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EVALUATING THE DRIS NORMS FOR WHEAT BELT OF DISTRICT HYDERABAD, PAKISTAN

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Diagnosis and Recommendation Integrated System (DRIS) is a well-known approach to quantify the nutrient balance for the determination of crop yield and quality. The DRIS interprets leaf analysis values on the basis of interrelationships among nutrients, rather than nutrient concentration. This approach is based on the comparison of crop nutrient ratios with optimum values from a high yielding group (DRIS norms). There are controversies regarding use of DRIS norms. Different researchers argue that the DRIS norms developed within one region can also be used for another, while others recommend developing local norms. We conducted a study to evaluate the local DRIS norms for wheat, involving Hyderabad district of Sindh province of Pakistan which is a famous wheat-belt. The objectives of this study were to develop the DRIS norms for Hyderabad district and to compare these norms with the available literature for clarifying the universality of DRIS norms of wheat. One hundred eighty one wheat fields from the whole wheat-belt of the study area were selected on the basis of a survey of wheat-growing areas for two consecutive seasons (2007-08 and 2008-09). Plant sampling of wheat was done for shoot material at GS-29 and for leaf tissue at GS-39 to diagnose the concentration of various nutrients. The study revealed that the DRIS norms for developmental stages GS-29 and GS-39 varied only slightly. Often, slightly higher values can be observed in leaf tissue than for shoot material. However, these differences were non-significant (p=0.05). The study concluded that the DRIS norms for wheat were found same for the development stages GS-29 and GS-39.
Keywords: Nutrient status, DRIS norms, plant analysis, Wheat, Hyderabad

INTRODUCTION

The use of plant analysis as a diagnostic tool for determining the nutrient status of plants, in conjunction with soil testing, is a key component of balanced fertilization. The critical level approach, proposed by Ulrich and Hills (1967), is one of the pioneer methods for assessing plant nutrient status through foliar analysis. Moreover, in contrast to conventional approach of using single critical level, plant nutritionists successfully interpreted plant analysis results using a full concentration range of nutrients (Havlin *et al*., 2014). However, plant analysis requires careful interpretation when using critical ranges or critical values (Rosell *et al*., 1992). Nonetheless, the critical values of a number of plant species also vary with the growth stage. Hence, DRIS (Diagnosis and Recommendation Integrated System) method was developed and successfully used to interpret plant analysis results more accurately (Beaufils, 1973; Ramakrishna *et al*., 2009). This approach provides a valid diagnosis irrespective of plant age or tissue origin, to rank nutrients in their limiting order, and highlight the importance of nutrient balance (Jones, 1993). It compares elemental ratio indices of elements with the established norms from an optimum high-yielding population. A norm is reckoned as a standard value that is used to evaluate nutrient status/relationships in a plant tissue to be diagnosed. Walworth and Sumner (1987) recommended randomly selected several thousand entries to determine DRIS norms. Jones (1993) reported that 10% of the total samples should be selected for high yielding group. The DRIS ranks nutrients, according to the degree of deficiency (or sufficiency), and hence, emphasize the importance of balanced plant nutrition (Jones, 1993). Several plant nutritionists have reported international DRIS norms. However, it has been strongly suggested to determine DRIS norms using local data for the accurate interpretation of plant analysis results (Dara *et al*., 1992). It seems more practicable to use site-specific data for developing preliminary DRIS norms, due to the spatial and temporal variation among various soil types, i.e. various benchmark soil series that differ with respect to their soil physico-chemical properties and nutrient status. A critical review of the scientific literature reveals that although the DRIS norms exist for a number of crop species but these norms are scarce wheat. The present study was conducted to develop the DRIS norms for wheat grown in Southern Sindh province, which is typically the most important wheat-growing belt of Pakistan.

MATERIALS AND METHODS

***Location*:** The study was conducted in Hyderabad district of the southern Sindh, Pakistan. The lands are known to be the most fertile irrigated plains in the region. The Indus River

flows on the northwest side of the district, and the desert Rann of Kach is located in the southeast.

***Cropping pattern*:** Due to low rainfall and high evapotranspiration, canal and groundwater is used for irrigating the crops in the region. The study area is mainly cultivated with wheat-cotton and wheat-sugarcane rotation. Cotton-wheat rotation is the most common practice in the region. Wheat-sugarcane is also practiced where some fields are used for intercropping of sugarcane with wheat.

***Site selection*:** The farmer's fields were selected on the basis of a survey of wheat growing areas of Hyderabad region. Both low- and high-yielding areas, with different crop production management, were involved in this study. Since the DRIS implementation requires over 100 tissue samples for a successful diagnosis of the plant nutrition status in a region, a comprehensive plant sampling was conducted in famers' fields at different development stages during the wheat cropping seasons 2007-2008 (80 samples) and 2008-2009 (101 samples). All samples were collected randomly in places representative of the area (Fig. 1).

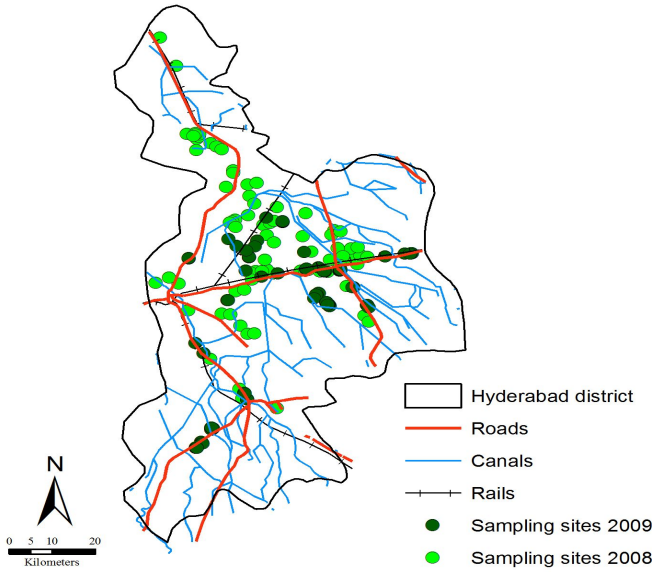

Figure 1. Plant sampling locations in district Hyderabad, Sindh, Pakistan.

***Sampling strategy*:** For sampling, the different growth stages of the wheat crop for determination of mineral nutrients and the assessment by the diagnosis and recommendation integrated system (DRIS) were selected according to recommendations of Reuter and Robinson (1986). The first sampling was done at development stage of plant based on the Zadok scale (Zadok *et al*., 1974). This scale was used since it is internationally recognized for cereal growth stages for research. The whole shoot material was taken above the ground level at the end of the tillering stage (GS-29) from every plot. Four samples were taken from every plot and subsequently pooled. The second sampling was conducted at the emergence of the flag leaf (GS-39). Here the youngest leaf (not flag leaf) was taken from 20 different plants that were randomly selected in the field. These samples were homogenized to make one representative sample of the field. The third sampling was done at harvesting. Plants were counted on one meter square for yield calculation. Twenty plants were selected randomly, and the ears were used to assess the number of grains per spike, number of spikelets and thousand-grains weight.

Plant analysis:

***Drying of wheat plant material* :** The tissues were air-dried in the laboratory, placed in paper bags, oven-dried at 80°C, homogenized, ground and stored in airtight plastic bags. From the composite samples, sub-samples were taken for the analysis of macronutrients (N, P, K) and micronutrients (Zn, Cu, Fe, Mn, and B). The analysis was carried out in the laboratory of the Institute of Plant Nutrition at Bonn University, Germany, in accordance with methods of the Association of German Agricultural Analytical and Research Institutes (VDLUFA). The samples were analyzed in duplicate for each nutrient to reduce analytical error.

***Digestion of plant material*:** The material was wet-digested in Polytetrafluoroethylene (PTFE) bombs, according to Vigler *et al*. (1980) and Okamoto and Fuwa (1984). Dried plant material was subjected to pressure digestion in duplicate: 0.5-g plant material was weighed in Teflon digesting cups, and 4ml of 65% nitric acid (analytical grade) was added for digestion. The PTFE cups were kept in a heating oven at constant temperature (180°C) for one hour. After digestion, the samples were kept overnight for cooling. Then the cups were opened and several rinses were done with ultrapure water (Millipore-Q GmbH, Eschborn) and a constant volume was made in duplicate by the addition of ultrapure water in micro tubes (Eppendorf) for the elemental analysis.

***Elemental analysis*:** Shoot and leaf total nitrogen were determined by the Kjeldahl method, using Vapodest Kjeldahl (Gerhardt GmbH and Co., Bonn). Phosphate in the extract was measured by the reaction of phosphate with ammonium molybdate in an acid medium to form molybdophosphoric acid. Potassium was determined by using a flame photometer (ELEX 6361; Eppendorf). Boron was determined using the modified and miniaturized spectrophotometric curcumin method (Wimmer and Goldbach, 1998). The micronutrients (Zn, Fe, Cu and Mn) were analysed by atomic absorption spectrometry.

***Yield calculation*:** In order to develop the DRIS norms for high-yielding populations, the estimated yield was calculated as the product of number of spikes per square meter, average number of grains per spike and estimated grain weight (mg per 10,000). These data were collected for each site during field work. For determining the number of spikes per square meter, a wooden frame of $1m^2$ was constructed and from the

best 20 plants, ear heads were collected and the number of grains per spike counted. Using a "Numagrain" seed counter, 1000 healthy grains were counted and weighed.

***Establishment of Hyderabad DRIS norms for wheat crop*:** Sumner (1979) suggested a survey-type approach for collecting the crop production data from the random experimental or farmer fields to develop the DRIS norms. These crop production data are used to differentiate between low yielding and high yielding populations. The high yielding population data sets are used to develop the norms. Adopting this approach, yield and nutrient data were collected randomly from 181 sites to represent the wheat production area. This population of observations was then divided into two sub-populations, i.e., high-yielding and low-yielding population, on the basis of yield data. To divide the population, a simple statistical approach was used as described below.

***Partitioning data into high- and low-yielding sub-populations*:** Previous studies have shown that that the selection of the reference population has a significant impact on the effectiveness and success of DRIS. There are several ways to select the reference population. For example, Walworth and Sumner (1987) suggested that the reference limit to separate two populations should be arbitrarily selected, as each population is supposed to present the normal distribution. Letzsch and Sumner (1984) recommended that the reference population should contain at least 10% of the overall database observations. Malavolta *et al*. (1989) recommended that the reference population should be obtained with 80% maximum yield observations. However, in this study, the cut-off value between the high-yielding and low-yielding populations was determined by the most sophisticated statistical method proposed by Cate and Nelson (1971), which is often referred to as a statistical Critical Value Approach (CVA). First, the yield data were arranged in descending order. Starting with the initial yield value (I), the corrected sum of squares of the two populations that result from moving to each successive yield value were calculated, which is also referred to as R^2. By this simple iterative process, a series of R^2 values was obtained from which the maximum R^2 value was selected as a cut-off point, i.e., the yield value where R^2 maximum is a cut-off value between the high-yielding and low-yielding sub-populations.

From the high-yielding population, the mean and coefficient of variance was calculated as proposed by Sumner (1977) for each expression. The expressions representing the norms selected for this study were: N/P, N/K, N/Cu, N/Fe, N/Mn, N/Zn, N/B, P/K, P/Cu, P/Fe, P/Mn, P/Zn, P/B, K/Cu, K/Fe, K/Mn, K/Zn, K/B, Cu/Fe, Cu/Mn, Cu/Zn, Cu/B, Fe/Mn, Fe/Zn, Fe/B, Mn/Zn, Mn/B and Zn/B.

Applying the Cate and Nelson (1965) approach, the maximum R^2 value for shoot material and leaf tissue for both the data sets was 54.68. The samples with higher R^2 values than maximum were referred to as the high-yield or reference population, whereas the remaining samples were referred as low-yielding population. Using this R^2 value, 86 out of 181 samples were referred to as high-yielding or reference population. Sample size selected for high yielding population for developing the DRIS norms (86% of the total samples) was satisfactory as suggested by Walworth (1986) and Jones (1993).

After dividing the nutrient concentrations for all the elements N, P, K, Ca, Mg, Zn, Fe, Cu and Mn into two subgroups, the means and standard deviations of the high and low yielding populations for GS-29 (Table 1) and for GS-39 (Table 2) were compared. Based upon the results of the standard deviations, the sufficiency level with coefficient of variance were also developed (Table 3 & 4).

RESULTS AND DISCUSSION

Results show that the means of the nutrients of the low-yielding population are mostly lower than those of the high-yielding population at the end of the tillering stage. These differences are more visible in the shoot material, where all nutrients of the low -yielding population have a lower concentration than the high-yielding population. The results of the one way univariate analysis of variance (ANOVA) using F and p-values show that the concentration of almost all elements differ significantly at the 5% confidence interval except for Mn and B.

Table 1. Comparison of nutrient concentrations in shoot material (dry weight) at growth stage GS-29; mean and standard deviation (SD) between the high-and low-yielding populations of irrigated wheat 2007-2009

Nutrient	High-yielding population		Low-yielding population		Univariate one-way ANOVA	
	Mean	SD	Mean	SD	F-value	p-value
N (%)	3.76	0.79	2.80	0.78	67.09319	<.05*
P (%)	0.37	0.11	0.22	0.07	124.7834	<.05*
K (%)	5.49	0.79	4.21	0.82	115.0557	<.05*
Fe (mg/kg)	296.53	70.41	260.65	73.66	11.16904	0.001*
Mn (mg/kg)	46.43	11.95	44.62	11.97	1.036494	0.31
Zn (mg/kg)	24.82	6.18	21.79	5.56	12.08809	0.001*
Cu (mg/kg)	11.63	2.28	9.20	2.45	47.59187	<.05*
B (mg/kg)	12.07	6.63	11.11	5.36	1.165241	0.28

Table 2. Comparison of nutrient concentrations in leaf tissue (dry weight) at growth stage GS-39; mean and coefficient of variation (CV) between the high- and low-yielding population in irrigated wheat 2007-2009.

Nutrient	High-yielding population		Low-yielding population		Univariate one-way ANOVA	
	Mean	SD	Mean	SD	F-value	p-value
N (%)	3.80	0.61	3.91	0.59	1.62	0.21
P (%)	0.30	0.11	0.28	0.10	0.67	0.41
K (%)	4.29	0.72	3.99	0.61	9.44	<.05*
Fe (mg/kg)	411.63	59.96	288.77	50.50	223.65	<.05*
Mn (mg/kg)	52.44	15.47	43.95	12.44	16.68	<.05*
Zn (mg/kg)	20.86	5.80	19.14	4.98	4.58	0.03*
Cu (mg/kg)	10.66	2.24	9.32	2.02	18.03	<.05*
B (mg/kg)	11.55	5.04	8.84	5.04	13.04	<.05*

Table 3. Statistical parameters of nutrients in shoot material (dry weight) at growth stage GS-29 for high-yielding population in irrigated wheat 2007-2009

Nutrient	Mean	Sufficiency level	Coefficient of Variance (%)
N (%)	3.76±0.79	2.96-4.55	0.21
P (%)	0.37±0.11	0.25-0.47	0.31
K (%)	5.49±0.79	4.71-6.28	0.14
Fe (mg/kg)	296.53±70.41	226.12-366.93	0.24
Mn (mg/kg)	46.43±11.95	34.48-58.38	0.26
Zn (mg/kg)	24.82±6.18	18.64-31	0.25
Cu (mg/kg)	11.63±2.28	9.35-13.91	0.20
B (mg/kg)	12.07±6.63	5.44-18.70	0.55

Table 4. Statistical parameters of nutrients of leaf tissue (dry weight) at growth stage GS-39 for high-yielding population in irrigated wheat 2007-2009

Nutrients	Mean	Sufficiency level	Coefficient of Variance (%)
N (%)	3.80±0.61	3.19-4.41	0.16
P (%)	0.3±0.11	0.19-0.40	0.37
K (%)	4.27±0.72	3.58-5.01	0.17
Fe (mg/kg)	411.63±59.96	351.67-471.59	0.15
Mn (mg/kg)	52.44±15.47	36.97-67.91	0.30
Zn (mg/kg)	20.86±5.8	15.06-26.65	0.28
Cu (mg/kg)	10.66±2.24	8.42-12.91	0.21
B (mg/kg)	11.55±5.04	6.51-16.59	0.44

The statistical analysis of the nutrients in leaf tissue at growth stage GS-39 yielded almost the same results as for the earlier sampling at growth stage GS-29. The *p-value* is below 0.05 for almost all nutrients except P. This is the first indication that high- and low -yielding populations differ significantly. Although this analysis does not have any influence on developing the DRIS norms for the interpretation of the nutrient availability, this analysis gives a first impression on the nutrient concentrations at both plant-growth stages. The ANOVA (*F* and *p*-test) for the comparison of the means of the nutrient ratios between the high- and low-yielding populations for shoot material showed that 17 out of 28 ratios differed significantly at the 0.05 confidence interval (Table 5). The results were almost the same when the analysis was conducted for leaf tissue (Table 6). The ratios in the leaf tissue were also 17, but 9 of these ratios were different from the shoot tissue. The ratios with significant differences between the high- and low-yielding populations for shoot material include N/P, Fe/N, Mn/N, N/Zn, K/P, Fe/P, Mn/P, Zn/P, Cu/P, B/P, Fe/K, Mn/K, K/Zn, Fe/Cu, Mn/Zn, Mn/Cu, and Zn/Cu. The ratios with significant differences between the high- and low-yielding populations for leaf tissue are N/K, Fe/N, Mn/N, N/Zn, N/Cu, N/B, Fe/P, B/P, Fe/K, Mn/K, K/B, Fe/Mn, Fe/Zn, Fe/Cu, Mn/B, Zn/B, and Cu/B.

***Norms for shoot material and leaf tissue*:** All ratios with a significant difference between the high and low-yielding populations were considered as DRIS norms (Table 7). However, ratios that yielded non-significant variance relations between the low and high-yielding population can be included in the analysis according to Beaufils and Sumner (1977) that retained the highest variance relation in order to be sure to take into consideration the interaction with other elements.

According to the original concept of the DRIS, the system should be applicable irrespective of the variety and age of the sampled plants (Sumner, 1981). This capacity of DRIS was also rated as a major advantage over the critical value approach. Keeping this advantage in mind, the norms of leaf tissue (sampled at GS-39) and shoot material (sampled at GS-29) should be similar. To test the validity of this approach, an analysis of variance (ANOVA) was performed (Table 8) between GS-29 and GS-39. The ANOVA was applied for the ratios that were similar in both samples: Fe/N, Mn/N, N/Zn, Fe/P, B/P, Fe/K, Mn/K, and Fe/Cu. It can be seen that the norms for leaf tissue and shoot material differ slightly. Often, slightly higher values can be observed in leaf tissue than for shoot material. However, these differences are non-significant at p = 5%.

Table 5. Comparison of individual nutrients, nutrient ratio means and coefficient of variation (CV) between the high- and low-yielding populations for shoot material (GS-29)

	High-yielding population		Low-yielding population		Univariate one-way ANOVA	
Ratio	**Mean**	**CV (%)**	**Mean**	**CV (%)**	**F-value**	**p-value**
N/P	11.47±5.35	47	14.18±6.22	44	1.68	0.002*
N/K	0.7±0.19	27	0.71±0.28	39	7.87	0.95
Fe/N	83.61±31.69	38	110.15±85.5	78	123.33	0.007*
Mn/N	13.32±7.04	53	18.65±14.14	76	15.01	0.002*
N/Zn	0.16±0.05	32	0.14±0.06	43	4.64	0.0043*
N/Cu	0.33±0.09	26	0.33±0.14	42	8.05	0.86
N/B	0.4±0.23	56	0.39±0.42	108	10.14	0.93
K/P	16.66±7.21	43	21.3±7.84	37	0.076	<0.05*
Fe/P	898.19±426.33	47	1322.69±559.52	42	19.53	<0.05*
Mn/P	141.36±67.03	47	227.34±95.66	42	3.06	<0.05*
Zn/P	76.49±38.36	50	110.67±44.94	41	0.041	<0.05*
Cu/P	35.12±14.68	42	46.91±20.74	44	1.25	<0.05*
B/P	37.1±27.34	74	56.79±33.72	59	5.53	<0.05*
Fe/K	55.01±15.26	28	63.68±19.65	31	55.28	0.002*
Mn/K	8.53±2.19	26	10.96±3.59	33	4.62	<0.05*
K/Zn	0.23±0.06	26	0.2±0.06	30	.0003	0.002*
K/Cu	0.48±0.08	16	0.47±0.09	19	1.185	0.46
K/B	0.61±0.41	67	0.57±0.57	100	7.695	0.56
Fe/Mn	6.92±2.78	40	6.34±2.78	44	10.345	0.16
Fe/Zn	12.55±3.89	31	12.64±4.38	35	35.282	0.89
Fe/Cu	26.26±7.48	28	29.52±8.95	30	11.864	0.0089*
Fe/B	32.67±21.76	67	34.49±34.12	99	0.142	0.67
Mn/Zn	1.97±0.73	37	2.2±0.87	40	2.646	0.06*
Mn/Cu	4.07±1.07	26	5.21±2.05	39	0.285	<0.05*
Mn/B	5.12±3.53	69	6.23±6.62	106	3.273	0.17
Zn/Cu	2.18±0.54	25	2.5±0.8	32	0.231	0.0024*
Zn/B	2.76±2.08	75	2.84±2.54	89	7.305	0.82
Cu/B	1.26±0.79	63	1.18±1.01	86	5.483	0.54

Table 6. Comparison of individual nutrients, nutrient ratio means and coefficient of variation (CV) between the high- and low-yielding populations for leaf tissue (GS-39)

Ratio	High-yielding population		Low-yielding population		Univariate one-way ANOVA	
	Mean	**CV (%)**	**Mean**	**CV (%)**	**F-value**	**p-value**
N/P	14.64±6.53	45	15.91±6.61	42	1.68	0.197
N/K	0.91±0.21	24	1.01±0.26	26	7.87	0.006*
Fe/N	111.72±27.41	25	75.18±15.86	21	123.33	<0.05*
Mn/N	14.28±4.98	35	11.62±4.25	37	15.01	0.000*
N/Zn	0.2±0.07	34	0.22±0.06	27	4.64	0.033*
N/Cu	0.38±0.15	40	0.44±0.15	34	8.05	0.005*
N/B	0.45±0.39	87	0.68±0.56	82	10.14	0.002*
K/P	16.37±6.49	40	16.11±6.27	39	0.076	0.784
Fe/P	1565.83±606.73	39	1191.57±532.57	45	19.53	0.000*
Mn/P	203.03±105.48	52	178.26±84.75	48	3.06	0.082
Zn/P	79±34.14	43	77.88±39.68	51	0.041	0.839
Cu/P	41.08±19.04	46	38.03±17.64	46	1.25	0.266
B/P	45.09±27.38	61	36.11±23.98	66	5.53	0.020*
Fe/K	98.53±21.85	22	74.65±21.33	29	55.28	<0.05*
Mn/K	12.32±3.39	27	11.22±3.5	31	4.62	0.033*
K/Zn	0.22±0.08	37	0.22±0.07	32	0.0003	0.986
K/Cu	0.43±0.20	46	0.46±0.21	46	1.185	0.278
K/B	0.49±0.40	81	0.71±0.61	86	7.695	0.006*
Fe/Mn	8.55±2.77	32	7.21±2.82	39	10.345	0.002*
Fe/Zn	21.23±6.45	30	16.1±5.17	32	35.282	<0.05*
Fe/Cu	41.96±23.47	56	32.61±11.64	36	11.864	0.001*
Fe/B	47.64±40.11	84	49.86±39.4	79	0.142	0.707
Mn/Zn	2.78±1.50	54	2.47±1.07	43	2.646	0.106
Mn/Cu	5.47±4.35	79	5.18±2.89	56	0.285	0.594
Mn/B	6.05±5.13	85	7.85±7.86	100	3.273	0.072
Zn/Cu	2.1±1.27	61	2.18±1.03	47	0.231	0.631
Zn/B	2.33±1.78	76	3.25±2.63	81	7.305	0.008*
Cu/B	1.22±0.99	81	1.62±1.31	81	5.483	0.020*

* Significant at 5 % level of probability. CV = Coefficient of variance

Table 7. Statistical parameters of nutrients forms for high- and low-yielding population in irrigated wheat 2007-2009 for shoot and leaf tissue.

Expression	Norms for leaf tissue		Expression	Norms for shoot material	
	Mean	Coefficient of variance (%)		Mean	Coefficient of variance (%)
N/K	0.91±0.21	24	N/P	11.47±5.35	47
Fe/N	111.72±27.41	25	Fe/N	83.61±31.69	38
Mn/N	14.28±4.98	35	Mn/N	13.32±7.04	53
N/Zn	0.2±0.07	34	N/Zn	0.16±0.05	32
N/Cu	0.38±0.15	40	K/P	16.66±7.21	43
N/B	0.45±0.39	87	Fe/P	898.19±426.33	47
Fe/P	1565.83±606.73	39	Mn/P	141.36±67.03	47
B/P	45.09±27.38	61	Zn/P	76.49±38.36	50
Fe/K	98.53±21.85	22	Cu/P	35.12±14.68	42
Mn/K	12.32±3.39	27	B/P	37.1±27.34	74
K/B	0.49±0.40	81	Fe/K	55.01±15.26	28
Fe/Mn	8.55±2.77	32	Mn/K	8.53±2.19	26
Fe/Zn	21.23±6.45	30	K/Zn	0.23±0.06	26
Fe/Cu	41.96±23.47	56	Fe/Cu	26.26±7.48	28
Mn/B	6.05±5.13	85	Mn/Zn	1.97±0.73	37
Zn/B	2.33±1.78	76	Mn/Cu	4.07±1.07	26
Cu/B	1.22±0.99	81	Zn/Cu	2.18±0.54	25

Table 8. Statistical parameters of nutrients forms for high- and low-yielding populations in irrigated wheat 2007-2009

Source of Variation	SS	df	MS	F	P-value	F crit.
Between populations	36840	1	36840.0	0.19149	0.6684	4.60
Within populations	2693350	14	192382.2			

Table 9. Comparison of DRIS norms of wheat for different regions

Nutrient Ratio	Canada			Washington			Hyderabad		
	Mean	CV	SD	Mean	CV	SD	Mean	CV	SD
N/P	12.74	22.00	2.80	8.40	37.00	3.10	11.47	47.00	5.35
K/N	0.68	24.00	0.16	0.93	38.00	0.36	1.10	24.00	0.21
K/P	8.80	17.00	1.50	7.23	36.00	2.58	16.66	43.00	7.21
N/S	14.22	23.00	3.27	10.77	20.00	2.16			

From the above results, it can be concluded that the developed DRIS norms can be universally applied in the Hyderabad districts of Sindh province. This research work has been done to provide the detailed information regarding available nutrient levels, and identify all nutritional factors that retard optimum crop production of the study area. Furthermore, the DRIS approach can evaluate the nutritional balance of plant nutrients and ranking nutrient levels in relative order, from most deficient to most excessive manner. The results of this study (Table 9) further reveal comparison of DRIS norms of wheat for different regions. In the current study, we developed norms for 28 ratios. The intensive review of the literature illustrates that there is little work done on establishing the DRIS norms for wheat. We can only find 4 nutrient ratios (DRIS norms) for wheat and these are also developed for only macro-nutrients. Therefore, we could not establish a direct comparison of DRIS norms which we developed with the available literature. However, the comparison with the available ratios also highlighted considerable differences between DRIS norms of Hyderabad for wheat and for Washington and Canada.

According to Beaufils (1973), once DRIS norms have been established for a particular crop from a representative data bank incorporating all the variation likely to occur in the areas where the crop is cultivated, they are generally applicable to the crop wherever it might be grown. However, different workers used different nutrient concentration of the high-yielding (or desirable) group to derive their DRIS norms and found that by using different DRIS norms, there will be different optimum nutrient balance which lead to different interpretation (Sumner, 1977; Escano *et al*., 1981; Elwali *et al*., 1985). Indeed, very negligible work has been done on developing the DRIS norms for wheat and there is no direct comparison available, especially for micronutrients.

Moreover, several factors make the universal use of DRIS norms unsuitable, such as climate, soil, and crop genotypes, etc. Hence, we strongly recommend develop/calibrate the local DRIS norms for wheat before interpretation using the DRIS methodology.

The farmers need to know the nutrient concentrations normally found in their high-yielding crops and to adopt those DRIS standards with nutrient ratio values similar to those found in their high-yielding crops before using the DRIS to evaluate the crop nutritional status. Therefore, in the absence of DRIS norms locally calibrated, norms developed under one set of conditions should only be applied to another if the nutrient concentrations of high-yielding plants from these different sets of conditions are similar.

Conclusion: By developing the first-ever wheat DRIS norms for Hyderabad, Pakistan, we concluded that regionally derived norms enable DRIS to provide more reliable nutrient diagnoses for wheat than norms developed from other regions. Hence, the DRIS norms developed under one set of conditions should only be applied to another if the nutrient concentrations of high-yielding plants from these different sets of conditions are similar.

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