Use Diagnosis and Recommendation Integrated System (DRIS) Model to Diagnose For Nutrient Balance and Productivity of Lettuce Plants under Fertigation with Different Potassium Fertilizer Sources

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Abstract: A field experiment was conducted on a loamy sandy soil at Om Saber Farm (110 km from Cairo), South El-Tahrer Province, El-Behiera Governorate, Egypt during the winter production season of 2013. The current work was an attempt to investigate the effect of different combinations of three potassium fertilizers, i.e. KNO_3, K_2SO_4 and KCl on nutrients balance by using DRIS model, and the extent of the impact on the yield of lettuce plants (*Lactuca sativa* L., Ice -berg cv.). Fertigation was applied at the following twelve combination ratios of potassium chloride (63 % K_2O), potassium nitrate (13 % N and 46 % K_2O) and potassium sulfate (50 % K_2O) : (100 , 75 , 50 and 25) for each relative to 100 that equal to the total K requirement during growth stage (90 unit for lettuce). Lettuce crops with 29 treatments were ranked in the high-yielding population (yield $\geq$ 8 ton fed.$^{-1}$), while 19 treatments yielded < 8 ton fed^{-1} were ranked in the low- yielding. DRIS norms and indices established and Nutritional Balance Index (NBI) calculated for lettuce crop should be useful to evaluate lettuce nutritional status and to calibrate fertilizer programs. Data revealed that the lowest nutrient balance index was recorded from combination treatments 50 % KCl + 50 % KNO_3 + 0 % K_2SO_4, 0 % KCl + 50 % KNO_3 + 50 % K_2SO_4, 0 % KCl + 25 % KNO_3 + 75 % K_2SO_4 and 0 % KCl + 100 % KNO_3 + 0 % K_2SO_4 were attained 59.10, 66.93, 68.60 and 75.70, respectively; this treatments achieved high exportable yield which were 13.0, 11.75, 11.49 and 10.14 ton fed^{-1}, respectively. Selection of these treatments shows that the diversity of the use of sources of potassium leads to more efficient use of potassium fertilizer.

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Key words: DRIS index, Lettuce ((*Lactuca sativa* L.), Nutrient balance, Potassium fertilizer, Yield.

1. Introduction

Lettuce (*Lactuca sativa* L.) is a native of Europe, Asia and Northern Africa and has been cultivated for over 5000 years. It is the most popular among the salad crops. It is rich in vitamins and minerals. Also, lettuce grown in Egypt for local consumption and exportation **(Michael *et al.,* 2012)**. Nitrogen (N), phosphorus (P), and potassium (K) are required for successful lettuce production and can influence lettuce quality **(Hoque *et al.,* 2004).**

The nutritional diagnose of plant consists on determination of nutrients content, this determination is made with the comparison of the nutrient content with standard values, and this procedure called by leave diagnose that uses information from chemical analyses of plant tissue. However, there is the visible diagnose that is made with visual observation of nutritional deficiency or excess symptoms. The tissue analyses has been considered the direct way to evaluation the nutritional state of plants, but to do this evaluation, it is necessary a well specific part from the plant to take this diagnose, this specific part is the leaf tissue that is the most used **(Hallmark & Beverly, 1991)**. The leave diagnose can be a useful tool to assess the nutritional status of plant, but the procedure to analyses the data must be appropriate. Because of the natural dynamic of the leaf tissue composition that is strongly influenced by leaf age, maturation stage and interaction among nutrients on uptake and translocation into the plant, if all the damages criteria were not observed the leaf diagnose becomes very difficult to understand and used **(Walworth and Sumner, 1987)**.

The interpretation of nutrients contents in leaf analyses can be assessed by several methods to plant nutritional status. To interpretative the results of traditional chemical analyses of plant tissue for assessment of the nutritional status of plants, the methods of critical level and sufficiency range are used more frequently **(Camacho *et al*., 2012 and Serra *et al*., 2012)**. There are other diagnoses systems, such as: Compositional Nutrient Diagnosis (CND) **(Parent and Dafir, 1992)** and plant analyses with standardized scores (PASS) **(Baldock and Schulte, 1996).**

The Diagnosis and Recommendation Integrated System (DRIS) relate the nutrient contents in dual ratios (N/P, P/N, N/K, K/N ……), because of the relation between two nutrients, the problem with the biomass accumulation and reduction of the nutrients concentration in plants with its age is solved **(Beaufils, 1973 and Singh *et al*., 2000)**. The use of DRIS on concept of nutritional status of plants, this method puts the limitation of nutrients in order of plant demand, enabling the nutritional balance between the nutrients in leaf sample. With the use of dual relation on DRIS, the problem with the effect of concentration or dilution on the nutrients in plants is solved (**Beaufils, 1973 and Walworth & Sumner, 1987).** The disadvantage of this methodology is that the DRIS index is not independent, because one nutrient concentration can have hard influence on the other DRIS index for one nutrient but this problem can be corrected in parts with a hard selection of the nutrient that will compound the DRIS norms **(Baldock and Schulte, 1996)** .

Considering that DRIS uses the nutritional balancing concept (relationship among nutrients), it is postulated that this method might be more precise than the others in the detection of nutritional deficiencies or/and excesses **(Bhaduri and Pal , 2013)**.

Therefore, the aim of the research was to study the effect of three sources of potassium fertilizer under fertigation system on the nutrients balance and the impact on the lettuce crop by using DRIS model.

2. Materials and Methods

A field experiment was conducted on a loamy sandy soil at Om Saber Farm (110 km from Cairo), South El-Tahrer Province, El-Behiera Governorate, Egypt during the winter production season of 2013. To identify the initial characteristics of the experimental soil, a surface soil sample (0-40 cm depth) was collected before the beginning of the experiment and subjected to some physical and chemical analyses according to **Jackson (1973)**, **Page *et al*. (1982)** and **Gee and Bauder (1986)** as well as some soil essential nutrients status **(Follett and Lindsay, 1971; Soltanpour and Schwab, 1977; and Lindsay and Norvell, 1978)**. The obtained results are presented in Table 1.

Table 1: Some physical, chemical and fertility characteristics of the experimental soil.

Soil characteristics	Value	Soil characteristics.	Value
Particle size distribution %:	*Soil paste extract:*		
Sand	83.9	EC (dS/m)	0.83
Silt	7.13	*Soluble cations (m molc L^{-1}):*	
Clay	8.97	Ca^{++}	3.38
Texture class	Loamy sand	Mg^{++}	1.89
Infiltration rate (cm h^{-1})	7.15	Na^{+}	2.67
$CaCO_3$ %	1.42	K^{+}	0.39
Available nutrients (mg kg^{-1} soil)		*Soluble anions (m molc L^{-1}):*	
		CO_3^{-}	0.00
N (potassium sulphate)	22.04	HCO_3^{-}	1.65
P (sodium bicarbonate)	3.98	Cl^{-}	4.50
Ca (ammonium acetate)	360.10	SO_4^{--}	2.18
Mg (ammonium acetate)	219.12	pH (1:2.5 soil water suspension)	7.52
K (ammonium acetate)	63.40	Organic matter %	0.26
Fe (DTPA)	4.95	CEC (c molc kg^{-1})	8.32
Mn (DTPA)	0.87	Soil total N %	0.013
Zn (DTPA)	0.77	Soil organic carbon %	0.155
Cu (DTPA)	0.63	Soil C/N ratio	12.06

To evaluate the response of the lettuce plants (*Lactuca sativa* L., Ice-berg cv.) to K-fertilization throughout a modern system of fertigation, by using different potassium fertilizer forms, *i.e.,*KCl, KNO_3 and K_2SO_4, applied as solely or together. The experimental area was divided into 48 beds of 10m long and 110cm width, with an area of 11 m^2 for each plot and 160 plants per bed. Four beds were replicates for each treatment; however, beds were arranged in the field as a split plot design. The experimental plots were irrigated by drip irrigation system that was characterized by 25 mm PE header line, 16 mm lateral pipes and 2.3 L h^{-1} discharge.

The samples of lettuce were dried at 65C° for 48 hrs, ground and wet digested using H_2SO_4: H_2O_2 method **(Cottenie, 1980)**. The digests samples were then subjected to measurement of N and NO_3 using Micro-Kjeldahle method; P was assayed using molybdenum blue method and determined by spectrophotometer **(Chapman and Pratt, 1961)**; K was determined by Flame Photometer, while Fe, Zn and Mn were determined using atomic absorption spectrophotometer.

Calculation of DRIS indices:

The DRIS indices were calculated by using the following index equations by **Bailey *et al.*, (1997)**:-

$$\text{N- Index} = \frac{-f(P/N) - f(K/N) - f(Ca/N) - f(Mg/N) - f(NO_3/N) + f(N/Cl)}{n}$$

$$\text{P-Index} = \frac{f(P/N) + f(P/K) + f(P/Ca) + f(P/Mg) + f(P/NO_3) + f(P/Cl)}{n}$$

$$\text{K- Index} = \frac{f(K/N) - f(P/K) + f(K/Ca) + f(K/Mg) + f(K/NO_3) + f(K/Cl)}{n}$$

$$\text{Ca-Index} = \frac{f(Ca/N) - f(P/Ca) - f(K/Ca) + f(Ca/Mg) + f(Ca/NO_3) + f(Ca/Cl)}{n}$$

$$\text{Mg-Index} = \frac{f(Mg/N) - f(P/Mg) - f(K/Mg) - f(Ca/Mg) + f(Mg/NO_3) + f(Mg/Cl)}{n}$$

$$NO_3\text{-Index} = \frac{f(NO_3/N) - f(P/NO_3) - f(K/NO_3) - f(Ca/NO_3) - f(Mg/NO_3) + f(NO_3/Cl)}{n}$$

$$\text{Cl- Index} = \frac{-f(N/Cl) - f(P/Cl) - f(K/Cl) - f(Ca/Cl) - f(Mg/Cl) - f(NO_3/Cl)}{n}$$

where

$f(A/B) = 1000\,[(A/B)/(a/b)-1]/CV$ when $A/B > a/b$

or

$f(A/B) = 1000\,[(1-(a/b)/(A/B)]/CV$ when $a/b > A/B$

in which A/B is the value of the ratio of the two nutrients (N, P, K, Ca, Mg, Cl and NO_3) in the head of lettuce, and a/b is the value of corresponding norm, n is the number of function, and CV is the coefficient of variation associated with each nutrient ratio norm.

The Nutritional Balance Index (NBI) was calculated by summing the value in module of the index generated in sample. This NBI may be useful to indicate the nutritional status of the plant. The higher NBI is the greater the nutritional imbalance **(Beaufils, 1973).**

3. Results and Discussion

DRIS norms established for lettuce crop (Table, 2) should be useful to evaluate lettuce nutritional status and to calibrate fertilizer programs, but they must be validated before lettuce growers adopt them.

Lettuce crops in 29 treatments were ranked in the high-yielding population (yield ≥ 8 ton $fed.^{-1}$), while 19 treatments yielded < 8 ton fed^{-1} were ranked in the low- yielding. The mean, coefficient of variation, variance of all nutrient ratios of the high- (S^2_h) and low-yielding population (S^2_l) and the variance ratio between the low- and high- yielding population (S^2_l/S^2_h) ratio are shown in (Table, 2). The selection of a nutrient ratio as DRIS norms (i.e.: N/P or P/N) is indicated by the S^2_l/S^2_h ratio **(Hartz *et al.*, 1998)**. The higher S^2_l/S^2_h ratio, the more specific the nutrient ratio must be in order to obtain a high yield **(Payne *et al.*, 1990)**. The selected DRIS norms were P/N : 9.766, K/N: 9.198, Ca/N: 4.551, Mg/N: 3.533, NO_3/N: 3.340, N/Cl: 1.587, P/K: 1.00, P/Ca: 3.681, P/Mg: 1.285, P/NO_3: 1.90, P/Cl: 2.834, K/Ca: 4.277, K/Mg: 2.399, K/NO_3: 2.422, K/Cl: 6.772, Ca/Mg: 1.127, Ca/NO_3: 1.810, Ca/Cl: 4.021, Mg/NO_3: 2.852, Mg/Cl: 2.780 and NO_3/Cl: 0.490. DRIS method is one of the important methods that reflect the state of the nutrients within the plant tissue where it does not reflect the nutrients individually, but expressed in the form of ratios, and through which knowledge nutrients balance inside the plant tissues and that it was found the best ratios of different nutrients, which by finding the best nutrients balance inside the plant, through which leads to increase the efficiency of these nutrients resulting in getting the maximum crop.

A nutrient index is a mean of the deviation from the optimum or norms values. The negative index values indicate that the nutrient levels are below the optimum. Consequently, the more negative index, the more deficient the nutrient, similarly a positive index indicates that the nutrient levels are above the optimum, and the more positive index the more excessive the nutrient that is relative to normal, and the DRIS index is equal to zero indicating that the nutrient is at optimum levels. However, some authors did not consider a nutrient deficiency or excessive when the DRIS indices are negative or positives and near to zero **Soltanpour *et al.*, 1995).** The combination effect between different potassium fertilizers combination ratios on nutrient indices and NBI in heads of lettuce plants are presented in Table (3).

Table (2): Mean, coefficient of variation (CV) and variance (S^2) of nutrient ratios of the low- and high-yielding populations, the variance ratio (S^2_l / S^2_h) and the selected ratios for lettuce DRIS norms.

Nutrients ratios	Low-yielding population			High-yielding population			S^2_l / S^2_h	Selected ratios
	Mean	CV (%)	Variance (S^2_l)	Mean	CV (%)	Variance (S^2_h)		
N/P	3.945	27.554	1.1816	7.272	19.458	2.0022	0.590	
P/N	0.278	35.971	0.0100	0.143	22.378	0.0010	9.766	*
N/K	0.33	30.000	0.0098	0.65	25.077	0.0266	0.369	
K/N	3.377	38.348	1.6770	1.637	26.084	0.1823	9.198	*
N/Ca	2.115	40.095	0.7191	2.934	27.846	0.6675	1.077	
Ca/N	0.548	40.876	0.0502	0.368	28.533	0.0110	4.551	*
N/Mg	5.145	39.339	4.0966	7.307	32.968	5.8033	0.706	
Mg/N	0.222	37.252	0.0068	0.15	29.333	0.0019	3.533	*
N/NO_3	1.152	49.479	0.3249	1.396	29.011	0.1640	1.981	
NO_3/N	1.061	44.958	0.2275	0.847	30.815	0.0681	3.340	*
N/Cl	7.788	20.2320	20.2320	5.826	61.277	12.7449	1.587	*
Cl/N	0.157	0.0042	0.0042	0.241	55.602	0.0180	0.235	
P/K	0.085	22.353	0.0004	0.09	21.111	0.0004	1.000	*
K/P	12.354	23.725	8.5908	11.63	25.262	8.6318	0.995	
P/Ca	0.545	30.275	0.0272	0.405	21.235	0.0074	3.681	*
Ca/P	2.027	34.731	0.4956	2.585	22.824	0.3481	1.424	
P/Mg	1.324	28.852	0.1459	1.032	32.655	0.1136	1.285	*
Mg/P	0.817	29.743	0.0590	1.088	36.121	0.1544	0.382	
P/NO_3	0.291	35.052	0.0104	0.187	39.572	0.0055	1.900	*
NO_3/P	3.854	34.510	1.7689	6.232	40.116	6.2500	0.283	
P/Cl	1.954	39.458	0.5944	0.803	57.036	0.2098	2.834	*
Cl/P	0.573	31.239	0.0320	1.704	57.101	0.9467	0.034	
K/Ca	6.459	27.729	3.2077	4.560	18.991	0.7500	4.277	*
Ca/K	0.164	23.171	0.0014	0.227	18.943	0.0018	0.781	
K/Mg	15.81	25.117	15.7688	11.32	22.650	6.5741	2.399	*
Mg/K	0.067	26.866	0.0003	0.093	22.581	0.0004	0.735	
K/NO_3	3.437	30.113	1.0712	2.060	32.282	0.4422	2.422	*
NO_3/K	0.313	25.240	0.0062	0.535	0.0290	0.0237	0.263	
K/Cl	24.213	47.536	132.48	8.761	50.485	19.562	6.772	*
Cl/K	0.049	36.735	0.0003	0.144	45.139	0.0042	0.077	
Ca/Mg	2.565	29.591	0.5761	2.571	27.810	0.5112	1.127	*
Mg/Ca	0.430	34.884	0.0225	0.426	33.333	0.0202	1.116	
Ca/NO_3	0.562	39.502	0.0493	0.465	35.484	0.0272	1.810	*
NO_3/Ca	1.993	30.808	0.3770	2.431	35.747	0.7552	0.499	
Ca/Cl	3.974	57.323	5.1893	2.020	56.238	1.2905	4.021	*
Cl/Ca	0.310	40.968	0.0161	0.669	52.915	0.1253	0.129	
Mg/NO_3	0.227	33.480	0.0058	0.183	24.590	0.0020	2.852	*
NO_3/Mg	4.852	30.317	2.1638	5.822	27.138	2.4964	0.867	
Mg/Cl	1.564	46.164	0.5213	0.809	53.523	0.1875	2.780	*
Cl/Mg	0.74	35.270	0.0681	1.631	52.054	0.7208	0.095	
NO_3/Cl	7.037	31.320	4.8576	4.852	64.880	9.9099	0.490	*
Cl/NO_3	0.157	34.395	0.0029	0.309	61.489	0.0361	0.081	

Table (3): Effect of between different potassium fertilizers combination ratios on nutrient indices, NBI and exportable fresh yield in heads of lettuce plants

Treatments $KCl:KNO_3:K_2SO_4$	Nutrient Index							NBI	Exportable fresh yield (ton fed^{-1})
	N	P	K	Ca	Mg	NO_3	Cl		
100 : 0 : 0	-25.93	21.60	30.33	-30.71	-33.22	-14.27	52.20	208.3	8.30
75 : 25 : 0	-12.28	16.43	17.93	12.48	5.360	-4.330	-12.94	91.80	9.31
50 : 50 : 0	11.47	-1.894	1.400	-22.60	-2.260	16.71	-2.830	59.10	13.0
25 : 75 : 0	20.71	6.657	1.570	-29.82	-14.05	26.89	-12.44	112.1	8.89
0 : 100 : 0	-6.985	-11.20	21.43	15.44	0.760	0.220	-19.65	75.70	10.14
0 :75 : 25	-1.693	16.59	19.79	9.440	-3.890	5.570	-45.81	102.8	9.52
0 : 50 : 50	6.545	5.815	7.650	-5.430	-12.80	13.46	-15.23	66.93	11.75
0 : 25 : 75	-11.24	17.44	0.600	-20.15	7.690	-2.910	8.560	68.60	11.49
0 : 0 : 100	-89.53	44.47	49.16	-18.76	25.23	-73.88	63.31	364.3	6.81
25 : 0 : 75	-64.09	37.96	42.23	5.710	21.05	-50.69	7.840	229.6	9.00
50 : 0 : 50	-47.08	18.64	42.38	25.12	9.850	-37.61	-11.29	192.0	8.68
75 : 0 : 25	-42.0	4.06	49.16	-16.64	-23.13	-30.91	46.89	212.8	7.75

Data revealed that the lowest Nutrient Balance Index (NBI) was recorded from combination treatments 50 % KCl + 50 % KNO_3 + 0 % K_2SO_4, 0 % KCl + 50 % KNO_3 + 50 % K_2SO_4, 0 % KCl + 25 % KNO_3 + 75 % K_2SO_4 and 0 % KCl + 100 % KNO_3 + 0 % K_2SO_4 were attained 59.10, 66.93, 68.60 and 75.70, respectively; this treatments achieved high exportable yield which were 13.0, 11.75, 11.49 and 10.14 ton fed^{-1}, respectively. Selection of these treatments shows that the diversity of the use of sources of potassium leads to more efficient use of potassium fertilizer, which may be due to the change of the anion accompanying K^+ in the solution around plant roots, which may lead to increase absorption of nutrients in lettuce plants. There was no significant difference between the leaf K concentration for the vines receiving KCl or K_2SO_4. Applying K as KCl increased the leaf Cl concentration, while applying K as K_2SO_4 had no significant effect on the leaf S concentration at that time. **(Buwalda and Smith, 1991)**.

Conclusion:

There are four advantages DRIS: (1) the scale of interpretation is continuous scale, and easy to use, (2) put the nutrients in order of the most deficiency to the most excessive, (3) identify cases where the yield of plant is limited by into factor as nutritional status and (4) the Nutritional Balance Index (NBI) give a result of combined effects of nutrients.

In economic terms, it is preferable to include fertilizer potassium chloride as a source of potassium fertilizers to plant lettuce where it leads to lower costs for the use of potassium fertilizers, since it is cheap price compared to the rest of the prices of the used potassium fertilizers.

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