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Determination of appropriate leaf positions to establish the diagnosis and recommendation integrated systems for plant pineapple (*Ananas comosus* L.) cultivated on acid sulfate soils

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Abstract

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Because pineapple is an important crop in Vietnam, it is crucial to assess the nutrition status of the pineapple. Although the diagnosis and recommendation integrated system (DRIS) is a reliable approach, finding the right leaf position to diagnose is vital. Therefore, the aim of the current study is to determine suitable leaf positions for creating DRIS norms for macro- and micronutrients in pineapple leaf. Healthy pineapple leaves without pest or disease damages were sampled from 60 pineapple farms and analyzed for N, P, K, Na, Ca, Mg, Cu, Fe, Zn, and Mn concentrations. The results revealed that the critical yield was 13.3 t ha^{-1} among the 60 farms, dividing into 23 farms as the high-yielding group (≥ 13.3 t ha^{-1}) and 37 farms as the low-yielding group (< 13.3 t ha^{-1}). The concentrations of mineral nutrients (N, P, K, Ca, Mg, Cu and Zn) and pineapple fruit yields in the high-yielding group were greater than those in the low-yielding one. On the other hand, the Na, Fe, and Mn concentrations showed the opposite pattern. Selected leaf positions must possess significantly different nutrient ratios and have more than 14 nutrient ratio pairs between the two yield groups. Therefore, leaf positions from +15 to +19 were selected to create DRIS norms. Nine sets of DRIS norms have been created at leaf +1, +3, +7, +9, +16, +18, +21, +22, and +29 for plant pineapples.

Keywords: Acid sulfate soils; diagnosis and recommendation integrated system; mineral nutrition; plant pineapple

Introduction

Pineapple (*Ananas comosus* L.) is a tropical crop with tasty fruits containing plenty of nutrients, including fibers, organic acid, vitamins, minerals, and bromelain enzyme, which support the digestive system (Ancos et al., 2016; Ali et al., 2020). The total exporting amount of pineapples was the highest among numerous tropical fruits in 2020, with 2.9 million tons (FAO, 2022). However, the average pineapple yield in Vietnam is 18.3 t ha^{-1}, which is lower than that in the world by 34.2% (27.8 t ha^{-1}) (FAO, 2021). There are two types of pineapple, including plant pineapple and ratoon pineapple. The plant pineapple grows from crowns and suckers that are planted on a new field. The ratoon pineapple grows from shoots of the mother plant after harvesting (Bartholomew et al., 2002; Bleich, 2021). Therefore, the nutrient status between the plant and ratoon pineapples is different. Cultivar, soil, and farming techniques are considered as rea-

sons affecting pineapple yield in the Vietnamese Mekong Delta (VMD) (Hossain, 2016). Soil factor is the most important because almost pineapples in the VMD are cultivated on acid sulfate soils. This soil has low soil pH and fertility, while its concentrations of toxic substances that harm plants and uptake of other essential substances are high. In particular, the high concentrations of Al^{3+} and Fe^{2+} led to decrease the availability of Ca, K, and Mg for plant (Hidayat & Fahmi, 2020; Minh et al., 2020).

In addition, concentrations and presenting forms of those nutrients in soil affect plant nutrient uptakes (Guo et al., 2019; Briat et al., 2020). Simultaneously, practically in fertilization, many nutrients are applied at the same time, so their interactions, rather than individual nutrients, are noticed (Lemaire et al., 2019). Therefore, evaluating plant nutrition status requires a more integrative approach (Briat et al., 2020). Compared to methods of nutrition status diagnosis, the diagnosis and recommendation integrated system (DRIS) is a step forward to precisely assess pineapple nutrition status because this approach is based on the average ratio of nutrient concentrations to clarify the status of excess, balance, and deficiency. In the same line, DRIS also ranks nutrients in an order from the most to the least essential for plants (Bhaduri & Pal, 2013).

Up till now, DRIS has been popularly applied and established for many plants, such as maize (Aliyu et al., 2021), almond (Ferrández-Cámara et al., 2021), cocoa (Chinnappan, 2022), persimmon (Morales et al., 2022), and banana (Neto et al., 2022). For pineapple, DRIS norms have been founded by Agbangba et al. (2011a, b) and Teixeira et al. (2007). Additionally, DRIS norms have been built and applied to detect the nutrition status of pineapples by Angeles et al. (1990), Sema et al. (2010), and Khuong et al. (2022a). Although, DRIS was established for determining the nutrition status of ratoon pineapples (Khuong et al., 2022b), it has not been founded for plant pineapple. Nevertheless, due to the specificity in soil properties, cultivars, and cultivating techniques, a DRIS norm set need to be constructed for specific regions (Bangroo et al., 2010). Therefore, the study was conducted to determine proper leaf positions to create DRIS norms for N, P, K, Ca, Mg, Na, Cu, Fe, Zn, and Mn in plant pineapples cultivated on acid sulfate soil.

Material and Methods

Samples collection and analysis of soil chemical properties

Soils were sampled from 60 plant pineapple farms in the town of Vinh Vien and Vinh Vien A commune in Long My District, Hau Giang Province, and communes of Hoa Tien and Tan Tien in Vi Thanh City, Hau Giang Province. They were left to dry naturally, ground, and sieved via a 0.5 and 2.0 mm strainer for its chemical properties analysis. The soil analysis method was gathered by Sparks et al. (1996) and summarized below.

Soil samples were extracted by distilled water with a soil: water ratio of 1:2.5 in order to measure the pH_{H2O} by a pH meter. The electrical conductivity (EC) was measured by an EC meter. Soil samples for pH_{KCl} measurement were extracted by 1.0 M KCl with a soil: KCl ratio of 1:2.5, and measured by a pH meter. Soil samples for the titratable acidity measurement were extracted by 1.0 M KCl with a soil: KCl ratio of 1: 12.5, and titrated by 1% phenolphthalein and 0.01 N NaOH.

Soil samples were digested by a mixture of saturated H_2SO_4: $CuSO_4$: Se with a ratio of 100:10:1 to determine total N concentration. The digested solution was measured by the Kjeldahl distilling method, and titrated by 0.01 N H_2SO_4. The ammonium concentration was determined from a solution extracted by 2.0 M KCl, indicated in colour by a mixture of sodium nitroprusside, sodium salicylate, sodium citrate, sodium tartrate, sodium hydroxide, and sodium hypochlorite, and measured by a spectrophotometer at the 650 nm wavelength. In order to determine the NO_3^- concentration, soil was extracted by 2.0 M KCl, colorized by 0.5 M HCl, vanadium (III) chloride, sulfanilamide, and N-(1-naphthyl) ethylenediamine dihydrochloride, and quantified by a spectrophotometer at the 540 nm wavelength.

Soil total P determination were digested by a mixture of saturated H_2SO_4 and $HClO_4$, indicated in the colour of phosphomolybdate reduced by ascorbic acid, and measured by a spectrometer at 880 nm wavelength. The Fe-P, Al-P, and Ca-P concentrations were determined by extracting soil with a corresponding chemical of 0.1 M NaOH, 0.5 M NH_4F, and 0.25 M H_2SO_4, colorized by ascorbic acid, and measured by a spectrophotometer at 880 nm wavelength. The available P concentration was determined by the method of Bray II, in which soil samples were extracted by a mixture of 0.1 N HCl and 0.03 N NH_4F with a soil:mixture ratio of 1:7, and measured by a spectrophotometer at the 880 nm wavelength. The organic matter in soil was oxidized by a mixture of saturated H_2SO_4 and $K_2Cr_2O_7$, and titrated by 0.5 N $FeSO_4$.

In order to determine exchangeable aluminium concentrations, soil samples were extracted by 0.1 N KCl, colorized by a mixture of 1% 8-hydroxyquinoline, hydroxylamine hydrochloride, 1.0 M sodium acetate, 0.2% phenanthroline, and butyl acetate, and measured by a spectrophotometer at the 395 nm wavelength. The Fe^{2+} and soluble Fe concentrations were determined by being

extracted by 1.0 N KCl with a soil: KCl ratio of 10:25 from soil samples, and colorized by acetate-acetic acid, 10% hydroxylamine chloride, and 0.25% octophenanthroline at the 520 nm wavelength. The Fe_2O_3 content was extracted by oxalate-oxalic acid, and the total Fe contents was digested into inorganic forms, both contents were measured by an atomic absorption spectrophotometer (AAS) at the 248.3 nm wavelength. The total Mn was measured by an AAS at the 279.5 nm wavelength.

Soil samples for cation exchange capacity (CEC) were extracted by 0.1 M $BaCl_2$ and titrated by 0.01 M EDTA. Soil was extracted by 0.1 M $BaCl_2$ in order to determine exchanging cations (K^+, Na^+, Ca^{2+}, and Mg^{2+}) concentrations measured by an AAS at the wavelengths of 766, 589, 422.7, and 285.5 nm, respectively.

Methods for sampling, processing, and analyzing pineapple leaves

In each farm, 25 plant pineapple plants were sampled by blossoming. In each plant, 30 leaves were sampled from E leaf (the leaf position +1) to the leaf position +30. Then, soil and dust were removed from leaf tissues, and immature or old sections of leaves were eliminated. Subsequently, leaves were cut into pieces in the size of a paper bag, dried up at 70 °C for 96 h, and finely ground. Nutrient concentrations in leaf samples were determined according to the method by Houba et al. (1997). The N concentration was determined by the Kjeldahl distilling method. The P concentration was determined by the colorimetric method with ascorbic acid in a spectrometer at the 880 nm wavelength. The K, Ca, Mg, Na, Cu, Fe, Zn, and Mn concentrations were measured by an AAS at the wavelengths of 766, 422.7, 285.2, 589, 325, 248.3, 214.1, and 279.5 nm, respectively.

Creation of the diagnosis and recommendation integrated system

The method of Beaufils (1973) was applied to create the DRIS norms in the current study. In detail, the division between the high-yielding and the low-yielding groups followed the method by Letzsch & Sumner (1984). The selection for either nutrient ratio pairs or their reverse pairs was conducted following the method by Letzsch (1985) and Walworth & Sumner (1987), with variance ratios between nutrients in the high-yielding group (r) and those in the low-yielding one (b): $[S^2(A/B)b / S^2 (A/B)r]>[S^2(B/A)b / S^2 (A/B)r]$: the correlation of norms = A/B; $[S^2(A/B)b / S^2 (A/B)r]<[S^2(B/A)b / S^2 (A/B)r]$: the correlation of norms = B/A. Simultaneously, a DRIS norm set consisted of means, standard deviation, and variances from nutrient ratio pairs in the high-yielding group.

Statistical analysis

The comparisons between means was subjected to T-test. The variance analysis of differences between the 90 nutrient ratio pairs was subjected to F-test in the Microsoft Excel software, version 2017. The principal component analysis (PCA) of acid sulfate soil characteristics and graphical figures were subjected to the XLSTAT 2017 software within the Microsoft Excel 2017.

Results

Principal component analysis of properties of soil utilized for pineapple cultivation

The Figure 1A shows correlations between soil chemical properties according to their average concentration ratios, coefficient of variation (CV), variances, and variance ratios in the high-yielding group. There were six clear clusters. The first one contained the total Mn, Fe_2O_3, and K^+ concentrations, and had high influences on the second principal component (SPC), that is, close to the F2 axis. This cluster was reversely correlated with a cluster containing available P, total N, NO_3^-, and EC values; that is, the two clusters were opposite to each other via the origin of coordinates. Likewise, the dissolved Fe and Fe^{2+} concentrations were opposite to the NH_4^+ concentration and pH_{H2O}, which all affected heavily on the first principal component (FPC). The last cluster pairs consisted of the one containing P-Fe, P-Ca, Mg^{2+}, and Ca^{2+} and the other with organic matter, pH_{KCl}, and Al^{3+} concentration, which reversely correlated to each other and had high influences on the SPC and medium influences on the FPC.

The Figure 1B illustrates correlations of pH_{H2O} versus dissolved Fe and Fe^{2+}, which were reversely correlated to each other and highly influenced the FPC; that is, their scores were close to the F1 axis. In addition, Mg^{2+}, total N, NH_4^+ concentrations, and total acid had negative correlations with pH_{KCl}, and they were all heavy weights to the FPC. For the SPC, organic matter, Al^{3+}, and total P had the most influences and reverse correlations with total P. According to distributions of soil properties in Vinh Vien A commune, concentrations of NH_4^+, total acid, Ca^{2+}, NO_3^-, and Al-P were distributed far from the F1 axis. Thus, they less affected the FPC.

The Figure 1C shows that the trends of soil properties were likely the same in Tan Tien commune. The amount of available N and pH_{H2O} values were proportionally correlated to each other and reversely corresponded to EC, Fe^{2+}, and dissolved Fe concentration; that is, they were on two opposite sides via the origin of coordinates and had heavy influences on the FPC. Moreover, concentrations of total N, available N, available P, and total P had the heaviest influences on the SPC; that is, they were close to the F2 axis

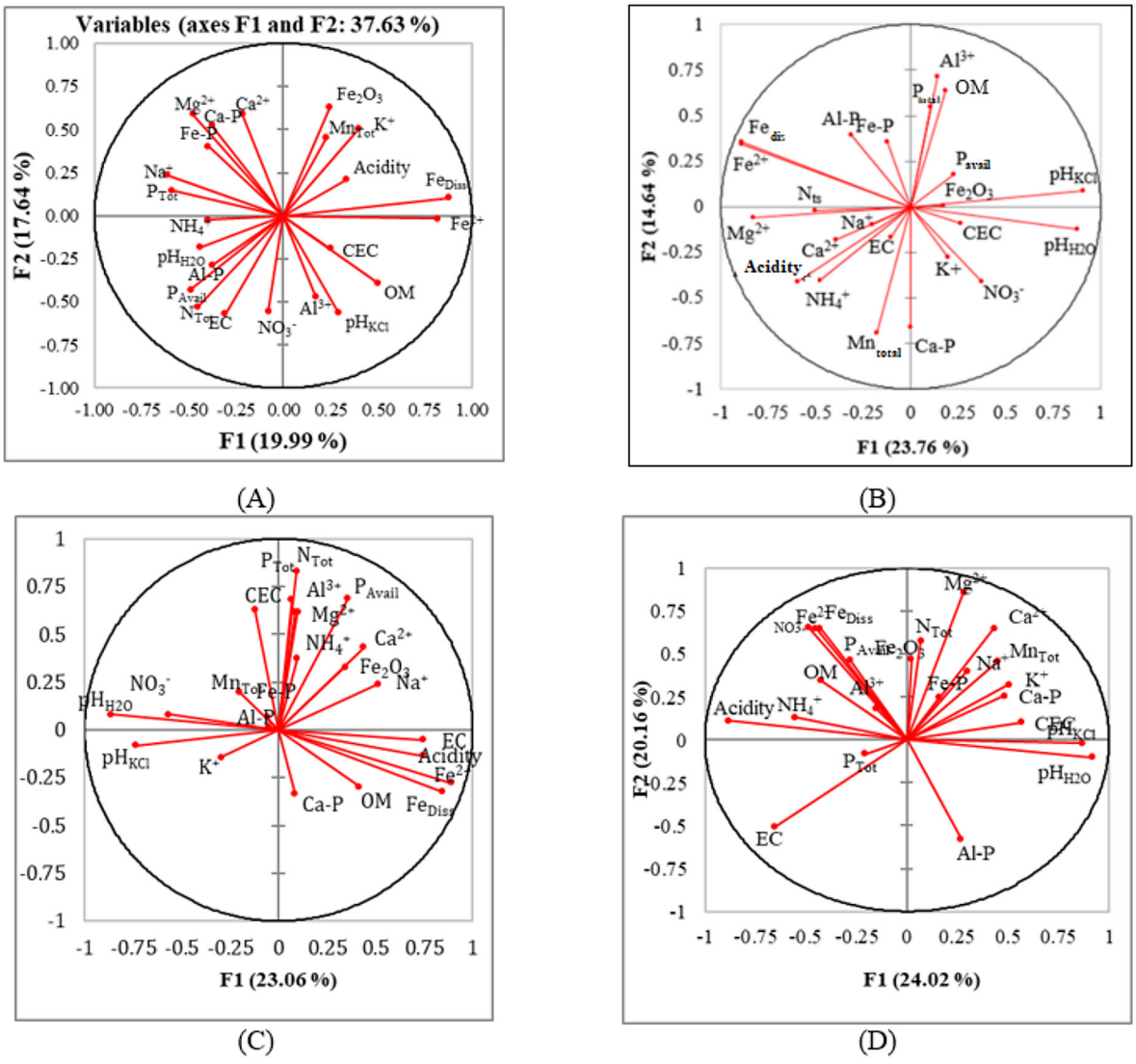

Fig. 1. Principal component analysis of properties of acid sulfate soil for pineapple cultivation in (A) Vinh Vien, (B) Vinh Vien A, (C) Tan Tien, (D) Hoa Tien A communes

the most. Meanwhile, the concentrations of Mg^{2+}, Ca^{2+}, and Fe_2O_3 were moderate. Last but not least, the pH_{KCl} and Na^+ concentrations possessed heavy weights on the FPC and were reversely correlated to each other.

For soil chemical properties in Hoa Tien A commune, the Figure 1D illustrates that the roles of them were slightly different from those in the other locations. The influences of the total N and total P concentrations were moderate on the SPC and low on the second one, respectively. However, pH_{KCl} and pH_{H2O} still expressed heavy influences on the FPC. In addition, the Al^{3+} concentration had reverse correlations with the available P and NO_3^- concentrations; that is, the higher the amount of Al^{3+}, the lower the concentration of available P and NO_3^-. Meanwhile, in the form of NH_4^+, being close to the F2 axis, the available N concentration was reversely correlated with values of pH_{H2O} and pH_{KCl}. It would explain that NH_4^+ could transform into the NO_3^- form and release H^+.

Determination of proper leaf positions for creating DRIS norms

The Table 1 shows that the mean yield in 60 pineapple farms was different at 1% significant level between the high-yielding and the low yield-yielding groups. There were 23 farms in the high-yielding group (≥ 13.3 t ha^{-1}) and 37 farms in the low-yielding one (< 13.3 t ha^{-1}). The mean yield

in the high-yielding and the low-yielding groups was correspondingly 17.8 t ha^{-1} and 10.6 t ha^{-1}. Means of the concentrations of N, P, K, Ca, Mg, Cu, and Zn in the high-yielding group were dominantly higher with differences at 5–10% significant level than those in the low-yielding group. Nevertheless, mean concentrations of Na, Fe, and Mn in the low-yielding group were higher than those in the high-yielding one.

From the Tables 2 to 10, there were 9 out of 30 leaf positions selected for creating DRIS norms because the number of not less than 15 nutrient ratio pairs was able to fulfil both requirements, including (i) high variance ratios between the nutrient ratio pairs and their reverse versions and (ii) differences at 1, 5, or 10% significant level in means and variances of the chosen nutrient ratio pairs. The number of ratio pairs selected at leaf +1, +3, +7, +9, +16, +18, +21, +22, and +29 was 19, 19, 18, 19, 16, 16, 19, 19, and 15 pairs, respectively.

Creation of the diagnosis and recommendation integrated system for plant pineapple at different leaf positions

The Table 2 introduces the DRIS norm set at leaf +1. There were 19 nutrient ratio pairs, including N/K, Ca/N, Mg/N, Fe/100 N, Zn/N, Mn/N, Fe/1000 P, Zn/100 P, Ca/K, Mg/K, Cu/K, Fe/100 K, Zn/K, Mn/K, Fe/1000 Ca, Fe/1000 Mg, Fe/10000 Na, Fe/10 Cu, and Fe/Mn chosen in a DRIS norm set. In the high-yielding group, the mean concentration ratios fluctuated between 0.035 and 62.4, and the CV was roughly 23.8–122.3%. Simultaneously, the variances of the selected ratio pairs at leaf +1 were in a range of 0.00049–1914.3, with the variance ratios ranging from 2.05 to 150.7.

At leaf +3, the Table 3 reveals that the study has chosen 19 nutrient ratio pairs for creating the DRIS norm set: Ca/N, Fe/100 N, Mn/N, P/Na, 10 P/Cu, Fe/1000 P, Mn/100 P, Ca/K, Fe/100 K, Mn/K, Fe/1000 Ca, Fe/1000 Mg, Mn/100 Mg, Fe/10000 Na, Mn/1000 Na, Fe/10 Cu, Mn/Cu, Fe/Zn, and Mn/Zn. In the high-yielding group, the mean concentration ratios were approximately 0.039–41.1, the CV was 36.6–116.9%, the variances were 0.00053–229.4, and the variance ratios between the low-yielding group and the high-yielding group were from 2.09 to 19.9.

The Table 4 shows the selected nutrient ratio pairs for

Table 1. Mean concentration, coefficient of variation, variances and variance ratios of N, P, K, Ca, Mg, Na, Cu, Fe, Zn and Mn nutrients at leaf +1, +3, +7, +9, +16, +18, +21, +22 and +29

Item	Yielding group	+1				+3				+7			
		Mean	CV (%)	Variance	S^2_l/S^2_h	Mean	CV (%)	Variance	S^2_l/S^2_h	Mean	CV (%)	Variance	S^2_l/S^2_h
Yield (mg ha^{-1})	High	17.8***	15.4	7.49	0.161ns								
	Low	10.6	10.4	1.20									
N (%)	High	1.75***	8.04	0.020	1.81*	1.69***	14.4	0.060	1.27ns	1.92***	14.0	0.072	0.752ns
	Low	1.38	13.7	0.036		1.49	18.5	0.076		1.49	15.6	0.054	
P (%)	High	0.200***	24.1	0.0023	0.450ns	0.164	18.4	0.00092	9.95***	0.117	23.5	0.00076	1.40ns
	Low	0.144	22.4	0.0010		0.173	55.1	0.0091		0.164***	19.9	0.0011	
K (%)	High	3.89***	26.5	1.06	0.599ns	3.28**	33.6	1.21	0.595ns	3.76***	24.8	0.866	0.797ns
	Low	2.50	31.9	0.636		2.65	32.1	0.723		2.25	37.0	0.691	
Ca (%)	High	0.136	67.8	0.0085	1.00ns	0.118	53.0	0.0039	2.24**	0.116	54.3	0.0040	1.95*
	Low	0.153	60.5	0.0086		0.153	60.9	0.0087		0.148	59.4	0.0077	
Mg (%)	High	0.250	24.0	0.0036	1.46ns	0.230	23.0	0.0028	1.23ns	0.235	33.1	0.0060	0.728ns
	Low	0.240	30.1	0.0052		0.237	24.6	0.0034		0.228	29.0	0.0044	
Na (%)	High	0.036	77.0	0.00079	0.535ns	0.043	85.4	0.0014	0.218ns	0.039	70.9	0.00076	0.340ns
	Low	0.033	61.4	0.00042		0.028	60.5	0.00030		0.031	51.6	0.00026	
Cu (ppm)	High	15.9	48.6	60.1	1.97**	15.5	52.1	65.0	1.29ns	14.4	45.2	42.5	1.28ns
	Low	16.2	67.3	118.5		15.9	57.8	83.9		13.9	53.2	54.6	
Fe (ppm)	High	150.9	96.9	21381.3	24.9***	140.2	101.6	20294.0	6.01***	170.6	107.2	33440.5	4.46***
	Low	484.6**	150.5	531971.8		340.3***	102.7	122052.7		327.2**	118.0	149062.0	
Zn (ppm)	High	34.1	36.2	152.1	1.68ns	34.2	76.4	682.6	0.791ns	43.5	134.1	3395.5	0.036ns
	Low	39.5	40.5	255.4		34.8	66.7	539.8		27.6	40.2	122.9	
Mn (ppm)	High	108.1	66.1	5099.0	1.11ns	69.1	39.5	743.8	6.12***	79.8	29.8	567.1	8.68***
	Low	122.3	61.4	5637.7		116.8***	57.7	4548.7		124.4***	56.4	4925.4	

High-yield ≥ 13.3 Mg ha^{-1}; low-yield < 13.3 Mg ha^{-1}; mean yield and foliar nutrient contents of low- and high-yielding groups are significantly different at 1% (***) and 5% (**) level of probability by T test; variances of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference

Table 1. Continued

Item	Yielding group	+9				+16				+18			
		Mean	CV (%)	Variance	S^2_f/S^2_h	Mean	CV (%)	Variance	S^2_f/S^2_h	Mean	CV (%)	Variance	S^2_f/S^2_h
Yield (mg ha^{-1})	High	17.8***	15.4	7.49	0.161^{ns}								
	Low	10.6	10.4	1.20									
N (%)	High	1.80***	15.1	0.073	0.713^{ns}	1.84**	16.8	0.096	1.28^{ns}	1.82**	12.8	0.054	1.57^{ns}
	Low	1.57	14.6	0.052		1.65	21.2	0.123		1.67	17.5	0.085	
P (%)	High	0.139	22.4	0.0010	2.96***	0.126	25.9	0.0011	2.12**	0.132	29.8	0.0015	0.914^{ns}
	Low	0.147	36.3	0.0029		0.135	35.4	0.0023		0.131	28.5	0.0014	
K (%)	High	3.87***	59.6	5.31	0.146^{ns}	2.91	45.9	1.78	0.614^{ns}	3.22	52.1	2.82	0.691^{ns}
	Low	2.44	36.1	0.775		2.63	39.7	1.09		2.54	54.9	1.94	
Ca (%)	High	0.111	53.1	0.0035	2.58**	0.111	46.3	0.0026	8.64***	0.117	48.5	0.0032	2.32**
	Low	0.152**	62.2	0.0089		0.166**	91.1	0.023		0.157	55.1	0.0075	
Mg (%)	High	0.249	28.9	0.0052	1.41^{ns}	0.240	29.7	0.0051	1.16^{ns}	0.246	24.8	0.0037	1.18^{ns}
	Low	0.222	38.4	0.0073		0.247	31.1	0.0059		0.238	27.9	0.0044	
Na (%)	High	0.033	91.7	0.00094	0.315^{ns}	0.037	64.6	0.00057	1.06^{ns}	0.032	77.1	0.00059	0.887^{ns}
	Low	0.030	57.8	0.00030		0.039	62.6	0.00060		0.037	62.2	0.00052	
Cu (ppm)	High	13.4	45.4	37.2	0.987^{ns}	13.0	65.1	72.0	0.597^{ns}	14.7	55.5	66.8	1.05^{ns}
	Low	14.4	42.0	36.7		13.6	48.3	43.0		14.9	56.5	70.4	
Fe (ppm)	High	167.8	97.8	26908.5	4.52***	159.7	99.8	25393.4	4.31***	194.8	114.1	49408.9	3.51***
	Low	345.9**	100.8	121605.6		350.1***	94.5	109372.0		441.5***	94.4	173525.8	
Zn (ppm)	High	27.2	41.7	128.6	1.03^{ns}	24.8	39.5	96.0	1.01^{ns}	24.9	49.2	149.4	10.3***
	Low	27.8	41.5	132.8		26.9	36.7	97.4		38.7	101.3	1533.5	
Mn (ppm)	High	86.3	34.9	906.4	6.78***	93.1	46.9	1905.4	4.74***	80.7	48.9	1560.5	4.65***
	Low	132.7***	59.1	6148.0		156.0***	60.9	9031.8		145.1***	58.7	7257.8	
Item	Yielding group	+21				+22				+29			
		Mean	CV (%)	Variance	S^2_f/S^2_h	Mean	CV (%)	Variance	S^2_f/S^2_h	Mean	CV (%)	Variance	S^2_f/S^2_h
Yield (mg ha^{-1})	High	17.8***	15.4	7.49	0.161^{ns}								
	Low	10.6	10.4	1.20									
N (%)	High	1.87	18.1	0.115	54.5***	1.94***	13.1	0.065	1.10^{ns}	1.99***	10.4	0.043	1.20^{ns}
	Low	2.00	125.5	6.28		1.70	15.7	0.072		1.78	12.7	0.051	
P (%)	High	0.141	29.9	0.0018	1.77*	0.124	15.4	0.00036	2.79***	0.118	31.6	0.0014	1.50^{ns}
	Low	0.133	42.1	0.0032		0.117	27.2	0.0010		0.120	38.0	0.0021	
K (%)	High	3.32	40.0	1.76	0.970^{ns}	2.79	55.5	2.40	0.477^{ns}	2.78**	47.3	1.73	0.792^{ns}
	Low	2.85	45.8	1.71		2.49	43.0	1.14		2.06	56.9	1.37	
Ca (%)	High	0.121	57.7	0.0049	1.85*	0.112	43.1	0.0023	5.90***	0.117	40.3	0.0022	5.21***
	Low	0.159	59.6	0.0090		0.160**	73.4	0.014		0.158	68.4	0.012	
Mg (%)	High	0.262	37.9	0.0099	0.486^{ns}	0.249	30.0	0.0056	1.16^{ns}	0.227	32.3	0.0054	0.898^{ns}
	Low	0.245	28.3	0.0048		0.241	33.5	0.0065		0.235	29.6	0.0048	
Na (%)	High	0.041	81.8	0.0011	0.530^{ns}	0.041	74.8	0.00090	0.756^{ns}	0.042	69.1	0.00085	0.483^{ns}
	Low	0.039	62.0	0.00059		0.039	65.7	0.00068		0.043	47.5	0.00041	
Cu (ppm)	High	13.9	44.4	38.2	3.40***	12.9	47.6	37.8	0.970^{ns}	15.1	54.6	68.3	0.960^{ns}
	Low	15.4	74.1	130.1		13.5	44.8	36.7		15.1	53.5	65.5	
Fe (ppm)	High	141.2	89.0	15783.3	9.10***	156.5	82.6	16717.5	6.81***	150.3	89.1	17924.2	7.37***
	Low	377.3***	100.4	143593.0		361.1***	93.4	113841.0		390.2***	93.1	132018.6	
Zn (ppm)	High	25.8	35.2	82.6	2.07**	24.6	37.8	86.4	2.09**	24.3	51.6	157.7	0.705^{ns}
	Low	33.3**	39.3	171.2		29.3	45.9	180.6		29.6	35.6	111.2	
Mn (ppm)	High	100.9	33.4	1136.2	12.7***	98.5	45.3	1987.1	7.87***	92.5	34.0	988.8	14.1***
	Low	162.6***	73.9	14448.0		165.7***	75.5	15635.7		159.3***	74.1	13940.8	

High-yield ≥ 13.3 Mg ha^{-1}; low-yield < 13.3 Mg ha^{-1}; mean yield and foliar nutrient contents of low- and high-yielding groups are significantly different at 1% (***) and 5% (**) level of probability by T test; variances of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference.

Table 2. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +1 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	9.25	25.8	5.68	9.98	22.8	5.16	0.909^{ns}	X
P/N	0.115	24.7	0.00080	0.106	24.9	0.00069	0.863	
N/K	0.481**	27.4	0.017	0.656	63.0	0.170	9.84***	X
K/N	2.25	29.7	0.445	1.85	33.4	0.380	0.855	
N/Ca	19.9	80.2	255.3	11.9	53.7	40.8	0.160	
Ca/N	0.079**	71.8	0.0032	0.116	70.2	0.0066	2.05**	X
N/Mg	7.39	23.6	3.04	6.15	26.5	2.65	0.869	
Mg/N	0.143***	23.8	0.0012	0.175	29.4	0.0027	2.29**	X
N/10 Na	7.68	80.3	38.0	5.61	55.1	9.57	0.252	
10 Na/N	0.207	75.8	0.025	0.240	56.0	0.018	0.733^{ns}	X
N/Cu	0.134	45.2	0.0037	0.110	52.0	0.0033	0.892	
Cu/N	9.13	47.7	19.0	11.7	61.6	52.1	2.75***	X
100 N/Fe	3.28	93.8	9.48	1.61	117.9	3.58	0.378	
Fe/100 N	0.904***	98.2	0.789	3.79	152.5	33.5	42.4***	X
N/Zn	0.056	27.3	0.00024	0.039	33.0	0.00017	0.712	
Zn/N	19.5***	35.3	47.2	28.9	39.8	131.9	2.79***	X
N/Mn	0.020	40.7	0.000069	0.014	46.0	0.000043	0.622	
Mn/N	62.4**	70.1	1914.3	91.7	71.1	4250.5	2.22**	X
P/K	0.055	35.8	0.00039	0.069	71.2	0.0024	6.22***	X
K/P	20.9	41.5	75.2	18.2	37.0	45.3	0.602	
P/Ca	2.22	75.8	2.83	1.23	60.3	0.550	0.194	
Ca/P	0.721**	70.8	0.261	1.10	56.8	0.388	1.49^{ns}	X
P/Mg	0.855	37.4	0.102	0.635	27.7	0.031	0.302	
Mg/P	1.33***	36.5	0.237	1.71	31.9	0.300	1.27^{ns}	X
P/Na	8.82	83.7	54.5	6.12	64.4	15.5	0.285	
Na/P	0.192	81.4	0.024	0.249	68.8	0.029	1.21^{ns}	X
10 P/Cu	0.154	51.2	0.0062	0.117	60.0	0.0049	0.790	
Cu/10 P	8.47	56.9	23.2	11.9	77.8	85.6	3.69***	X
1000 P/Fe	3.70	98.2	13.2	1.64	120.5	3.90	0.296	
Fe/1000 P	0.791**	96.3	0.581	3.92	183.1	51.5	88.7***	X
100 P/Zn	0.654	41.8	0.075	0.410	36.4	0.022	0.298	
Zn/100 P	1.81***	42.5	0.593	2.88	49.0	1.99	3.35***	X
100 P/Mn	0.236	52.0	0.015	0.146	45.7	0.0045	0.296	
Mn/100 P	5.81**	78.7	20.9	8.84	63.4	31.4	1.50^{ns}	X
K/Ca	40.8	64.8	698.4	20.8	57.1	141.3	0.202	
Ca/K	0.035***	62.7	0.00049	0.069	72.9	0.0025	5.16***	X
K/Mg	17.0	43.0	53.2	11.4	45.2	26.7	0.502	
Mg/K	0.070***	43.2	0.00092	0.116	70.1	0.0066	7.11***	X
K/100 Na	1.68	71.7	1.46	1.02	59.7	0.370	0.253	
100 Na/K	1.06	101.0	1.15	1.58	90.5	2.06	1.79*	X
K/Cu	0.316	60.9	0.037	0.204	70.3	0.021	0.554	
Cu/K	4.66**	67.0	9.72	7.65	90.8	48.3	4.96***	X
100 K/Fe	6.27	92.6	33.7	2.57	128.3	10.9	0.322	
Fe/100 K	0.350***	85.2	0.089	2.05	179.0	13.4	150.7***	X
K/Zn	0.127	41.4	0.0028	0.072	45.9	0.0011	0.390	
Zn/K	9.52***	52.4	24.9	18.5	64.6	142.7	5.73***	X
K/Mn	0.044	46.2	0.00041	0.026	56.1	0.00021	0.510	
Mn/K	27.5***	43.9	145.5	57.2	76.3	1904.0	13.1***	X

Table 2. Continued

Ca/Mg	0.601	94.7	0.324	0.724	81.0	0.344	1.06^{ns}	X
Mg/Ca	2.78	77.1	4.60	2.07	56.2	1.35	0.293	
Ca/Na	5.50	97.2	28.6	6.01	69.8	17.6	0.613	
Na/Ca	0.345	75.3	0.068	0.278	79.8	0.049	0.726^{ns}	X
10 Ca/Cu	0.104	71.0	0.0055	0.125	81.4	0.010	1.89*	X
Cu/10 Ca	20.3	134.4	745.8	14.1	94.8	178.1	0.239	
1000 Ca/Fe	2.02	94.4	3.62	1.25	118.9	2.21	0.610	
Fe/1000 Ca	1.34**	100.7	1.83	3.20	143.5	21.1	11.6***	X
100 Ca/Zn	0.436	61.0	0.071	0.439	66.5	0.085	1.20^{ns}	X
Zn/100 Ca	4.31	123.8	28.4	3.33	60.2	4.02	0.142	
100 Ca/Mn	0.153	73.3	0.013	0.145	55.7	0.0066	0.522^{ns}	X
Mn/100 Ca	11.8	100.1	138.9	9.87	73.1	52.0	0.374	
Mg/Na	10.8	85.6	85.3	9.88	66.5	43.2	0.506	
Na/Mg	0.142	57.5	0.0067	0.148	61.1	0.0081	1.21^{ns}	X
Mg/Cu	0.019	47.1	0.000078	0.020	62.4	0.00015	1.95	
Cu/Mg	66.8	56.6	1429.7	74.6	73.5	3011.6	2.11**	X
1000 Mg/Fe	4.77	87.6	17.5	2.92	121.1	12.5	0.716	
Fe/1000 Mg	0.733**	109.7	0.646	2.71	194.5	27.8	43.1***	X
100 Mg/Zn	0.785	28.5	0.050	0.669	36.8	0.061	1.21	
Zn/100 Mg	1.42	41.0	0.337	1.73	41.5	0.515	1.53^{ns}	X
100 Mg/Mn	0.295	48.1	0.020	0.245	52.0	0.016	0.805	
Mn/100 Mg	4.67	72.6	11.5	5.46	63.7	12.1	1.05^{ns}	X
100 Na/Cu	0.282	96.7	0.075	0.249	78.8	0.039	0.519^{ns}	X
Cu/100 Na	7.17	96.0	47.4	5.95	60.7	13.0	0.275	
10000 Na/Fe	6.10	107.0	42.6	4.31	154.0	44.0	1.03	
Fe/10000 Na	0.584***	99.9	0.340	1.73	109.0	3.54	10.4***	X
1000 Na/Zn	1.20	78.4	0.880	0.879	54.1	0.226	0.257^{ns}	X
Zn/1000 Na	1.60	99.6	2.54	1.49	51.0	0.581	0.228	
1000 Na/Mn	0.366	69.8	0.065	0.332	83.9	0.078	1.19	
Mn/1000 Na	3.93	66.3	6.80	4.88	90.1	19.4	2.85***	X
10 Cu/Fe	3.26	97.7	10.2	1.91	179.5	11.8	1.16	
Fe/10 Cu	1.45**	122.3	3.14	3.66	137.1	25.2	8.03***	X
Cu/Zn	0.511	59.7	0.093	0.434	54.0	0.055	0.591	
Zn/Cu	2.62	66.5	3.03	3.03	57.0	2.99	0.988^{ns}	X
Cu/Mn	0.186	58.2	0.012	0.172	125.0	0.046	3.94***	X
Mn/Cu	9.00	110.4	98.8	9.32	65.2	36.9	0.373	
Fe/Zn	5.45	114.4	38.9	16.4	209.3	1175.7	30.2***	X
Zn/Fe	0.640	90.9	0.338	0.445	124.6	0.308	0.910	
Fe/Mn	1.60**	107.9	2.96	4.23	132.6	31.5	10.6***	X
Mn/Fe	1.57	74.8	1.38	1.31	156.9	4.25	3.08	
Zn/Mn	0.408	63.8	0.068	0.407	61.8	0.063	0.932	
Mn/Zn	3.50	66.1	5.34	3.59	79.0	8.03	1.50^{ns}	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio.

the DRIS norm set at leaf +7, which were P/N, N/K, Ca/N, Fe/100 N, Mn/N, P/K, P/Mg, P/Na, 100 P/Zn, Ca/K, Mg/K, Fe/100 K, Mn/K, Mn/100 Mg, Fe/10000 Na, Mn/1000 Na, Fe/Zn, and Mn/Zn (18 pairs in total). The high-yielding group had the mean concentration ratios of 0.032–42.6. Moreover, the CV, the variances, and the variance ratios were determined to be 21.4–117.1%, 0.00017–233.1, and 2.07–31.9, respectively.

The Table 5 contains the nutrient ratio pairs chosen for creating the DRIS norm set at leaf +9, including P/N,

Table 3. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +3 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	10.7	25.6	7.53	9.73	32.9	10.3	1.37	
P/N	0.099	24.7	0.00060	0.120	56.3	0.0046	7.60***	X
N/K	0.583	41.5	0.059	0.719	91.4	0.432	7.36***	X
K/N	1.98	36.7	0.53	1.89	41.1	0.602	1.14	
N/Ca	19.9	72.1	204.8	15.9	117.2	345.9	1.69	
Ca/N	0.070***	51.2	0.0013	0.110	67.0	0.0054	4.14***	X
N/Mg	7.77	28.5	4.90	6.58	26.4	3.02	0.616	
Mg/N	0.138**	26.6	0.0014	0.162	26.1	0.0018	1.33ns	X
N/10 Na	6.49	62.2	16.3	7.60	73.7	31.4	1.93*	X
10 Na/N	0.261	91.4	0.057	0.195	60.9	0.014	0.249	
N/Cu	0.138	49.1	0.0046	0.121	59.5	0.0052	1.12	
Cu/N	9.23	57.0	27.7	10.9	57.0	38.9	1.41ns	X
100 N/Fe	3.61	103.4	14.0	2.60	119.5	9.65	0.690	
Fe/100 N	0.859***	105.1	0.814	2.59	107.8	7.79	9.58***	X
N/Zn	0.061	37.4	0.00051	0.052	45.1	0.00055	1.08ns	X
Zn/N	20.3	70.8	206.2	23.4	54.8	164.7	0.799	
N/Mn	0.027	34.2	0.000089	0.015	37.1	0.000	0.352	
Mn/N	41.1***	36.9	229.4	81.0	61.4	2470.2	10.8***	X
P/K	0.058	52.6	0.00094	0.078	81.2	0.0040	4.22***	X
K/P	21.2	44.3	87.7	17.2	41.8	52.0	0.593	
P/Ca	1.96	75.1	2.17	2.00	161.0	10.4	4.79***	X
Ca/P	0.766	68.1	0.272	1.02	67.1	0.469	1.72	
P/Mg	0.743	25.3	0.035	0.767	52.9	0.165	4.67***	X
Mg/P	1.42	22.3	0.100	1.54	36.4	0.316	3.16	
P/Na	6.02**	59.4	12.8	8.72	74.3	42.0	3.28***	X
Na/P	0.250	72.9	0.033	0.190	71.6	0.018	0.558	
10 P/Cu	0.136**	54.2	0.0054	0.142	75.3	0.011	2.09**	X
Cu/10 P	9.73	57.8	31.7	10.4	61.8	41.3	1.31	
1000 P/Fe	3.41	92.8	10.0	2.50	121.7	9.27	0.925	
Fe/1000 P	0.922***	111.8	1.06	2.25	116.5	6.86	6.46***	X
100 P/Zn	0.586	38.0	0.050	0.621	68.2	0.179	3.62***	X
Zn/100 P	2.11	69.5	2.15	2.29	72.3	2.74	1.28	
100 P/Mn	0.275	40.3	0.012	0.183	80.4	0.022	1.76	
Mn/100 P	4.52***	56.3	6.48	7.69	59.5	20.9	3.23***	X
K/Ca	35.2	55.5	383.0	24.3	88.4	463.6	1.21	
Ca/K	0.039***	59.7	0.00053	0.063	64.3	0.0017	3.09***	X
K/Mg	15.6	48.0	55.9	12.3	52.2	41.3	0.740	
Mg/K	0.082	52.2	0.0018	0.113	81.8	0.0085	4.67***	X
K/100 Na	1.34	67.5	0.812	1.32	66.6	0.78	0.960ns	X
100 Na/K	1.77	124.3	4.84	1.27	80.4	1.05	0.216	
K/Cu	0.275	63.6	0.031	0.216	60.4	0.017	0.557	
Cu/K	5.37	66.6	12.8	7.35	90.3	44.1	3.44***	X
100 K/Fe	5.87	107.7	40.0	3.47	117.7	16.7	0.417	
Fe/100 K	0.369***	79.0	0.085	1.24	100.2	1.55	18.3***	X
K/Zn	0.119	50.2	0.0035	0.098	58.3	0.0032	0.909	
Zn/K	11.7	81.7	92.1	16.3	88.7	210.1	2.28**	X
K/Mn	0.052	45.3	0.00055	0.027	46.6	0.00015	0.281	

Table 3. Continued

Mn/K	22.4***	36.6	67.4	51.2	71.6	1342.2	19.9***	X
Ca/Mg	0.554	75.4	0.175	0.727	81.2	0.348	1.99**	X
Mg/Ca	2.75	85.1	5.46	2.45	103.3	6.38	1.17	
Ca/Na	4.38**	83.1	13.2	6.78	66.4	20.3	1.53ns	X
Na/Ca	0.463	98.9	0.210	0.238	80.4	0.037	0.175	
10 Ca/Cu	0.098	67.4	0.0044	0.127	80.9	0.011	2.42	
Cu/10 Ca	18.7	89.9	283.2	20.3	219.7	1986.7	7.01***	X
1000 Ca/Fe	2.49	149.0	13.8	1.88	132.9	6.22	0.452	
Fe/1000 Ca	1.28**	86.9	1.23	2.44	113.5	7.66	6.23***	X
100 Ca/Zn	0.399	55.2	0.048	0.513	59.5	0.093	1.93*	X
Zn/100 Ca	3.66	82.5	9.10	3.19	97.9	9.76	1.07	
100 Ca/Mn	0.185	59.8	0.012	0.143	51.1	0.0053	0.431	
Mn/100 Ca	7.50	62.2	21.8	10.3	87.9	82.2	3.78***	X
Mg/Na	8.59	73.0	39.3	12.4	76.7	90.7	2.31**	X
Na/Mg	0.179	67.5	0.015	0.129	63.2	0.0066	0.451	
Mg/Cu	0.019	53.4	0.00010	0.019	50.0	0.000089	0.876	
Cu/Mg	71.2	63.4	2038.4	73.3	79.8	3422.4	1.68ns	X
1000 Mg/Fe	5.14	101.9	27.4	4.27	123.9	28.1	1.02	
Fe/1000 Mg	0.734***	115.8	0.723	1.68	101.9	2.92	4.05***	X
100 Mg/Zn	0.806	35.1	0.080	0.811	37.4	0.092	1.15ns	X
Zn/100 Mg	1.52	68.7	1.09	1.49	55.8	0.692	0.635	
100 Mg/Mn	0.380	41.5	0.025	0.241	41.7	0.010	0.409	
Mn/100 Mg	3.26***	57.3	3.48	5.28	65.2	11.9	3.41***	X
100 Na/Cu	0.355	106.0	0.142	0.235	92.6	0.047	0.332	
Cu/100 Na	6.03	90.2	29.6	8.75	142.2	155.0	5.24***	X
10000 Na/Fe	10.2	126.9	166.4	5.12	159.8	66.8	0.401	
Fe/10000 Na	0.577**	109.6	0.400	1.68	151.6	6.45	16.1***	X
1000 Na/Zn	1.51	96.3	2.12	0.926	63.3	0.343	0.162	
Zn/1000 Na	1.21	77.0	0.875	1.56	64.5	1.01	1.16ns	X
1000 Na/Mn	0.726	98.4	0.511	0.285	67.8	0.037	0.073	
Mn/1000 Na	2.69***	76.2	4.21	5.88	86.1	25.6	6.07***	X
10 Cu/Fe	3.25	117.2	14.5	2.67	130.8	12.2	0.84	
Fe/10 Cu	1.16***	116.9	1.83	2.96	116.2	11.8	6.44***	X
Cu/Zn	0.592	74.7	0.196	0.589	104.9	0.381	1.95*	X
Zn/Cu	3.19	121.9	15.1	2.65	64.0	2.88	0.191	
Cu/Mn	0.260	68.0	0.031	0.161	69.6	0.013	0.400	
Mn/Cu	5.84**	64.7	14.3	9.47	83.0	61.7	4.33***	X
Fe/Zn	5.35***	107.7	33.2	12.9	108.1	194.8	5.86***	X
Zn/Fe	0.886	169.1	2.24	0.712	181.4	1.67	0.744	
Fe/Mn	2.16	118.2	6.51	3.35	115.1	14.9	2.28**	X
Mn/Fe	1.38	117.0	2.61	1.66	121.0	4.02	1.54	
Zn/Mn	0.534	62.6	0.111	0.362	82.8	0.090	0.806	
Mn/Zn	2.46**	55.8	1.89	4.39	97.9	18.5	9.77***	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

Ca/N, Fe/100 N, Mn/N, P/K, Cu/10 P, Fe/1000 P, Zn/100 P, Mn/100 P, Ca/K, Cu/K, Fe/100 K, Mn/K, Ca/Mg, Fe/1000 Mg, Mn/100 Mg, Fe/10000 Na, Fe/Zn, and Mn/Zn. In detail, the mean concentration ratios, the CV, the variances, and the variance ratios in the high-yielding group were correspondingly 0.035–48.6, 27.8–120.3%, 0.00044–330.6, and 1.72–34.6.

The Table 6 possesses the nutrient ratio pairs for the DRIS

Table 4. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +7 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	17.2	25.3	18.8	9.46	25.4	5.78	0.307	
P/N	0.061***	21.4	0.00017	0.113	28.1	0.0010	5.91***	X
N/K	0.555***	39.8	0.049	0.807	57.7	0.217	4.43***	X
K/N	2.03	32.5	0.434	1.56	42.4	0.437	1.01	
N/Ca	24.1	87.0	440.7	13.8	63.7	77.2	0.175	
Ca/N	0.064***	63.8	0.0017	0.103	66.4	0.0047	2.83***	X
N/Mg	8.85	29.4	6.76	7.02	30.9	4.69	0.694	
Mg/N	0.122***	29.0	0.0013	0.155	28.1	0.0019	1.51ns	X
N/10 Na	7.01	59.6	17.5	6.18	61.6	14.5	0.830ns	X
10 Na/N	0.205	70.4	0.021	0.208	47.1	0.010	0.460	
N/Cu	0.166	56.3	0.0088	0.229	246.3	0.317	36.1***	X
Cu/N	7.67	45.9	12.4	9.50	56.6	28.9	2.33	
100 N/Fe	4.87	158.8	59.7	3.07	153.3	22.2	0.372	
Fe/100 N	0.946***	104.6	0.980	2.41	119.9	8.35	8.52***	X
N/Zn	0.071***	38.6	0.00074	0.062	39.2	0.00059	0.796ns	X
Zn/N	22.2	126.9	792.9	18.7	41.1	59.0	0.074	
N/Mn	0.026	28.0	0.000052	0.015	46.1	0.000047	0.910	
Mn/N	42.6***	35.8	233.1	85.4	59.3	2567.6	11.0***	X
P/K	0.033***	40.9	0.00019	0.086	49.4	0.0018	9.61***	X
K/P	34.4	38.5	174.8	14.1	41.9	34.8	0.199	
P/Ca	1.46	85.9	1.56	1.50	61.2	0.844	0.541	
Ca/P	1.09	69.8	0.581	0.942	64.3	0.367	0.631ns	X
P/Mg	0.551***	41.0	0.051	0.790	43.4	0.118	2.31**	X
Mg/P	2.12	39.0	0.684	1.45	33.6	0.236	0.345	
P/Na	4.35***	64.1	7.78	6.92	57.9	16.1	2.07**	X
Na/P	0.356	74.0	0.069	0.200	58.6	0.014	0.198	
10 P/Cu	0.105	65.8	0.0047	0.252	241.6	0.371	78.4***	X
Cu/10 P	13.6	61.8	70.7	8.68	51.7	20.2	0.285	
1000 P/Fe	2.82	164.3	21.5	2.93	132.6	15.1	0.704	
Fe/1000 P	1.55	105.7	2.70	2.28	144.3	10.8	4.00***	X
100 P/Zn	0.442***	45.9	0.041	0.700	47.2	0.109	2.65***	X
Zn/100 P	3.95	130.5	26.5	1.76	44.9	0.624	0.024	
100 P/Mn	0.156	30.8	0.0023	0.167	53.6	0.008	3.48***	X
Mn/100 P	7.18	38.0	7.44	7.90	57.6	20.7	2.78	
K/Ca	45.1	84.6	1456.7	19.9	62.2	153.1	0.105	
Ca/K	0.032***	54.7	0.00031	0.076	68.8	0.0027	8.75***	X
K/Mg	17.8	40.9	52.9	10.6	43.9	21.7	0.410	
Mg/K	0.067***	46.5	0.0010	0.122	60.2	0.0054	5.49***	X
K/100 Na	1.40	60.0	0.704	1.02	87.9	0.805	1.14	
100 Na/K	1.16	90.8	1.11	1.78	88.6	2.48	2.24**	X
K/Cu	0.331	74.0	0.060	0.450	325.4	2.14	35.8***	X
Cu/K	4.11	56.4	5.37	8.05	92.8	55.8	10.4	
100 K/Fe	7.43	112.7	70.0	3.48	144.4	25.2	0.360	
Fe/100 K	0.429***	101.5	0.190	1.65	149.0	6.04	31.9***	X
K/Zn	0.144	51.7	0.0055	0.095	52.3	0.0025	0.450	
Zn/K	12.6	132.3	278.0	15.2	74.8	129.1	0.465ns	X
K/Mn	0.050	33.4	0.00028	0.022	61.2	0.00019	0.666	

Table 4. Continued

Mn/K	22.7***	44.1	100.3	64.5	66.4	1833.8	18.3***	X
Ca/Mg	0.585	87.8	0.264	0.750	86.6	0.452	1.71*	X
Mg/Ca	2.95	89.3	6.93	2.13	66.6	2.01	0.290	
Ca/Na	4.31	86.8	14.0	5.55	61.6	11.7	0.834ns	X
Na/Ca	0.440	88.2	0.151	0.256	61.4	0.025	0.164	
10 Ca/Cu	0.099	73.8	0.0053	0.219	250.9	0.303	57.2***	X
Cu/10 Ca	17.9	102.0	332.6	12.4	78.3	94.2	0.283	
1000 Ca/Fe	1.98	105.0	4.34	1.96	150.3	8.67	2.00**	X
Fe/1000 Ca	1.69	129.9	4.82	2.07	102.0	4.44	0.921	
100 Ca/Zn	0.487	99.6	0.235	0.600	64.4	0.149	0.634ns	X
Zn/100 Ca	9.28	302.7	788.5	2.43	66.0	2.57	0.0033	
100 Ca/Mn	0.150	51.0	0.0059	0.135	55.5	0.0056	0.960ns	X
Mn/100 Ca	9.22	76.2	49.4	10.3	63.5	43.0	0.871	
Mg/Na	8.82	74.7	43.3	9.61	70.6	46.1	1.06ns	X
Na/Mg	0.182	74.5	0.018	0.145	53.1	0.0060	0.324	
Mg/Cu	0.021	69.7	0.00021	0.035	244.2	0.0074	35.6***	X
Cu/Mg	68.0	53.4	1318.1	69.0	83.6	3330.0	2.53	
1000 Mg/Fe	5.66	124.4	49.6	4.85	151.8	54.3	1.09	
Fe/1000 Mg	0.924	118.0	1.19	1.83	138.5	6.40	5.38***	X
100 Mg/Zn	0.838	40.7	0.116	0.938	43.6	0.168	1.44ns	X
Zn/100 Mg	1.99	147.7	8.67	1.29	51.3	0.439	0.051	
100 Mg/Mn	0.320	43.1	0.019	0.231	53.5	0.015	0.803	
Mn/100 Mg	3.86***	54.4	4.42	6.04	69.3	17.5	3.97***	X
100 Na/Cu	0.319	78.3	0.062	0.409	198.0	0.655	10.5***	X
Cu/100 Na	5.20	75.5	15.4	5.88	89.1	27.5	1.78	
10000 Na/Fe	9.56	133.2	162.4	7.36	191.6	199.1	1.23	
Fe/10000 Na	0.650**	107.8	0.491	1.30	107.7	1.96	3.98***	X
1000 Na/Zn	1.42	81.4	1.330	1.232	51.7	0.406	0.305ns	X
Zn/1000 Na	1.37	109.5	2.26	1.09	59.0	0.414	0.183	
1000 Na/Mn	0.511	72.8	0.139	0.291	58.6	0.029	0.210	
Mn/1000 Na	2.83***	54.5	2.37	4.76	61.1	8.44	3.56***	X
10 Cu/Fe	4.09	180.6	54.5	2.79	176.5	24.3	0.446	
Fe/10 Cu	1.65	143.1	5.58	4.80	253.7	148.5	26.6***	X
Cu/Zn	0.564	67.8	0.147	0.590	80.5	0.225	1.54	
Zn/Cu	3.84	135.6	27.1	3.88	221.9	74.1	2.73***	X
Cu/Mn	0.194	54.5	0.011	0.138	77.4	0.011	1.03	
Mn/Cu	6.81	57.4	15.3	15.3	165.9	646.8	42.2***	X
Fe/Zn	7.60**	117.1	79.2	13.8	104.0	204.9	2.59**	X
Zn/Fe	1.34	190.2	6.54	0.624	166.9	1.09	0.166	
Fe/Mn	2.14	99.6	4.56	3.21	132.6	18.1	3.96***	X
Mn/Fe	1.72	129.3	4.93	2.11	147.7	9.74	1.98	
Zn/Mn	0.591	136.9	0.655	0.267	47.7	0.016	0.025	
Mn/Zn	3.12***	67.1	4.39	5.23	75.8	15.7	3.59***	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

norm set at leaf +16, consisting of Ca/N, Fe/100 N, Mn/N, 10 P/Cu, Fe/1000 P, Mn/100 P, Ca/K, Fe/100 K, Mn/K, Mn/100 Ca, Fe/1000 Mg, Mn/100 Mg, Fe/10000 Na, Mn/1000 Na, Fe/10 Cu, and Fe/Zn. These pairs obtained the mean concentration ratios of 0.046–51.8 in the high-yielding group. At the same time, its CV, variances, and variance ratios were 36.9–119.5%, 0.00089–1014.9, and 1.79–13.7, respectively.

The Table 7 has the DRIS norm set at leaf +18 with

Table 5. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +9 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	13.6	27.3	13.8	12.3	48.0	34.7	2.51	
P/N	0.079**	27.8	0.00048	0.097	41.4	0.0016	3.31***	X
N/K	0.611	59.9	0.134	0.870	98.8	0.738	5.51***	X
K/N	2.26	69.6	2.48	1.61	42.0	0.455	0.183	
N/Ca	21.0	60.0	158.8	14.4	63.0	82.5	0.520	
Ca/N	0.062***	52.9	0.0011	0.101	67.1	0.0046	4.27***	X
N/Mg	7.87	32.9	6.68	8.37	58.9	24.3	3.63***	X
Mg/N	0.143	37.5	0.0029	0.143	36.6	0.0027	0.960	
N/10 Na	9.97	82.6	67.9	7.20	62.4	20.2	0.298	
10 Na/N	0.187	97.2	0.033	0.195	59.6	0.014	0.410ns	X
N/Cu	0.172	56.2	0.0093	0.132	51.4	0.0046	0.496	
Cu/N	7.78	52.3	16.5	9.46	46.1	19.0	1.15ns	X
100 N/Fe	3.16	102.7	10.5	2.73	149.9	16.8	1.60	
Fe/100 N	0.958***	99.7	0.912	2.38	102.2	5.94	6.51***	X
N/Zn	0.074	35.2	0.00069	0.064	37.8	0.00059	0.862	
Zn/N	15.2	36.4	30.5	17.8	41.3	54.5	1.78*	X
N/Mn	0.023	29.1	0.000043	0.015	44.7	0.000044	1.02	
Mn/N	48.6***	34.6	282.7	86.4	60.9	2767.1	9.79***	X
P/K	0.044***	47.6	0.00044	0.077	80.0	0.0038	8.57***	X
K/P	28.0	49.4	190.7	18.9	56.6	114.9	0.603	
P/Ca	1.70	69.6	1.40	1.33	70.3	0.876	0.626	
Ca/P	0.864	62.6	0.292	1.17	66.1	0.594	2.03**	X
P/Mg	0.594	33.1	0.039	0.760	49.6	0.142	3.68	
Mg/P	1.83	27.5	0.254	1.71	58.9	1.02	4.01***	X
P/Na	8.29	100.5	69.5	6.90	69.6	23.0	0.331	
Na/P	0.250	89.9	0.051	0.240	76.9	0.034	0.675ns	X
10 P/Cu	0.134	60.8	0.0067	0.122	55.4	0.0045	0.681	
Cu/10 P	10.4***	54.0	31.6	11.2	65.8	54.3	1.72*	X
1000 P/Fe	2.41	98.1	5.59	2.08	141.6	8.65	1.55	
Fe/1000 P	1.25**	97.0	1.48	2.37	93.4	4.90	3.32***	X
100 P/Zn	0.581	40.1	0.054	0.618	51.1	0.100	1.83	
Zn/100 P	2.05***	47.9	0.966	2.21	66.7	2.17	2.25**	X
100 P/Mn	0.178	37.7	0.0045	0.143	60.4	0.0075	1.67	
Mn/100 P	6.58**	44.1	8.40	10.7	81.1	75.0	8.93***	X
K/Ca	44.9	91.1	1672.0	20.8	63.1	172.3	0.103	
Ca/K	0.035***	65.5	0.00053	0.076	94.7	0.0051	9.66***	X
K/Mg	16.3	50.7	68.3	12.8	68.3	76.8	1.12	
Mg/K	0.081	58.5	0.0023	0.112	73.8	0.0068	3.01***	X
K/100 Na	2.63	137.5	13.1	1.08	65.4	0.499	0.038	
100 Na/K	1.18	114.9	1.84	1.50	83.1	1.56	0.845ns	X
K/Cu	0.353	65.2	0.053	0.197	56.1	0.012	0.230	
Cu/K	4.50**	75.0	11.4	7.50	103.7	60.6	5.33***	X
100 K/Fe	6.36	125.6	63.8	3.45	159.0	30.0	0.470	
Fe/100 K	0.447***	84.4	0.142	1.40	95.7	1.80	12.6***	X
K/Zn	0.163	63.9	0.011	0.104	54.7	0.0032	0.295	
Zn/K	9.17	70.4	41.7	15.8	118.3	351.2	8.43***	X
K/Mn	0.050	74.1	0.0014	0.023	58.4	0.00018	0.134	

Table 5. Continued

Mn/K	28.6**	63.6	330.6	74.3	143.8	11426.0	34.6***	X
Ca/Mg	0.483**	58.8	0.081	0.820	86.1	0.499	6.17***	X
Mg/Ca	3.07	87.9	7.28	1.98	65.0	1.65	0.227	
Ca/Na	5.57	71.9	16.0	6.06	65.2	15.6	0.973ns	X
Na/Ca	0.414	154.5	0.410	0.231	56.8	0.017	0.042	
10 Ca/Cu	0.100	64.2	0.0041	0.123	73.6	0.0083	1.99**	X
Cu/10 Ca	15.59	77.0	143.9	12.6	70.2	78.0	0.542	
1000 Ca/Fe	1.85	115.8	4.61	1.91	162.0	9.52	2.07	
Fe/1000 Ca	1.80	109.7	3.89	2.51	120.1	9.06	2.33**	X
100 Ca/Zn	0.474	87.7	0.172	0.615	71.8	0.195	1.13ns	X
Zn/100 Ca	3.06	57.2	3.07	2.35	56.2	1.75	0.569	
100 Ca/Mn	0.130	43.5	0.0032	0.132	62.5	0.0068	2.12**	X
Mn/100 Ca	9.37	49.5	21.5	10.5	54.6	33.0	1.53	
Mg/Na	14.9	101.4	226.9	9.91	77.6	59.2	0.261	
Na/Mg	0.145	89.8	0.017	0.148	56.6	0.0070	0.413ns	X
Mg/Cu	0.024	57.4	0.00018	0.019	68.4	0.00017	0.916	
Cu/Mg	59.8	60.4	1304.4	77.9	74.8	3399.3	2.61**	X
1000 Mg/Fe	4.73	103.4	23.9	3.59	141.1	25.7	1.07	
Fe/1000 Mg	0.857**	120.3	1.06	1.93	120.0	5.35	5.04***	X
100 Mg/Zn	1.00	37.4	0.141	0.888	40.5	0.130	0.918	
Zn/100 Mg	1.13	39.5	0.201	1.46	68.5	1.00	4.96***	X
100 Mg/Mn	0.318	41.0	0.017	0.218	58.9	0.016	0.967	
Mn/100 Mg	3.83**	51.8	3.93	7.80	111.8	76.1	19.3***	X
100 Na/Cu	0.270	76.8	0.043	0.244	82.1	0.040	0.933ns	X
Cu/100 Na	7.10	92.1	42.7	6.24	65.3	16.6	0.389	
10000 Na/Fe	6.75	173.2	136.8	4.71	149.4	49.6	0.363	
Fe/10000 Na	0.824**	110.3	0.827	1.53	109.2	2.80	3.38***	X
1000 Na/Zn	1.37	100.1	1.87	1.20	67.0	0.645	0.345ns	X
Zn/1000 Na	1.57	105.8	2.74	1.20	60.0	0.520	0.190	
1000 Na/Mn	0.405	107.0	0.188	0.262	60.7	0.025	0.135	
Mn/1000 Na	4.39	68.6	9.07	5.60	76.7	18.4	2.03**	X
10 Cu/Fe	2.32	122.9	8.12	2.30	169.5	15.1	1.86*	X
Fe/10 Cu	1.68	138.4	5.38	2.78	110.1	9.34	1.74	
Cu/Zn	0.579	61.0	0.125	0.603	54.8	0.109	0.873ns	X
Zn/Cu	2.65	73.9	3.82	2.39	71.8	2.94	0.768	
Cu/Mn	0.165	50.5	0.0070	0.127	49.9	0.0040	0.576	
Mn/Cu	7.78	55.5	18.7	9.99	53.9	29.0	1.55ns	X
Fe/Zn	8.48**	115.0	95.1	16.0	107.1	294.8	3.10***	X
Zn/Fe	0.607	132.9	0.650	0.506	154.8	0.613	0.942	
Fe/Mn	2.02	96.3	3.79	3.24	108.2	12.3	3.24	
Mn/Fe	1.52	117.9	3.22	2.10	159.0	11.1	3.46***	X
Zn/Mn	0.336	38.3	0.017	0.267	74.6	0.040	2.40	
Mn/Zn	3.62**	56.6	4.20	5.46	70.5	14.8	3.53***	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

its nutrient ratio pairs of Ca/N, Fe/100 N, Mn/N, 10 P/Cu, Fe/1000 P, Zn/100 P, Mn/100 P, Ca/K, 100 Na/K, Fe/100 K, Mn/K, Fe/1000 Mg, Zn/100 Mg, Mn/100 Mg, Fe/10000 Na, and Mn/1000 Na. The mean concentration ratios in the high-yielding group were 0.044–44.8. At the same time, the CV, the variances, and the variance ratios were recorded as 33.6–140.8%, 0.00070–523.9, and 2.36–56.6, respectively.

The Table 8 shows selected nutrient ratio pairs, includ-

Table 6. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +16 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	15.7	32.6	26.3	13.5	39.7	28.8	1.09	
P/N	0.071	38.5	0.00076	0.085	38.7	0.0011	1.42^{ns}	X
N/K	0.755	47.3	0.127	0.759	61.3	0.216	1.70*	X
K/N	1.63	53.4	0.757	1.66	46.3	0.594	0.785	
N/Ca	20.5	48.9	100.6	15.5	60.1	86.5	0.860	
Ca/N	0.061**	48.4	0.00089	0.108	101.9	0.012	13.7***	X
N/Mg	8.75	45.9	16.1	7.37	37.4	7.58	0.471	
Mg/N	0.137	41.0	0.0032	0.158	46.5	0.0054	1.70*	X
N/10 Na	7.36	68.7	25.6	6.25	64.8	16.4	0.643	
10 Na/N	0.209	72.0	0.023	0.251	70.6	0.031	1.39^{ns}	X
N/Cu	0.208	67.1	0.019	0.160	61.8	0.010	0.503	
Cu/N	7.46	72.2	29.0	8.76	58.4	26.2	0.901^{ns}	X
100 N/Fe	3.48	120.0	17.5	2.13	119.9	6.51	0.373	
Fe/100 N	0.814***	90.5	0.542	2.31	98.5	5.19	9.56***	X
N/Zn	0.087	49.5	0.0019	0.074	74.6	0.0030	1.64^{ns}	X
Zn/N	14.1	48.0	45.6	17.1	42.7	53.2	1.17	
N/Mn	0.024	44.9	0.00012	0.014	54.9	0.000061	0.528	
Mn/N	51.8***	49.1	648.3	102.1	72.5	5471.7	8.44***	X
P/K	0.051	46.0	0.00054	0.064	74.4	0.0023	4.18***	X
K/P	24.0	44.4	113.4	21.9	51.6	127.6	1.13	
P/Ca	1.48	66.9	0.979	1.27	67.3	0.735	0.751	
Ca/P	0.968	59.1	0.327	1.39	99.4	1.90	5.82***	X
P/Mg	0.566	32.7	0.034	0.599	51.3	0.094	2.75***	X
Mg/P	2.00	41.3	0.682	1.99	38.3	0.580	0.851	
P/Na	5.48	98.2	29.0	5.35	82.3	19.3	0.668^{ns}	X
Na/P	0.340	96.6	0.108	0.327	68.6	0.050	0.468	
10 P/Cu	0.128**	55.5	0.0051	0.132	72.8	0.0093	1.83*	X
Cu/10 P	10.1	53.5	29.0	11.3	58.1	42.9	1.48	
1000 P/Fe	2.58	119.7	9.55	1.55	108.6	2.83	0.296	
Fe/1000 P	1.46**	107.1	2.44	2.88	99.8	8.29	3.40***	X
100 P/Zn	0.574	44.1	0.064	0.581	65.1	0.143	2.23**	X
Zn/100 P	2.05	40.8	0.701	2.17	42.5	0.850	1.21	
100 P/Mn	0.166	52.8	0.0077	0.117	68.2	0.0064	0.830	
Mn/100 P	7.95***	55.0	19.1	12.8	63.0	64.7	3.38***	X
K/Ca	32.2	62.8	408.5	24.6	74.5	334.8	0.820	
Ca/K	0.046**	67.4	0.0010	0.071	83.1	0.0035	3.63***	X
K/Mg	13.1	46.7	37.3	11.9	60.8	52.8	1.41	
Mg/K	0.098	59.8	0.0035	0.114	62.4	0.0050	1.45^{ns}	X
K/100 Na	1.09	73.9	0.650	1.01	82.5	0.692	1.06	
100 Na/K	1.46	79.3	1.34	1.83	91.0	2.76	2.06**	X
K/Cu	0.344	97.8	0.113	0.249	66.6	0.028	0.244	
Cu/K	5.49	77.3	18.0	6.22	73.0	20.6	1.15^{ns}	X
100 K/Fe	4.85	106.6	26.8	3.30	129.1	18.2	0.679	
Fe/100 K	0.570***	97.6	0.309	1.50	94.5	2.00	6.49***	X
K/Zn	0.137	59.3	0.0066	0.121	80.3	0.010	1.44	
Zn/K	10.8	78.3	71.5	13.3	85.9	130.8	1.83*	X
K/Mn	0.038	58.4	0.00049	0.021	57.0	0.00015	0.303	

Table 6. Continued

Mn/K	39.5***	80.6	1014.9	68.2	75.5	2651.1	2.61***	X
Ca/Mg	0.534	80.0	0.183	0.843	132.7	1.25	6.86***	X
Mg/Ca	2.70	56.9	2.36	2.38	71.1	2.86	1.21	
Ca/Na	4.09	72.6	8.83	5.12	81.1	17.2	1.95*	X
Na/Ca	0.387	76.3	0.087	0.318	81.3	0.067	0.768	
10 Ca/Cu	0.142	102.9	0.021	0.137	81.0	0.012	0.574ns	X
Cu/10 Ca	16.5	94.5	242.8	11.5	67.6	60.3	0.248	
1000 Ca/Fe	2.14	157.0	11.3	1.38	110.5	2.33	0.206	
Fe/1000 Ca	1.60	108.5	3.00	2.79	122.1	11.6	3.87***	X
100 Ca/Zn	0.516	67.4	0.121	0.720	104.4	0.56	4.68***	X
Zn/100 Ca	2.73	57.3	2.45	2.44	59.8	2.12	0.865	
100 Ca/Mn	0.125	31.8	0.0016	0.114	65.6	0.0056	3.55	
Mn/100 Ca	8.96**	36.9	10.9	12.2	59.8	53.5	4.90***	X
Mg/Na	9.85	90.1	78.8	9.42	78.7	55.0	0.699	
Na/Mg	0.167	69.0	0.013	0.174	69.0	0.014	1.08ns	X
Mg/Cu	0.026	69.1	0.00032	0.024	76.8	0.00034	1.06ns	X
Cu/Mg	57.0	59.5	1153.8	60.1	56.8	1164.7	1.01	
1000 Mg/Fe	4.62	96.6	19.9	3.31	119.5	15.6	0.784	
Fe/1000 Mg	0.851**	118.1	1.01	1.71	108.5	3.43	3.39***	X
100 Mg/Zn	1.04	31.8	0.110	1.03	55.3	0.328	2.99***	X
Zn/100 Mg	1.08	38.0	0.167	1.15	35.0	0.161	0.964	
100 Mg/Mn	0.307	47.9	0.022	0.203	53.0	0.012	0.536	
Mn/100 Mg	4.29**	62.3	7.14	7.07	92.8	43.0	6.03***	X
100 Na/Cu	0.461	121.6	0.314	0.327	63.2	0.043	0.136	
Cu/100 Na	6.17	123.5	58.2	4.64	74.3	11.9	0.204ns	X
10000 Na/Fe	6.67	125.5	70.2	4.45	127.5	32.2	0.458	
Fe/10000 Na	0.571**	103.2	0.347	1.39	148.7	4.28	12.3***	X
1000 Na/Zn	1.72	80.7	1.93	1.68	92.8	2.44	1.26ns	X
Zn/1000 Na	0.988	79.1	0.611	0.972	65.5	0.406	0.664	
1000 Na/Mn	0.451	66.4	0.090	0.289	64.9	0.035	0.393	
Mn/1000 Na	3.48**	70.0	5.93	5.02	64.9	10.6	1.79*	X
10 Cu/Fe	2.85	126.5	13.0	1.81	122.9	4.97	0.382	
Fe/10 Cu	2.01**	116.3	5.48	3.96	127.0	25.3	4.62***	X
Cu/Zn	0.570	65.2	0.138	0.551	52.4	0.083	0.603	
Zn/Cu	2.58	62.8	2.63	2.45	61.8	2.29	0.870ns	X
Cu/Mn	0.178	78.2	0.019	0.105	61.7	0.0042	0.218	
Mn/Cu	11.0	85.1	88.3	13.1	55.9	53.6	0.607ns	X
Fe/Zn	8.74**	119.5	109.2	16.1	111.1	321.7	2.95***	X
Zn/Fe	0.592	143.6	0.722	0.353	119.2	0.177	0.245	
Fe/Mn	2.00	119.8	5.72	3.19	112.6	12.9	2.25**	X
Mn/Fe	1.71	121.0	4.30	1.89	126.2	5.67	1.32	
Zn/Mn	0.319	47.3	0.023	0.214	50.9	0.012	0.522	
Mn/Zn	4.49	77.3	12.0	6.27	67.3	17.8	1.48ns	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

ing Ca/N, Fe/100 N, Zn/N, Mn/N, Ca/P, Cu/10 P, Fe/1000 P, Zn/100 P, Mn/100 P, Ca/K, Fe/100 K, Zn/K, Mn/K, Fe/1000 Ca, Fe/1000 Mg, Zn/100 Mg, Fe/10000 Na, Fe/10 Cu, and Fe/Mn, for the DRIS norm set at leaf +21. The high-yielding group had the mean concentration ratios recorded to be 0.040–53.9. In addition, in the high-yielding group, the CV, the variances, and the variance ratios were correspondingly recorded as 28.5–140.7%, 0.00060–308.3, and 2.71–218.8.

Table 7. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +18 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	14.9	29.8	19.7	13.7	32.8	20.1	1.02	
P/N	0.074	33.3	0.00060	0.082	35.6	0.00086	1.43^{ns}	X
N/K	0.767	58.4	0.201	0.865	65.4	0.320	1.59^{ns}	X
K/N	1.83	59.0	1.16	1.57	55.2	0.749	0.644	
N/Ca	21.3	87.2	345.0	14.4	95.0	185.7	0.538	
Ca/N	0.065**	49.2	0.0010	0.106	82.5	0.0076	7.39***	X
N/Mg	7.96	34.2	7.41	7.83	42.9	11.3	1.52^{ns}	X
Mg/N	0.138	28.9	0.0016	0.147	31.9	0.0022	1.38	
N/10 Na	8.91	59.2	27.8	6.69	76.0	25.9	0.930	
10 Na/N	0.178	81.5	0.021	0.231	62.7	0.021	0.994^{ns}	X
N/Cu	0.166	60.2	0.010	0.252	177.9	0.202	20.1***	X
Cu/N	8.19	57.7	22.3	9.10	56.4	26.3	1.18	
100 N/Fe	3.16	84.9	7.20	2.61	126.7	11.0	1.52	
Fe/100 N	1.04***	109.7	1.29	2.97	101.2	9.04	6.98***	X
N/Zn	0.089	46.7	0.0017	0.065	56.4	0.0013	0.785	
Zn/N	13.7	45.0	38.2	25.0	119.5	890.7	23.3***	X
N/Mn	0.03	42.5	0.00013	0.015	71.9	0.00012	0.889	
Mn/N	44.8***	51.1	523.9	94.4	68.4	4173.8	7.97***	X
P/K	0.055	62.0	0.0012	0.068	62.5	0.0018	1.57^{ns}	X
K/P	26.3	59.2	243.0	21.5	67.2	207.8	0.855	
P/Ca	1.56	90.6	2.00	1.14	93.2	1.12	0.561	
Ca/P	0.966	55.1	0.283	1.32	61.0	0.652	2.30**	X
P/Mg	0.575	45.0	0.067	0.618	46.2	0.082	1.22^{ns}	X
Mg/P	2.00	35.5	0.506	1.94	38.4	0.554	1.09	
P/Na	6.40	75.9	23.6	5.53	83.8	21.5	0.911	
Na/P	0.242	68.2	0.027	0.322	68.3	0.048	1.78*	X
10 P/Cu	0.115**	54.9	0.0040	0.219	197.9	0.187	47.1***	X
Cu/10 P	11.4	50.8	33.5	12.3	58.2	50.9	1.52	
1000 P/Fe	2.41	93.5	5.08	1.91	134.1	6.59	1.30	
Fe/1000 P	1.73**	132.1	5.24	3.49	100.8	12.4	2.36**	X
100 P/Zn	0.645	53.8	0.120	0.521	64.5	0.113	0.939	
Zn/100 P	2.06***	62.6	1.66	3.10	102.6	10.2	6.10***	X
100 P/Mn	0.203	55.1	0.012	0.119	78.6	0.0087	0.696	
Mn/100 P	6.74***	61.4	17.1	12.3	69.5	72.5	4.23***	X
K/Ca	31.7	59.5	356.4	22.4	87.5	383.0	1.07	
Ca/K	0.044***	60.8	0.00070	0.084	84.7	0.0051	7.26***	X
K/Mg	14.6	68.3	99.7	12.3	79.0	93.9	0.941	
Mg/K	0.11	69.4	0.0056	0.122	66.9	0.0066	1.18^{ns}	X
K/100 Na	1.33	53.5	0.503	1.03	79.3	0.669	1.33	
100 Na/K	1.11**	80.1	0.791	2.12	101.8	4.65	5.88***	X
K/Cu	0.322	112.9	0.132	0.385	173.5	0.446	3.37***	X
Cu/K	6.06	70.4	18.2	8.21	91.1	55.9	3.07	
100 K/Fe	4.90	111.7	30.0	3.81	148.3	31.9	1.06	
Fe/100 K	0.572**	105.9	0.367	2.58	176.8	20.8	56.6***	X
K/Zn	0.17	77.7	0.017	0.104	100.8	0.011	0.629	
Zn/K	11.5	87.5	100.7	19.2	89.8	296.4	2.94***	X
K/Mn	0.045	53.8	0.00058	0.022	98.2	0.00046	0.780	

Table 7. Continued

Mn/K	31.0***	61.0	358.6	67.6	61.2	1712.6	4.78***	X
Ca/Mg	0.523	79.3	0.172	0.786	77.4	0.370	2.15**	X
Mg/Ca	2.86	91.5	6.83	2.11	98.4	4.29	0.628	
Ca/Na	5.39	64.5	12.1	5.24	62.3	10.7	0.885	
Na/Ca	0.331	83.4	0.076	0.280	96.5	0.073	0.96ns	X
10 Ca/Cu	0.114	80.6	0.0084	0.263	197.8	0.271	32.2***	X
Cu/10 Ca	19.3	125.6	590.3	12.4	136.6	288.6	0.489	
1000 Ca/Fe	1.77	92.0	2.66	1.76	135.9	5.71	2.15**	X
Fe/1000 Ca	1.84	150.1	7.66	3.19	116.3	13.7	1.79	
100 Ca/Zn	0.610	96.0	0.343	0.602	83.8	0.254	0.740	
Zn/100 Ca	2.86	93.6	7.17	2.78	83.4	5.38	0.751ns	X
100 Ca/Mn	0.162	47.9	0.0060	0.124	59.3	0.0054	0.901ns	X
Mn/100 Ca	8.36	70.0	34.3	10.4	53.0	30.4	0.887	
Mg/Na	12.6	74.5	88.3	9.74	98.1	91.2	1.03ns	X
Na/Mg	0.140	84.7	0.014	0.169	68.9	0.014	0.964	
Mg/Cu	0.023	70.9	0.00027	0.031	129.8	0.0017	6.24***	X
Cu/Mg	64.4	61.9	1585.9	70.1	69.1	2343.2	1.48	
1000 Mg/Fe	4.57	83.6	14.6	3.94	124.0	23.9	1.64	
Fe/1000 Mg	0.994**	140.8	1.96	2.38	105.0	6.26	3.19***	X
100 Mg/Zn	1.11	30.5	0.115	0.884	47.4	0.176	1.53	
Zn/100 Mg	0.991**	33.6	0.111	1.61	81.8	1.74	15.7***	X
100 Mg/Mn	0.377	50.1	0.036	0.212	77.6	0.027	0.76	
Mn/100 Mg	3.68**	73.6	7.33	7.59	114.9	76.0	10.4***	X
100 Na/Cu	0.277	90.8	0.063	0.455	139.3	0.401	6.35***	X
Cu/100 Na	7.18	93.2	44.9	5.37	106.8	32.9	0.734	
10000 Na/Fe	5.34	124.2	43.9	5.65	151.8	73.5	1.67	
Fe/10000 Na	0.774**	106.2	0.677	1.60	103.5	2.75	4.07***	X
1000 Na/Zn	1.63	93.0	2.29	1.39	89.6	1.55	0.674	
Zn/1000 Na	1.29	80.1	1.07	1.39	101.0	1.98	1.86*	X
1000 Na/Mn	0.393	55.5	0.048	0.314	74.1	0.054	1.13	
Mn/1000 Na	3.34**	51.5	2.97	5.22	67.1	12.3	4.13***	X
10 Cu/Fe	2.90	111.7	10.5	2.31	142.9	10.9	1.03	
Fe/10 Cu	2.10	141.1	8.80	6.63	161.0	113.9	12.9***	X
Cu/Zn	0.718	73.1	0.275	0.568	80.8	0.211	0.77	
Zn/Cu	2.25	74.9	2.84	5.59	184.3	106.0	37.3***	X
Cu/Mn	0.223	72.5	0.026	0.127	101.1	0.016	0.633	
Mn/Cu	7.41	79.8	35.0	20.4	158.7	1045.8	29.9***	X
Fe/Zn	12.3	141.6	303.6	18.2	110.5	404.8	1.33	
Zn/Fe	0.512	99.5	0.259	0.532	135.8	0.523	2.01**	X
Fe/Mn	2.39	106.3	6.48	3.94	104.4	17.0	2.62	
Mn/Fe	1.23	87.0	1.14	2.09	148.9	9.68	8.51***	X
Zn/Mn	0.375	53.2	0.040	0.288	66.0	0.036	0.904	
Mn/Zn	4.35	97.5	18.0	5.73	99.0	32.2	1.79*	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

The Table 9 indicates that the DRIS norm set at leaf +22 were formed from 19 nutrient ratio pairs of Ca/N, Fe/100 N, Zn/N, Mn/N, Ca/P, Cu/10 P, Fe/1000 P, Zn/100 P, Mn/100 P, Ca/K, Fe/100 K, Mn/K, Ca/Mg, Fe/1000 Ca, Fe/1000 Mg, Fe/10000 Na, Fe/10 Cu, Mn/Cu, and Fe/Zn. The mean concentration ratios, the CV, the variances, and the variance ratios in the high-yielding group were 0.051–51.3, 37.8–117.4%, 0.00071–1072.6, and 2.41–34.5, respectively.

Table 8. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +21 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	14.5	35.9	27.0	19.4	149.0	835.6	30.9***	X
P/N	0.079	40.1	0.0010	0.090	59.4	0.0028	2.85	
N/K	0.649	41.1	0.071	0.995	163.8	2.65	37.3***	X
K/N	1.81	41.4	0.562	1.87	54.1	1.03	1.83	
N/Ca	21.3	67.2	204.8	16.9	128.9	473.7	2.31	
Ca/N	0.066***	61.3	0.0016	0.105	71.6	0.0057	3.47***	X
N/Mg	8.17	43.2	12.5	8.41	94.4	62.9	5.05***	X
Mg/N	0.145	41.8	0.0037	0.155	37.4	0.0033	0.915	
N/10 Na	7.31	69.9	26.1	6.52	96.2	39.3	1.51ns	X
10 Na/N	0.223	82.7	0.034	0.237	61.3	0.021	0.625	
N/Cu	0.170	72.2	0.015	0.198	176.9	0.12	8.13***	X
Cu/N	7.72	52.8	16.6	9.67	68.5	43.9	2.64	
100 N/Fe	3.74	116.9	19.2	4.41	288.1	161.4	8.43	
Fe/100 N	0.756***	87.7	0.44	2.58	94.0	5.87	13.4***	X
N/Zn	0.088	70.4	0.0038	0.075	151.0	0.013	3.36	
Zn/N	14.2***	35.4	25.4	22.1	57.0	158.6	6.25***	X
N/Mn	0.020	27.3	0.000030	0.016	88.5	0.00021	7.08	
Mn/N	53.9***	28.5	236.2	101.4	79.3	6465.2	27.4***	X
P/K	0.048	43.2	0.00043	0.062	101.3	0.0039	9.02***	X
K/P	24.9	46.9	136.4	24.8	57.3	201.5	1.48	
P/Ca	1.54	56.2	0.747	1.19	119.4	2.01	2.69	
Ca/P	0.892**	59.3	0.279	1.43	76.3	1.20	4.28***	X
P/Mg	0.609	46.7	0.081	0.617	60.7	0.140	1.73	
Mg/P	1.99	45.8	0.832	2.37	100.0	5.60	6.73***	X
P/Na	5.50	69.7	14.7	5.39	81.4	19.3	1.31	
Na/P	0.308	86.4	0.071	0.416	131.5	0.299	4.22***	X
10 P/Cu	0.126	60.4	0.0058	0.124	74.4	0.0085	1.47	
Cu/10 P	10.7***	51.9	30.8	13.3	68.5	83.5	2.71***	X
1000 P/Fe	2.71	110.1	8.89	1.44	132.7	3.65	0.411	
Fe/1000 P	1.02***	90.0	0.836	2.98	110.8	10.9	13.1***	X
100 P/Zn	0.623	47.2	0.087	0.457	51.9	0.056	0.649	
Zn/100 P	1.96***	46.6	0.833	2.92	62.1	3.28	3.94***	X
100 P/Mn	0.162	62.4	0.010	0.133	82.4	0.012	1.17	
Mn/100 P	7.86***	46.6	13.4	15.5	91.6	200.7	14.9***	X
K/Ca	35.6	60.5	463.8	21.5	59.2	162.7	0.351	
Ca/K	0.040**	61.2	0.00060	0.067	87.8	0.0035	5.80***	X
K/Mg	14.6	54.1	62.3	13.1	65.3	73.6	1.18	
Mg/K	0.095	62.8	0.0035	0.111	70.3	0.0061	1.72*	X
K/100 Na	1.36	80.4	1.20	1.12	85.9	0.92	0.770	
100 Na/K	1.56	110.3	2.94	1.96	107.8	4.45	1.51ns	X
K/Cu	0.297	70.1	0.043	0.257	71.8	0.034	0.786	
Cu/K	4.93	64.6	10.1	8.96	240.7	464.4	45.9***	X
100 K/Fe	5.47	102.1	31.1	3.98	162.3	41.8	1.34	
Fe/100 K	0.403**	76.2	0.094	2.00	227.7	20.6	218.8***	X
K/Zn	0.150	63.9	0.0092	0.102	71.3	0.0053	0.578	
Zn/K	8.94***	49.4	19.5	14.5	63.3	84.0	4.31***	X
K/Mn	0.038	61.0	0.00053	0.028	97.8	0.00073	1.38	

Table 8. Continued

Mn/K	35.6***	49.4	308.3	70.8	86.3	3740.4	12.1***	X
Ca/Mg	0.526	83.3	0.192	0.776	94.8	0.541	2.82***	X
Mg/Ca	2.83	55.0	2.43	2.11	83.0	3.08	1.27	
Ca/Na	4.85	99.4	23.2	5.35	62.8	11.3	0.487	
Na/Ca	0.428	76.2	0.106	0.323	109.9	0.126	1.18ns	X
10 Ca/Cu	0.113	91.6	0.011	0.167	138.1	0.053	4.92	
Cu/10 Ca	17.1	87.1	221.9	19.6	286.5	3167.6	14.3***	X
1000 Ca/Fe	2.15	131.7	7.99	1.75	156.3	7.49	0.937	
Fe/1000 Ca	1.30**	84.6	1.21	2.43	101.0	6.05	5.01***	X
100 Ca/Zn	0.581	103.2	0.360	0.575	82.5	0.225	0.625	
Zn/100 Ca	2.94	69.7	4.18	2.73	68.9	3.54	0.847ns	X
100 Ca/Mn	0.134	78.2	0.011	0.128	58.7	0.0057	0.517	
Mn/100 Ca	11.2	61.3	47.1	12.3	104.0	164.7	3.49***	X
Mg/Na	9.83	73.5	52.2	9.08	74.3	45.5	0.871	
Na/Mg	0.164	74.2	0.015	0.176	75.8	0.018	1.20ns	X
Mg/Cu	0.024	70.2	0.00029	0.022	61.8	0.00019	0.651	
Cu/Mg	62.0	60.3	1398.2	67.9	80.1	2957.8	2.12**	X
1000 Mg/Fe	6.37	145.3	85.8	4.16	171.3	50.7	0.592	
Fe/1000 Mg	0.687***	105.4	0.524	1.959	119.6	5.49	10.5***	X
100 Mg/Zn	1.10	44.3	0.239	0.83	43.2	0.129	0.541	
Zn/100 Mg	1.05***	35.7	0.141	1.44	43.9	0.399	2.83***	X
100 Mg/Mn	0.282	37.8	0.011	0.222	62.0	0.019	1.67	
Mn/100 Mg	4.44	61.5	7.46	8.18	149.3	149.2	20.0***	X
100 Na/Cu	0.371	103.8	0.148	0.361	97.0	0.123	0.830ns	X
Cu/100 Na	5.70	89.3	25.9	5.27	75.6	15.9	0.615	
10000 Na/Fe	11.0	227.6	622.1	7.38	215.9	254.2	0.409	
Fe/10000 Na	0.548***	101.9	0.312	1.25	93.1	1.35	4.32***	X
1000 Na/Zn	1.80	82.9	2.23	1.40	84.6	1.41	0.630	
Zn/1000 Na	1.05	93.3	0.968	1.21	67.6	0.667	0.689ns	X
1000 Na/Mn	0.414	77.6	0.103	0.293	58.9	0.030	0.288	
Mn/1000 Na	3.66	60.2	4.84	4.90	82.0	16.1	3.33***	X
10 Cu/Fe	2.64	101.9	7.25	2.30	170.9	15.5	2.14	
Fe/10 Cu	1.43**	140.7	4.05	4.31	152.5	43.1	10.6***	X
Cu/Zn	0.623	63.6	0.157	0.528	103.1	0.297	1.89	
Zn/Cu	2.22	51.2	1.29	2.84	58.1	2.71	2.10**	X
Cu/Mn	0.152	48.0	0.0053	0.129	78.7	0.010	1.93	
Mn/Cu	9.56	97.9	87.5	14.1	94.6	178.0	2.04**	X
Fe/Zn	7.57	137.6	108.6	14.1	136.8	374.3	3.45***	X
Zn/Fe	0.566	122.3	0.479	0.477	183.3	0.765	1.60	
Fe/Mn	1.63**	102.9	2.82	3.28	119.4	15.3	5.43***	X
Mn/Fe	2.14	121.7	6.75	2.11	165.9	12.3	1.82	
Zn/Mn	0.294	52.4	0.024	0.297	61.3	0.033	1.40	
Mn/Zn	5.03	95.1	22.9	5.99	109.2	42.8	1.87*	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

The Table 10 presents the DRIS norm set at leaf +29 having Ca/N, Fe/100 N, Mn/N, 10 P/Cu, Fe/1000 P, Zn/100 P, Ca/K, Fe/100 K, Zn/K, Mn/K, Fe/1000 Ca, Fe/1000 Mg, Fe/10000 Na, Fe/Zn, and Fe/Mn nutrient ratio pairs. In the high-yielding group, the mean concentration ratios were 0.050–46.1, the CV values were 30.0–106.3%, the variances were 0.00053–838.6, and the variance ratios were 2.06–1040.7.

Table 9. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +22 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	16.0	20.1	10.3	16.8	78.5	174.6	16.9***	X
P/N	0.065	18.3	0.00014	0.070	29.2	0.00042	3.02	
N/K	1.01	78.6	0.634	1.01	104.8	1.11	1.75*	X
K/N	1.45	54.4	0.624	1.49	43.5	0.421	0.674	
N/Ca	22.0	63.5	195.2	14.8	54.8	65.9	0.338	
Ca/N	0.059***	45.0	0.00071	0.099	83.5	0.0068	9.67***	X
N/Mg	8.85	46.6	17.0	7.90	42.8	11.4	0.672	
Mg/N	0.133	37.5	0.0025	0.142	31.7	0.0020	0.809ns	X
N/10 Na	8.36	94.1	61.8	6.55	67.9	19.8	0.320	
10 Na/N	0.214	83.0	0.031	0.238	67.8	0.026	0.833ns	X
N/Cu	0.196	63.8	0.016	0.159	60.2	0.0091	0.586	
Cu/N	6.71	46.8	9.88	8.10	46.2	14.0	1.42ns	X
100 N/Fe	3.69	149.6	30.5	2.16	142.1	9.40	0.308	
Fe/100 N	0.793***	82.7	0.429	2.26	96.7	4.76	11.1***	X
N/Zn	0.091	42.1	0.0015	0.071	52.5	0.0014	0.953	
Zn/N	13.0**	40.5	27.6	17.4	46.8	66.5	2.41**	X
N/Mn	0.024	50.8	0.00015	0.014	49.1	0.000048	0.330	
Mn/N	51.3***	43.6	501.9	101.2	79.9	6533.4	13.0***	X
P/K	0.063	69.5	0.0019	0.067	101.8	0.0047	2.46**	X
K/P	22.7	55.0	156.2	23.7	68.0	260.1	1.67	
P/Ca	1.34	48.7	0.428	1.05	73.0	0.588	1.37	
Ca/P	0.912**	42.6	0.151	1.57	91.2	2.04	13.5***	X
P/Mg	0.549	38.8	0.045	0.552	42.9	0.056	1.23	
Mg/P	2.06	32.5	0.445	2.58	134.6	12.1	27.2***	X
P/Na	5.54	105.9	34.4	4.78	79.4	14.4	0.418	
Na/P	0.334	76.9	0.066	0.451	151.2	0.464	7.05***	X
10 P/Cu	0.125	65.4	0.0067	0.116	78.8	0.0083	1.24	
Cu/10 P	10.6***	47.2	25.1	13.8	89.8	152.7	6.08***	X
1000 P/Fe	2.59	162.8	17.8	1.29	149.1	3.69	0.208	
Fe/1000 P	1.29***	81.7	1.11	3.17	106.3	11.3	10.2***	X
100 P/Zn	0.573	40.9	0.055	0.474	49.8	0.056	1.02	
Zn/100 P	2.02***	37.8	0.583	2.74	71.0	3.79	6.50***	X
100 P/Mn	0.153	54.7	0.0070	0.097	51.9	0.0026	0.364	
Mn/100 P	8.21***	49.9	16.8	16.3	95.7	244.7	14.6***	X
K/Ca	26.5	45.9	148.0	21.3	67.8	208.8	1.41	
Ca/K	0.051**	71.1	0.0013	0.088	101.6	0.0080	6.10***	X
K/Mg	12.9	78.7	102.7	12.2	74.7	83.5	0.813	
Mg/K	0.127	67.4	0.0073	0.148	120.1	0.032	4.34***	X
K/100 Na	1.13	88.2	1.00	1.06	98.5	1.10	1.10	
100 Na/K	2.15	127.2	7.50	2.69	142.9	14.8	1.97**	X
K/Cu	0.289	95.4	0.076	0.229	75.7	0.030	0.394	
Cu/K	6.37	73.4	21.9	7.34	87.7	41.4	1.89*	X
100 K/Fe	4.48	157.4	49.8	2.77	147.2	16.6	0.333	
Fe/100 K	0.577***	67.5	0.152	1.77	129.4	5.24	34.5***	X
K/Zn	0.137	76.1	0.011	0.108	77.6	0.0070	0.647	
Zn/K	13.0	72.2	87.5	17.7	118.7	439.1	5.02***	X
K/Mn	0.033	74.4	0.00060	0.019	60.0	0.00013	0.218	

Table 9. Continued

Mn/K	47.3**	69.2	1072.6	80.1	79.7	4073.6	3.80***	X
Ca/Mg	0.479**	49.1	0.055	0.811	100.9	0.669	12.1***	X
Mg/Ca	2.66	53.8	2.05	2.15	67.4	2.09	1.02	
Ca/Na	4.22	72.0	9.25	5.04	66.6	11.3	1.22ns	X
Na/Ca	0.411	82.8	0.116	0.281	56.0	0.025	0.213	
10 Ca/Cu	0.109	68.7	0.0057	0.146	102.7	0.022	3.98***	X
Cu/10 Ca	13.9	65.7	82.9	11.2	65.7	54.0	0.651	
1000 Ca/Fe	2.26	181.6	16.9	1.45	124.5	3.28	0.195	
Fe/1000 Ca	1.51**	71.8	1.17	2.82	127.2	12.8	11.0***	X
100 Ca/Zn	0.516	66.1	0.117	0.658	81.3	0.286	2.45**	X
Zn/100 Ca	2.63	53.9	2.01	2.47	63.0	2.42	1.21	
100 Ca/Mn	0.127	51.9	0.0043	0.116	62.2	0.0052	1.21	
Mn/100 Ca	9.90	46.7	21.4	12.4	70.0	75.7	3.54***	X
Mg/Na	11.4	121.7	191.5	9.04	71.9	42.3	0.221	
Na/Mg	0.171	73.8	0.016	0.183	77.0	0.020	1.25ns	X
Mg/Cu	0.024	56.2	0.00018	0.022	66.6	0.00022	1.21	
Cu/Mg	56.1	56.5	1005.0	64.4	64.3	1718.8	1.71*	X
1000 Mg/Fe	5.90	167.6	97.7	3.83	190.5	53.1	0.544	
Fe/1000 Mg	0.781**	94.1	0.540	2.21	165.2	13.3	24.7***	X
100 Mg/Zn	1.11	42.8	0.226	0.941	46.6	0.192	0.850	
Zn/100 Mg	1.04	36.2	0.140	1.30	54.5	0.503	3.58***	X
100 Mg/Mn	0.310	61.3	0.036	0.197	52.1	0.011	0.291	
Mn/100 Mg	4.47	63.9	8.14	8.95	169.7	230.6	28.3***	X
100 Na/Cu	0.455	127.5	0.337	0.325	66.8	0.047	0.140	
Cu/100 Na	5.55	101.6	31.9	4.68	67.1	9.87	0.310ns	X
10000 Na/Fe	7.92	175.7	193.5	4.93	169.4	69.7	0.360	
Fe/10000 Na	0.585**	92.1	0.290	1.29	124.0	2.56	8.82***	X
1000 Na/Zn	1.76	76.7	1.83	1.74	108.7	3.59	1.96**	X
Zn/1000 Na	1.07	119.9	1.63	1.13	82.2	0.860	0.526	
1000 Na/Mn	0.453	74.0	0.112	0.320	86.8	0.077	0.687	
Mn/1000 Na	4.06	100.5	16.7	5.86	85.6	25.2	1.51ns	X
10 Cu/Fe	2.58	175.7	20.6	1.85	160.3	8.76	0.426	
Fe/10 Cu	1.67**	117.4	3.86	3.63	120.8	19.2	4.98***	X
Cu/Zn	0.564	53.2	0.090	0.598	78.7	0.222	2.46	
Zn/Cu	2.26	47.2	1.14	2.91	96.2	7.83	6.88***	X
Cu/Mn	0.155	62.0	0.0092	0.108	62.2	0.0045	0.490	
Mn/Cu	9.70**	69.5	45.4	14.4	77.2	122.9	2.71***	X
Fe/Zn	8.22**	101.8	70.1	18.1	132.5	574.9	8.21***	X
Zn/Fe	0.565	166.8	0.889	0.373	139.6	0.272	0.306	
Fe/Mn	1.99	115.2	5.28	2.83	105.9	9.00	1.70*	X
Mn/Fe	2.06	156.9	10.4	1.68	131.2	4.86	0.466	
Zn/Mn	0.284	42.1	0.014	0.233	54.8	0.016	1.13	
Mn/Zn	4.57	79.3	13.1	7.07	114.1	65.1	4.96***	X

Mean of nutrient ratios of low- and high-yielding groups are different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

Discussion

Pineapples are widely grown on types of soil containing loads of obstacles, such as acid sulfate soil, limiting plant development, despite the fact that they are capable of tolerating adverse conditions, such as low pH, low fertility, and high Al^{3+} and Fe^{2+} concentrations (Maia et al., 2020). An appropriate pH for pineapples is roughly 5.5 (Hossain et al.,

Table 10. Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding groups, the variance ratio (S^2_l/S^2_h) and the selected ratios for the leaf +29 DRIS norm set

Ratio of nutrients	High-yielding group (n = 23)			Low-yielding group (n = 37)			S^2_l/S^2_h	SR
	Mean	CV (%)	Variance (S^2_h)	Mean	CV (%)	Variance (S^2_l)		
N/P	21.2	88.7	353.0	18.0	73.3	173.5	0.492	
P/N	0.060	36.1	0.00047	0.068	36.4	0.00061	1.30^{ns}	X
N/K	0.946	67.1	0.403	1.42	111.0	2.49	6.18***	X
K/N	1.38	44.1	0.370	1.18	59.3	0.486	1.32	
N/Ca	21.5	61.5	174.7	15.5	53.1	67.7	0.387	
Ca/N	0.058**	39.4	0.00053	0.093	82.3	0.0058	11.0***	X
N/Mg	9.94	43.1	18.4	8.35	36.9	9.52	0.518	
Mg/N	0.115	33.8	0.0015	0.134	32.6	0.0019	1.26^{ns}	X
N/10 Na	7.50	106.5	63.8	5.39	63.9	11.9	0.186	
10 Na/N	0.212	71.0	0.023	0.243	49.4	0.014	0.637^{ns}	X
N/Cu	0.181	61.4	0.012	0.274	265.1	0.528	42.7***	X
Cu/N	7.74	58.9	20.8	8.67	54.5	22.4	1.08	
100 N/Fe	3.65	109.3	15.9	2.08	119.1	6.14	0.386	
Fe/100 N	0.723***	86.0	0.387	2.20	98.4	4.69	12.1***	X
N/Zn	0.102	45.3	0.0021	0.068	37.1	0.00063	0.294	
Zn/N	12.3**	52.4	41.7	16.8	34.7	33.8	0.810^{ns}	X
N/Mn	0.023	25.52	0.000035	0.015	45.4	0.000047	1.33	
Mn/N	46.1***	30.0	190.9	93.1	81.4	5740.1	30.1***	X
P/K	0.060	106.5	0.0040	0.094	111.3	0.011	2.73***	X
K/P	27.4	62.4	292.2	20.1	75.8	232.9	0.797	
P/Ca	1.30	77.2	1.00	1.08	73.4	0.629	0.628	
Ca/P	1.22	92.0	1.26	1.62	88.2	2.04	1.62^{ns}	X
P/Mg	0.601	58.4	0.12	0.569	54.6	0.097	0.786^{ns}	X
Mg/P	2.76	150.5	17.2	2.41	84.8	4.18	0.243	
P/Na	4.41	92.5	16.6	3.60	67.9	5.96	0.358^{ns}	X
Na/P	0.642	243.4	2.44	0.415	61.0	0.064	0.026	
10 P/Cu	0.104**	70.3	0.0053	0.234	339.0	0.630	118.0***	X
Cu/10 P	14.4	65.0	87.8	15.8	88.7	196.8	2.24	
1000 P/Fe	2.55	149.5	14.5	1.27	134.7	2.95	0.203	
Fe/1000 P	1.44***	89.8	1.67	3.28	93.7	9.42	5.63***	X
100 P/Zn	0.586	51.1	0.090	0.467	57.2	0.071	0.795	
Zn/100 P	2.48***	95.7	5.62	3.23	115.1	13.8	2.45**	X
100 P/Mn	0.140	42.5	0.0036	0.105	64.1	0.0046	1.28	
Mn/100 P	10.1	108.4	120.2	17.5	114.6	401.1	3.34***	X
K/Ca	26.4	50.9	180.6	16.8	75.1	159.8	0.885	
Ca/K	0.050***	56.6	0.00079	0.114	115.5	0.017	21.8***	X
K/Mg	14.2	72.3	105.8	9.73	71.4	48.2	0.456	
Mg/K	0.109	67.8	0.0055	0.188	124.6	0.055	10.0***	X
K/100 Na	0.937	68.2	0.409	0.669	104.3	0.487	1.19	
100 Na/K	2.02	105.0	4.50	3.59	135.2	23.6	5.23***	X
K/Cu	0.265	93.8	0.062	0.374	309.7	1.34	21.7***	X
Cu/K	7.83	111.8	76.7	13.0	158.7	423.3	5.52	
100 K/Fe	3.64	103.4	14.1	2.27	123.9	7.90	0.558	
Fe/100 K	0.463**	62.0	0.082	3.74	247.7	85.7	1040.7***	X
K/Zn	0.158	79.5	0.016	0.083	80.9	0.0045	0.284	
Zn/K	12.8**	88.6	128.6	25.3	130.5	1089.0	8.47***	X
K/Mn	0.032	54.0	0.00030	0.016	75.5	0.00015	0.516	

Table 10. Continued

Mn/K	42.4***	68.2	838.6	105.2	89.4	8852.7	10.6***	X
Ca/Mg	0.552	48.2	0.071	0.784	94.5	0.549	7.74***	X
Mg/Ca	2.36	65.4	2.37	2.08	61.6	1.64	0.689	
Ca/Na	3.77	61.0	5.28	4.31	70.2	9.15	1.73*	X
Na/Ca	0.418	79.3	0.110	0.345	63.0	0.047	0.43	
10 Ca/Cu	0.110	78.1	0.0074	0.240	238.2	0.327	44.1***	X
Cu/10 Ca	16.8	80.0	180.9	13.3	78.9	109.5	0.605	
1000 Ca/Fe	2.11	158.2	11.2	1.29	109.0	1.97	0.176	
Fe/1000 Ca	1.26**	75.4	0.900	2.77	116.2	10.4	11.5***	X
100 Ca/Zn	0.600	66.6	0.159	0.611	78.2	0.229	1.43ns	X
Zn/100 Ca	2.59	76.3	3.91	2.66	74.0	3.86	0.986	
100 Ca/Mn	0.133	43.6	0.0033	0.113	50.5	0.0032	0.966	
Mn/100 Ca	9.42	53.7	25.6	11.4	53.6	37.6	1.47ns	X
Mg/Na	7.85	82.7	42.1	7.29	78.6	32.9	0.780	
Na/Mg	0.194	61.4	0.014	0.203	62.3	0.016	1.12ns	X
Mg/Cu	0.021	67.7	0.00021	0.029	179.3	0.0027	12.8***	X
Cu/Mg	81.2	85.9	4865.5	68.7	57.7	1572.8	0.323	
1000 Mg/Fe	4.49	118.0	28.1	2.98	123.0	13.5	0.480	
Fe/1000 Mg	0.792***	101.4	0.644	2.07	114.5	5.61	8.70***	X
100 Mg/Zn	1.07	39.3	0.178	0.862	39.6	0.116	0.653	
Zn/100 Mg	1.11	48.3	0.287	1.33	37.0	0.243	0.847ns	X
100 Mg/Mn	0.269	39.1	0.011	0.194	48.4	0.0088	0.800	
Mn/100 Mg	4.69	60.9	8.14	7.91	127.2	101.2	12.4***	X
100 Na/Cu	0.384	97.3	0.140	0.574	220.9	1.61	11.5***	X
Cu/100 Na	5.54	93.0	26.5	4.60	88.2	16.5	0.620	
10000 Na/Fe	8.27	133.6	121.9	4.76	137.4	42.8	0.351	
Fe/10000 Na	0.500**	100.0	0.25	1.07	111.8	1.44	5.75***	X
1000 Na/Zn	1.97	72.1	2.02	1.64	65.1	1.15	0.569	
Zn/1000 Na	0.797	84.5	0.453	0.924	85.3	0.621	1.37ns	X
1000 Na/Mn	0.457	58.4	0.071	0.331	55.1	0.033	0.47	
Mn/1000 Na	3.11	78.3	5.92	4.25	71.4	9.22	1.56ns	X
10 Cu/Fe	2.89	116.2	11.3	1.91	131.4	6.31	0.560	
Fe/10 Cu	1.60	141.5	5.12	7.51	321.2	581.5	113.5***	X
Cu/Zn	0.793	79.9	0.401	0.548	61.4	0.113	0.282	
Zn/Cu	2.18	77.3	2.85	3.47	176.7	37.5	13.2***	X
Cu/Mn	0.182	70.04	0.016	0.124	68.44	0.0072	0.443	
Mn/Cu	8.26	64.6	28.5	19.2	183.0	1238.0	43.5***	X
Fe/Zn	9.16**	106.3	94.6	15.4	90.6	195.3	2.06**	X
Zn/Fe	0.579	146.0	0.715	0.389	124.5	0.235	0.329	
Fe/Mn	1.65**	91.8	2.29	3.35	111.9	14.0	6.12***	X
Mn/Fe	1.71	129.1	4.86	1.74	136.8	5.64	1.16	
Zn/Mn	0.283	51.8	0.021	0.247	51.2	0.016	0.745	
Mn/Zn	4.82	71.0	11.7	6.32	99.5	39.6	3.38***	X

Mean of nutrient ratios of low- and high-yielding groups different at 1% (***), 5% (**) and 10% (*) significant level of probability by T test; variances of nutrient ratios of low- and high-yielding groups are significantly different at 1% (***), 5% (**) and 10% (*) level of probability by F test; ns: no significant difference; SR: Selected ratio

2016). In the present study, the soil for pineapple plantation in Hoa Tien, Tan Tien, Vinh Vien, and Vinh Vien A had low pH and high concentrations of Al^{3+} and Fe^{2+} up to 20.4 meq Al^{3+} 100 g^{-1} and 787.7 mg kg^{-1}, respectively (Our preliminary data). According to Panhwar et al. (2015), the Al^{3+} toxicity is a factor limiting plant growth in acid sulfate soils (ASS) the most. At the same time, P availability is affected by pH value. Low pH results in bonding between Al^{3+} and Fe^{2+} and P,

Table 11. Comparison between the created DRIS norm sets for pineapples in acid sulfate soil and other DRIS norm sets in the world

Ratio of nutrients	Norms at leaf +1		Norms at leaf +3		Norms at leaf +7		Agbangba et al. (2011a)		Agbangba et al. (2011b)		Teixeira et al. (2009)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Ca/N	–	–	0.070	51.2	–	–	–	–	–	–	–	–
Ca/K	0.035	52.7	0.039	59.7	0.032	54.7	–	–	0.9	38.6	0.20	33
Ca/Mg	–	–	–	–	–	–	–	–	–	–	–	–
Ca/N	0.079	71.8	–	–	0.064	63.8	–	–	–	–	–	–
Ca/P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/10 P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/K	4.66	67.0	–	–	–	–	–	–	–	–	–	–
Fe/10 Cu	1.45	122.3	1.16	116.9	–	–	–	–	–	–	–	–
Fe/100 K	0.350	85.2	0.369	79.0	0.429	101.5	–	–	–	–	–	–
Fe/100 N	0.904	98.2	0.859	105.1	0.946	104.6	–	–	–	–	–	–
Fe/1000 Ca	1.34	100.7	1.27	86.9	–	–	–	–	–	–	–	–
Fe/1000 Mg	0.733	109.7	0.734	115.8	–	–	–	–	–	–	–	–
Fe/1000 P	0.791	96.3	0.922	111.8	–	–	–	–	–	–	–	–
Fe/10000 Na	0.584	99.9	0.577	109.6	0.650	107.8	–	–	–	–	–	–
Fe/Zn	–	–	5.35	107.7	7.60	117.1	–	–	–	–	–	–
Fe/Mn	1.60	107.9	–	–	–	–	–	–	–	–	–	–
Mg/N	0.143	23.8	–	–	–	–	0.6	32.2	–	–	–	–
Mg/K	0.070	43.2	–	–	0.067	46.5	–	–	0.4	42.9	0.14	27
Mn/100 Mg	–	–	3.26	57.3	3.86	54.4	–	–	–	–	–	–
Mn/100 P	–	–	4.52	56.3	–	–	–	–	–	–	–	–
Mn/1000 Na	–	–	2.69	76.2	2.83	54.5	–	–	–	–	–	–
Mn/Cu	–	–	5.84	64.7	–	–	–	–	–	–	–	–
Mn/K	27.5	43.9	22.4	36.6	22.7	44.1	–	–	–	–	–	–
Mn/N	62.4	70.1	41.1	229.4	42.6	35.8	–	–	–	–	–	–
Mn/Zn	–	–	2.46	55.8	3.12	67.1	–	–	–	–	–	–
Mn/100 Ca	–	–	–	–	–	–	–	–	–	–	–	–
N/K	0.481	27.4	–	–	0.555	39.8	–	–	0.6	44.5	0.59	30
100 Na/K	–	–	–	–	–	–	–	–	–	–	–	–
P/K	–	–	–	–	0.033	40.9	–	–	0.3	54.4	0.04	18
P/N	–	–	–	–	0.061	21.4	0.3	41.9	–	–	0.08	21
P/Na	–	–	6.02	59.4	4.35	64.1	–	–	–	–	–	–
P/Mg	–	–	–	–	0.551	41.0	–	–	–	–	0.34	22
Cu/10 P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/K	–	–	–	–	–	–	–	–	–	–	–	–
10 P/Cu	–	–	0.136	54.2	–	–	–	–	–	–	–	–
100 P/Zn	–	–	–	–	0.442	45.9	–	–	–	–	–	–
Zn/100 Mg	–	–	–	–	–	–	0.0021**	50.4	–	–	–	–
Zn/100 P	1.81	42.5	–	–	–	–	0.0046*	60.6	–	–	–	–
Zn/K	9.52	52.4	–	–	–	–	0.0007	56.1	–	–	–	–
Zn/N	19.5	35.3	–	–	–	–	0.0013	49.6	–	–	–	–

Note: * Value of the ratio pair of Zn/P; ** Value of the ratio pair of Zn/Mg

and when pH values reach 5.5, the available P concentration in soil rises (Mayakaduwage et al., 2021).

However, pineapples require P nutrient for metabolic growth processes (Chen et al., 2021). Ljung et al. (2009) have also considered that ASS is the poorest soil type due to its low pH leading to an increase in concentrations of

Table 11. Comparison between the created DRIS norm sets for pineapples in acid sulfate soil and other DRIS norm sets in the world (to be continued)

Ratio of nutrients	Norms at leaf +9		Norms at leaf +16		Norms at leaf +18		Agbangba et al. (2011a)		Agbangba et al. (2011b)		Teixeira et al. (2009)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Ca/N	0.062	52.9	0.061	48.4	0.065	49.2	–	–	–	–	–	–
Ca/K	0.035	65.5	0.046	67.4	0.044	60.8	–	–	0.9	38.6	0.20	33
Ca/Mg	0.483	58.8	–	–	–	–	–	–	–	–	–	–
Ca/N	–	–	–	–	–	–	–	–	–	–	–	–
Ca/P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/10 P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/K	–	–	–	–	–	–	–	–	–	–	–	–
Fe/10 Cu	–	–	2.01	116.3	–	–	–	–	–	–	–	–
Fe/100 K	0.447	84.4	0.570	97.6	0.572	105.9	–	–	–	–	–	–
Fe/100 N	0.958	100.0	0.814	90.5	1.04	109.7	–	–	–	–	–	–
Fe/1000 Ca	–	–	–	–			–	–	–	–	–	–
Fe/1000 Mg	0.857	120.3	0.85	118.1	0.994	140.8	–	–	–	–	–	–
Fe/1000 P	1.25	97.0	1.46	107.1	1.73	132.1	–	–	–	–	–	–
Fe/10000 Na	0.824	110.3	0.571	103.2	0.774	106.3	–	–	–	–	–	–
Fe/Zn	8.48	115.0	8.74	119.6	–	–	–	–	–	–	–	–
Fe/Mn	–	–	–	–	–	–	–	–	–	–	–	–
Mg/N	–	–	–	–	–	–	0.6	32.2	–	–	–	–
Mg/K	–	–	–	–	–	–	–	–	0.4	42.9	0.14	27
Mn/100 Mg	3.83	51.8	4.29	62.3	3.68	73.6	–	–	–	–	–	–
Mn/100 P	6.58	44.1	7.95	55.0	6.74	61.4	–	–	–	–	–	–
Mn/1000 Na	–	–	3.48	70.0	3.34	51.5	–	–	–	–	–	–
Mn/Cu	–	–	–	–	–	–	–	–	–	–	–	–
Mn/K	28.6	63.7	39.5	80.6	31.0	61.1	–	–	–	–	–	–
Mn/N	48.6	34.6	51.8	49.1	44.8	51.1	–	–	–	–	–	–
Mn/Zn	3.62	56.6			–	–	–	–	–	–	–	–
Mn/100 Ca	–	–	9.00	36.9	–	–	–	–	–	–	–	–
N/K	–	–	–	–	–	–	–	–	0.6	44.5	0.59	30
100 Na/K	–	–	–	–	1.11	80.1	–	–	–	–	–	–
P/K	0.044	47.6	–	–	–	–	–	–	0.3	54.4	0.04	18
P/N	0.079	27.8	–	–	–	–	0.3	41.9	–	–	0.08	21
P/Na	–	–	–	–	–	–	–	–	–	–	–	–
P/Mg	–	–	–	–	–	–	–	–	–	–	0.34	22
Cu/10 P	10.4	54.0	–	–	–	–	–	–	–	–	–	–
Cu/K	4.50	75.0	–	–	–	–	–	–	–	–	–	–
10 P/Cu	–	–	0.128	55.5	0.115	54.9	–	–	–	–	–	–
100 P/Zn	–	–	–	–	–	–	–	–	–	–	–	–
Zn/100 Mg	–	–	–	–	–	–	0.0021**	50.4	–	–	–	–
Zn/100 P	2.05	47.9	–	–	2.06	62.6	0.0046*	60.6	–	–	–	–
Zn/K	–	–	–	–	–	–	0.0007	56.1	–	–	–	–
Zn/N	–	–	–	–	–	–	0.0013	49.6	–	–	–	–

Note: *Value of the ratio pair of Zn/P; ** Value of the ratio pair of Zn/Mg

potent toxins and a reduction in the availability of nutrients supplied for plants. Globally, some sets of DRIS norms have been created and applied. In detail, studies by Teixeira et al. (2007) and Agbangba et al. (2011a) have been conducted in sandy soil whose fertility is low. When growing pineapple in this type of soil, proper fertilization is a

Table 11. Comparison between the created DRIS norm sets for pineapples in acid sulfate soil and other DRIS norm sets in the world (to be continued)

Ratio of nutrients	Norms at leaf +21		Norms at leaf +22		Norms at leaf +29		Agbangba et al. (2011a)		Agbangba et al. (2011b)		Teixeira et al. (2009)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Ca/N	0.066	61.3	0.059	45.0	0.058	39.4	–	–	–	–	–	–
Ca/K	0.040	0.00060	0.051	71.1	0.050	56.6	–	–	0.9	38.6	0.20	33
Ca/Mg	–	–	0.479	49.1	–	–	–	–	–	–	–	–
Ca/N	–	–	–	–	–	–	–	–	–	–	–	–
Ca/P	0.892	59.3	0.912	42.6	–	–	–	–	–	–	–	–
Cu/10 P	–	–	–	–	–	–	–	–	–	–	–	–
Cu/K	–	–	–	–	–	–	–	–	–	–	–	–
Fe/10 Cu	1.43	140.7	1.67	117.4	–	–	–	–	–	–	–	–
Fe/100 K	0.403	76.2	0.577	67.5	0.463	62.0	–	–	–	–	–	–
Fe/100 N	0.756	87.7	0.792	82.7	0.723	86.0	–	–	–	–	–	–
Fe/1000 Ca	1.30	84.6	1.50	71.8	1.26	75.4	–	–	–	–	–	–
Fe/1000 Mg	0.687	105.4	0.781	94.1	0.792	101.4	–	–	–	–	–	–
Fe/1000 P	1.02	90.0	1.29	81.7	1.44	89.8	–	–	–	–	–	–
Fe/10000 Na	0.548	101.9	0.585	92.1	0.500	100.0	–	–	–	–	–	–
Fe/Zn	–	–	–	–	9.16	106.3	–	–	–	–	–	–
Fe/Mn	–	–	–	–	1.65	91.8	–	–	–	–	–	–
Mg/N	–	–	–	–	–	–	0.6	32.2	–	–	–	–
Mg/K	–	–	–	–	–	–	–	–	–	–	0.14	27
Mn/100 Mg	–	–	–	–	–	–	–	–	–	–	–	–
Mn/100 P	7.86	46.6	8.21	49.9	–	–	–	–	–	–	–	–
Mn/1000 Na	–	–	–	–	–	–	–	–	–	–	–	–
Mn/Cu	–	–	9.70	69.5	–	–	–	–	–	–	–	–
Mn/K	35.6	49.4	47.3	69.2	42.5	68.2	–	–	–	–	–	–
Mn/N	53.9	28.5	51.3	43.6	46.1	30.0	–	–	–	–	–	–
Mn/Zn	–	–	–	–	–	–	–	–	–	–	–	–
Mn/100 Ca	–	–	–	–	–	–	–	–	–	–	–	–
N/K	–	–	–	–	–	–	–	–	0.6	44.5	0.59	30
100 Na/K	–	–	–	–	–	–	–	–	–	–	–	–
P/K	–	–	–	–	–	–	–	–	0.3	54.4	0.04	18
P/N	–	–	–	–	–	–	0.3	41.9	–	–	0.08	21
P/Na	–	–	–	–	–	–	–	–	–	–	–	–
P/Mg	–	–	–	–	–	–	–	–	–	–	0.34	22
Cu/10 P	10.7	51.9	10.6	47.2	–	–	–	–	–	–	–	–
Cu/K	–	–	–	–	–	–	–	–	–	–	–	–
10 P/Cu	–	–	–	–	0.104	70.3	–	–	–	–	–	–
100 P/Zn	–	–	–	–	–	–	–	–	–	–	–	–
Zn/100 Mg	1.05	35.7	–	–	–	–	0.0021**	50.4	–	–	–	–
Zn/100 P	1.96	46.6	2.02	37.8	2.48	95.7	0.0046*	60.6	–	–	–	–
Zn/K	8.94	49.4	–	–	12.8	88.6	0.0007	56.1	–	–	–	–
Zn/N	14.2	35.4	13.0	40.6	–	–	0.0013	49.6	–	–	–	–

Note: *Value of the ratio pair of Zn/P; ** Value of the ratio pair of Zn/Mg

key approach for improving qualities of both plants and soil (Liu et al., 2021). Simultaneously, overfertilization of chemical fertilizers results in a reduction in soil pH, due to the conversion from N in the form of NH_4^+ to NO_3^- releasing H^+ (Hlisnikovský et al., 2022). Ultimately, DRIS norm sets were built for pineapples cultivated in ASS in Hau Giang Province, Vietnam (Table 11).

In the current study, the pineapple yield in the high-yielding group (≥ 13.3 t ha^{-1}) was lower than that in studies by Teixeira et al. (2007) and Agbangba et al. (2011a), where

the yield threshold was > 88 t ha^{-1} and > 65 t ha^{-1}, respectively. This lower yield result might have been caused by several reasons. However, based on significantly different statistical results, mean concentration ratios and variances of a nutrient, differences in yield were due to influences of nutrients. This has also been claimed by Bailey et al. (1997). Various studies for DRIS in pineapples showed that there was potentials in creating DRIS norms at other leaf positions, beside the D leaf (Teixeira et al., 2007; Sema et al., 2010: Agbangba et al., 2011a). Thus, apart from D leaf, leaf positions at +1, +3, +7, +9, +16, +18, +21, +22, and +29 were also suitable for creating norms for pineapple (Tables 2–10). At the same time, this study also evaluated elements, including Na, Cu, Fe, and Mn, so the number of nutrients was higher than those in the norms created by Angeles et al. (1990); Teixeira et al. (2007); Agbangba et al. (2011a, b). Therefore, the number of nutrient ratio pairs was higher, with 40 pairs in total. In addition, there were 11 nutrient ratio pairs, including Ca/K, Mg/N, Mg/K, N/K, P/K, P/N, P/Mg, Zn/100 Mg, Zn/100 P, Zn/K, and Zn/N, similar to those in studies by Teixeira et al. (2007) and Agbangba et al. (2011a, b). In the study by Angeles et al. (1990), a standard set of DRIS norms for pineapple has been established from 1,185 samples from many previous publications in different countries. However, in this study, DRIS norm sets were built in order to precisely evaluate nutrient status of plant pineapples cultivated in acid sulfate soil, which was popularly utilized in VMD, Vietnam.

Conclusions

Pineapple yield in the high-yielding group was higher than that in the low-yielding one, with the corresponding yield at 17.8 and 10.6 t ha^{-1}. On the other hand, at leaf positions from +1 to +30, nutrient concentrations of N, P, K, Ca, Mg, Na, Cu, Fe, Zn, and Mn differed at 1 or 5% significant level between the high-yielding and the low-yielding groups. DRIS norms were created at leaf +1, +3, +7, +9, +16, +18, +21, +22, and +29, with the corresponding number of nutrient ratio pairs of 19, 19, 18, 19, 16, 16, 19, 19, and 15 pairs. Moreover, the created DRIS norm sets were highly reliable due to high variance ratios of the nutrient ratio pairs.

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