Increase of productivity in arugula variety folha-larga under the application of foliar fertilizers

Aumento da produtividade em rúcula variedade folha-larga com aplicação de fertilizantes foliares

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ABSTRACT

Organomineral fertilizers are fertilizers of organic origin enriched with mineral nutrients that have been presenting positive responses in several vegetable groves. The aim of this work was to use the experimental factorial design methodology 3^2 and response surface analysis to verify the influences of the variable productivity of the arugula var. Folha Larga. Vegetation® and Spin® foliar fertilizers were applied in factorial design 3^2, with three repetitions at the central point. The results of this research lead us to affirm that the central point (test 6) with application of 60 mL L^{-1} of the Vegetation® leaf fertilizers associated with Spin® obtained higher values for the productivity of arugula var. Folha Larga relative to the control.

Palavras-chave: *Eruca sativa*, leaf fertilization, Vegetation®, Spin®, Organomineral fertilizers.

RESUMO

Os fertilizantes organominerais são fertilizantes de origem orgânica enriquecidos com nutrientes minerais que têm apresentado respostas positivas em diversos pomares de hortaliças. O objetivo deste trabalho foi utilizar a metodologia de planejamento fatorial experimental 32 e análise de superfície de resposta para verificar as influências da variável produtividade da rúcula var. Folha Larga. Os fertilizantes foliares Vegetation® e Spin® foram aplicados em esquema fatorial 32, com três repetições no ponto central. Os resultados desta pesquisa nos levam a afirmar que o ponto central (teste 6) com aplicação de 60 mL L-1 do fertilizante foliar Vegetation® associado ao Spin® obteve maiores valores para a produtividade de rúcula var. Folha Larga em relação ao controle.

Palavras-chave: Eruca sativa, fertilização foliar, Vegetation®, Spin®, fertilizantes organominerais.

1 INTRODUCTION

Leaf fertilization is a strategic alternative to provide faster growth and supplement the plant's nutritional needs (Faquin, 2005; Pôrto et al., 2012). Leaf nutrient replacement favors nutritional balance, thus maintaining the photosynthesis rate and reflecting in a higher production (Alves et al., 2012). However, nutrient application via leaf is fast and efficient, thus being an additional strategy for fertilizer application in crops as a way to supply micronutrients, presenting low application cost and increased productivity in vegetables (Luz et al., 2010; Alves et al., 2012; Pedó et al., 2013).

Arugula (Eruca sativa Miller) is a vegetable species belonging to the herbaceous and annual-cycle Brassicaceae family, which needs mild temperatures for cultivation, presents rapid growth and easy cultivation in beds, so it becomes a great option for small producers (Cunha et al., 2013; Santos et al., 2020). In Brazil the most cultivated arugula varieties are: “Cultivada” and “Folha Larga”. Among the vegetables, arugula is considered one of the most rich in iron and contains calcium, phosphorus, vitamins A and

C, fibers, polyphenols and flavonoids and can be classified as a functional food (Luengo et al., 2011; Xu et al., 2014).

Leafy vegetables are considered nutrient demanding due to their short cycle (Grangeiro et al., 2011). Therefore, the management of foliar fertilization is essential for supplementation of soil fertilization and faster correction of eventual or systematic deficiencies, which may result in high yields (Filgueira, 2013; Kawamoto et al., 2019). Research has shown that the application of foliar fertilizers on different vegetable species showed yield increases in Citrullus lanatus (Martins et al., 2013), Cucurbita moschata (Pinto et al., 2016), Solanum lycopersicum (Nanini & Bueno, 2017), Cucurbita pepo (Matos et al., 2017), Lactuca sativa (Kawamoto et al., 2019), Brassica oleracea var. botrytis (Silva Curvelo et al., 2019) and Solanum gilo (Alcantara & Porto, 2019).

The objective was to use the experimental factorial design methodology 32 and response surface analysis to verify the influences of the variable productivity of the arugula var. Folha Larga.

2 MATERIAL AND METHODS

The experiment was conducted under field conditions, from April 11 to May 16, 2019, in the experimental area located at the Adroaldo Augusto Colombo State Agricultural College (CAEAAC), in Palotina, Paraná, Brazil (24°20'49”S, 53°43'19”W, 366 ma.s.l.). According to Nitsche et al. (2019), mention that the soil in the municipality of Palotina is predominated as a type 3 soil (soil that has more than 35% clay), the region's climate is characterized as mesothermal Cfa, characterizing as a humid temperate climate with hot summer. Soil samples from the experimental area were collected in the 0 - 0.20 m layers and submitted to chemical analysis according to Raij et al. (2001) Table 1. The soil was classified as a very clayey eutrophic Red Latosol (Embrapa, 2018).

Table 1. Chemical analysis of the soil.

Amostras de solo (m)	**pH**	**S.B.**	**H+Al**	**Ca**	**Mg**	**K**	**Al**	**P**
	H_2O	(%)	cmmol$_c$ dm^{-3}					mg dm^{-3}
0 – 0,20	6,00	71,06	2,71	3,00	1,30	1,12	0,00	12,70

Source: Authors
Being: **S.B.:** sum of bases; **Ca:** calcium; **Mg:** magnesium; **K:** potassium; **Al:** aluminum; **P:** phosphorus, cmmolc dm^{-3}.

The soil of the experimental area did not require limestone and/or specific fertilization corrections. However, it was applied 15 days before planting 15 kg ha-1 of “bovine tanned manure” in the dry base as a source of nutrients. hand-raised beds with hoes. In the week prior to planting the 8-20-20 NPK soil fertilizer was applied at a dosage of 100 g treatment-1, the experiment was done in triplicate.

Arugula seeds of wide leaf variety were deposited direct in the beds with spacing of 0.2 x 0.2 m, containing two seeds per pit. After the formation of the plants was thinned them. The plants were irrigated twice a day during the experimental period.

The analyzes were made with 5 plants per line, totaling 45 plants per treatment. Fertilizer applications were performed by costal pump (Costal Xp - 20 liters jet), the fertilizers were diluted to final volume of 20 liters according to Table 2, was applied 5 liters per bed 15 days after emergence (DAE). The experimental plots consisted of 5 row beds with 9 row-1 plants, totaling 2.40 m2 per treatment.

For statistical analysis of factor planning, STATSTICA™ software, version 8.0, from STATSOFT was used, considering the Surface Design module, in which the levels of the variables were defined according to the matrix Table 2, which follows its own criteria the construction of the data matrix, aiming at the generation of a second order model, considering that this matrix is neither orthogonal nor rotatory. A very useful alternative to factor planning is the matrix proposed by Doehlert (1970), which requires fewer experiments and can move across the entire range (domain) of variables. For planning with two variables, both variables evaluating with 3 levels. This allows a free choice of factors to be assigned with more or less levels. Normally, to establish 2 or more levels, one chooses the factor that has the most effect.

In order to verify the influence of the variables: application of Spin® foliar fertilizer along with Vegetation® foliar fertilizer evaluating arugula productivity by elaborating an experimental factorial design 32 with three repetitions at the central point, as shown in Table 2.

Table 2. Factorial planning matrix 3^2, with three repetitions at the central point. Experimental planning with 2 factors and 3 levels with central point, being 3^2.

V	S	V x S	V (mL L^{-1})	S (mL L^{-1})
-	0	-	40.0	60.0
-	-	+	40.0	40.0
+	+	+	80.0	80.0
0	-	-	60.0	40.0
+	-	-	80.0	40.0
0	0	0	60.0	60.0
+	0	+	80.0	60.0
0	+	+	60.0	80.0
-	+	-	40.0	80.0

Source: Authors
V - Vegetation® e S - Spin®

As response variables (dependent) were evaluated the dosages of leaf fertilizers Vegetation® (Liquid fertilizer containing total organic carbon (TOC), nitrogen (N), sulfur (S), boron (Bo), copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn). Contains amino acids in their formulation, enabling the best use of these nutrients for the indicated crops, with TOC 2.30 p p-1 29.90 g L-1, N 3.00 p p-1 39.00 g L-1, S 2.80 p p-1 36.40 g L-1, Bo 0.30 p p-1 3.90 g L-1, Cu 0.30 p p-1 3.90 g L-1, Mn 4.00 p p-1 52.00 g L-1, Mo 0.08 p p-1 1.04 g L-1 and Zn 1.00 p p-1 13.00 g L-1) and Spin® (Liquid fertilizer containing nitrogen (N), phosphorus (P), potassium (K) and molybdenum (Mo). Contains algae extract in its formulation, enabling the best use of these nutrients for the indicated cultures having 1% N + 1% P2O5 + 1% K2O + 0.75% Mo p p-1 or 10.5 g L-1 N + 21 g L-1 P2O5 + 10 0.5 g L-1 of K2O + 7.88 g L-1 of Mo). The levels of the independent variables used in ascending order (-1; 0; +1) were 40.0 mL L-1 (-1.0), 60.0 mL L-1 (0.0), and 80.0 mL L-1 (1.0) Table 3.

3 RESULTS AND DISCUSSION

With the application of foliar fertilizer an increase in arugula yield is sought, Table 3 presents the results of arugula yield var. Broad Sheet obtained according to factorial design 32 with center point. It was observed that the highest values of productivity were those of the central point of the planning, which corresponds to the average dosage of each fertilizer.

Table 3. Factorial Design Matrix 3^2 (2 factors and 3 levels) for 2 variables (Vegetation® - V and Spin® - S) to evaluate the productivity of arugula var. Folha Larga.

Assay	b	S	Productivity (kg ha^{-1})
1	-1,0	0,0	4100
2	-1,0	-1,0	3600
3	+1,0	+1,0	3500
4	0,0	-1,0	3900
5	+1,0	-1,0	3800
6	**0,0**	**0,0**	**4500**
7	+1,0	0,0	3800
8	0,0	+1,0	3700
9	-1,0	+1,0	3200
Average			**3789**

Source: Authors
V - Vegetation® e S - Spin®

In general, comparing the results obtained in the tests with their respective controls shows that the highest value stands out only for the tests of the central point (test

6), that is, in this test we obtained values highest in arugula yield var. Broad Sheet relative to the control.

The maximum yield presented an average of 4500 kg ha-1 for the central point, where it was bought that in an experimental design, the higher dosage of the dependent variable is not always the best result, confirming these results Godinho et al. (2018), reinforced that by applying a foliar fertilizer to the arugula, the response was increased height, fresh shoot and dry mass of plant.

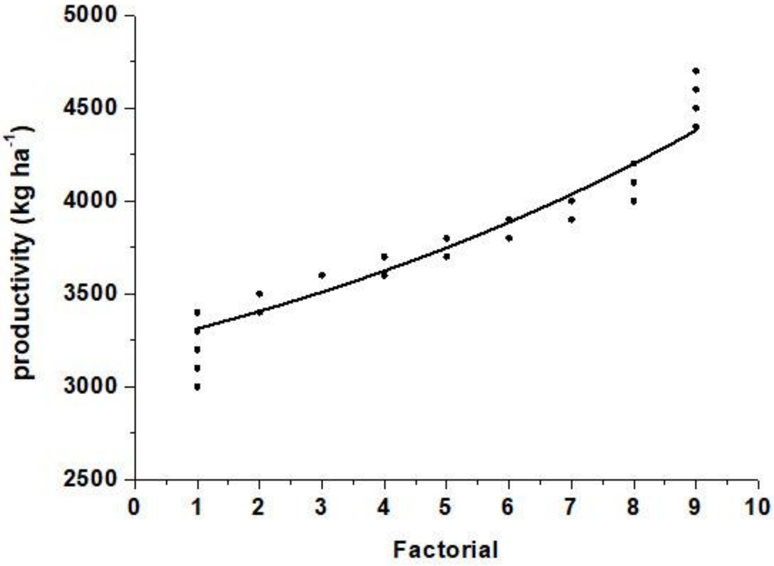
Invigorating the results presented in Table 3, the productivity of 4500 kg ha-1 at the central point, where this point demonstrates that when applied experimental design, the best result is not always when using the largest variable in the experiment, because in this research was It was presented that using 60 mL L-1, which is the central point of the treatments, obtained the highest yield, and when using the maximum dosage of each fertilizer the yield was 3500 kg ha-1, corresponding 22.22% lower in relation to higher productivity.

There was a significant effect on the dosages of the variables for yield Table 3 which may be related to the large amount of phosphorus present in the soil, and thus all treatments presented satisfactory levels for good arugula production, corroborating with Raij (2001), who reports that P deficiency results in less developed plants, which was not the case in the present work.

Reinforcing the productivity results shown in Table 3, Godinho et al. (2018) reported that applying a leaf fertilizer to the arugula after germination resulted in an average leaf height of 33.10 cm, which may reinforce an increase in yield. However, similar results with different crops indicate that application of foliar fertilizer results in increased plant height, biomass and yield in Solanum lycopersicum (Nanini & Bueno, 2017), Cucurbita pepo (Matos et al., 2017), Lactuca sativa (Kawamoto et al., 2019), Brassica oleracea var. botrytis (Silva Curvelo et al., 2019) and Solanum gilo (Alcantara & Porto, 2019).

With the experimental results obtained for each analyzed dosage, from the factorial design, it is possible to adjust the data to obtain a linear model that relates the productivity with the studied parameters. It is good to remember that the obtained models are empirical and only applicable in a certain region, as shown in Figure 1. According to the experimental data the highest productivity values are for 60 mL L-1 of each leaf fertilizer.

Figure 1. Productivity graph (kg ha^{-1}) in relation to the variables of factorial design.



Source: Authors

Confirming the results presented in Figure 1, the model obtained for productivity is presented by Equation 1. The coefficient of determination (R2) quantifies the quality of the adjustment, as it provides a measure of the proportion of the variation explained by the regression equation in relation to total variation of responses, ranging from 0 to 100% (Charnet et al., 1999), the R2 obtained in this regression was 0.93, or 93%, which confirms the higher the R2, the more explanatory the model, the better it fits the sample, so with R2 at 93%, it shows that the dependent variable can be explained by the regressors present in the model.

$$y=0.00101x^2+0.02484x+0.07964 \quad (1)$$

The values of Vegetation (V) and Spin (S) fertilizers satisfy the condition of higher yields, as presented in the model above. According to Ferreira et al. (2016), the advantage of using geometric mean is that the overall solution is achieved in a balanced manner, allowing all responses to reach the expected values, forcing the algorithm to approach the imposed specifications.

Due to its slower initial growth, arugula needs higher nutritional requirements at the end of the cycle, thus, the best response was obtained by applying the central point of both fertilizers, reinforcing these data Grangeiro et al. (2011), showed that the nutrient applications in the initial period that coincides with the highest nutritional demand of the crop and is also the moment when the plant reaches the maximum leaf area.

The maximum estimated crop yield (4500 kg ha-1 center point) was obtained with 3 g L-1 of N, 29.9% higher than the lowest crop yield (3200 kg ha-1 point 9). Purquerio & Tivelli (2016), under field conditions, obtained maximum yield of arugula var. Cultivated, with application of 240 kg ha-1.

The p-values are presented indicating that the effects of terms whose p-value are below the established significance level ($\alpha < 0.05$) are significant. In this case, the values shown in bold in Table 4 obey this indication. That is, for the productivity response only the quadratic term of V and the interaction of both variables VxS are significant and influence the response at the considered level of significance. The negative sign of the effect indicates that increasing the variable level decreases the response value.

CV (%) is interpreted as the variability of the data in relation to the mean. The smaller the CV (%) the more homogeneous the data set. The results of the descriptive statistics for the coefficients of variation (CV) of the variables related to the application of Vegetation® and Spin® fertilizers on arugula yield, where they are described in Table 4.

It is verified that the variable whose CV values appear most Frequencies were, in descending order: Quadratic Spin® (QS), Linear Spin® (LS), Quadratic Vegetation® (QV), Linear Vegetation® (LV), and Vegetation® Spin® (VS) interaction.

The Spin® variable (QS) presented the highest estimate of the total amplitude of the coefficient of variation values (6.50%), followed in decreasing order, respectively, by the Spin® variables (QS 4.50%), Vegetação® (QV 3.20%), Vegetation® (LV 2.35%) and Vegetation® Spin® interaction (VS 1.25%).

This wide range of data within the variables demonstrates the influence of a large number of factors and justifies the need for specific classification of CV (%) for each variable analyzed, as well as what is verified by other authors in plant characteristics the field (Ferreira et al., 2016).

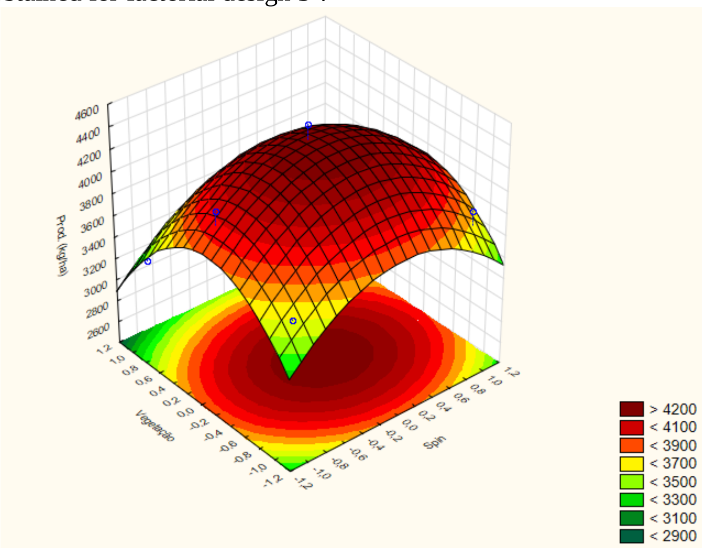
Table 4. Effects and coefficients obtained in the factorial matrix 3^2 for V (Vegetation) and S (Spin) (α = 0.05).

Term.	Productivity (kg ha^{-1})			
	Effect	***p*-value**	**Coefficient**	**CV (%)**
LV	-300.00	0.1251	-150.00	2.35
QV	**516.67**	**0.0183**	**258.33**	**3.20**
LS	66.67	0.6895	33.33	4.50
QS	366.67	0.0525	183.33	6.70
VS	**3788.89**	**0.0000**	**3788.89**	**1.25**

Source: Authors
LV: Linear Vegetation; QV: Quadratic Vegetation; LS: Linear Spin; QS: Quadratic Spin; VS: Vegetation and Spin interaction CV: Coefficient of variation.

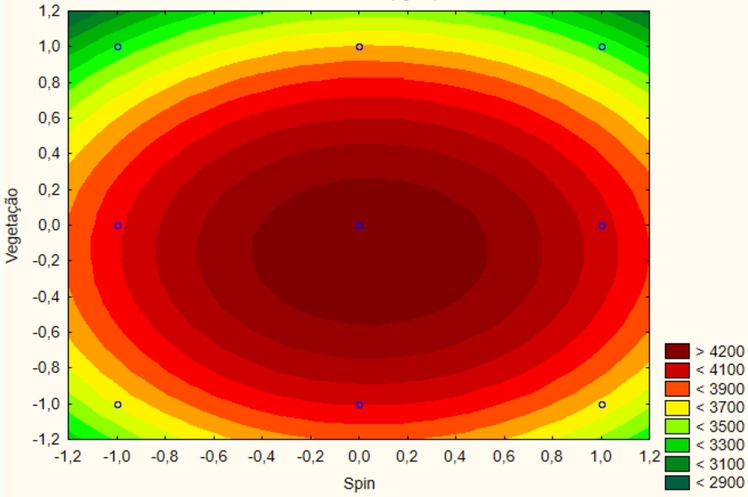
Figure 2 shows the response surface obtained for arugula productivity, proving that the result is in agreement with the statistical analysis, since the result is very close to the central point. Being a peak productivity at the central point of the planning. However, the results of this analysis showed that the best productivity of arugula should be obtained in the experiment in which the fertilizers are in the central point condition (using the average dosages). This can be seen in the contour diagram inserted in Figure 3. From the contour plots (Fig. 3), it is evident that, taking an average level for both fertilizers (V and S), the optimal yield point (maximum) is in the central part of the figure, helping to locate a possible optimum point.

Figure 2. Productivity response surface arugula var. Folha Larga for different levels of Vegetation (V) and Spin (S) fertilizers obtained for factorial design 3^2.



Source: Authors

Figure 3. Contour diagram of the V x S system in production arugula var. Folha Larga.



Source: Authors

4 CONCLUSION

The results indicated an increase in the productivity of arugula var. Folha Larga using the union of the Vegetation® and Spin® foliar fertilizers, being the best result (4500 kg ha-1) obtained in the condition of the central point of the experimental planning 32, which corresponds to the Vegetation® dosage at 60 mL L-1 and Spin® 60 mL L-1. The use of planning 32 that contributed to a fast and efficient process optimization and provided important information about the interaction between the variables. It can be concluded that among the presented results the productivity ranged from 3200 to 4500 kg ha-1.

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