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Blackcurrant Variety Specific Growth and Yield Formation as a Response to Foliar Fertilizers

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Abstract: Recently, there has been a growing interest in supplementing plant nutrition with foliar fertilizers. Foliar application of nutrients is considered a promising environmentally friendly strategy for improving the yield and nutrient efficiency of crops. Little work with foliar appliances on perennial fruits bushes, blackcurrant (*Ribes nigrum* L.), respectively, has been reported. This study was conducted to evaluate the growth and yield response of three blackcurrant varieties to macro and micronutrients' foliar fertilizer solutions. Principal component analysis and factors environmental fitting were performed for the global assessment of growth and increases in branches length responsible for yield production throughout the entire vegetation period and reported to the final development. The results endorsed the benefits of foliar fertilization. Each variety has a preference for a specific foliar treatment. The highest increases in branches length for Ruben variety was with Ascovigor foliar fertilizer; for Tiben with Kombimax; for Tines with Mikromix. The varieties growth dynamics due to fertilizers was best fitted to foliar Kombimax. Stable models were found to all blackcurrant varieties depending on developmental stage and foliar fertilization application. Application of foliar fertilizer is very profitable in terms of pairing each variety with optimum product, which will increase its specific yield potential.

Keywords: growing season; leaf application; branches; biostimulant; nutrients; income

1. Introduction

The growing consumers interest trend in *Ribes nigrum* L. is largely due to the variety of bioactive compounds potentially beneficial to health, such as high content of ascorbic acid (vitamin C), antioxidants [1–4] and fatty acids [5,6]. The bioactive compounds are found not only in fruit but also in leaves and buds. This requires a constant balancing between berry production and vegetative growth [7]. For high and qualitative yields, new branches are needed, however vegetative growth and yield formation both compete for the same resources [7–9]. The main aim in blackcurrant cultivation is to obtain rapidly and subsequently high yields [7].

Knowing the requirements and consumption level of different nutrients according to the phenophases periods has an effect an optimized fertilization system for the quantity and quality of the harvest [10]. Each nutrient must be available in the right time of its maximum consumption from budding to ripening–harvesting of the plants. Some studies highlight that the blackcurrant did not respond to the increase in mineral fertilizer amount (NPK) [11] when the soil was previously rich in organic matter [7]. Flower bud formation in blackcurrant takes place under short day conditions in the autumn of the year before. Since flowering and fruiting in blackcurrants take place on young, vigorous shoots, the yields are clearly related to the increase in shoot number in the preceding season [7,12]. As a perennial crop, the indirect yield potential of blackcurrant is determined a year ahead, while the direct potential depends on the agro-climatic conditions during fruit development [12].

The main environmental concern in the cropping strategies around the world [13] is the pollution elevated by the chemical fertilization use. For a sustainable agriculture, the strategies to improve nutrient uptake, crop performance and economic efficiency are mandatory [14].

The producers and the researchers need to streamline the crop production system and management practices to benefit from environmentally friendly fertilization strategies. In this context, foliar fertilizers or application of biostimulators are generally considered to target only the plant and reduce the environment pollution [15–17] in terms of nitrate leaching [18]. Furthermore, foliar plant nutrition is considered very versatile, mostly because it provides immediately available nutrients to plant if early signs of deficiencies are detected [16].

A close relationship between leaf values and nutrient content was found [14]. Based on this and other studies [11,12,14,19], the use of foliar fertilization could state in an improvement in intensive and sustainable blackcurrant cultivation technologies.

Yield prediction is complex, while in addition to macronutrients, the microelements from foliar products are essential [11,12,19] along with optimum temperature and water access [7,20]. Fertilization on this crop is, therefore, rather complex and challenging, from here, it becomes the importance of fertilization-type studies. We tried to address as many aspects of shoot fertilization as possible on blackcurrant cultivation. This is why the entire experiment of blackcurrant was presented in two different scientific articles [21]. This experiment aim was to assess the specific effect of three foliar formulas on the branches' growth and yield of three blackcurrant varieties. The hypotheses tested were (i) Is there a difference in the specific response of each variety to the application of foliar fertilizers? (ii) Is there a variety preference to a specific foliar fertilizer? (iii) Do the growth models for each variety use the same development parameters or are there differences in the selection of biometrics? Additionally, the yield economic efficiency was calculated based on yield observed in each treatment.

2. Materials and Methods

Our study was conducted in the area of Micula, Satu Mare county, Romania, in a crop established in 2016 when a base fertilization of 20 t ha^{-1} manure was applied. Experimental design was a two-factorial type, based on complete randomized blocks, as described by Vâtcă et al. [21].

Three varieties of blackcurrant, Factor A (var), were observed during entire vegetation period. All varieties were created in Poland [22] and are adapted to Romania's ecological conditions. Based on the description provided by Pluta and Żurawicz [23], Ruben (R) is a productive mid-season ripening variety, with medium to large fruits and high levels of extract, ascorbic acid and anthocyanins. Tiben (TB) is a high productive variety with medium-sized fruits, with a high level of anthocyanins, acidity and extract and a medium level of ascorbic acid. Tines (TI) is a fairly productive, early ripening variety, with medium to large fruits, which possess an amount of extract and medium levels of ascorbic acid and anthocyanins.

Fertilizers, Factor B (treat), comprised four graduations and consisted of foliar formulas of Ascovigor (A), Mikromix (M) and Kombimax (K), to which a non-fertilized control (Co) was added. All fertilizers were produced (Table 1) by Agria Poland (a part of the Agri intelligence group) and were applied in a quantity of 3 L ha^{-1} in 3 successive growth stages. The first treatment was applied when 10% of the flowers were open, which consist of growth phase 61 according to Meier's BBCH scale [24]. The second and third treatment were applied after 14 and 28 days, when 50% and all petals, respectively, were fallen.

Table 1. Composition of applied foliar fertilizers (% of total volume) [21].

Fertilizer	N	K_2O	CaO	MgO	SO_3	B
Ascovigor	3.17	1.9	0.18		2.54	3.81
Kombimax	27.6	20.7	-	5.52	2.3	0.0276
Mikromix	7.25	14.5	-	4.35	7.54	0.435
Fertilizer	**Cu**	**I**	**Fe**	**Mn**	**Mo**	**Zn**
Ascovigor	0.0004	0.004	0.006	1.02	-	0.64
Kombimax	0.069	-	0.138	0.069	0.0014	0.069
Mikromix	0.7254	-	1.45	2.175	0.0145	1.45

All varieties were subjected to measurements on branches length, starting with the moment of the first treatment (*ds*). Measurements were repeated every 14 days and coded as development (*d*) and number of days from the first treatment until full ripening (14–98): d14, d28, d42, d56, d70, d84 and d98. The final development of branches (d98) was used as a report value for each of the previous measurements. Based on the differences between 2 successive periods (*c*), the increases in branch length were calculated: c14, c28, c42, c56, c70, c84 and c98. The two databases, growths and increases, comprise 684 observations for each parameter.

The entire data analysis was performed with R Studio software, (R Studio, MA, USA), version 1.1.463 [25,26]. We used the package "psych" [27] for the analysis of data validity and descriptive statistics, which provide us the mean ± standard deviations for each combination of variety *x* treatment. ANOVA and Tukey's honestly significant differences (HSD) tests were used to identify differences between variants based on formulas provided by "agricolae" [28] package. Single factor and two-factorial influence over growth and increases in branches were analyzed through ANOVA. HSD was used to explore the differences within treatments for each variety, which provided information about their specific use of fertilizers and made possible the treatments ranking. Regressions were used to explore the relation between the final branches' growth and their development phase, both due to specific response of variety to treatments and their preference for nutrients included in the recipes. All regressions were designed with the "stats" package from the R Studio base and verified through "MASS" package [29]. Akaike information criterion (AIC) was used for the selection of most important nutrients from the fertilizer recipes with the packages "vegan" [30] and "caret" [31]. Principal component analysis (PCA) and environmental fitting of factor were performed for the global assessment of growth and increases in branches length throughout the entire vegetation period and reported to the final development (*d98*), based on formula included in the "vegan" package. To complete this research, we calculated the economic efficiency of the blackcurrant varieties, based on yields for each combination of variety x treatment.

3. Results

Based on ANOVA results, the variety showed the highest influence on branches development after the second and third application of foliar fertilizers (Table 2). Overall, during the entire growing season, the variety played a very important role in the growth of blackcurrant plants. The influence of foliar fertilizers shows a non-homogenous gradual increase from the first application of treatments. For the period when fertilizers were applied (ds, d14 and d28), the singular impact of treatments was not significant. The maximum influence of treatments is observed at 84 days form the crop start, when all treatments were applied and the growth was more influenced by their residual effects. The specific response of each variety produces large fluctuations between growth stages of the branches, but the global effect of variety *x* treatment interaction was not significant.

Table 2. Effect of singular and combined effect of variety *x* treatment interaction on the branches' development.

	Var F	*p* Value	Treat F	*p* Value	Var: Treat F	*p* Value
ds	4.71	0.009	0.84	0.471	0.25	0.961
d14	4.74	0.009	0.59	0.619	0.38	0.894
d28	5.76	0.003	1.31	0.271	0.67	0.677
d42	5.40	0.005	2.93	0.033	0.58	0.744
d56	4.76	0.009	3.74	0.011	0.58	0.750
d70	4.73	0.009	3.88	0.009	0.61	0.726
d84	4.60	0.010	5.97	0.001	0.56	0.763

Note: var—variety, treat—treatment, var: treat—interaction between variety *x* treatment. A full description of treatment recipes is provided in Table 1. *d*—development of branches, *s*—first development stage, numbers 14, 28, 42, 56, 70, 80—days after the first treatment.

Observations over branches development, due to the interaction of variety with foliar fertilizers shows reduced differences between variants due to applied fertilizers (Table 3). For the first three stages of development, the differences are not significant. Starting with the first period after all three fertilizers were applied, there are significant differences between the Tines variety fertilized with Kombimax and Ruben variety, when Mikromix was applied. Those differences were maintained until d84, when the Tines variety fertilized with Kombimax maintains as the most performant combination, with significant differences compared to Ruben (control and Ascovigor) and Tiben (control).

Table 3. Blackcurrant variety-specific development of branches (cm) during the vegetation period.

	ds	Sig.	d14	Sig.	d28	Sig.	d42	Sig.	d56	Sig.	d70	Sig.	d84	Sig.
RCo	48.50 ± 1.08	a	50.48 ± 1.08	a	54.63 ± 1.08	a	56.63 ± 1.08	ab	58.61 ± 1.07	ab	60.61 ± 1.07	ab	61.89 ± 1.05	b
RA	46.95 ± 1.08	a	48.89 ± 1.07	a	54.22 ± 1.08	a	56.35 ± 1.07	ab	58.40 ± 1.06	ab	60.44 ± 1.06	ab	62.47 ± 1.05	ab
RM	47.56 ± 1.08	a	49.52 ± 1.08	a	53.90 ± 1.08	a	55.92 ± 1.08	b	57.92 ± 1.08	b	59.92 ± 1.08	b	61.86 ± 1.08	b
RK	47.07 ± 0.95	a	49.07 ± 0.95	a	54.18 ± 0.95	a	57.12 ± 0.94	ab	59.78 ± 0.94	ab	61.80 ± 0.94	ab	63.80 ± 0.94	ab
TBCo	49.48 ± 1.02	a	50.59 ± 1.01	a	54.54 ± 1.00	a	56.54 ± 1.00	ab	58.54 ± 1.00	ab	60.54 ± 1.00	ab	61.55 ± 1.01	b
TBA	48.64 ± 1.26	a	50.77 ± 1.26	a	56.00 ± 1.24	a	58.17 ± 1.24	ab	60.74 ± 1.22	ab	62.77 ± 1.21	ab	64.06 ± 1.19	ab
TBM	48.31 ± 0.99	a	50.24 ± 1.00	a	54.94 ± 1.00	a	56.98 ± 1.00	ab	59.00 ± 1.00	ab	60.93 ± 1.01	ab	62.78 ± 1.02	ab
TBK	49.36 ± 1.13	a	51.58 ± 1.12	a	57.44 ± 1.12	a	59.89 ± 1.10	ab	62.09 ± 1.10	ab	64.20 ± 1.10	ab	66.27 ± 1.10	ab
TICo	50.11 ± 0.92	a	52.11 ± 0.92	a	56.18 ± 0.93	a	58.18 ± 0.93	ab	60.18 ± 0.93	ab	62.18 ± 0.93	ab	63.25	ab
TIA	48.58 ± 1.08	a	50.58 ± 1.08	a	55.72 ± 1.08	a	57.77 ± 1.07	ab	59.80 ± 1.07	ab	61.80 ± 1.07	ab	63.82	ab
TIM	49.92 ± 1.07	a	51.90 ± 1.07	a	56.85 ± 1.08	a	58.88 ± 1.09	ab	60.92 ± 1.09	ab	62.93 ± 1.09	ab	64.97	ab
TIK	50.36 ± 1.00	a	52.36 ± 1.00	a	58.11 ± 1.00	a	60.85 ± 0.99	a	62.90 ± 1.00	a	64.90 ± 1.00	a	66.90	a

Note: Values presented in the table are the means of the three tested varieties (Ruben—R, Tiben—TB and Tines—TI) ± standard error. Means followed by different letters indicate differences at $p < 0.05$ according to Tukey honestly significant differences (HSD) test; *d*—development of branches, *s*—first development stage, numbers 14, 28, 42, 56, 70, 80—days after the first treatment. Co—control, A—Ascovigor, M—Mikromix, K—Kombimax. A full description of treatment recipes is provided in Table 1.

Compared to branch length at each development stage, the increases from one stage to another are strongly influenced by each factor and their interactions (Table 4).

Table 4. Singular and combined effect of variety *x* treatment interaction on the stage increases in branches.

	Var F	*p* Value	Treat F	*p* Value	Var: Treat F	*p* Value
c14	30.02	$p < 0.001$	77.67	$p < 0.001$	81.67	$p < 0.001$
c28	13.36	$p < 0.001$	307.12	$p < 0.001$	16.04	$p < 0.001$
c42	10.59	$p < 0.001$	231.08	$p < 0.001$	11.00	$p < 0.001$
c56	22.06	$p < 0.001$	43.56	$p < 0.001$	34.52	$p < 0.001$
c70	0.14	0.870	2.03	0.108	2.18	0.044
c84	52.12	$p < 0.001$	360.89	$p < 0.001$	28.82	$p < 0.001$
c98	0.70	0.498	783.76	$p < 0.001$	10.03	$p < 0.001$

Note: var—variety, treat—treatment, var: treat—interaction between variety *x* treatment. A full description of treatment recipes is provided in Table 1. *c*—increases in branches, numbers 14, 28, 42, 56, 70, 80—days after the first treatment.

Increases in branch length are significantly influenced by variety, with the exception of c70 and c98, when the plants are close to the end of vegetation period. However, the variety shows its specificity of growth at 84 days after first treatment. Foliar treatments have a great influence over the branches increases in the first stages, with a maximum after 28 and 42 days from the first treatment. At the end of vegetation period, the residual effect of foliar treatments is significant for the increases especially at 84 and 98 days. The interaction variety *x* treatment acts synergistically after the first treatment, producing significant variations between variants. The increases in the stage c70 are not significant.

Increases in branch length are both related to variety and applied foliar treatments (Table 5). The interval of increases after the first treatment (c14) is 1.11–2.22, with significant differences between varieties due to their response to treatments. The Tiben variety possess the highest and the lowest increases, which sustain the idea of fertilizer application for this variety. Ascovigor and Kombimax represent a good fertilization solution for this variety. Both Ruben and Tines have a reduced reaction to applied fertilizers in this stage. Application of the second foliar fertilizer treatments (c28) produce the highest increases in the branches' length. Kombimax produces more than 5.75 increases in both the Tiben and Tines varieties. As an opposite, the lack of foliar treatments in the control variants maintain the increases at approximately 4 cm for all varieties, with significant differences compared to the other variants. For the c42 stage, the best fertilizer is Kombimax, both for Ruben and Tines, with a shift between the last one and Tines at the stage c56. The stage c70 is the most stable one, with differences observed only for Tiben variety, with Mikromix producing the lowest increases and Kombimax the highest ones. The effect of treatments became variety-specific starting with c84 stage. Each variety have a preference for a specific foliar treatment: Ruben for Ascovigor, Tiben for Kombimax and Tines for Mikromix. These combinations produce the highest increases in branches length. The increases in the control variant remains low, but an interesting case is the significant reduced increase in Tiben, due to the Ascovigor treatment. The final increases in varieties produce the largest differences at the end of vegetation period, when the observed increases occupy the largest interval: 3.07–6.20. Tiben have the highest increases due to the treatments with Kombimax, followed by Tines and Ruben with the same treatment. Ascovigor is the second treatment for all varieties with significant differences from Kombimax. Mikromix maintains the increases between 4.42 and 5.02 but is classified as the third treatment for all varieties.

PCA ordination of specific growth for each variety have a potential variance explanation of over 99% based on first two axes (Supplementary Materials Table S1). Each variety have a specific reaction to the nutrients provided by fertilizers (Supplementary Materials Table S1) and, thus, a specific position within the ordination graph (Figure 1).

Table 5. Blackcurrant variety-specific increases in branches (cm) during the vegetation period.

	c14	Sig.	c28	Sig.	c42	Sig.	c56	Sig.	c70	Sig.	c84	Sig.	c98	Sig.
RCo	1.98 ± 0.02	bc	4.15 ± 0.06	ef	2.00 ± 0.00	d	1.98 ± 0.02	c	2.00 ± 0.00	ab	1.28 ± 0.06	c	3.20 ± 0.07	h
RA	1.95 ± 0.04	c	5.33 ± 0.07	b	2.13 ± 0.05	d	2.05 ± 0.03	bc	2.04 ± 0.03	ab	2.04 ± 0.03	a	5.49 ± 0.09	cd
RM	1.96 ± 0.03	c	4.38 ± 0.07	e	2.02 ± 0.02	d	2.00 ± 0.00	c	2.00 ± 0.00	ab	1.94 ± 0.03	ab	4.42 ± 0.10	g
RK	2.00 ± 0.00	bc	5.1 ± 0.05	bc	2.93 ± 0.03	a	2.67 ± 0.06	a	2.02 ± 0.02	ab	2.00 ± 0.00	ab	5.78 ± 0.07	bc
TBCo	1.11 ± 0.04	d	3.95 ± 0.05	f	2.00 ± 0.00	d	2.00 ± 0.00	c	2.00 ± 0.00	ab	1.02 ± 0.02	d	3.11 ± 0.06	h
TBA	2.13 ± 0.07	ab	5.23 ± 0.12	bc	2.17 ± 0.07	d	2.57 ± 0.09	a	2.02 ± 0.10	ab	1.30 ± 0.07	c	5.13 ± 0.14	def
TBM	1.93 ± 0.04	c	4.70 ± 0.07	d	2.04 ± 0.03	d	2.02 ± 0.02	bc	1.93 ± 0.04	b	1.85 ± 0.06	b	4.87 ± 0.05	f
TBK	2.22 ± 0.06	a	5.85 ± 0.10	a	2.45 ± 0.07	c	2.20 ± 0.06	b	2.11 ± 0.04	a	2.07 ± 0.04	a	6.20 ± 0.08	a
TICo	2.00 ± 0.00	bc	4.07 ± 0.04	ef	2.00 ± 0.00	d	2.00 ± 0.00	c	2.00 ± 0.00	ab	1.07 ± 0.03	d	3.07 ± 0.03	h
TIA	2.00 ± 0.00	bc	5.13 ± 0.06	bc	2.05 ± 0.03	d	2.03 ± 0.03	bc	2.00 ± 0.00	ab	2.02 ± 0.02	ab	5.27 ± 0.07	de
TIM	1.98 ± 0.02	bc	4.95 ± 0.04	cd	2.03 ± 0.02	d	2.03 ± 0.02	bc	2.02 ± 0.02	ab	2.03 ± 0.02	a	5.02 ± 0.07	ef
TIK	2.00 ± 0.00	bc	5.75 ± 0.06	a	2.74 ± 0.06	b	2.05 ± 0.03	bc	2.00 ± 0.00	ab	2.00 ± 0.00	ab	5.84 ± 0.05	b

Note: Values presented in the table are the means of the three tested varieties (Ruben—R, Tiben—TB and Tines—TI) ± standard error. Means followed by different letters indicate differences at $p < 0.05$ according to Tukey HSD test. *c*—increases in branches, numbers 14, 28, 42, 56, 70, 80—days after the first treatment. Co—control, A—Ascovigor, M—Mikromix, K—Kombimax. A full description of treatment recipes is provided in Table 1.

For Ruben variety (Figure 1), the combination of N, K_2O, CaO, MgO, SO_3, B, I contained by fertilizers have a very significant influence for growth stability process. In the absence of fertilizers (Co), this variety can expand its branches in the interval of 15 to a maximum of 20 cm, with the majority of growth between 16 and 17 cm. Application of Mikromix to Ruben variety causes growths between 18 and 20 cm, but in some cases, branches can have growths under 17 cm, while the maximum is 21 cm. This fertilizer offers a reduced stability for the growths. The most efficient treatment for Ruben is Ascovigor, which maintains the large majority of growths within 20–21 cm. The best fertilizer for this variety is Kombimax, but the potential growths of branches lack stability and homogeneity. For the Tiben variety, nutrient preference is significantly related to the amount of N, K_2O, MgO and SO_3 quantities. Branches growth shows a similar use of Mikromix and Ascovigor, and a larger difference in the center of PCA compared to control and Kombimax (Figure 1). Control variants maintain their growths in the interval 14–18 cm, while Kombimax start with 19 up to 25 cm. The area occupied by Mikromix and Ascovigor is located in the large majority in the interval 19–22 cm, but both recipes can produce large fluctuations in the development of branches. The Tiben variety have a non-homogenous reaction to all applied treatments, which is visible in the dispersion of growths on PCA ordination. The Tines variety (Figure 1) is significantly influenced by all nutrients from the fertilizer recipe. It is the only variety, where the control variant is clearly separate from all fertilizers, and shows the smallest dispersion of data on ordination and the highest stability of growths. Lack of fertilization maintain growths in the interval 16–17 cm, while any application of fertilizers produces an increase up to 19–23 cm. Its reaction to Ascovigor and Mikromix is similar, both fertilizers maintaining the growths between 19–21 cm, and application of Kombimax extends the length of branches in the interval 22–23 cm.

Based on the reaction to fertilizers, four development models were developed for each studied variety (Tables 6–8). There are two simple models that comprise only growth stages or increases, and two complex models that present the supplementary role of nutrients. Final growths of Ruben variety (Table 6) are positive based on the value reached with 14 days before and of growing season and in a reduced way on the registered development at 42 days from the first treatment. The values observed at d14 and d70 act as a decrease in the final value. By combining nutrients with stage growths, the model shows an almost equal development with the value registered at d84 and 1.10 cm for each unit of applied CaO. Nitrogen and potassium act adversely in the model, with similar coefficients. Increases from one stage to another are important in the development model only at 28 days from the first treatment and in a negative manner at c70 (−8.51). The intercept value in the complex model increases *x* nutrients have a high value: 92.24. Based on this model, c42, c70 and c84 act as reducers of final length of branches, while c28 along with K_2O and especially CaO assure the positive values.

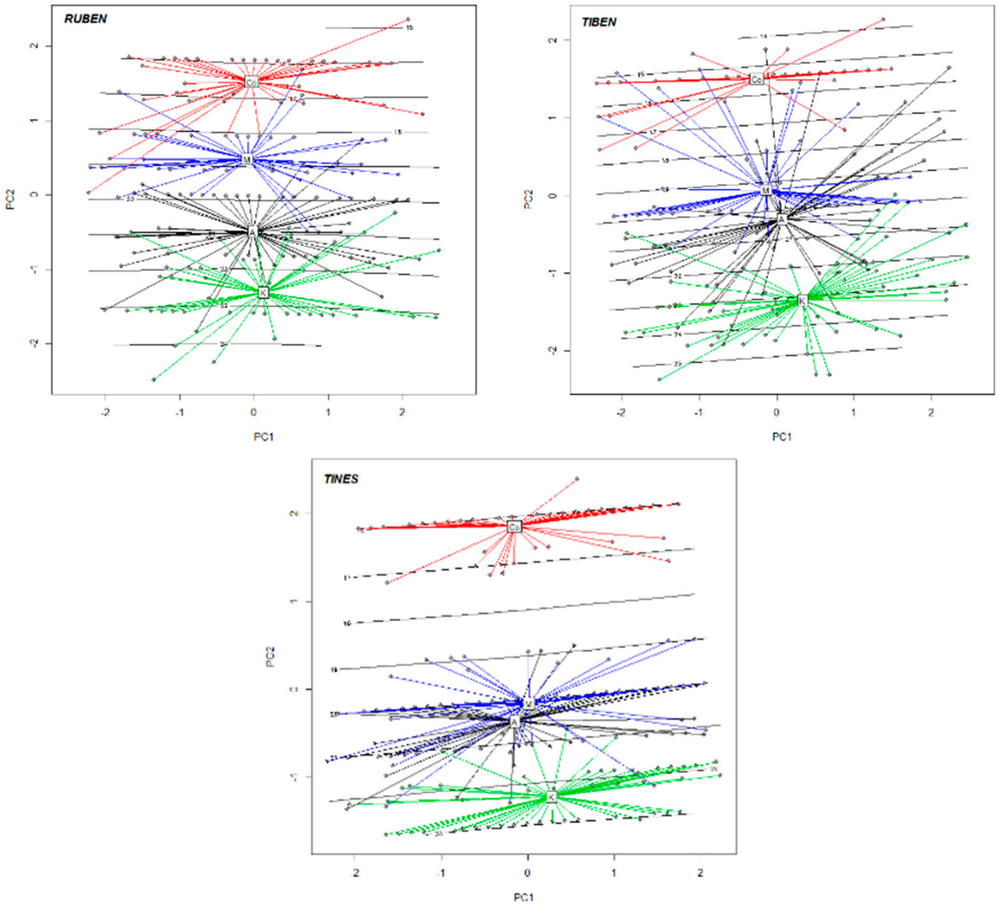

Figure 1. Growth dynamics of varieties due to fertilizers projected to the final growth (d98). Co—control, A—Ascovigor, M—Mikromix, K—Kombimax. A full description of treatment recipes is provided in Table 1.

Table 6. Modelling of Ruben variety final growth (d98) based on development stage and applied nutrient.

G		G + N		I		I + N	
Inter	−3.33	Inter	0.85	Inter	72.76	Inter	92.24
d14	−0.68	d14	−0.29	c28	2.46	c28	1.61
d42	0.37	d56	0.23	c70	−8.51	c42	−5.36
d70	−0.66	d84	1.06			c70	−9.03
d84	1.98	N	−0.02			c84	−3.66
		K_2O	0.03			K_2O	0.06
		CaO	1.10			CaO	2.11
ANOVA							
F	6792		6512		6.36		4.69
p.val	$p < 0.001$		$p < 0.001$		0.002		$p < 0.001$

Note: G—development stage of branches; N—nutrients from fertilizer recipe; I—stage increases in branches; Inter.—Intercept. *d*—development of branches; *c*—increases in branches; *s*—first development stage, numbers 14, 28, 42, 56, 70, 80, 98—days after the first treatment.

Table 7. Modelling of the Tiben variety final growth (d98) based on development stage and applied nutrients.

G		G + N		I		I + N	
Inter	−1.42	Inter	2.39	Inter	57.39	Inter	69.77
d14	−0.63	ds	−0.08	c14	2.03	c42	−2.33
d42	0.25	d42	−0.28	c28	1.49	K2O	0.05
d56	−0.25	d70	0.29			CaO	2.27
d70	−0.34	d84	1.05				
d84	1.67	N	−0.03				
		K2O	0.05				
		CaO	0.96				
ANOVA							
F	4038		6176		9.508		10.61
p.val	$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$

Note: G—development stage of branches; N—nutrients from fertilizer recipe; I—stage increases in branches; Inter.—Intercept. *d*—development of branches; *c*—increases in branches; *s*—first development stage, numbers 14, 28, 42, 56, 70, 80, 98—days after the first treatment.

Table 8. Modelling of the Tines variety final growth (d98) based on development stage and applied nutrients.

G		G + N		I		I + N	
Inter	−3.24	Inter	2.16	Inter	56.12	Inter	66.32
ds	−0.43	ds	−1.03	c28	2.70	N	−0.06
d70	−1.06	d14	1.18			K_2O	0.11
d84	2.48	d42	−0.19			CaO	1.56
		d84	1.04				
		N	−0.04				
		K_2O	0.07				
		CaO	1.39				
ANOVA							
F	15000		11530		13.77		6.75
p.val	$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$

Note: G—development stage of branches; N—nutrients from fertilizer recipe; I—stage increases in branches; Inter.—Intercept. *d*—development of branches; *c*—increases in branches; *s*—first development stage, numbers 14, 28, 42, 56, 70, 80, 98—days after the first treatment.

Tiben growths during vegetation period are lacking in homogeneity and growth models combine both positive and negative coefficients (Table 7). When using only stage growth as base for the final length of branches, just d42 and d84 have a positive influence, with 0.25 cm, respectively, 1.67 cm for each cm existent in that stage. Lengths registered at d14, d56 and d70 reduces the final length with 0.63, respectively, 0.25 and 0.34 for each cm of branch. The entire model has a very low base value, with the intercept being −1.42. By combining growths with nutrients, a new and more equilibrate model is achieved. The base is set up to 2.39, with a reduced negative impact of the first growth (ds = −0.08). For this model, d42 and quantity of applied N reduce the final length of branches. The highest positive influence is due to the length of branches at d84 and the quantity of CaO applied, both acting for the increase in branches with approximately 1 cm per unit. The second-class models for this variety are based on stage increases and applied nutrients. The intercept in both models is set to high values, with almost 70 cm start base for the combined increase + nutrients model. Only K and Ca play a positive role in the final growth, with 2.27 cm per unit of applied CaO.

Tines is a variety, which base its final development of the previous growths (d84 = 2.48) in a simple model with negative values of intercept and first development (Table 8). By adding the influence of nutrients within a complex model, the intercept for growth became positive (2.16), with the growths at first and last stages (ds and d84) cancelling each other. Both d42 and applied N have negative influence in the complex model, compensated by the high value of growths after first treatment (d14 = 1.18) and the amount of applied CaO (1.39). For this variety, the use of stage increases in branch length for the forecasting of final branch growth provide two opposite models. The only influence of increases is due to c28 (2.70) based on an intercept of more than 56 cm. When nutrients are used along the stage increases, only N, K and Ca are present in the model, with 1.56 cm per unit of applied Cao. The difference between the base lengths (as intercept) are more than 10 cm, which sustain the two approaches as different models of forecast.

Blackcurrant has the greatest economic importance in this genus and is cultivated in temperate Europe, North America, Asia and mountainous regions of South America, New Zealand and North Africa [32–34].

From an economic efficiency point of view, the difference in obtained yield per hectare was followed after the administration of foliar fertilizers and, respectively, the additional incomes that can be obtained from the capitalization of the production difference, compared to the control group. The maintenance works carried out on all the varieties studied are the same, which ensures constant expenses from this point of view. The difference being given only by the expenses with the foliar fertilizer's administration with the trade names Ascovigor, Kombimax, Mikromix (Ascovigor-77 RON ha^{-1}, Kombimax-70 RON ha^{-1}, Mikromix-75 RON ha^{-1}). The average capitalization price of one kg of currant fruits was 9 RON/kg (≈1.86 EUR kg^{-1}). In the case of the Ruben variety, where the foliar fertilizer with the trade name Kombimax was administered, there was an increase in production of over 18%, compared to the control group, which ensures an additional income of over RON 30,000 per hectare (≈6196 EUR ha^{-1}) and, respectively, an additional profit compared to the control of 30,818 RON/ha (≈6365 EUR ha^{-1}). The productivity of the Tiben variety bushes, lot 3, ensures a higher average production per bush of approximately 5.93 kg by 14.7% more than the control group, production that ensures an additional income of 22,572 RON ha^{-1} (≈4662 EUR ha^{-1}). In the case of the Tines variety, following the application of Kombimax fertilizer, the average production per bush is 1.87 kg higher than that of the control group, an increase of approximately 36%. This difference can ensure a higher production per hectare compared to the control by approximately 6171 kg, and additional profit from the capitalization of the production difference of RON 55,469 (≈11,456 EUR ha^{-1}).

In the case of the three varieties studied (Ruben, Tiben and Tines), from the economic point of view (Table 9), the highest productivity was obtained in the case of the Tines variety, using the foliar fertilizer Kombimax, respectively, about 7 kg of fruit/bush (≈23,100 kg ha^{-1}). The average annual income that can be obtained from the capitalization of this production being around 200,000 RON ha^{-1} (≈43,000 EUR ha^{-1}).

Table 9. Economic efficiency indicators for the three blackcurrant varieties production under foliar fertilizers treatments.

No.	Specification	UM	Variety Ruben				Variety Tiben				Variety Tines			
			Co	A	M	K	Co	A	M	K	Co	A	M	K
1.	Average yield/bush	kg	5.53	5.93	6.57	5.57	5.17	5.77	5.87	5.93	5.2	6.53	7.07	6.1
2.	Average yield/ha	kg	18,249	19,569	21,681	18,381	17,061	19,041	19,371	19,569	17,160	21,549	23,331	20,130
3.	Production difference *	kg	-	1320	3432	132	-	1980	2310	2508	-	4389	6171	2970
4.	Yield increase *	%	-	7.23	18.81	0.72	-	11.61	13.54	14.70	-	25.58	35.96	17.31
5.	Revenue recovery	lei	-	11,880	30,888	1188	-	17,820	20,790	22,572	-	39,501	55,539	26,730
6.	Yield profit difference *	lei	-	11,803	30,818	1113	-	17,743	20,720	22,497	-	39,424	55,469	26,655

Note: * compared to the control; Co—control, A—Ascovigor, M—Mikromix, K—Kombimax. A full description of treatment recipes is provided in Table 1.

4. Discussion

Foliar application of fertilizers induced a specific difference and adaptability within individual varieties. Many studies agree that genotype is the main source of fruit variation in ascorbic acid [35], phenolic compounds, anthocyanins, antioxidant capacity, dry matter content, soluble solids, pH, as well as yield and berry weight [7,12,36–39]. Our results state clearly a variety preference upon a single fertilizer type. Following this aspect, we could interpret and propose a deep look into fertilizer composition for each variety aspect.

Ruben variety had the highest branch growth when Ascovigor foliar fertilizer was applied, which is correlated with variety characteristics (ascorbic acid—AsA and anthocyanins—AnT) and foliar fertilizer chemical components. Therefore, for the formation of a high level in terms of AsA and AnT, blackcurrant plant needs an input of CaO, B and I. This can be sustained by other studies, where the role of calcium was fitted to cellular membrane, cellular walls formation and biosynthesis of proteins and other compounds [40]. Boron as well was highlighted to be essential in blackcurrant crop [19], and it participates to metabolism, protein transport, applied in the flowering phase to improve fruit characteristics and consequently increase yield [19,37,41].

In case of the Tiben variety for a high level of AnT and a medium level of AsA, the application of fertilizer (Kombimax) with high content in macronutrients is essential, especially N, a medium content in Fe and a relatively low inputs of B and Mo. Additionally, Mo could act as a restrictive factor for the AsA and AnT levels. Nitrogen is the indispensable for amino acids, protein substances, nucleic acids, chlorophyll, coenzymes, vitamins composition [42] and together with Fe and Mo regulates a medium level of AsA in the favor of AnT [12,43].

For a medium content of AsA and AnT, the Tines variety requires a fertilizer (Mikromix) with a medium content of macronutrients (N), also a medium B content and high content of Cu, Fe, Mn and Zn compared with the other foliar fertilizers. It has been shown that the accumulation of ascorbic acid is highest during the fruit expansion phase [44] and that a medium content of macronutrients and micronutrients crop-fitted need persist until later ripening stages [36].

The current trend in agronomy is oriented to economic and ecologic efficiency [45–48]. Digital agriculture can assure the sustainability of crop production by harmonizing biological traits of each species with its nutritional and climatic requirements [49–51]. However, this approach is holistic and implies large database and complex models. In this context, physiological studies on current cultivated varieties creates the premise for the identification of biogeographical optimum of each species. Additionally, it will facilitate the process of better selection of new varieties, with a high acclimation for site-specific conditions. Future research is required to explain, argue and deeply understand the physiology of blackcurrant. This species is one of the crops that provides high beneficial compounds for human nutrition. Thus, in contrast to yield chemistry, there are lack of studies on variety specific development. This is needed in order to provide complex and viable models of varietal biology of growth and development. Based on both agronomic and biochemistry research, this crop can be directed to a high level of profitability.

Our results highlighted Rubes variety as being the most stable after modeling the growth and fertilizer effect. Another study place Ruben cultivar as having a good effect of general and specific abilities of fruit yield, weight and AsA content at least in two consecutive years [52]. Their study also concludes that the lowest yield production is at Tines variety compared with Ruben variety. We have obtained similar results in terms of yield only in the control variant with no fertilization and for Ascovigor fertilizer effect, slightly different when Mikromix and Kombimax were applied.

In addition, we could also appreciate that foliar fertilizer determined an increase in shoot length with a maximum effect in d28 and d42, because the fertilizer effect is usually seen at the beginning of the vegetation stage. Wójcik and Filipczak [36] found that Tiben plants supplied with mineral fertilizers also had stronger vigor, higher photosynthetic rates, more chlorophyll in the leaves and greater yields than did those grown with manure only or no fertilizer. They also stated that fertilizers influence the level of acidity in fruits (AsA), with an exception for AnT content.

5. Conclusions

Foliar fertilizer application produces large differences within individual cultivars. Although blackcurrant crop is self-fruitful, we recommend a mixed-cultivar planting for a greater and constant yield, and for sustainable economic efficiency. We also recommend fertilizing Ruben variety with Ascovigor foliar fertilizer; Tiben cultivar with Kombimax and Tines variety with Mikromix. Foliar fertilizer appliance increases shoot development, as well as the growth of blackcurrant bushes and at the end of vegetation period, the fruit yield with a specificity connected to the cultivar preference type. This crop assures high and economically efficient yields due to the application of a personalized foliar product for each variety.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4395/10/12/2014/s1, Table S1. PCA variance and variety-specific growth as a reaction fertilizer composition.

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