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EFECTUL APLICĂRII FERTILIZĂRII FOLIARE ȘI RADICULARE ASUPRA COMPOZIȚIEI CHIMICE A FRUNZELOR LA SOIUL DE PRUN 'STANLEY' (*PRUNUS DOMESTICA* L.)

EFFECT OF FOLIAR AND SOIL FERTILIZERS APPLICATION ON THE CHEMICAL COMPOSITION OF THE LEAVES OF PLUM (*PRUNUS DOMESTICA* L.) CV. 'STANLEY'

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Abstract

The experiment was conducted in the period 2019-2022 in plum (*Prunus domestica* L.) cv. 'Stanley' plantation of the Institute of Agriculture – Kyustendil, Bulgaria. The orchard was established in 2013 with distances between trees of 5x5 m. The soil and foliar fertilizers were applied as follows: V 1 – unfertilized – (control), V 2 – Ecofol program, V 3 – Humustim, V 4 – Chicken manure Vita organic 2.5 kg/tree and V 5 – Chicken manure Vita organic 5.0 kg/tree. The influence of the fertilization treatments on the nitrogen, phosphorus and magnesium content of the plum leaves cv. 'Stanley' was non-statistically significant. The Vita organic chicken manure with a rate of 2.5 kg/tree increased the potassium content in the leaves by 15.3% above the control, and the rate of 5.0 kg/tree – by 21.0%, confirmed by the analysis, which showed statistically significant differences ($P < 0.001$). The foliar treatment has been proven to increase the calcium content – Humustim – by 11.3% at $P < 0.001$, and the application of the Ecofol program – by 14.3%. A positive correlation was established for the pairs nitrogen-yield – r = 0.576*, phosphorus-calcium – r = 0.564*, phosphorus-magnesium – r = 0.655* and calcium-magnesium – r = 0.683*.

Cuvinte cheie: conținutul frunzelor în minerale, corelații.
Key words: leaves mineral content, correlations.

1. Introduction

Plum (*Prunus domestica* L.) is one of the main fruit crops grown in Bulgaria. The most widespread cultivar in the country is 'Stanley', which, according to 2017 data, occupies an area of 8,252.4 ha, representing 73.4% of all plum plantations (xxx, 2017). In 2024, the plum ranks second in area after walnut (*Juglans regia* L.) (***, 2025).

The leaves chemical composition of plum is an indicator of its nutritional status and is influenced by many factors. Among the main ones are: the soil supply (Lascu et al., 2016) or substrate supply (Sun et al., 2022) with nutrients; the varietal affiliation (Milošević et al., 2012; Milošević et al., 2013; Hamdani et al., 2024), the used rootstock (Sharma et al., 2019; Angelova et al., 2022), as well as the specific cultivar-rootstock combination (Mayer et al., 2018; Reig et al., 2018; Stefanova, 2018; Akova et al., 2019; Popova et al., 2020).

Other factors influencing the mineral content of leaves are: growing location (Haroon et al., 2015), plant age (Orduz-Rios et al., 2020), phenological phase (Lascu et al., 2016; Hristova et al., 2020), soil surface training systems (Popski and Stefanova, 2019; Lisek and Stępień, 2021), fertilization methods (Marinova et al., 2014; Popova et al., 2020; Al-Shujairy and Al-Hadethi, 2021; Stojanova et al., 2023; Stojanova et al., 2024), irrigation (Jaroszewska et al., 2023; Khalil and Bani, 2023), pruning (Kumar and Thakur, 2012), crop load (Sayed et al., 2021), as well as the year of the study (Milošević and Milošević, 2012).

The aim of this study was to determine the influence of soil and foliar fertilization on the nutrient content in the leaves of plum cv. 'Stanley'.

2. Material and methods

The experiment was conducted in the period 2019-2022 in plum (*Prunus domestica* L.) cv. 'Stanley' plantation of the Institute of Agriculture – Kyustendil, Bulgaria. The orchard was established in 2013 with distances between trees of 5x5 m. The foliar and soil fertilizers were applied, as follows:

V 1 – Unfertilized – (control).

V 2 – Ecofol program – treatment applied in the following phenophases once (BBCH-scale (Meier, 2001) – in 2019 with: Amino Expert® Balans – 160 ml/da (flower buds (55 BBCH)), GO! BIO Total – 220 ml/da (development of fruit (72 BBCH)), Amino Expert® Balans – 220 ml/da (development of fruit (76 BBCH)), GO! BIO (K) – 400 ml/da (development of fruit (78 BBCH)) and GO! BIO (Ca) – 320 ml/da (beginning of fruit colouring (81 BBCH)); in 2020 the program was updated: Amino Expert Balance – 160 ml/da (flower buds (55 BBCH)), Helasol (B) 100 ml/da (end of flowering (69 BBCH)), GO! BIO Total – 220 ml/da (development of fruit (72 BBCH), GO! BIO (K) – 400 ml/da (development of fruit (78 BBCH) and GO! BIO (Ca) – 320 ml/da (beginning of fruit colouring (81 BBCH)).

V 3 – Humustim – treatment by phenophases four times with 100 ml/da (end of flowering (69 BBCH)), (development of fruit (72 BBCH), the next treatments were applied in 78 BBCH and 81BBCH stages.

V 4 – Chicken manure Vita organic 2.5 kg/tree (flower buds (55 BBCH).

V 5 – Chicken manure Vita organic 5.0 kg/tree (flower buds (55 BBCH).

Chemical composition of fertilizers (W/W%):

Amino Expert® Balans (Ecofol AD): amino acids – 50.0, C – 25.0, N – 8.7, SO_3 – 1.3.

Helasol (B) (Ecofol AD): B – 11.0.

GO! BIO Total (Ecofol AD): amino acids – 26.0, C – 13.0, N – 4.0, MgO – 0.8, S – 1.5, Fe – 1.0, B – 1,50, Mn – 0,1, Zn – 0,1, Mo – 0,0010.

GO! BIO (K) (Ecofol AD): amino acids – 10.0, C – 22.0, N – 4.0, K_2O – 5.0, S – 1.0, CaO – 0.5, MgO – 0.1, P_2O_5 – 0.1.

GO! BIO (Ca) (Ecofol AD): amino acids 22.0, C – 11.0, N – 3.5, CaO – 8.0.

Humustim (Agrospace Ltd): C > 23,0, N > 2,0, K_2O > 6,5, P_2O_5> 1,0, CaO > 2,0, MgO > 0,5.

Chicken manure Vita organic (Eco Re EOOD): humus – 19.38, C – 11.13, N 1.2, P – 1.99, K – 2.5, Ca 10.85, Mg – 0.75, Zn 350 mg/kg, Cu – 50 mg/kg, Mn – 443 mg/kg, Fe – 3450 mg/kg.

The chemical composition of leaves was determined as follows: nitrogen (Kjeldahl method), phosphorus (photoelectric colorimetry), potassium (flame photometry), calcium and magnesium (complexometric) in samples of 60 leaves taked during the period 01-15.08 on each of the three replications (Stanchev et al., 1968); Statistical method used was one-factor analysis of variance LSD; Pearson correlation coefficient (r) (Dowdy and Wearden, 1983).

3. Results and discussions

The optimal content of macroelements in plum leaves established by different authors was presented in Table 1. The observed deviations between individual soil-climatic regions were, due to a greater extent, assigned to differences in the analytical methods used for the samples than to real variations in the physiological requirements of the plants (Stoilov, 1977).

Nitrogen is a key macronutrient for the development of stone fruit species. This macroelement plays an essential role in leaf development, increases photosynthetic activity and promotes the synthesis of sugars and carbohydrates, which are essential for fruit growth and development (Chawla and Sharma, 2025). In addition, nitrogen is a major structural component of proteins and chlorophyll (Roy et al., 2006).

The average nitrogen content in the leaves of cv. 'Stanley' plum in the period 2019-2022 showed statistically significant differences between fertilization variants (Table 2). In 2019, all variants (V 2 – V 5) showed significantly higher nitrogen content compared to V 1, with the highest value recorded in V 4 (2.05), which represents an increase of 65.3% compared to the control. In 2020, V 4 again showed the best results (2.19), with statistical significance at $P < 0.001$.

Similar results were obtained by Akova et al. (2019), where in the first year of the study in the 'Jojo' cv./*P. cerasifera* combination, the nitrogen content in the leaves was highest when 400 kg ha^{-1} ammonium nitrate was applied. In cv. 'Topgigant Plus' grafted on *P. cerasifera* and Docera 6 rootstocks, nitrogen content exceeded that in the control variant and at lower fertilization rates – 260 and 330 kg ha^{-1}.

In the following years, the 9th and 10th vegetation, the content of element in all variants was lower than the standard, the same results being obtained in an experiment with ten fertilization variants with 'African Rose' and 'Pioneer' cultivars (Shakweer and Abd El-Wahab, 2023). Low nitrogen supply was also found by Stefanova (2018) in 'Stanley', 'Hanita', 'Jojo' and 'Čačanska lepotica' cultivars.

On average for the period 2019-2022 highest nitrogen content value was recorded in V 4 (1.88), followed by V 2 (1.86). In both variants, a slight improvement was observed compared to the control (V 1 – 1.80), as well as in the experiment of Vangdal et al. (2010) with 'Avalon', 'Excalbur' and 'Victoria' cultivars. However, the results in which manure was applied by Marinova et al. (2014) and Hassan et al. (2010), significantly increased the content of macroelement in the leaves of cv. 'Hollywood', which shows a different effect depending on the type of fertilizer and cultivar used.

Phosphorus is important for growth, cell division, root elongation, and the development of seeds and fruits (Roy et al., 2006). As an element involved in energy metabolism, phosphorus influences the processes of photosynthesis and respiration (Stoilov, 1977), participates in the synthesis of proteins, the accumulation of sugars, and the normal maturation of wood (Mitov et al., 2008).

The phosphorus content in the leaves of optimally supplied plants ranged from 0.40 to 0.60% (Stoilov, 1977). The trees from the present experiment were optimally supplied with phosphorus (Table 3). In all years of the study phosphorus content in leaves of all variants was higher than the control, except for V 2 in 2022, where the deviation was approximately 2.0%. On average for the period, foliar application increased the amount of element from 21.3% to 34.0% compared to the control, but the difference was unproved. In other experiments with foliar treatment a significant decrease (Vangdal et al., 2010) or an insignificant difference with the control (Hassan et al., 2010) was found.

In the soil application, the increase in phosphorus was in the range 19.1 – 23.4%, but the difference also was unproved, whereas in other experiments, the increase was found significant (Marinova et al., 2014; Stojanova et al., 2024), and Shyam et al. (2024). They found an excess in the leaves of cv. 'Black Amber' in all variants of mineral and organic fertilization.

Potassium performs electrochemical and catalytic functions, influences metabolism and regulation of transpiration, and is one of the indispensable factors of photosynthesis and respiration (Stoilov, 1977). The element regulates the water regime, and increases the drought and cold resistance of plants (Roy et al., 2006).

In the first year of the study, all variants proved to increase the potassium content in the leaves (Table 4). In the foliar treatment, the amount of the element was higher than the control by 18.4% in V 3 and by 36.3% in V 2. In the soil application, a greater increase was found – by 50.0 – 59.2% depending on the variant. On average, for the period of the study, the influence of foliar treatment on the content of the element was insignificant – the application of fertilizers according to the Ecofol program increased the content of the element by 4.5%, and other authors reported a proven increase (Hassan et al., 2010). Treatment with Humustim reduced the amount of potassium by 1.7%, as in the studies of Vangdal et al. (2010) and Ghanem and Ben Mimoun, (2010) where foliar treatment with potassium sulfate with 100% K (optimal rate) and with 50% K, as well as a variant with fertigation with 100% K, had no effect on the mineral content of the leaves of 'Strival' and 'Black Star' cultivars.

Chicken manure with a rate of 2.5 kg/tree increased the potassium content in the leaves by 15.3%, and the rate of 5.0 kg/tree – by 21.0%, where the differences were proven at $P < 0.001$. Similar results from fertilization with a rate of 60 t/ha of manure on nine plum cultivars were published by Marinova et al. (2014). The relationship of the fertilizer rate with the element content was strong positive - $r = 0.967$.

Calcium is part of cell walls and membranes, it is involved in cell division, growth, root elongation, activation or inhibition of enzymes (Roy et al., 2006). Also, it is included in metabolism by neutralizing organic acids (Stoilov, 1977).

The applied foliar fertilizers on average for the experimental period had proven to increase the calcium content at $P < 0.001$ – when treated with Humustim by 11.3% and by 14.3% – with the Ecofol program (Table 5), in contrast to the experience of Vangdal et al. (2010), where the content of the element in the foliar treatment was lower than the control.

Chicken manure at a rate of 2.5 kg/tree had proven to increase significantly the amount of the element at $P < 0.05$%, and at the higher investigated rate the decrease was unproven. Fertilizer trials were conducted with NPK+Oligomix (Stojanova et al., 2023) and calcium nitrate and with urea+lime (Saini et al., 2013) in which the calcium content was higher than the standard.

The experimental trees were optimally supplied with calcium.

Magnesium is a component of chlorophyll and is vital for photosynthesis. Has an impact on the absorption and transport of phosphates and it is necessary for a number of enzymatic reactions and for the synthesis of proteins (Stoilov, 1977; Roy et al., 2006).

The higher concentration of magnesium was significant only in the first year of the experiment in three of the variants, with an increase above the standard which varied from 35.6 to 64.4% (Table 6). On average for the period of the experiment, the applied Ecofol program increased the content of the element by 11.8%, and the variant with Humustim – by 25.4% above the control, but the differences were not significant. Vangdal et al. (2010), found a lower concentration of magnesium in the foliar treatment in comparison to the control.

Soil application of 2.5 kg/tree Vita organic increased the content of the Mg element, but the difference was unproven. The effect of the fertilizer rate of 5.0 kg/tree on magnesium was similar to that of calcium – an unproven decrease compared to the control. An experiment with NPK+Oligomix increases the magnesium content in the leaves of plum cv. 'Stanley' (Stojanova et al., 2023).

The trees were optimally supplied with magnesium.

A statistically significant positive correlation was established between the nitrogen content in the leaves and the yield – $r = 0.576^*$ (Table 7). The data on the yield from foliar fertilization for the period 2019-2021 were presented in the publication by Krishkova and Zdravkova, (2023), and those from soil fertilization – in Zdravkova and Krishkova, 2023 paper. On average for the period 2019-2022, the yield (in kg/tree) by variant was as follows: V 1 – 6.4; V 2 – 10.5; V 3 – 9.3; V 4 – 11.0 and V 5 – 6.7.

A similar positive correlation between the nitrogen content and reproductive indicators was also established by other authors: Vitanova (1990) and Iancu & Găgeanu (2007) for cv. 'Anna Spath' (r = 0.56**), as well as by Kumar et al. (2019) for cv. 'Santa Rosa', where the correlation was significantly high (r = 0.975).

The opposite results were reported by Milošević et al. (2012) in a study covering ten plum cultivars in Serbia, where a negative correlation was found between nitrogen content and specific yield (expressed in kg/cm²) – r = -0.70*.

The degree of positive correlation of nitrogen with average fruit weight was weak.

A positive correlation was found between the content of phosphorus, calcium and magnesium with yield. A similar correlation was found between the concentration of phosphorus in leaves and yield in an experiment in India, while the relationship of the element with average fruit weight was negative (Kumar et al., 2019).

No correlation was found between potassium content and yield, as opposed to other experiments, where the relationship was positive – (r = 0.37*) (Iancu and Găgeanu, 2007) and (r = 0.974) (Kumar et al., 2019). The potassium-average fruit weight relationship was weak – r = 0.198, and in other experiments it has been proven positive (r = 0.34*) (Iancu and Găgeanu, 2007) or negative – (r = -0.865) (Kumar et al., 2019).

The correlation coefficients between nitrogen and other macronutrients were found to be positive, but non-significant. In the cv. 'Santa Rosa', the nitrogen-phosphorus and nitrogen-potassium relationships werw reported as significantly positive (Kumar et al., 2019), whereas a study by Milošević et al. (2012) – reported non-significant negative. The phosphorus-magnesium relationship was positive – r = 0.655*. The relationships between the two elements were synergistic (Stoilov, 1977). A negative relationship was found between potassium and calcium – r = -0.541, which was in accordance with the results published by Milošević et al. (2012), where r = -0.537. The potassium-magnesium correlation was also negative. Potassium was in antagonistic relations with calcium and magnesium (Stoilov, 1977). In a study by Milošević et al. (2012) the correlation coefficient between calcium and magnesium was positive – r = 0.570, as in the present experiment – r = 0.683*.

4. Conclusions

The influence of the fertilization treatments on the content of nitrogen, phosphorus and magnesium in the leaves of the plum cv. 'Stanley' was statistically unproven.

The Vita Organic chicken manure with a rate of 2.5 kg/tree increased the potassium content in the leaves by 15.3% above the control and the rate of 5.0 kg/tree – by 21.0%, with the statistically significant differences at $P < 0.001$.

The foliar treatment increased significant the calcium content – Humustim – by 11.3% at $P < 0.001$, and the application of the Ecofol program - by 14.3%.

A positive correlation was established for the pairs nitrogen-yield – r = 0.576*, phosphorus-calcium r = 0.564*, phosphorus-magnesium – r = 0.655* and calcium-magnesium – r = 0.683*.

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Tables

Table 1. Optimal macroelements concentration in the plum leaves, % of dry matter

Authors	Macroelement				
	N	P	K	Ca	Mg
Beyers, 1962	2.2-3.0	0.11-0.20	2.0-3.2	1.2-2.6	0.30-0.60
Szücs, 2005	2.2-3.2	0.17-0.23	2.0-3.0	2.0-2.8	0.50-0.70
Mitov et al., 2008	2.6-3.2	0.16-0.22	2.0-3.0	-	0.40-0.70
Ebert, 2009	1.8-3.2	0.14-0.35	1.5-3.5	1.2-3.0	0.20-0.80
Apostolova et al., 2014	2.2-3.2	0.18-0.35	1.6-2.5	-	0.30-0.60

Table 2. Nitrogen (N) content in the leaves of plum cv. 'Stanley', % of dry matter

Variant	Year									
	2019		2020		2021		2022		2019-2022	
	N	%*	N	%	N	%	N	%	N	%
V 1	1.24	100.0	1.90	100.0	2.23	100.0	1.83	100.0	1.80	100.0
V 2	1.91	154.0	2.17**	114.2	1.94**	87.0	1.42	77.6	1.86	103.3
V 3	1.94	156.5	2.09**	110.0	1.82***	81.6	1.43	78.1	1.82	101.1
V 4	2.05	165.3	2.19***	115.3	1.82***	81.6	1.45	79.2	1.88	104.4
V 5	1.90	153.2	2.01	105.8	1.85***	83.0	1.46	79.8	1.81	100.3
f	2312.5		9.78		15.79		40.97		4.90	
sd	9.49		5.45		6.16		3.91		2.28	
LSD 0.05	2.193		0.126		0.142		9.028		5.256	
LSD 0.01	3.187		0.183		0.207		13.13		7.646	
LSD 0.001	4.784		0.275		0.310		19.69		11.46	

** - P < 0.01, *** - P < 0.001. %* - percent to the unfertilized variant

Table 3. Phosphorus (P_2O_5) content in the leaves of plum cv. 'Stanley', %

Variant	Year									
	2019		2020		2021		2022		2019-2022	
V 1	0.47	100.0	0.50	100.0	0.37	100.0	0.54	100.0	0.47	100.0
V 2	0.58	123.4	0.61	122.0	0.56	154.1	0.53	98.1	0.57	121.3
V 3	0.53	112.8	0.72	144.0	0.63	170.3	0.62	114.8	0.63	134.0
V 4	0.55	117.0	0.54	108.0	0.62	167.6	0.60	111.1	0.58	123.4
V 5	0.54	114.9	0.58	116.0	0.55	148.6	0.57	105.6	0.56	119.1
f	20.92		43.00		61.04		7.31		64.93	
sd	1.27		1.79		1.91		1.96		1.02	
LSD 0.05	2.943		4.125		4.41		4.529		2.361	
LSD 0.01	4.280		6.000		6.414		6.588		3.434	
LSD 0.001	6.421		9.000		9.622		9.882		5.151	

Table 4. Potassium (K_2O) content in the leaves of plum cv. 'Stanley', %

Variant	Year									
	2019		2020		2021		2022		2019-2022	
V 1	1.52	100.0	1.72	100.0	2.12	100.0	1.69	100.0	1.76	100.0
V 2	2.07***	136.2	1.85	107.6	1.71*	80.7	1.73	102.4	1.84	104.5
V 3	1.80**	118.4	1.73	100.3	1.78*	84.0	1.61	95.3	1.73	98.3
V 4	2.42***	159.2	1.54*	89.50	2.19	103.3	1.95*	115.4	2.03***	115.3
V 5	2.28***	150.0	1.87	108.7	2.30	108.5	2.07**	122.5	2.13***	121.0
f	37.29		6.72		8.51		8.32		28.26	
sd	8.42		1.72		2.12		1.69		1.76	
LSD 0.05	0.194		0.165		0.292		0.221		0.107	
LSD 0.01	0.283		0.240		0.424		0.322		0.155	
LSD 0.001	0.424		0.360		0.637		0.483		0.233	

* - P < 0.05, ** - P < 0.01, *** - P < 0.001.

Table 5. Calcium (Ca) content in the leaves of plum cv. 'Stanley', %

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Variant	Year									
	2019		2020		2021		2022		2019-2022	
V 1	1.62	100.0	2.47	100.0	2.79	100.0	2.62	100.0	2.38	100.0
V 2	2.71***	167.3	2.55	103.2	2.87	102.9	2.75	105.0	2.72***	114.3
V 3	2.83***	174.7	2.45	99.2	2.67	95.7	2.66	101.5	2.65***	111.3
V 4	2.84***	175.3	2.49	100.8	2.31***	82.8	2.27**	86.6	2.48*	104.2
V 5	2.33***	143.8	2.10**	85.0	2.41***	86.4	2.35*	89.7	2.30	96.6
f	111.56		9.23		32.81		13.34		55.57	
sd	6.92		0.08		5.92		8.09		3.39	
LSD 0.05	0.160		0.190		0.137		0.187		0.783	
LSD 0.01	0.233		0.276		0.199		0.272		1.139	
LSD 0.001	0.349		0.415		0.299		0.408		1.708	

* - P < 0.05, ** - P < 0.01, *** - P < 0.001.

Table 6. Magnesium (Mg) content in the leaves of plum cv. 'Stanley', %

Variant	Year									
	2019		2020		2021		2022		2019-2022	
V 1	0.45	100.0	0.71	100.0	0.62	100.0	0.59	100.0	0.59	100.0
V 2	0.61*	135.6	0.73	102.8	0.69	111.3	0.60	101.7	0.66	111.8
V 3	0.74***	164.4	0.80	112.7	0.72	116.1	0.69	116.9	0.74	125.4
V 4	0.71***	157.8	0.66	93.0	0.74	119.4	0.75	127.1	0.72	122.0
V 5	0.41	91.1	0.51	71.8	0.61	98.4	0.65	110.2	0.55	93.2
f	20.74		17.87		4.24		11.08		41.29	
sd	0.05		3.63		3.94		2.79		1.77	
LSD 0.05	0.106		8.374		9.101		6.451		4.082	
LSD 0.01	0.155		12.18		13.23		9.384		5.938	
LSD 0.001	0.232		18.27		19.85		14.07		8.906	

* - P < 0.05, *** - P < 0.001.

Table 7. Pearson correlation coefficient matrix (r) between reproductive parameters and macroelements content in the leaves of plum cv. 'Stanley'

Parameter	Yield	Average fruit weight	N	P_2O_5	K_2O	Ca	Mg
Yield	1.00						
Average fruit weight	0.455	1.00					
N	0.576*	0.128	1.00				
P_2O_5	0.426	0.221	0.291	1.00			
K_2O	0.108	0.198	0.133	0.053	1.00		
Ca	0.348	0.254	0.329	0.564*	-0.541	1.00	
Mg	0.468	0.227	0.492	0.655*	-0.370	0.683*	1.00

* - P < 0.05 (N – 15, df – 13)