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N, P, AND K BALANCE IN WINTER WHEAT IN THE PAMPEAN SEMIARID REGION OF ARGENTINA*

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RESUMEN

BALANCE DE N, P Y K EN TRIGO DE LA REGION SEMIARIDA, ARGENTINA

El Sistema Integrado de Diagnóstico y Recomendación (DRIS) permite establecer el estado y balance nutricional de un cultivo empleando las relaciones de concentración entre nutrientes, independiente de las condiciones ecológicas y de la edad de la planta.

El método se aplicó a la determinación del balance nutricional de N, P y K en diferentes variedades de trigo muestreadas en encañazón y antesis, durante los años 1984, 1985 y 1986 en tres zonas de la región semiárida Argentina.

En casi todos los casos el N aparentó ser el nutriente más deficiente seguido en algunos casos por el K y en otros por el P. También el muestreo de planta entera indicaría una mayor uniformidad en el orden de requerimientos nutricionales en las tres zonas bajo estudio.

Palabras clave: Trigo. Determinación y balance de N, P y K. Método DRIS. Zona semiárida.

SUMMARY

Diagnosis and Recommendation Integrated System (DRIS) allows one to establish the nutritional level and balance of a crop using the nutrient concentration relationships, regardless the ecological condition and the plant age.

The DRIS approach was applied to the determination of the N, P and K nutritional balance of winter wheat sampled at stem elongation (whole plant; Zadoks' scale number 32) and anthesis (2^{nd} and 3^{rd} leaves; number 65) during 1984, 1985 and 1986 in Argentina' semi-arid region.

Each year nitrogen was the most limit nutrient followed, in order of importance, by potassium and in some cases by phosphorus in both sampling stages. The element sequence of the nutritional balance was more uniform when the whole plant was sampled. However, the nutrient balance index (NBI) was lower in the 2^{nd} and 3^{rd} leaf sample, thus indicating a better N-P-K nutritional balance.

Key words: Wheat. N, P and K balance and determination. DRIS method. Semiarid Argentina.

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INTRODUCTION

Soils under wheat cultivation show nutrient deficiencies in Argentina. Nitrogen (N) and, in minor occurrence, phosphorus (P) and potassium (K), are the main essential elements which affect negatively plant growth and yield (Rosell *et al.*, 1987).

In attempting to make diagnoses of conditions limiting crop performance, it should be considered that the yield and quality of wheat are determined by various factors having influence on crop growth. Nutrient elements are one of these direct factors. Plant analysis is an excellent tool to define nutritional needs of crops, but it requires careful interpretation when using the so-called "critical levels" (Melsted *et al.*, 1969). Wolf (1982) employed field observations and soil and plant analysis to get a more complete picture of the crop needs.

The Diagnosis and Recommendation Integrated System (DRIS) proposed by Beaufils (1973) has been used to determine the N, P, K, and some times sulphur (S), calcium (Ca), magnesium (Mg), and micronutrients requirements for various crops. The DRIS procedure is used to measure deviations of actual nutrient concentration ratios in plant tissues from the values of the same ratios previously established as reference values, or norms. These are derived from distributions of certain variables within low and high yielding plant populations from an overall data base. The norms are utilized in empirically-derived equations which result in a set of indices denoting sufficiency or deficiency of each element studied (Beaufils, 1973; Jones, 1985; Sumner, 1977a, b, c, 1981). The lowest (or more negative) DRIS index indicates the most deficient or yield-limiting nutrient in comparison with the other elements tested (Walworth and Sumner, 1987). A DRIS index equal to zero means that the element is present in quantity associated with a high yielding crop. The sum of elemental DRIS indices equals zero; therefore, an assessment of the relative balance among diagnosed nutrients is also possible.

Some of the reasons for using the DRIS procedure are based on the following principles:

a) Ratios of nutrient concentration are often better indicators of nutrient deficiencies than are single nutrient concentrations, regardless the age or part plant selected.

b) Maximum crop yields are obtained when the values of important ratios approach an optimum value, which is close to the main value of the same ratio in a selected high-yielding population.

c) A DRIS index can be calculated for each nutrient. This index is based on the mean deviation of each important ratio from its optimum value.

d) The optimum DRIS index for any nutrient is zero. Negative or positive indices indicate nutrient deficiency or sufficiency, respectively.

The objective of this study was to apply the DRIS procedure to obtain

the N, P, and K nutrient status of several winter wheat *(Triticum aestivum)* varieties in three production zones of semi-arid Argentina.

MATERIALS AND METHODS

Sampling zones

The following three zones of the southern pampean semi-arid region in the Province of Buenos Aires (36° to 38° 44' S; 62° to 64° W), Argentina, distant approximately 150 km among them, were selected for plant sampling in the years 1984, 1985 and 1986:

- Bahía Blanca-Cabildo (on the eastern edge).
- Bordenave (on the western edge).
- Puàn (on the northern edge).

The mean annual precipitation of the region ranges between 550 (on the West) to 650 mm (on the East). Mean annual temperature and evapotranspiration are 15.3 °C and 794 mm (Thornthwaite), repectively. 188 sites of the region were sampled in farmer's fields during the three-year period.

Soils

Soils of the region are typical and/or entic Argiustolls (Bahía Blanca-Cabildo) and Haplustolls (Bordenave and Puàn), fine sandy loam, thermic, pH 6.5 to 7.5, with a caliche or calcareous layer between 50 to 80 cm deep. Soil nutrient levels are not included in this report. Some of them were published previously (Rosell *et al.*, 1982; Landriscini *et al.*, 1990).

Plants

Winter wheat varieties used by farmers in this study were: Buck Napostá, Buck Pucará, Chasicó-INTA, Cooperación Cabildo, and others of minor distribution.

Composite samples of 15 whole plants, excluded the roots, at anthesis (stadium 65 in the Zadoks' international scale; Tottman and Makepeace, 1979) in 1984 and at stem elongation (stadium 32) in 1985 and 1986 were obtained. Samples of the 2nd and 3rd leaves at anthesis (stadium 65) were also made in 1984, 1985 and 1986. Plant samples were washed with distill water, dried in oven at 60 °C and ground (< 40 mesh) in a Wiley mill.

Wheat yields in each site were not recorded. However, it is known the zonal and regional average yield which ranges between 1300 and 1900 kg ha^{-1}.

Analytical procedures

Nutrient plant content, expressed in percent over dry matter, was obtained as follows: nitrogen, semi-micro Kjeldahl; phosphorus and potassium, plant samples were oven-burned at 500-550 °C, and dissolved in dilute hydrochloric acid to a known volume.

Aliquots for P (ammonium vanadate colorimetry) and K (flame photometry) determinations were used.

Nutrient DRIS indices

DRIS indices were obtained by

using the following relationships (Beaufils, 1971, 1973):

N index = [f (N:P + f (N:K)]: X;
P index = [− [f (N:P) + f (K:P)] : X

and

K index = [f (K:P) − f (N:K)]: X
where X = number of functions in the numerator (2)

For the N index:

f (N:P) = [(N:P/n:P) − 1] 1000:CV,

when N:P < n:p and N:P is the actual value of the ratio of % N and % P in the plant being diagnosed; n:p is the value of the reference norm from high-yielding wheat plants.

CV, is the coefficient of variation of this norm's population (Table 1) and, 1000, (100 x 10), where the value 100 is used to cancel out the denominator of the coefficient of variation expressed as a percentage and 10 is a value included as a matter of practicality to give the resultant indices convenient magnitudes and having no actual functional purpose.

The P and K indices were similarly calculated.

DRIS indices have positive (sufficient) and negative (deficient) values. Their sum is equal to zero for any nutrient combination.

The nutritional balance index (NBI) was calculated as the absolute sum of the indices for the individual nutrients (Elwali and Gascho, 1984, 1988; Jones *et al.*, 1986). Balance among any group of nutrients improves as the NBI approaches zero.

TABLE 1

DRIS foliar diagnostic reference norms for N, P and K in wheat (Sumner, 1981).

RELATIONSHIP	MEAN VALUE	COEFFICIENT OF VARIATION, %
n:p	12.74	22
n:k	1.45	20
k:p	8.80	17

RESULTS AND DISCUSSION

Tables 2, 3 and 4 contain the nutrient composition, DRIS indices, order of deficiency and its relative frequency (percentage of cases with the same order of deficiency) and NBI of winter wheat sampled at different growth stages in the southern pampean semi-arid region of Argentina in 1984, 1985 and 1986, respectively. Table 5 presents the weighed average DRIS diagnosis and the standard deviation for the three sites and the three years under study. Table 6 shows the soil availa-

ble water (AW) obtained from rainfall precipitated in the fallow periods, assuming a 15% efficiency of the accumulated water (Galantini *et al.*, in press), plus rainfall registered from wheat seeding to plant sampling, and the corresponding NBI values in the same years.

The data allows one to formulate some observations and predictions as follows:

— Winter wheat nutrient diagnoses had similar values and tendencies in the three studied zones of the semi-arid region of Argentina and during three consecutive years.

— The order of deficiency of the whole plant sampling either at elongation or anthesis present more uniformity (higher relative frequency) than the leaf sampling.

— Nitrogen was the most deficient nutrient, being either K or P, alternatively, in the second order of deficiency.

TABLE 2

Nutrient composition, DRIS indices, order of deficiency and NBI for winter wheat in semi-arid Argentina, 1984.

PLANT NUTRIENT, (%)			DRIS INDICES			ORDER OF DEFICIENCY	REL. 1 FREQ. (%)	2 NBI
N	P	K	N	P	K			
WHOLE PLANT AT ANTHESIS								
Cabildo (22 sites)								
1.17	0.19	1.43	–48	36	12	N>K>P	77	96
Bordenave (13 sites)								
1.06	0.19	1.54	–59	35	24	N>K>P	61	118
Puán (37 sites)								
0.78	0.15	0.97	–52	45	7	N>K>P	81	104
2ND & 3RD LEAVES AT ANTHESIS								
Cabildo (22 sites)								
2.69	0.25	1.71	– 1	16	–15	K>N>P	59	32
Bordenave (13 sites)								
1.79	0.21	1.94	–28	11	17	N>P>K	54	56
Puán (37 sites)								
1.29	0.17	1.69	–39	10	29	N>P>K	67	78

1 Rel. Freq., relative frequency.
2 NBI, Nutritional Balance Index.

TABLE 3

Nutrient composition, DRIS indices, order of deficiency and NBI for winter wheat in semi-arid Argentina, 1985.

PLANT NUTRIENT, (%)			DRIS INDICES			ORDER OF DEFICIENCY	REL. 1 FREQ. (%)	2 NBI
N	P	K	N	P	K			
WHOLE PLANT AT STEM ELONGATION								
				Cabildo (27 sites)				
2.21	0.26	2.72	–32	4	27	N>P>K	78	63
				Bordenave (13 sites)				
1.71	0.26	2.67	–55	19	36	N>P>K	85	110
				Puán (17 sites)				
1.81	0.25	2.90	–52	9	43	N>P>K	94	104
2ND & 3RD LEAVES AT ANTHESIS								
				Cabildo (27 sites)				
1.57	0.15	1.43	–14	2	12	N>P>K	37	28
				Bordenave (13 sites)				
0.81	0.09	0.40	– 1	41	–40	K>N>P	100	82
				Puán (18 sites)				
1.43	0.19	1.42	–26	20	6	N>K>P	70	52

1 Rel. Freq., relative frequency.
2 NBI, Nutritional Balance Index.

— K deficiencies were enhanced and more widespread at anthesis. Moisture stress was common at this growth stage; this situation may have acted upon K, slowing down its movement toward the root (Mengel, 1982).

— In the semiarid regions when the soil available water (AW) increases, nutritional deficiencies are immediately shown. Larger NBI values indicated greater nutrient imbalances. This effect was more evident at whole plant sampling (Table 6).

TABLE 4

Nutrient composition, DRIS indices, order of deficiency and NBI for winter wheat in semi-arid Argentina, 1986.

PLANT NUTRIENT, (%)			DRIS INDICES			ORDER OF DEFICIENCY	REL. 1 FREQ. (%)	2 NBI
N	P	K	N	P	K			
WHOLE PLANT AT STEM ELONGATION								
				Cabildo (32 sites)				
1.68	0.24	2.13	–43	21	22	N>P>K	53	86
				Bordenave (9 sites)				
1.05	0.17	1.08	–41	39	2	N>K>P	89	82
2ND & 3RD LEAVES AT ANTHESIS								
				Cabildo (32 sites)				
1.56	0.16	1.55	–20	2	18	N>P>K	50	40
				Bordenave (9 sites)				
1.12	0.12	1.65	–45	–13	58	N>P>K	56	116

1 Rel. Freq., relative frequency.
2 NBI, Nutritional Balance Index.

TABLE 5

Weighed averaged and standard deviation of DRIS foliar diagnosis for wheat in the semi-arid region (Cabildo, Bordenave and Pudn) of Argentina during 1984, 1985 y 1986.

PLANT PART AND STAGE	NUMBER OF SAMPLES	DRIS INDICES			ORDER OF DEFICIENCY	1 NBI
		N	P	K		
Whole plant at stem elong.	99	–43 (15)	16 (17)	27 (15)	N>P>K	86
2nd & 3rd leaves at anthesis	170	–22 (21)	11 (25)	11 (30)	N>P≥K	44

1 NBI, Nutritional Balance Index.

TABLE 6

Soil available water (AW) and NBI values during 1984-85-86.

SITE	AW (mm)	NBI	
		WHOLE PLANT	2ND & 3RD LEAVES
		Year 1984	
Cabildo	593	96	32
Bordenave	890	118	56
Puán	711	104	78
		Year 1985	
Cabildo	451	63	28
Bordenave	713	110	82
Puán	799	104	52
		Year 1986	
Cabildo	486	86	40
Bordenave	460	82	116

CONCLUSIONS

As mentioned previously the use of the DRIS indices shows that:

— Nitrogen was the most deficient nutrient; in some cases potassium showed imbalances (deficiency or excess) and phosphorus was deficient in more than 50% of the studied cases.

— The most important advantage of the DRIS approach is its ability to make diagnosis at any stage of the crop's development.

— The order of nutrient requirements obtained from the DRIS is likely the same, irrespective of the plant part sampled.

— The most limitant factor to be considered in the DRIS diagnosis is the variability of rainfall in the Argentina semi-arid region.

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