulation (producing more than 46.67 t/ha) were: $V_N^* = 0.998\pm0.066$, $V_P^* = -1.499\pm0.124$, $V_K^* = -0.189\pm0.283$, $V_{Ca}^* = 0.217\pm0.213$, $V_{Mg}^* = -1.035\pm0.267$, $V_{R5}^* = 1.508\pm0.144$.

The optimum ranges for leaf nutrient concentrations were: N = 27.23±1.79 g/kg, P = 2.26±0.32 g/kg, K = 8.63±2.50 g/kg, Ca = 12.73±2.66 g/kg, Mg = 3.71±1.12 g/kg, R_5 = 45.44±3.95 g/kg.

The regression relating CND to DRIS and DOP indices were significant linear. There was a multinomial regression equation between CND r^2 and DRIS NBI, also between CND r^2 and ∑DOP.

ACKNOWLEDGMENT

This study was funded by the ‘Twelfth Five-Year Plan’ of the national science and technology support project in China: ‘The Integration and Demonstration of Crop-fruit-animal Compound Cycle Technology in the Loess Plateau’ (project number: 2012BAD14B11). MinXu would like to acknowledge the scientific guidance of Prof. Wu and Prof. Wang. I also thank all the students in my university for their assistance.

REFERENCES

An, G.Y., 2004. Studies on the standard range of leaf nutritional element content and its effect factors. M.S. Thesis, Northwest A & F University, Yangling, Shannxi.

Bates, T.E., 1971. Factors affecting critical nutrient concentrations in plant and their evaluation, a review. Soil Sci., 112: 116-130.

Beaufils, E.R., 1956. Mineral equilibrium in the foliage and latex of Hevea brasiliensis. Ann. Agron., 2: 205-218.

Beaufils, E.R., 1973. Diagnosis and Recommendation Integrated System (DRIS). Soil Sci. Bull. No. 1. University of Natal, Durban, South Africa.

Beverly, R.B., 1987. Modified DRIS method for simplified nutrient diagnosis of ‘valencia’ oranges. J. Plant Nutr., 10: 1401-1408.

Caron, J. and L.E. Parent, 1989. Derivation and assessment of DRIS norms for greenhouse tomatoes. Can. J. Plant Sci., 69: 1027-1035.

Chapman, H.D. and P.F. Pratt, 1961. Methods of Analysis for Soils, Plants and Waters. University of California, Division of Agricultural Science, Berkeley, CA.

FAO, 2010. FAOSTAT. Retrieved form: http://faostat3.fao.org/home/index.html. (Accessed on: Nov. 30, 2012)

Gangli, L., S. Runyu and S. Tsuin 1987. Studies on the nutritional ranges in some deciduous fruit trees. Acta Hortic. Sin., 14(2): 81-89.

Goh, K.M. and M.J. Malakouti, 1992. Preliminary nitrogen, phosphorus, potassium, calcium and magnesium DRIS norms and indexes for apple orchards in Canterbury, New Zealand. Commun. Soil Sci. Plan., 23: 1371-1385.

Hanson, E.J., 1987. Fertilizer use efficiency: Integrating soil tests and tissue analysis to manage the nutrition of high bush blueberries. J. Plant Nutr., 10: 1419-1427.

Hartz, T.K., E.M. Miyao and J.G. Valencia, 1998. DRIS evaluation of the nutritional status of processing tomato. HortScience, 33: 830-832.

Khiari, L., L.E. Parent and N. Tremblay. 2001a. Selecting the high-yielding subpopulation for diagnosing nutrient imbalance in crops. Agron. J., 93: 802-808.

Khiari, L., L.E. Parent and N. Tremblay, 2001b. The phosphorus compositional nutrient diagnosis range for potato. Agron. J., 93: 815-819.

Khiari, L., L.E. Parent and N. Tremblay, 2001c. Critical compositional nutrient indexes for sweet corn at early growth stage. Agron. J., 93: 809-814.

Kumar, P.S.S., S.A. Geetha, P. Savithri, R. Jagadeeswaran and P.P. Mahendran, 2003. Diagnosis of nutrient imbalances and derivation of new RPZI (Reference Population Zero Index) values using DRIS/MDRIS and CND approaches in the leaves of turmeric (*Curcuma longa*). J. Appl. Hortic., 5: 7-10.

Malavolta, E., S.A. Oliveika and G.C. Vitti, 1993. The use of Diagnosis Recommendation Integrated System (DRIS) to evaluate the nutritional status of healthy and blight affected citrus trees. Proceeding of the 8ht International Colloquium for the Optimization of Plant Nutrition. Kluwer Academic Publishers, Dordrecht, Netherlands, pp: 157-159.

Mayfield, J.L., E.H. Simonne, C.C. Mitchell, J.L. Sibley, R.T. Boozera and L. Edgar, 2002. Effect of current fertilization practices on nutritional status of double cropped tomato and cucumber produced with plasticulture. J. Plant Nutr., 25: 1-15.

Montañésa, L., L. Herasa, J. Abadíaa and M. Sanza, 1993. Plant analysis interpretation based on a new index: Deviation from Optimum Percentage (DOP). J. Plant Nutr., 16(7): 1289-1308.

Parent, L.E. and M. Dafir, 1992. A theoretical concept of CND. J. Am. Soc. Hortic. Sci., 117: 239-242.

Parent, L.E., A. Karam and S.A. Visser, 1993. Compositional nutrient diagnosis of the greenhouse tomato. HortScience, 28: 1041-1042.

Parent, L.E., A.N. Cambouris and A. Muhawenimana, 1994. Multivariate diagnosis of nutrient imbalance in potato crops. Soil Sci. Soc. Am. J., 58: 1432-1438.

Raghupathi, H.B. and B.S. Bhargava, 1999. Preliminary nutrient norms for ‘Alphonso’ mango using diagnosis and recommendation integrated system. Indian J. Agr. Sci., 69: 648-650.

Raghupathi, H.B., B.M.C. Reddy and K. Srinivas, 2002. Multivariate diagnosis of nutrient imbalance in banana. Commun. Soil Sci. Plan., 33: 2131-2143.

Raj, G.B. and A.P. Rao, 2006. Identification of yield-limiting nutrients in mango through DRIS indices. Commun. Soil Sci. Plan., 37(11): 1761-1774.

Schaffer, B., K.D. Larson, G.H. Snyder and C.A. Sanchez, 1988. Identification of mineral deficiencies associated with mango decline by DRIS. HortScience, 23: 617-619.

Singh, N.P., R.P. Awasthi and A. Sud, 2000. Diagnosis and Recommendation Integrated System (DRIS) norms for apple (Malus × Domestica Borkh. L. CV. Starking Delicious) in Himachal Pradesh. Indian J. Hortic., 57(3): 196-204.

SPBS (Shaanxi Provence Bureau of Statistic), 2010. Statistical Communique of fruit in Shaanxi Province. Retrieved form: http://www.sn.stats.gov.cn/news/qsgb/201132390305.htm. (Accessed on: Nov. 30, 2012)

Srivastava, A.K. and S. Singh, 2008. DRIS norms and their field validation in Nagpur mandarin. J. Plant Nutr., 31(6): 1091-1107.

Walworth, J.L. and M.E. Sumner, 1986. Foliar diagnosis-a review. Adv. Plant Nutr., 3: 193-241.

Zeng, Y.J., 2011. Effect of fertilization on yield and quality of Fuji apple in Shaanxi. M.S. Thesis, Northwest A & F University, Yangling.