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Diagnosis and Recommendation Integrated System Norms for Jackfruit (*Artocarpus heterophyllus* Lam.) Nutrient Status Evaluation

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Abstract

In China, the balanced fertilization was neglected in jackfruit orchards from lack of monitoring nutrient status. Therefore, for identification deficiency or excess of nutrients and determination the order of nutrient requirement, the jackfruit diagnosis and recommendation integrated system (DRIS) was provided. The jackfruit DRIS norms about N, P, K, Ca, Mg, S, Fe, Mn and B were developed using 2 years data of high-yielding orchards and low-yielding orchards of Hainan, China. Based on the DRIS norms, the DRIS indices of low-yielding orchards were defined, and then determined the order of nutrient requirement. Meanwhile, the DRIS norms were used to derive the standard of DRIS index grade, which identified deficiency or excess of nutrients for jackfruit orchards. Eventually, we found that the order of low-yielding orchards nutrient requirement was Ca > K > Fe > P > N > S > Mg > B > Mn, and the deficient nutrients were Ca, K and Fe. Therefore, the establishment of the DRIS approach is very important for jackfruit nutrient status diagnosis. It may be beneficial to fertilizer plan of Hainan jackfruit orchards.

Keywords: DRIS norm, index grade standard, nutrient ratio, nutritional status evaluation, optimum range

1. Introduction

Foliar analysis has been practiced widely in plants for nutritional status evaluation and fertilizer programs planning. Usually, plant nutritional status evaluation is done by sufficiency range approach. Compared leaf nutrient concentration with the values of sufficiency range, below it is considered as hidden hunger or severe deficiency, and above it is considered as luxury absorption or excessive toxicity. It would affect the plant growth, yield and quality of fruit, whatever below or above the sufficiency range. The approach has become an essential practice for nutritional status evaluation, however, it only evaluates deficiency or excess of a single nutrient at a time, and fails to measure nutrient balance and also dose not consider various interactions (Elwali & Gascho, 1984; Jones, Eck, & Voss, 1990; Kelling & Matocha, 1990).

The DRIS approach uses the principle of nutrient interrelationships in determining the order of nutrient requirement (Elwali, Gascho, & Sumner, 1985; Bailey, Dils, Foy, & Patterson, 2000; Hundal, Dhanwinder-Singh, & Brar, 2005). It is based on a theory about that, as plants approach their growth potential, their nutrient status becomes less variable (Beaufils, 1973; Walworth, Sumner, Isaac, & Plank, 1986; Angeles, Sumner, & Lahav, 1993). DRIS index values that describe the relative status of each nutrient are generated during a DRIS assessment. This approach uses nutrient concentration ratios rather than nutrient concentrations, and gives a rating of relative balances among nutrients by means of DRIS index that can have positive or negative values with zero indicating balance. The more negative about the nutrient index value, the more limiting the nutrient is, and vice versa. The DRIS approach has been used in many plants, such as sweet potato, sugarcane and fir trees (Elwali & Gascho, 1984; Hockman, Burger, & Smith, 1989; Bailey, Ramakrishna, & Kirchhof, 2009). For example, in Papua New Guinea, the deficiency of P, K and S were determined by DRIS in sweet potato orchards, and the main nutritional constraints were resolved by increasing the content of P, K and S in soil (Bailey et al., 2009). However, there is short of the DRIS norms in jackfruit, and thus more data needs to be provided. The objective of this study was to develop DRIS norms and to derive the standard of DRIS index for jackfruit nutrient status diagnosis.

2. Materials and Methods

2.1 Site

During 2013-2014, experiments were performed at 16 orchards of jackfruit in Hainan, China. The sites were located in north latitude 18°9′-20°11′, east longitude 108°21′-111°03′ and altitude 1-1000 m. The tropical climate was characterized by average annual temperature of 23-25 °C and average annual rainfall of 1000-2000 mm. The soil of the experimental orchards was latosol (sandy clay loam).

2.2 Sampling

The leaf samples were collected in the 3-6 month-old leaves from the central canopy between April and May of 2013-2014 (Sun et al., 2015). The leaves were sampled on a population of 10 representative trees in each plot. The collected samples should be brought to the laboratory on the same day. All samples were washed in distilled water.

2.3 Samples Analysis

The analyses were carried out on dry leaf samples after grinding. The diacid (H_2SO_4-H_2O_2) digests were used for determination of N, P, K, Ca, Mg, Fe, Mn, Cu and Zn. N was determined by the Kjeldahl digestion method. P was determined by Mo-Sb Anti spectrophotometric method. K was determined by flame photometer. Ca, Mg, Fe, Mn, Cu and Zn were determined by atomic absorption spectrophotometry. S was determined by BaCl turbidimetry after acid (HNO_3-$HClO_4$-HCl) digestion method. B was determined by azomethine-H spectrophotometric method (Mahesh & Singh, 2005; Anjaneyulu, 2007).

2.4 Determination of Norms and Indices of DRIS

The whole population was divided into two subpopulations (high-yielding orchards and low-yielding orchards) on the basis of yield: high-yielding orchards in which fruit yield were equal or exceeded 90 t/ha, and low-yielding orchards in which fruit yield were lower than 60 t/ha. Mean values of nutrient ratios for high-yielding and low-yielding orchards together with their respective coefficients of variance (CV) and variances (V_{low} and V_{high}) were calculated. The data of high-yielding orchards reflected conditions which were deemed desirable, and some the mean values in the high-yielding orchards were ultimately chosen as the diagnostic norms for plants (Meldal-Johnson & Sumner, 1980; Payne, Rechcigl, & Stephenson, 1990; Bailey, Cushnahan, & Beattie, 1997b). Subsequently, the selection criteria of diagnostic norms include four points. The first was to select nutrients that the concentration data were relatively symmetrical in the high-yielding orchards (skewness values < 2.0), so that they provided realistic approximations about the nutrients range. The second was to select nutrient ratio expressions that had relatively unskewed distributions in the high-yielding orchards (skewness values < 1.0), in order to ensure that calculated mean values of these ratios would match well with the true values at maximum crop yield. The third was to select nutrient variance ratios expressions (V_{low}/V_{high}) which were relatively large (V_{low}/V_{high} > 1.0), so that they provided the best differentiate between ‘healthy plant’ and ‘unhealthy plant’ (Walworth & Sumner, 1986, 1987). The fourth was to select equal numbers of nutrient ratio expressions for each of the selected nutrients. This was an absolute orthogonal requirement of the mathematical model (Bailey, Beattie, & Kilpatrick, 1997a; Ramakrishna, Bailey, & Kirchhof, 2009). In order to evaluate the balance of nutrient and the order of nutrient requirement, the formulae for calculation of DRIS indices for plants were as follows:

$$A \text{ index } = \frac{[f(A/B)+f(A/C)+f(A/D)...+f(A/N)]}{z} \quad (1)$$

$$B \text{ index } = \frac{[-f(A/B)+f(B/C)+f(B/D)...+f(B/N)]}{z} \quad (2)$$

$$N \text{ index } = \frac{[-f(A/N)-f(B/N)+f(N/C)...+f(N/M)]}{z} \quad (3)$$

Where, $f(A/B) = (\frac{A/B}{a/b} - 1)\frac{1000}{CV}$, when $A/B \geq a/b$ or $f(A/B) = (1 - \frac{a/b}{A/B})\frac{1000}{CV}$ when $A/B < a/b$.

A/B was the nutrient ratio of the plant under diagnosis; *a/b* was the value of the corresponding norm; CV was the coefficient of variation associated with the norm; *z* was the number of functions. The other functions were calculated in a similar manner.

The DRIS approach can also be employed to compute deficient, low, optimum, high and excess ranges for nutrients (Hundal, Dhanwinder-Singh, Kuldip-Singh, & Brar, 2008; Feng, Zhang, & Zhong, 2009). The standard of DRIS index grade which consists of deficient range, low range, optimum range, high range and excess range for each index, has been derived using the mean and standard deviation (SD) of DRIS indices of high-yielding orchards. The optimum range was the values derived from 'mean - 4/3 SD to mean + 4/3 SD'; the low range was obtained by calculating 'mean - 4/3 SD to mean - 8/3 SD' and the values below 'mean - 8/3 SD' were considered as deficient range; the values from 'mean + 4/3 SD to mean + 8/3 SD' were taken as high range and the values above 'mean + 8/3 SD' were taken as excessive range. The same as sufficiency range approach, below the optimum range was considered as nutrient hidden hunger or severe deficiency, and above the optimum range was considered as nutrient luxury absorption or excessive toxicity.

All statistics were calculated using SPSS (version 19.0) statistical software.

3. Results and Discussion

Statistics data of nutrient and nutrient ratio expressions were shown in Table 1 and Table 2. The DRIS norms were selected in the following steps. Firstly, all nutrients had skewness values less than 2.0. They were relatively symmetrical, and hence were selected for DRIS norms establishment. Secondly, nutrient ratios were selected that had skewness values less than 1.0, thereby thirty-five nutrient ratio expressions were eliminated. Thirdly, fifty nutrient ratio expressions had V_{low}/V_{high} greater than 1.0. Then, for eligible reciprocal expressions such as N/P and P/N, the more appropriate nutrient ratio expression was selected; in all Cu and Zn expressions, only six expressions (Cu/K, Cu/Fe, Zn/K Mg/Zn S/Zn and Fe/Zn) had V_{low}/V_{high} greater than 1.0, and hence were deemed unequal numbers of nutrient ratio expressions, and Cu and Zn were unsuitable for DRIS model development. Therefore, the mean values in the high-yielding orchards of thirty-four nutrient expressions (e.g., N/P) involving nine nutrients (N, P, K, Ca, Mg, S, Fe, Mn and B) were chosen as the diagnostic norms for jackfruit. These expressions get the maximum potential to differentiate between 'healthy plant' and 'unhealthy plant'. Finally, in order to obtain the equal number of nutrient ratio expressions for each of the nine nutrients, some additional nutrient ratio expressions, such as Mn/Mg and Mn/S were re-selected. The data of DRIS norms were shown in table 3.

The jackfruit growth consumes large amounts of nutrients from soil. However, the traditional nutrient management in Hainan usually depended on the experience and little attention was paid to micronutrient fertilizer. Annual fertilization consumption includes manure 25 kg, urea 1 kg, superphosphate 0.5 kg and potassium chloride 1.5 kg for each jackfruit plant. The balanced fertilization was neglected. From the plant nutrient standpoint, the deficiency or excess of some nutrients depends on the application of other nutrients. For example, in the grassland sward research, sometimes, if having an adequate supply of N, P and K, there was a deficiency of Ca and Mg; if not, there was an excess of Ca and Mg (Bailey et al., 1997a). On the other hand, the recovery of one nutrient from the soil or a fertilizer application depended on the availability of some other nutrient. For example, K uptake and efficiency from either soil or K applications often depended on the rate of N used (Ebelhar, Kamprath, & Moll, 1987). Likewise, K was known to have a key role in N uptake and translocation (Cushnahan, Bailey, & Gordon, 1995). Therefore, some nutrients (such as N and K) need to be kept in the specific nutrient ratios to develop the plants. The jackfruit DRIS norms put emphasis on nutrient concentration ratios, and hence it was very important for jackfruit nutrient status diagnosis. Using these norms, the nutrient requirement order was obtained, which could helpful for balanced fertilization.

Table 1. Statistics data of nutrients for high-yielding orchards

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Mean/%	2.49	0.18	2.01	1.30	0.22	0.19	0.009	0.03	0.001	0.004	0.004
CV/%	0.04	0.07	0.03	0.14	0.24	0.10	0.23	0.27	0.47	0.49	0.13
Skewness	0.17	0.27	0.84	0.40	-0.23	1.29	1.69	-0.06	-0.26	0.86	-0.66

Table 2. Statistics data of nutrient ratios for high-yielding orchards and low-yielding orchards

Nutrient ratio	High-yielding orchards				Low-yielding orchards			V_{low}/V_{high}
	Mean	CV/%	Skewness	V_{high}	Mean	CV/%	V_{low}	
N/P	14.13	0.06	-0.22	0.65	14.45	0.13	3.38	5.18
P/N	0.07	0.06	0.39	0.00002	0.07	0.12	0.0001	4.27
N/K	1.24	0.02	1.18	0.001	1.45	0.27	0.15	161.42
K/N	0.81	0.02	-1.11	0.0004	0.73	0.25	0.03	84.18
N/Ca	1.94	0.10	-0.75	0.04	2.77	0.15	0.17	4.23
Ca/N	0.52	0.11	0.97	0.003	0.37	0.15	0.003	0.99
N/Mg	11.85	0.29	0.57	11.83	8.46	0.40	11.44	0.97
Mg/N	0.09	0.28	-0.18	0.001	0.13	0.40	0.003	4.62
N/S	12.86	0.07	-0.50	0.90	11.53	0.17	3.84	4.25
S/N	0.08	0.08	0.63	0.00003	0.09	0.17	0.0002	6.79
N/Fe	291.91	0.18	-0.79	2859.18	284.53	0.27	5792.81	2.03
Fe/N	0.004	0.20	1.32	0.000001	0.004	0.26	0.000001	1.79
N/Mn	96.77	0.33	1.07	1034.88	60.76	0.35	453.92	0.44
Mn/N	0.01	0.31	0.03	0.00001	0.02	0.36	0.00004	3.68
N/Cu	2293.81	0.56	1.15	1674563.27	1738.36	0.32	305831.29	0.18
Cu/N	0.001	0.47	-0.27	0.00000007	0.001	0.30	0.00000004	0.54
N/Zn	686.67	0.52	1.06	125566.65	1133.22	0.55	391178.02	3.12
Zn/N	0.002	0.51	1.02	0.0000008	0.001	0.57	0.0000004	0.53
N/B	659.44	0.14	1.15	9142.10	528.70	0.20	11118.38	1.22
B/N	0.002	0.14	-0.79	0.00000004	0.002	0.22	0.0000002	4.16
P/K	0.09	0.05	-1.17	0.00002	0.10	0.29	0.001	49.76
K/P	11.39	0.05	1.30	0.30	10.47	0.27	7.75	25.48
P/Ca	0.14	0.08	1.40	0.0001	0.19	0.14	0.001	5.93
Ca/P	7.32	0.08	-1.25	0.33	5.26	0.14	0.55	1.66
P/Mg	0.84	0.30	0.17	0.06	0.59	0.40	0.05	0.86
Mg/P	1.27	0.29	-0.06	0.14	1.92	0.38	0.53	3.80
P/S	0.91	0.10	0.25	0.008	0.80	0.14	0.01	1.67
S/P	1.10	0.10	0.17	0.01	1.27	0.15	0.04	3.27
P/Fe	20.82	0.23	0.02	22.66	19.85	0.28	31.56	1.39
Fe/P	0.05	0.24	0.69	0.0001	0.05	0.26	0.0002	1.40
P/Mn	6.85	0.32	0.76	4.96	4.22	0.35	2.16	0.44
Mn/P	0.16	0.31	-0.03	0.002	0.26	0.34	0.008	3.45
P/Cu	159.15	0.51	1.15	6617.88	119.50	0.25	863.26	0.13
Cu/P	0.01	0.43	-0.37	0.00001	0.01	0.27	0.00001	0.56
P/Zn	49.33	0.57	1.41	789.02	81.91	0.62	2615.35	3.31
Zn/P	0.03	0.50	0.65	0.0002	0.02	0.62	0.0001	0.69
P/B	46.95	0.19	1.89	79.07	37.28	0.28	106.09	1.34
B/P	0.02	0.16	-1.79	0.00001	0.03	0.27	0.00006	4.86
K/Ca	1.56	0.10	-0.11	0.03	2.06	0.35	0.53	21.04
Ca/K	0.64	0.10	0.22	0.004	0.55	0.42	0.05	12.28
K/Mg	9.52	0.27	0.31	6.84	6.53	0.58	14.43	2.11
Mg/K	0.11	0.27	-0.06	0.001	0.21	0.61	0.02	17.79
K/S	10.38	0.09	-0.88	0.94	8.47	0.35	8.65	9.16
S/K	0.10	0.10	1.05	0.0001	0.13	0.35	0.002	22.77
K/Fe	236.14	0.20	-0.75	2338.00	208.55	0.34	5108.04	2.18

Fe/K	0.004	0.23	1.36	0.000001	0.01	0.51	0.000008	7.73
K/Mn	77.68	0.31	0.82	580.48	46.34	0.54	623.37	1.07
Mn/K	0.01	0.30	0.21	0.00002	0.03	0.54	0.0002	13.44
K/Cu	1843.52	0.56	1.28	1078887.75	1296.19	0.47	373312.18	0.35
Cu/K	0.001	0.46	-0.38	0.0000001	0.001	0.46	0.0000002	1.88
K/Zn	556.22	0.53	1.19	88435.16	870.28	0.68	348354.06	3.94
Zn/K	0.002	0.51	0.89	0.000001	0.002	0.79	0.000002	1.59
K/B	532.58	0.16	1.28	7542.82	393.49	0.38	22605.18	3.00
B/K	0.002	0.15	-1.00	0.0000001	0.003	0.48	0.000002	24.76
Ca/Mg	6.25	0.36	0.05	5.01	2.98	0.29	0.72	0.14
Mg/Ca	0.18	0.36	0.10	0.004	0.36	0.30	0.01	2.80
Ca/S	6.69	0.14	1.30	0.88	4.18	0.15	0.38	0.43
S/Ca	0.15	0.13	-1.00	0.0004	0.24	0.15	0.001	3.43
Ca/Fe	152.35	0.25	1.33	1463.14	103.15	0.27	772.97	0.53
Fe/Ca	0.01	0.22	-0.55	0.000002	0.01	0.21	0.000005	1.97
Ca/Mn	50.90	0.38	0.40	372.99	21.57	0.25	27.99	0.08
Mn/Ca	0.02	0.38	0.50	0.0001	0.05	0.28	0.0002	2.74
Ca/Cu	1169.23	0.52	0.94	366492.38	621.09	0.22	18566.66	0.05
Cu/Ca	0.001	0.46	-0.12	0.0000002	0.002	0.25	0.0000002	0.79
Ca/Zn	370.51	0.62	1.35	53459.94	409.65	0.55	49855.87	0.93
Zn/Ca	0.004	0.59	1.04	0.000004	0.003	0.55	0.000003	0.68
Ca/B	346.06	0.25	1.47	7464.26	191.75	0.19	1321.81	0.18
B/Ca	0.003	0.22	-0.78	0.0000004	0.01	0.19	0.000001	2.50
Mg/S	1.16	0.30	-0.58	0.12	1.48	0.29	0.19	1.54
S/Mg	0.93	0.35	1.14	0.11	0.72	0.28	0.04	0.40
Mg/Fe	26.60	0.35	-1.08	88.13	38.68	0.56	474.79	5.39
Fe/Mg	0.04	0.48	1.78	0.0004	0.03	0.42	0.0002	0.41
Mg/Mn	8.13	0.10	0.01	0.63	7.30	0.09	0.42	0.67
Mn/Mg	0.12	0.10	0.01	0.0001	0.14	0.08	0.0001	0.87
Mg/Cu	210.13	0.72	1.78	22775.92	214.49	0.21	2088.99	0.09
Cu/Mg	0.01	0.52	-0.06	0.00001	0.005	0.21	0.000001	0.10
Mg/Zn	58.18	0.44	0.56	648.11	151.11	0.71	11395.40	17.58
Zn/Mg	0.02	0.41	-0.15	0.0001	0.01	0.66	0.00004	0.60
Mg/B	58.55	0.25	-1.49	207.58	70.09	0.44	936.55	4.51
B/Mg	0.02	0.31	1.81	0.00003	0.02	0.39	0.00004	1.30
S/Fe	22.62	0.15	-0.25	10.82	25.74	0.43	120.79	11.17
Fe/S	0.04	0.15	0.44	0.00004	0.04	0.32	0.0002	4.13
S/Mn	7.64	0.40	1.60	9.30	5.17	0.23	1.37	0.15
Mn/S	0.14	0.32	-0.84	0.002	0.20	0.22	0.002	0.95
S/Cu	177.50	0.53	0.64	8715.97	148.04	0.15	485.28	0.06
Cu/S	0.01	0.49	0.07	0.00001	0.01	0.14	0.000001	0.08
S/Zn	52.86	0.48	0.90	641.87	104.58	0.65	4604.63	7.17
Zn/S	0.02	0.49	1.07	0.0001	0.01	0.63	0.0001	0.62
S/B	51.22	0.11	0.85	32.00	47.41	0.33	238.77	7.46
B/S	0.02	0.11	-0.57	0.000004	0.02	0.30	0.00005	10.62
Fe/Mn	0.35	0.54	1.79	0.04	0.23	0.39	0.01	0.21
Mn/Fe	3.34	0.40	-0.78	1.74	5.31	0.58	9.58	5.51
Fe/Cu	8.34	0.61	0.27	26.03	6.49	0.38	5.93	0.23

Cu/Fe	0.16	0.61	0.19	0.01	0.18	0.55	0.01	1.00
Fe/Zn	2.35	0.42	-0.69	0.96	3.91	0.49	3.74	3.90
Zn/Fe	0.51	0.57	1.74	0.09	0.30	0.43	0.02	0.20
Fe/B	2.30	0.17	0.07	0.14	1.90	0.17	0.10	0.72
B/Fe	0.44	0.17	0.66	0.01	0.54	0.16	0.01	1.28
Mn/Cu	25.11	0.64	1.74	259.59	29.18	0.14	16.45	0.06
Cu/Mn	0.05	0.47	-0.43	0.0006	0.03	0.15	0.00003	0.05
Mn/Zn	7.27	0.49	1.10	12.57	21.04	0.73	237.69	18.92
Zn/Mn	0.16	0.42	-0.14	0.005	0.07	0.64	0.002	0.43
Mn/B	7.29	0.27	-1.84	4.00	9.62	0.45	18.65	4.67
B/Mn	0.15	0.37	1.96	0.003	0.12	0.36	0.002	0.61
Cu/Zn	0.39	0.92	1.93	0.13	0.74	0.72	0.29	2.24
Zn/Cu	3.93	0.55	-0.63	4.66	2.10	0.70	2.14	0.46
Cu/B	0.36	0.56	0.72	0.04	0.33	0.43	0.02	0.50
B/Cu	3.54	0.56	0.73	3.95	3.43	0.39	1.82	0.46
Zn/B	1.12	0.40	1.13	0.20	0.56	0.39	0.05	0.24
B/Zn	1.00	0.37	0.46	0.14	2.03	0.40	0.65	4.65

In this study, the mean values of these thirty-six selected nutrient ratio expressions (Table 3) were taken as the reference values for calculation of DRIS indices. Take the low-yielding orchards for example. The leaf nutrients were determined, and the calibration formulae calculates relative indices that range from negative to positive values depending on whether nutrients are relatively deficient or excessive. The order of nutrient requirement was obtained (table 4). It was indicated that Mn might be the least limiting factor, and Ca might be the most limiting factor for jackfruit production. However, some studies showed that the results of DRIS were often affected by the level of nutrient supply and the selected orchards (Kelling & Schulte, 1986; Soltanpour, Malakouti, & Ronaghi, 1995). For the more accurate and reliable diagnosis, the standard of DRIS index grade was shown in table 5. The optimum index range of N, P, K, Ca, Mg, S, Fe, Mn and B was obtained. Below the optimum range was considered as nutrient be considered ashidden hunger or severe deficiency, and above the optimum range was considered as nutrient luxury absorption or excessive toxicity. On the basis of the standard of DRIS index grade, the deficiency of Ca, K and Fe was found in low-yielding orchards. Thus, more than one nutrient was limiting the yield in the low-yielding orchards, and when supplying the Ca, K and Fe, the nutrient composition of the tissue was approaching the balance, and the yield might be greatly increased (Amundson & Koehler, 1987; Payne et al., 1990; Hundal et al., 2008). In conclusion, the DRIS put emphasis on nutrient balance, and hence might be considered to be a good nutrient diagnosis tool for jackfruit fertilization guidance. However, to know the availability of fertilizers, we should consider the weather, climate, soil differences, as well as genetic differences in specific plants. Therefore, how to determine the amount of fertilizers application was needed further research.

Table 3. DRIS norms of jackfruit

Selected ratio	Mean(Norm)	CV/%	Selected ratio	Mean(Norm)	CV/%
N/P	14.13	0.06	K/Fe	236.14	0.20
K/N	0.81	0.02	Mn/K	0.01	0.30
N/Ca	1.94	0.10	B/K	0.002	0.15
Mg/N	0.09	0.28	Mg/Ca	0.18	0.36
N/S	12.86	0.07	S/Ca	0.15	0.13
N/Fe	291.91	0.18	Fe/Ca	0.01	0.22
Mn/N	0.01	0.31	Mn/Ca	0.02	0.38
B/N	0.002	0.14	B/Ca	0.003	0.22
P/K	0.09	0.05	Mg/S	1.16	0.30
Ca/P	7.32	0.08	Mg/Fe	26.60	0.35
Mg/P	1.27	0.29	Mn/Mg	0.12	0.10
S/P	1.10	0.10	Mg/B	58.55	0.25
P/Fe	20.82	0.23	S/Fe	22.62	0.15
Mn/P	0.16	0.31	Mn/S	0.14	0.32
B/P	0.02	0.16	B/S	0.02	0.11
K/Ca	1.56	0.10	Mn/Fe	3.34	0.40
Mg/K	0.11	0.27	B/Fe	0.44	0.17
K/S	10.38	0.09	Mn/B	7.29	0.27

Table 4. DRIS indices and order of nutrient requirement of low-yielding orchards

	N	P	K	Ca	Mg	S	Fe	Mn	B
Index	19.55	3.08	-222.41	-359.14	143.04	94.35	-22.88	197.60	146.82
Order of requirement			Ca > K > Fe > P > N > S > Mg > B > Mn						

Table 5. The standard of DRIS index grade of leaf nutrient

Index	Deficiency	Low	Optimum	High	Excess
N	<-4.61	-4.61 – -1.10	-1.09 – 5.95	5.96 – 9.47	>9.47
P	<-11.50	-11.50 – -3.23	-3.22 – 13.35	13.36 – 21.63	>21.63
K	<-8.29	-8.29 – -3.05	-3.04 – 7.44	7.45 – 12.68	>12.68
Ca	<-16.50	-16.50 – -3.32	-3.31 – 23.08	23.09 – 36.27	>36.27
Mg	<-45.00	-45.00 – -30.68	-30.67 – -2.02	-2.01 – 12.30	>12.30
S	<-12.38	-12.38 – -3.70	-3.69 – 13.67	13.68 – 22.35	>22.35
Fe	<-18.71	-18.71 – -2.83	-2.82 – 28.97	28.98 – 44.86	>44.86
Mn	<-53.82	-53.82 – -37.06	-37.05 – -3.52	-3.51 – 13.24	>13.24
B	<-23.12	-23.12 – -12.07	-12.06 – 10.05	10.06 – 21.10	>21.10

4. Conclusion

In this study, based on the selection criteria of diagnostic norms, the mean values of thirty-six nutrient expressions involving nine nutrients (N, P, K, Ca, Mg, S, Fe, Mn and B) were chosen as the diagnostic norms for jackfruit. The DRIS indices were computed from the nutrient ratio of the low-yielding orchards plant and the value of the corresponding DRIS norm, and they were useful in the analysis of nutrient imbalance in these areas. Meanwhile, this study has determined the standard of DRIS index grade. Using the standard, the deficiency of K, Ca and Fe was found in low-yielding orchards, therefore, application of Ca, K and Fe fertilizers might be able to enhance the yield of jackfruit. This test has been continued for 2 years in the typical large jackfruit orchards of Hainan, China, and the data of the DRIS approach may be used for jackfruit nutrient status diagnosis, and help to plan fertilizer programs.

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