DRIS Norms for grafted and non-grafted red bell pepper in semi arid climate conditions in a greenhouse

Esteban Sánchez[1]; Juan Manuel Soto-Parra[2]; Pablo Preciado-Rangel[3]; Alfonso Llanderal[4]; María Teresa Lao[4]

[1]Centro de Investigación en Alimentación y Desarrollo A.C. Delicias, Chihuahua. Mexico; [2]Facultad de Ciencias Agrotecnológicas, Universidad Autónoma de Chihuahua, Chihuahua, México; [3]Instituto Tecnológico de Torreón, Torreón, Coahuila, México; [4]Agronomy Department of Higher Engineering School, University of Almeria, Agrifood Campus of International Excellence ceiA3, Ctra. Sacramento s/n, La Cañada de San Urbano, Almería, Spain; mtlao@ual.es (corresponding author)

ABSTRACT

The objective of this study was to compute and compare DRIS norms for grafted and non-grafted red bell pepper crops grown in semi arid climate conditions. DRIS norms were computed with 84 samples of first young mature leaves collected during developed stage. The experiment had a completely randomized block design, and the values obtained for each plant and each variable were considered as independent replicates. Thirty-two DRIS norms nutrient ratios and coefficients of variation (CV) were computed from N, P, K, Ca, Mg, Fe, Cu, Zn and Mn analytical results. The ratios P/N and K/N in grafted and non-grafted pepper plants, showed low CV and therefore may play a fundamental role in crop production according with the DRIS norms calculated, since as light modification in the nutrient concentration led to a significant change in the nutritional balance. In conclusion, DRIS norms are sensitive for grafted and non-grafted plants. This work may signify an improvement in the nutritional diagnosis of grafted and non-grafted red bell pepper in semi arid climate conditions under a shaded greenhouse.

Keywords: *Capsicum annuum*, Diagnostic and Recommendation Integrated System, foliar diagnostic, leaf analysis, nutrient ratio, macronutrients.

RESUMO

Normas DRIS para pimentão vermelho com e sem enxerto em condicões semiáridas em casa de vegetação

O objetivo desse estudo foi avaliar e comparar as normas DRIS para o cultivo de pimentão vermelho com e sem enxerto, cultivado em condicões semi-áridas. As normas DRIS foram obtidas com 84 amostras de folhas recentemente amadurecidas, considerando o período de desenvolvimento da cultura. O delineamento experimental foi por blocos completamente ao acaso, e os valores obtidos de cada planta e cada variável foram considerados como réplica independente. Dos resultados analíticos de N, P, K, Ca, Mg, Fe, Cu, Zn e Mn foram computados trinta e duas normas Dris e seu coeficiente de variação (CV). As quantidades ou proporções de P/N e K/N em plantas de pimentão com e sem enxerto mostraran baixos CV e, por tanto, de acordo com as normas DRIS, têm função fundamental no desenvolvimento da cultura, devido ao fato que uma pequena modificação pode ocasionar variação significativa no balanço nutricional da planta. Concluindo, as normas DRIS são sensíveis ao enxerto em plantas. Este trabalho pode significar melhoria significativa na diagnose nutricional do pimentão vermelho, com e sem enxerto, em condições semiáridas em casa de vegetação sob sombra.

Palavras-chave: *Capsicum annuum*, análise foliar, diagnóstico foliar, quantidade de nutrientes, macronutrientes.

Red pepper is a vegetable of extraordinary economic and social importance, as it is one of the most important vegetable crops in the world, with a production area of 4,537,088 ha (FAOSTAT, 2016). From the point of view of health, red pepper has high content of provitamin A, due to the high concentrations of β-carotene and β-cryptoxanthin, anticancer compounds linked with oxygenated carotenoids (xanthophylls) and anti-ulcer properties (Mínguez-Mosquera & Hornero-Méndez, 1993).

Alkaline-calcareous soils, low organic matter content associated with nutrient deficiency in intensive crops and unbalanced fertilizer supply, prevail in many arid and semi arid regions of the world where red pepper is grown (Rashid *et al.*, 2002). Also, the persistent exploitation of the soil, monoculture and the intensification of production processes, leads to the development of soil diseases. Bell pepper (*Capsicum annuum*) is very susceptible to nutritional disorders (Nabi *et al.*, 2006), so it is important to generate information about these nutritional disorders and their impact on productivity and quality. This, together with the abiotic stresses, mainly salinity, suboptimal temperatures and water stress, can induce the appearance of physiopathies in the pepper such as blossom-end rot (BER) and cracking, inducing vegetal senescence and decreasing not only production, but also the quality of the product (Nabi *et al.*, 2006).

To alleviate these problems the grafting technique has been introduced. Chávez-Mendoza *et al.* (2015) found that fruits obtained from grafted plants increased β-carotene and vitamin C concentrations and improved the antioxidant capacity, but had no influence on total phenol

or lycopene contents.

Nevertheless, some studies have reported differences in nutrient composition in leaves of pepper between grafted and non-grafted plants (Sánchez-Torres *et al.*, 2016). One of the most used techniques in nutrient diagnosis is the Diagnosis and Recommendation Integrated System (DRIS) which consists of a dual relationship between a pair of nutrients in leaves (N/P, P/N, N/K, K/N, etc.) and comparisons between series of nutrient indices (Abd El-Rheem*et al.*, 2012; Llanderal, 2017). DRIS indices enable the evaluation of nutritional balance of a crop, ranking nutrient levels in relative order; negative results (below zero) mean nutrient deficiency, and positive results indicate nutrient excess (Beaufils, 1973). The calculation of DRIS index depends on the establishment of reference norms.

DRIS norms consist of the mean, variance and coefficient of variation of the dual ratio between nutrients (N/P, P/N, N/K, K/N, etc.) obtained from a crop reference population that shows a high yield population (Beaufils, 1973). The data bank to compose DRIS norms is composed by the highest crop yield and chemical analysis of leaf tissue. The method to select the form of ratio for a pair of nutrients to be used in DRIS calculation is described by Walworth & Sumner (1987) and Nick (1998).

Current information concerning red bell pepper DRIS norms in this area is limited. Therefore, we conducted this experiment in order to compute and compare DRIS norms for grafted and non-grafted red bell pepper crops grown under shaded greenhouse in semi arid climate conditions.

MATERIAL AND METHODS

This study was performed with the data from experimental crops obtained in Delicias (Chihuahua, Mexico) during spring-summer growing season. Climatic parameters outside the shaded greenhouse were provided by the agro-climatic station of National Water Commission (CONAGUA, Mexico). During spring-summer growing season, maximum and minimum temperature

ranged from 28 to 10ºC. Maximum and minimum relative humidity (RH) ranged from 80% to 45%, and global radiation ranged from 5.2 to 8.9 kWh m^{-2}. A sandy-clay soil was used with the following composition: 50.17 ppm of N-inorganic, 64.14 ppm of P, 32.5 meq 100 g^{-1} of CEC, electrical conductivity 0.84 dS m^{-1}, 1.68% of organic matter content and pH 7.72.

The experiment was carried out in a shaded greenhouse. Red bell pepper cv. "Fascinato" was evaluated. Plants were grafted on cultivar "Terrano" as rootstock (Syngenta Seed, Houston, TX, USA). The crop was grown with a planting density of 2 plants m^{-2} and fertigated with 3 L h^{-1} drippers. Spacing between plants was 0.5 m and between rows was 1 m. Fertilization used during plant growth was carried out with the fertilizers: NH$_4$NO$_3$ (50 g m^{-2}), UAN32 (Urea Ammonium Nitrate Solution, 16%, 8%, 8% N) (38 g m^{-2}), 5-30-00 (56 g m^{-2}), KNO$_3$ (45 g m^{-2}), Ca(NO$_3$)$_2$ (162 g m^{-2}), K$_2$SO$_4$ (201 g m^{-2}) and Mg$_2$SO$_4$ (108 g m^{-2}). Fertilizers were applied via fertigation every two days. Selection of the reference population is an important factor for the effectiveness and success of DRIS. Yield in the reference plots was in the range of 3.32 to 8.38 kg m^{-2}. This was acceptable for production in this area with a mean yield of 5.54 kg m^{-2} (Sánchez *et al.*, 2015). The reference group presented a normal distribution as recommended by Walworth & Sumner (1987).

Database consisted of 84 samples. Leaf samples were composed of 15-30 healthy and fully developed leaves obtained from various plants. In laboratory, leaves were washed, and petioles disengaged. Samples were dried in an air-forced drying oven at 70ºC for 24 hours, until constant weight was attained. Then, they were pulverized and sifted through an 80 micron mesh sieve and homogenized (Ministry of Agriculture and Fishing, 1994). Lastly, they were preserved in airtight polyvinyl chloride (PVC) containers, sealed with paraffin and stored in a dark, dry place. Each sample was divided into two subsamples, one was mineralized by the dry way method (Ruiz *et al.*, 1999) and used to determine total P concentration

by the ammonium molybdate method (Hogue *et al.*, 1970), and total potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn). Concentrations were determined by atomic absorption spectrometry (Ministry of Agriculture and Fishing, 1994). The other subsample was used to directly determine total N concentration by Kjeldahl digestion procedure (Ministry of Agriculture and Fishing, 1994).

To choose the ratio order of nutrients, the criteria proposed by Nick (1998) termed "R value" was selected. This consists of the calculation of the correlation coefficient (r) among productivity values obtained along with the relationships between pairs of nutrients, either in inverse or direct order. The order of the relationship that presents the largest absolute value of the coefficient of correlation (r) is selected:

If: r A/B > r B/A then: relationship in the norm = A/B

If: r A/B < r B/A then: relationship in the norm = B/A

Where |r A/B| is the absolute value of the correlation coefficient between productivity, and A/B is the ratio among concentrations of nutrients A and B of the population; |r B/A| and B/A are the same as above for nutrients B and A in inverse order. The order of the relationship that presents the largest absolute value of the correlation coefficient (r) is selected. In the selection of the ratio order only database of harvesting was used.

The experiment had a completely randomized block design, and the values obtained for each plant and each variable were considered as independent replicates. Analysis of variance (ANOVA) and the least significant difference (LSD) tests (P<0.05) were used to assess the differences between grafted and non-grafted. All statistical analyses were performed using Statgraphics Plus Software (version 5.1.).

RESULTS AND DISCUSSION

Mineral composition
Recent studies show that the rootstock

induces changes in the nutritional status of the graft (Charlo *et al.*, 2012). So, generating knowledge concerning the rootstock and graft relationship could be useful to help identify root systems that are tolerant to soil deficiencies or toxic to certain nutrients. Moreover, this would help us to develop specific fertilization programs for rootstock-graft combination.

The concentration gradient of macro and micronutrients in relation to the studied organs was greater to lesser: leaf>peduncle>fruit, except for P (Table 1). There were no significant differences in the concentration of all nutrients studied in fruits and peduncle. In the case of leaves, there were only significant differences in Mn and Mg concentration with the highest values in grafted plants (Table 1).

Previous studies by Ruiz *et al.* (1997) indicate that the response of some macronutrients, such as K, Ca, Mg, P and S, was mainly homogeneous. Rouphael *et al.* (2008) reported that total and commercial yields in mini-watermelons were 115% and 61% higher respectively in grafted plants compared to non-grafted plants. The concentration of N, K and Mg in mini-watermelons leaves was elevated in 7.4, 25.6 and 38.8%, respectively, in grafted plants compared to non-grafted plants.

Differences in nutrient concentration between non-grafted and grafted pepper plants were due to the effect of the rootstock-graft interaction (Table 1).

Ruiz *et al.* (1996) reported that the use of rootstocks can improve some morphological and/or physiological characteristics to increase soil nutrient uptake and translocation to graft leaves. In other studies, on grafted cherry, nutrient levels were less affected by the rootstock used (Neilsen & Kappel, 1996).

Data obtained in the present work are in agreement with previous publications, which indicate the influence that genetic characteristics and vigour of the graft exert on mineral content of the leaf, since few nutrients are affected by the rootstock (Brown *et al.*, 1994). The macronutrients more affected by the rootstock/graft interaction were: K, Ca, and Mg; while for micronutrients were: Fe, Cu, Zn and Mn. These results allow a selection of the rootstocks/variety more adapted or efficient in nutrient uptake. This efficiency could be attributed to the varieties grafted on the "Terrano" rootstock.

Development of dris norms

Currently, there are no specific DRIS norms for red bell pepper. The norms derived from this work have been generated from a representative population variability under semi arid climate conditions where this culture is widely developed. Means, coefficients of variation and correlation coefficients of macronutrient ratios of the reference for 2 populations (grafted and non-grafted red bell pepper) are shown in Table 2. Values in bold correspond to

the ratios among selected nutrients. The common coefficients selected for grafted and non-grafted red bell pepper populations are P/K, K/N, Ca/N, Ca/P, Ca/K, Mg/Ca, Mg/Fe, Fe/N, Fe/K, Fe/Zn, Cu/N, Cu/Fe, Cu/Mn, Zn/N, Zn/Mn and Mn/Ca.

It is worth noting that some of the relationships among the nutrients showed a lower relationship between the ratio and each pair of nutrients and fruit productivity. Only the relationships N/Mn, K/N, K/Zn, Ca/N, Ca/P, Ca/K and Mg/Ca, Mg/Fe, Mg/Zn, Fe/N, Fe/K, Cu/N, Cu/P, Cu/K, Zn/P, Zn/Mn, Mn/Fe in grafted plants and P/Mn, K/Mn, Mg/K, Fe/Mn, Zn/Mn, Mn/N, Mn/Ca in non-grafted plants were greater than 0.30. In the other cases, the choice of the relationship was accomplishment using a very low correlation coefficient.

Variability of DRIS norms (CV) within grafted and non-grafted plants is attributable to the varietal ability in uptake and nutrient use efficiency in the plant being higher in grafted plants (Velasco-Alvarado, 2016). Comparing CV of grafted and non-grafted plants with other authors, it is important to note that CV of the different ratios were lower than the CV proposed by Abd El-Rheem *et al.* (2012) which ranged from 13 to 126%. A lower value in CV from the norms obtained with the DRIS technique means that a slight modification in nutrient concentration leads to a great change in the nutritional balance as proposed by Franco-Hermida

Table 1. Nutrient concentrations (g kg⁻¹ dry matter) in fruit, leaf and peduncle in grafted and non-grafted red bell pepper plants. Delicias, Chihuahua, Mexico, CIAD, 2012.

Nutrient	Fruit		Leaf		Peduncle	
	Grafted	**Non-grafted**	**Grafted**	**Non-grafted**	**Grafted**	**Non-grafted**
N	2.05 ± 0.30 a	2.15 ± 0.34 a	3.85 ± 0.33 a	3.85 ± 0.37 a	3.05 ± 0.86 a	3.11 ± 0.92 a
P	0.23 ± 0.06 a	0.24 ± 0.07 a	0.14 ± 0.04 a	0.12 ± 0.02 a	0.18 ± 0.06 a	0.17 ± 0.05 a
K	3.70 ± 0.26 a	3.73 ± 0.18 a	4.68 ± 0.15 a	4.65 ± 0.13 a	4.38 ± 0.16 a	4.30 ± 0.25 a
Ca	0.21 ± 0.11 a	0.27 ± 0.15 a	2.03 ± 0.40 a	2.17 ± 0.50 a	0.41 ± 0.29 a	0.52 ± 0.71 a
Mg	0.57 ± 0.08 a	0.57 ± 0.07 a	1.95 ± 0.14 a	1.64 ± 0.12 b	0.64 ± 0.09 a	0.59 ± 0.15 a
Fe	0.93 ± 0.30 a	0.76 ± 0.20 a	4.65 ± 1.06 a	4.49 ± 0.66 a	1.31 ± 0.44 a	1.18 ± 0.40 a
Cu	0.18 ± 0.04 a	0.19 ± 0.09 a	1.40 ± 0.74 a	1.19 ± 0.63 a	0.27 ± 0.14 a	0.28 ± 0.25 a
Zn	0.39 ± 0.08 a	0.41 ± 0.06 a	2.05 ± 0.29 a	2.02 ± 0.35 a	0.45 ± 0.06 a	0.42 ± 0.10 a
Mn	0.14 ± 0.02 a	0.13 ± 0.02 a	1.99 ± 0.35 a	1.40 ± 0.20 b	0.17 ± 0.04 a	0.15 ± 0.04 a

*Means with different letters in the same column indicate significant differences between treatments using LSD test at P≤0.05.

Table 2. DRIS norms (mean, coefficient of variation and correlation coefficient) peduncle in grafted and non-grafted red bell pepper plants. Delicias, Chihuahua, Mexico, CIAD, 2012.

Grafted					Non-grafted				
Norms	Means	CV (%)	r		Norms	Means	CV (%)	r	
N/P	27.34	23.17	0.01	ns	N/P	31.49	18.62	-0.03	ns
N/K	0.82	8.97	-0.47	*	N/K	0.83	9.98	-0.06	ns
N/Ca	1.98	26.22	-0.53	*	N/Ca	1.86	23.91	0.02	ns
N/Mg	1.98	13.93	-0.28	**	N/Mg	2.36	14.17	0.22	ns
N/Fe	0.88	28.09	-0.57	*	N/Fe	0.88	20.65	0.03	ns
N/Cu	4.05	71.12	-0.22	**	N/Cu	4.61	67.96	0.02	ns
N/Zn	1.91	16.35	-0.79	**	N/Zn	1.95	17.11	0.01	ns
N/Mn	**2.09**	**19.40**	**-0.30**	*	N/Mn	2.64	23.05	0.47	**
10*P/N	**0.39**	**24.76**	**0.02**	ns	**10*P/N**	**0.33**	**19.42**	**0.04**	ns
10*P/K	0.32	22.90	-0.20	ns	**10*P/K**	**0.27**	**17.96**	**0.02**	ns
10*P/Ca	0.77	38.87	-0.38	*	10*P/Ca	0.61	30.33	0.06	ns
10*P/Mg	0.76	22.09	-0.16	ns	**10*P/Mg**	**0.77**	**19.78**	**0.22**	ns
10*P/Fe	**0.33**	**30.01**	**-0.55**	*	10*P/Fe	0.29	24.75	0.09	ns
10*P/Cu	1.59	89.57	-0.21	ns	**10*P/Cu**	**1.55**	**77.02**	**0.05**	ns
10*P/Zn	0.74	29.82	-0.43	**	**10*P/Zn**	**0.64**	**26.70**	**0.05**	ns
10*P/Mn	0.80	30.84	-0.21	ns	**10*P/Mn**	**0.87**	**29.69**	**0.39**	**
K/N	**1.23**	**8.48**	**0.49**	**	**K/N**	**1.22**	**9.61**	**0.08**	ns
K/P	**33.22**	**21.27**	**0.21**	ns	K/P	38.17	17.94	0.01	ns
K/Ca	2.42	26.30	-0.39	*	K/Ca	2.25	22.56	0.03	ns
K/Mg	2.41	7.13	0.06	ns	K/Mg	2.85	8.34	0.43	**
K/Fe	1.07	27.04	-0.45	**	K/Fe	1.06	16.90	0.09	ns
K/Cu	4.89	68.70	-0.16	ns	**K/Cu**	**5.54**	**66.15**	**0.04**	ns
K/Zn	**2.32**	**14.11**	**-0.63**	**	K/Zn	2.36	17.14	0.02	ns
K/Mn	2.54	16.47	0.09	ns	**K/Mn**	**3.19**	**19.23**	**0.58**	*
Ca/N	**0.53**	**21.93**	**0.58**	**	**Ca/N**	**0.57**	**25.62**	**0.10**	ns
Ca/P	**14.50**	**30.29**	**0.42**	*	**Ca/P**	**17.97**	**32.60**	**0.08**	ns
Ca/K	**0.43**	**20.52**	**0.41**	**	**Ca/K**	**0.47**	**24.29**	**0.05**	ns
Ca/Mg	1.04	20.44	0.42	**	Ca/Mg	1.33	24.55	0.15	ns
Ca/Fe	**0.46**	**26.98**	**-0.13**	ns	**Ca/Fe**	**0.49**	**27.63**	**0.15**	ns
Ca/Cu	2.20	79.35	0.01	ns	**Ca/Cu**	**2.60**	**62.46**	**0.04**	ns
Ca/Zn	**1.00**	**21.26**	**0.02**	ns	**Ca/Zn**	**1.10**	**27.28**	**0.06**	ns
Ca/Mn	1.12	30.13	0.21	ns	Ca/Mn	1.47	23.86	0.42	**
Mg/N	**0.51**	**12.10**	**0.29**	*	**Mg/N**	**0.43**	**12.73**	**-0.23**	ns
Mg/P	**13.84**	**22.38**	**0.19**	ns	Mg/P	13.50	20.72	-0.14	ns
Mg/K	**0.42**	**7.04**	**-0.07**	ns	**Mg/K**	**0.35**	**8.23**	**-0.44**	**
Mg/Ca	**1.01**	**25.24**	**-0.43**	**	**Mg/Ca**	**0.79**	**21.91**	**-0.17**	**
Mg/Fe	**0.45**	**27.88**	**0.47**	*	**Mg/Fe**	**0.37**	**19.43**	**-0.12**	ns
Mg/Cu	2.08	73.12	-0.16	ns	Mg/Cu	1.98	68.39	-0.02	ns
Mg/Zn	**0.97**	**16.82**	**-0.58**	**	Mg/Zn	0.83	17.32	-0.21	ns
Mg/Mn	1.06	19.65	-0.11	ns	Mg/Mn	1.12	14.95	0.49	**
Fe/N	**1.22**	**24.95**	**0.62**	*	**Fe/N**	**1.18**	**17.23**	**-0.12**	ns
Fe/P	32.71	30.15	0.50	*	**Fe/P**	**36.78**	**22.00**	**-0.10**	ns

Table 2. continuation

	Grafted					Non-grafted			
Norms	**Means**	**CV (%)**	**r**		**Norms**	**Means**	**CV (%)**	**r**	
Fe/K	**0.99**	**22.19**	**0.49**	**	**Fe/K**	**0.97**	**15.11**	**-0.18**	**ns**
Fe/Ca	2.37	31.36	0.02	ns	Fe/Ca	2.16	23.86	0.05	ns
Fe/Mg	2.39	24.24	0.44	**	Fe/Mg	2.75	16.53	0.02	ns
Fe/Cu	4.76	72.71	-0.04	ns	Fe/Cu	5.32	73.00	0.05	ns
Fe/Zn	**2.26**	**17.74**	**0.13**	**ns**	**Fe/Zn**	**2.25**	**14.20**	**-0.15**	**ns**
Fe/Mn	2.48	22.01	0.38	**	**Fe/Mn**	**3.09**	**24.42**	**0.38**	**
Cu/N	**0.36**	**51.93**	**0.38**	**	**Cu/N**	**0.31**	**55.09**	**0.03**	**ns**
Cu/P	**9.82**	**54.72**	**0.35**	*	Cu/P	9.86	56.12	0.04	ns
Cu/K	**0.30**	**51.75**	**0.30**	**	Cu/K	0.25	52.08	0.03	ns
Cu/Ca	**0.72**	**52.13**	**0.17**	**ns**	Cu/Ca	0.60	67.94	0.03	ns
Cu/Mg	**0.73**	**55.71**	**0.29**	**	Cu/Mg	0.73	52.71	0.10	ns
Cu/Fe	**0.30**	**47.43**	**0.06**	**ns**	**Cu/Fe**	**0.26**	**49.94**	**0.10**	**ns**
Cu/Zn	**0.67**	**49.22**	**0.14**	**ns**	Cu/Zn	0.58	52.11	0.06	ns
Cu/Mn	**0.73**	**51.58**	**0.22**	**ns**	**Cu/Mn**	**0.82**	**58.94**	**0.24**	**
Zn/N	**0.54**	**17.80**	**0.76**	*	**Zn/N**	**0.53**	**18.48**	**0.02**	**ns**
Zn/P	**14.76**	**31.70**	**0.45**	**	Zn/P	16.81	29.78	0.01	ns
Zn/K	0.44	15.05	0.61	**	**Zn/K**	**0.44**	**18.74**	**-0.03**	**ns**
Zn/Ca	1.05	22.94	-0.01	ns	Zn/Ca	0.97	26.12	-0.02	ns
Zn/Mg	1.06	17.17	0.54	**	Zn/Mg	1.24	18.11	0.14	ns
Zn/Fe	0.46	20.98	-0.11	ns	Zn/Fe	0.46	15.51	0.08	ns
Zn/Cu	2.08	65.27	-0.04	ns	**Zn/Cu**	**2.37**	**70.21**	**0.07**	**ns**
Zn/Mn	**1.11**	**17.09**	**0.41**	**	**Zn/Mn**	**1.38**	**20.91**	**0.51**	*
Mn/N	0.50	21.69	0.28	**	**Mn/N**	**0.39**	**19.42**	**-0.49**	*
Mn/P	**13.47**	**28.22**	**0.22**	**ns**	Mn/P	12.50	29.57	-0.35	**
Mn/K	**0.40**	**17.73**	**0.11**	**ns**	Mn/K	0.32	19.26	-0.56	*
Mn/Ca	**1.00**	**39.47**	**-0.23**	**ns**	**Mn/Ca**	**0.72**	**25.94**	**-0.48**	*
Mn/Mg	**0.98**	**19.04**	**0.12**	**ns**	Mn/Mg	0.92	15.48	-0.47	*
Mn/Fe	**0.43**	**25.24**	**-0.43**	**	Mn/Fe	0.34	25.65	-0.35	**
Mn/Cu	1.86	57.11	-0.21	ns	Mn/Cu	1.77	60.91	-0.13	ns
Mn/Zn	0.93	18.22	-0.40	**	Mn/Zn	0.76	20.78	-0.48	*

The values in bold correspond to the ratios among nutrients selected. **indicates significant differences at P≤0.01.

et al. (2013), Serra et al. (2012) and Llanderal et al. (2018). The ratios reported by Abd El-Rheem et al. (2012) in non-grafted sweet pepper were: P/N, K/N, N/Fe, N/Zn, Mn/N, K/P, P/Fe, P/Zn, Mn/P, K/Fe, K/Zn, Mn/K, Fe/Zn, Mn/Fe and Mn/Zn with 10 and 4 ratios being in common for grafted and non-grafted peppers, respectively. The different ratios obtained by Abd El-Rheem et al. (2012) could be related to the establishment of DRIS norms under different climatic conditions as proposed by Bangroo et al. (2010).

It is important to note that ratios of K/N and P/N in our experiment (grafted and non-grafted plants) (Table 2) showed lower coefficients of variation compared with values established by Abd El-Rheem et al. (2012). A suitable N/K relationship determines the equilibrium between the processes of growth and fruiting in the plant (Hernández et al., 2009). The importance of the relationship between N/K in the fertilizer used on pepper has been proposed by Contreras et al. (2013). The relevance of the P/N ratio could be due to great uptake of both elements in the fruit as proposed by Betancourt & Pierre (2013) because of high metabolic requirement of the fruits.

In conclusion, DRIS norms presented in this paper could improve the nutritional diagnosis of red bell pepper. DRIS norms are sensitive to

grafted and non-grafted plants. The DRIS norms developed in this study could be used in semi arid climate conditions under shaded greenhouse.

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