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GREENHOUSE PERENNIAL WALL-ROCKET CROP AS INFLUENCED BY MULCHING AND FERTILIZATION PRACTICES

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Abstract

This research was carried out in North-Eastern Romania in order to evaluate the effects of mulching and fertilization on the yield of fresh leaves for the perennial wall-rocket crop - Diplotaxis tenuifolia (L.) D.C. grown in the tunnel. Comparisons were made between three variants of soil mulching: non-mulched (NM), mulched with white polyethylene (WLDPE) and mulched with black polyethylene (BLDPE) and three variants of fertilization: non-fertilized (NF), chemical fertilization (Ch) and application of microorganisms (M). The best combinations in terms of production were obtained by the variants WLDPE x Ch (25.3 t·ha^{-1}) and WLDPE x M (23.9 t·ha^{-1}), productions that were also supported by the highest Leaf Area Index (LAI) and the highest weight of the dry matter. The highest chlorophyll content was recorded by the NM x Ch variant. Following the experiments carried out, both mulching with white film and chemical fertilization determined good production results, but the combination of the two factors led to the phenomenon of synergism, generating the highest yields. For the fall harvest cycle, the species behaves well in the North-East of Romania conditions.

Key words: *Diplotaxis tenuifolia (L.) D.C., Leaf Area Index, perennial wall-rocket, physiological and biometrical analysis.*

INTRODUCTION

Diplotaxis tenuifolia (L.) D.C. - the perennial wall-rocket is a species belonging to the *Brassicaceae* (*Cruciferae*) family (Warwick and Sauder, 2005). The specific common name "perennial wall-rocket" - perennial rocket, is currently preferred for differentiating it from other species of the *Diplotaxis* genus (Caruso *et. al*., 2018). The species is currently cultivated in many agricultural areas, especially in Italy, where it covers an area of about 4000 ha (Bonasia *et al*., 2017). Here it is known under the common name "rucola selvatica" (wild rocket), as opposed to the name "rucola cultivata" (cultivated rocket), which refers to the species *Eruca sativa* Mill. (sin *Eruca vesicaria* L.) (Parsons and Cuthbertson, 1992, cited by Caruso *et al*., 2018).

Up until two decades ago, *Eruca sativa* was the dominant species being cultivated, while *Diplotaxis tenuifolia* was mostly harvested from the spontaneous flora. The extension of the areas cultivated with perennial rocket in the last two decades is due to its fine and succulent leaves that correspond to the consumers' requirements (Bell and Wagstaff, 2019), the leaves of this species being rich in mineral elements and antioxidants (Caruso *et al*., 2019a).

Diplotaxis tenuifolia is a perennial species that regenerates easily after harvesting by cutting the leaves 3-5 cm above the soil surface. Besides the harvesting-related reasons, the cosmopolitan distribution of the *D. tenuifolia* species results from its easy adaptability and propagation (Hurka *et al*., 2003; Acar *et al*., 2019).

The economic interest for the cultivation of perennial rocket has increased as a consequence of the progressive distribution of ready-to-eat salads, the so-called "fourthgeneration vegetables", an efficient marketing model of keeping the freshness and the typical smell of the leaves, thus increasing the duration of storage, storage and availability on the market (Bonasia *et al.*, 2017).

In our country, this species is not known in the native specialized literature. In this context, the *purpose* of this paper is to evaluate the effects of mulching and fertilization on some physiological and production characteristics for a perennial wall-rocket grown in protected spaces (in protected crop).

Based on these first results, research perspectives may open to highlight the value of this species and, possibly, to promote it within the vegetable assortment of our country.

MATERIALS AND METHODS

Experimental Design

Preliminary research on the *Diplotaxis tenuifolia* L. (perennial wall-rocket) species was carried out in 2019, in a polytunnel on an area of 130 s.m., from the experimental field of the vegetable growing discipline belonging to USAMV Iasi, on an anthropic cambic chernozem soil with 2.86% organic matter; pH 7.2; 2.8 g·kg^{-1} N; 32 mg·kg^{-1} P, 218 mg·kg^{-1} K.

The evolution of temperature, atmospheric humidity and dew point, measured at the plant level during the experimental period, for the autumn crop cycle, are presented in Figure 1.

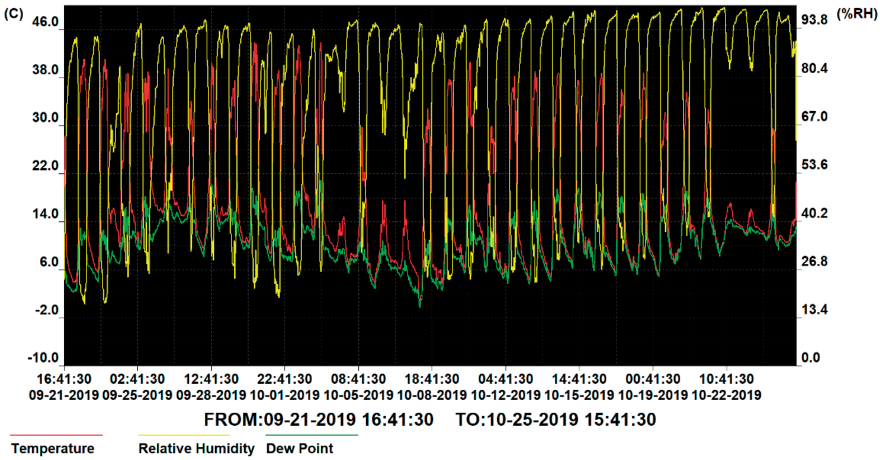

Figure 1. Trend of temperature, relative humidity and dew point inside of polytunnel

The experimental protocol set up the establishment of a bifactorial experiment with three replications (Figure 2). The first experimental factor was mulching with three gradations: non-mulched (NM), mulched with white polyethylene film (WLDPE) and mulched with black polyethylene film (BLDPE), both 60 µm thickness, and the second factor was the type of fertilization with three gradations: non-fertilized (NF), chemical fertilization (Ch) and application of microorganisms (M).

The fertilization treatments were:

1. Control treatment (NF), without the application of fertilizers.

2. Chemical fertilization (Ch) applied at 360 kg·ha^{-1} Cristaland®, a solid chemical fertilizer. The composition of this fertilizer was: 30% total N of which ammoniacal N 2% and ureic N 28%; 10% water soluble P_2O_5; 10% water soluble K_2O; 2% water soluble MgO.

3. Biological fertilization (M) were applied at 80 kg·ha^{-1} Micoseeds MB®, a microgranulated fertilizer based on microorganisms. It predominantly contains spores of arbuscular mycorrhizal fungi (AMF), based on *Glomus* spp. and enriched with *Beauveria* sp. and *Metarhizium* sp.

Figure 2. Aspects of the perennial wall-rocket experiment

On the land preparation, the soil was organically fertilized with 500 kg·ha^{-1} Orgevit®, a chicken fertilizer on granular form, 90% dry matter, 65% OM, 4% N, 3% P_2O_5, 2.5% K_2O, 1% MgO, 0.02% Fe, 0.01% Mn, 0.01% B, 0.01% Zn, 0.001% Cu, 0.001% Mo. The soil was ploughed and hoed, arranged in 100 cm wide raised beds. The soil mulching was performed in accordance with the experimental protocol.

The sowing performed in order to produce the seedlings was carried out on August 22nd in alveolar trays with a volume of 31.3 cm^3. The planting of the 24-day seedlings was carried out on September 19th, at distances of 20 cm by 20 cm between plants, 80 cm between beds. The result density was 14.3 nests per square meter (Caruso *et al*., 2019b). The same time with the planting process, the fertilization was also performed, according to the experimental protocol. In the vegetation period, during the first crop cycle, the maintenance works were applied, according to the specialized literature (Caruso *et al*., 2018): the weed control was carried out by two weeding and one hoeing works, irrigation being done by dripping. Leaf harvesting was performed by cutting 3-5 cm above the cotyledons to allow efficient regeneration of the vegetative apex (Schiattone *et al*., 2018). The harvesting moment was achieved when the first leaves forming the rosette reached the maximum size, respectively on October 22nd.

CCI Determination

Assimilatory pigment content was measured with a non-destructive portable chlorophyll content meter CCM-200 plus, from the Opti-Science Company, performing 50 readings on undamaged wall-rocket leaves for each experimental variant, the results being expressed in CCI (Chlorophyll Content Index).

Yield and Biometrical Determinations

Leaf samples were collected from each experimental plot, which were sent immediately to the laboratory for a series of determinations to be made, such as: weight and number of marketable leaves, their length and width, leaf area, dry matter content.

The leaf area index (LAI) was determined using the Li-3100 Area Meter, produced by LI-COR, inc. Lincoln, Nebraska, USA. The leaves' dry biomass was measured by weighing the samples after dehydrating the fresh leaves in a MOV-112F oven, produced by SANYO Electric Co., Ltd, Japan, whose temperature was set to 70°C, until reaching a constant weight of the leaves.

Statistical Analysis

The production results were processed using the least significant differences method (LSD), and for the other parameters analyzed the data were statistically processed by ANOVA and the mean separation was performed through Tukey's test at 0.05 probability level, using the SPSS software version 20. The results were reported as means ± standard deviation.

RESULTS AND DISCUSSIONS

The average leaf production ranged from 17.7 t·ha^{-1} in the case of the non-mulched (Ct) variant and 23.0 t·ha^{-1} in the case of the variant mulched with white film (Table 1). The difference of 5.3 t·ha^{-1}, respectively 29.24% recorded by the variant mulched with white film, is considered positively significant compared to the non-mulched variant, while the difference of 1.1 t·ha^{-1}, respectively 6.21% recorded by the version mulched with black film is insignificant compared to the control variant of the experiment.

Table 1. Results obtained regarding the influence of mulching and fertilization on the perennial wall-rocket yield

Experimental factor	Yield			Differences significance
	$t \cdot ha^{-1}$	% vs. Control	Differences from Control	
Mulch type				
NM	17.7	100.00	0.0	Ct
WLDPE	23.0	129.24	5.3	*
BLDPE	18.8	106.21	1.1	ns
LSD 5% = 3.5 $t \cdot ha^{-1}$; LSD 1% = 5.8 $t \cdot ha^{-1}$; LSD 0.1% = 10.9 $t \cdot ha^{-1}$				
Fertilization type				
NF	17.3	100.00	0.0	Ct
Ch	22.9	132.37	5.6	***
M	19.2	110.98	1.9	*
LSD 5% = 1.5 $t \cdot ha^{-1}$; LSD 1% = 2.2 $t \cdot ha^{-1}$; LSD 0.1% = 3.1 $t \cdot ha^{-1}$				

Ct – Control; ns - no statistically significant difference
NM – non-mulched
WLDPE - white polyethylene film
BLDPE - black polyethylene film
NF – non-fertilized
Ch – chemical fertilization
M – biological fertilization

Regarding the type of fertilization, the chemically fertilized variant registered a yield increase of 5.6 $t \cdot ha^{-1}$, respectively 32.37% compared to the non-fertilized variant, this difference being very significant. The variant on which microorganisms were applied registered a significant yield increase compared to the control variant, respectively of 1.9 $t \cdot ha^{-1}$ (10.98%).

Regarding the combined influence of the two studied factors, mulching x fertilization (Table 2), the yields obtained for the perennial wall-rocket crop in the first harvesting cycle (autumn) ranged between 15.7 $t \cdot ha^{-1}$ in the NM x NF variant and 25.3 $t \cdot ha^{-1}$ in the case of the WLDPE x Ch variant. Compared with the control variant (NM x NF), all the combinations of factors achieved yield increases with different degrees of significance. The highest yield increases, with very significant differences from the control variant, were registered for the variants: WLDPE x Ch - 61.15%, WLDPE x M - 52.23%, BLDPE x Ch - 42.04%, NM x Ch - 35.03%. Positive differences distinctly significant from the control variant were registered for the WLDPE x NF combination, with a yield increase of 25.48%. The other variants registered yield increases compared to the control variant, but they were non-significant.

Table 2. Results regarding the influence of the mulching x fertilization combination on the perennial wall-rocket yield

Experimental variant	Yield			Differences significance
	$t \cdot ha^{-1}$	% vs. Control	Differences from Control	
NM x NF	15.7	100.00	0.0	Ct
NM x Ch	21.2	135.03	5.5	***
NM x M	16.2	103.18	0.5	ns
WLDPE x NF	19.7	125.48	4.0	**
WLDPE x Ch	25.3	161.15	9.6	***
WLDPE x M	23.9	152.23	8.5	***
BLDPE x NF	16.5	105.10	0.8	ns
BLDPE x Ch	22.3	142.04	6.6	***
BLDPE x M	17.5	111.46	1.8	ns

LSD 5% = 2.7 $t \cdot ha^{-1}$; LSD 1% = 3.7 $t \cdot ha^{-1}$; LSD 0.1% = 5.3 $t \cdot ha^{-1}$
Ct – Control; ns - no statistically significant difference
NM – non-mulched
WLDPE - white polyethylene film
BLDPE - black polyethylene film
NF – non-fertilized
Ch – chemical fertilization
M – biological fertilization

Compared with the results obtained in our experimental field, Caruso *et al.*, 2019c, reported yields between 11.0 $t \cdot ha^{-1}$ for the non-mulched variant and 12.5 $t \cdot ha^{-1}$ for the variant mulched with standard black film LDPE, 45 μm thick. Schiattone *et al.*, 2018, mentioned yields between 10.5 and 17.9 $t \cdot ha^{-1}$, these being registered in the first harvest cycle (December) at a low nitrogen level, respectively in the third cycle (March) in the case of a high level of nitrogen.

The highest yield value (23.0 $t \cdot ha^{-1}$) achieved in the case of mulching with white film, is supported by the highest value of leaf area (3.27 $m^{-2} \cdot m^{-2}$), by the highest quantity of dry matter (421.0 $g \cdot m^{-2}$), as well as the highest average leaf weight (1.28 g), these production indicators having significant values compared to the non-mulched variant. At the same time, the yield increase was also influenced by the number of leaves/nest (126.6 leaves/nest), even though it presented non-significant values compared to the non-mulched variant (Table 3).

In the case of fertilization, the variant to which chemical fertilizers were administered determined the highest production of leaves, being supported by the highest values of leaf area (3.30 $m^{-2} \cdot m^{-2}$), of dry matter (375.6.0 gm^{-2}), the number of leaves/nest (126.2 leaves/nest) and the average leaf weight (1.27 g). These indicators show significant values compared to the control variant (Table 3).

The average length and width of the leaf, presenting non-significant values both to the control variant and to the other variants, did not influence the yield achieved, for any of the studied factors.

In the case of combination between those two factors, the highest yields obtained by WLDPE x Ch (25.3 $t\cdot ha^{-1}$) and WLDPE x M (23.9 $t\cdot ha^{-1}$) variant are correlated with the highest values of leaf area (3.51 $m^{-2}\cdot m^{-2}$), of dry matter (466.8 $g\cdot m^{-2}$, respectively 454.9 $g\cdot m^{-2}$) and of the number of leaves/nest (136.8, respectively 141.7 leaves/nest), these indicators having significant values compared to the control variant. The average leaf weight, although it had significantly higher values for the two variants above compared with the control, was outweighed by the WLDPE x NF variant which presented the highest average leaf weight (1.36 g/leaf).

The average values of leaf length and width were non-significant, as they did not influence the yields obtained from the combinations of the two factors (Table 4).

Similar results to those obtained in our experiment were also reported by Schiattone *et al*., 2018, the leaf area values ranging between 1.88 $m^{-2}\cdot m^{-2}$ in the first crop cycle and 3.32 $m^{-2}\cdot m^{-2}$ in the third crop cycle. Caruso *et al*., 2019a,c, reported in their works lower values of the leaf area in the first crop cycle, of 1.36 $m^{-2}\cdot m^{-2}$, respectively 1.40 $m^{-2}\cdot m^{-2}$.

For Schiattone *et al*., 2018, the average number of leaves ranged from 4.6 leaves/plant during the 1st crop cycle to 16.2 leaves/plant during the last one. The leaf length increased from 14.8 cm in the first cycle, to 20.1 cm in the last cycle, while the width varied from 1.4 cm in the second and third crop cycles up to 1.84 cm in the first cycle. The above mentioned results are lower compared to those obtained in our study.

Caruso *et al*., 2019c, mentioned a number of leaves between 119.0 leaves/nest in the winter cycle and 155.3 leaves/nest in the spring cycle, while in our study the obtained values were between 101.2 and 136.8 leaves/nest. Also, in the same article, Caruso *et al*. reports an average leaf weight between 0.51 g and 0.8 g, the values being lower than those obtained during our research (Tables 3 and 4).

Table 3. Productivity indicators for the perennial wall-rocket crop based on the type of mulching and fertilization

Experimental factor	LAI ($m^2\cdot m^{-2}$)	Dry matter ($g\cdot m^{-2}$)	Number of leaves/nest	Average length/leaf (cm)	Average width/leaf (cm)	Average weight/leaf (g)
Mulch type						
NM	2.76±0.16 b	290.3±8.60 b	112.6±3.68 ns	25.82±0.29 ns	5.95±0.43 ns	1.10±0.16 b
WLDPE	3.27±0.41 a	421.0±69.30 a	126.6±22.08 ns	25.14±0.23 ns	5.50±0.07 ns	1.28±0.09 a
BLDPE	3.04±0.38 ab	320.3±34.62 b	115.4±9.57 ns	24.90±0.27 ns	6.35±2.05 ns	1.13±0.10 b
Fertilization type						
NF	2.74±0.12 b	308.1±30.04 b	108.6±6.63 b	25.58±0.49 ns	5.37±0.48 ns	1.13±0.21 b
Ch	3.30±0.33 a	375.6±84.62 a	126.2±10.72 a	25.16±0.38 ns	5.53±0.07 ns	1.27±0.03 a
M	3.03±0.42 ab	347.9±92.86 ab	119.9±18.90 ab	25.13±0.55 ns	6.90±1.61 ns	1.11±0.07 b

Within each column, ns - no statistically significant difference, values associated to different letters are significantly different according to Tukey's test at $p<0.05$.

NM – non-mulched
WLDPE - white polyethylene film
BLDPE - black polyethylene film
NF – non-fertilized
Ch – chemical fertilization
M – biological fertilization

Table 4. Productivity indicators for the perennial wall-rocket crop based on the mulching x fertilization combination

Experimental variant	LAI ($m^2 \cdot m^{-2}$)	Dry matter ($g \cdot m^{-2}$)	Number of leaves/nest	Average length/leaf (cm)	Average width/leaf (cm)	Average weight/leaf (g)
NM x NF	2.60±0.31 b	282.7±18.37 c	114.1±21.30 ab	26.13±0.67 ns	5.81±0.18 ns	0.98±0.13 d
NM x Ch	2.92±0.34 ab	299.6±48.46 c	115.3±5.86 ab	25.57±1.50 ns	5.61±0.71 ns	1.28±0.05 ab
NM x M	2.74±0.22 ab	288.6±27.27 c	108.4±11.11 ab	25.75±1.24 ns	6.43±0.69 ns	1.05±0.03 cd
WLDPE x NF	2.80±0.36 ab	341.3±38.69 bc	101.2±7.50 b	25.39±0.98 ns	5.43±0.45 ns	1.36±0.05 a
WLDPE x Ch	3.51±0.20 a	466.8±48.94 a	136.8±13.46 a	25.09±1.55 ns	5.49±0.87 ns	1.29±0.06 ab
WLDPE x M	3.51±0.15 a	454.9±37.36 ab	141.7±2.52 a	24.95±1.89 ns	5.57±0.69 ns	1.18±0.06 abc
BLDPE x NF	2.81±0.11 ab	300.3±20.54 c	110.3±7.02 ab	25.21±1.00 ns	4.87±0.37 ns	1.04±0.01 cd
BLDPE x Ch	3.48±0.40 a	360.3±43.67 abc	126.4±12.81 ab	24.81±1.70 ns	5.49±0.88 ns	1.23±0.08 abc
BLDPE x M	2.83±0.38 ab	300.3±64.70 c	109.4±17.59 ab	24.69±1.61 ns	8.69±3.80 ns	1.11±0.08 bcd

Within each column, ns - no statistically significant difference, values associated to different letters are significantly different according to Tukey's test at $p<0.05$.
NM – non-mulched
WLDPE - white polyethylene film
BLDPE - black polyethylene film
NF – non-fertilized
Ch – chemical fertilization
M – biological fertilization

The highest content of chlorophyll pigments was identified both in the case of the non-mulched variant and in the chemically fertilized version. By contrast, both the variant mulched with black film and the non-fertilized variant recorded the lowest values of photosynthetic pigments (Figure 3).

In the case of the combination of the two factors (Figure 4), the highest content of chlorophyll pigments was registered in the NM x Ch variant, thus generating yields with very significant positive differences compared to the control variant. Similarly, the combination between mulching with black film and chemical fertilization recorded the second highest value in terms of chlorophyll pigments content, generating, as in the case of the non-mulched x chemical fertilization variant, leaf yield supported at a statistically significant level compared to the control variant.

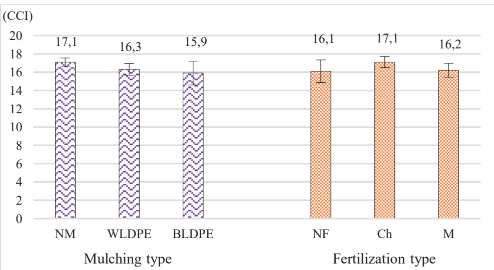

Figure 3. Chlorophyll pigments content in perennial wall-rocket leaves expressed as CCI, as influenced by mulching and fertilization.
Values associated to different letters are significantly different according to Tukey's test at p<0.05

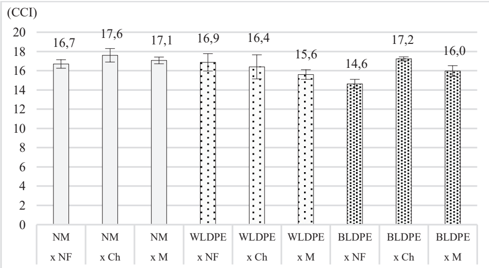

Figure 4. Chlorophyll pigments content in perennial wall-rocket leaves expressed as CCI, as influenced by the interaction between mulching and fertilization.
Values associated to different letters are significantly different according to Tukey's test at p<0.05

CONCLUSIONS

Following the experiments carried out on the *Diplotaxis tenuifolia* (L.) D.C. species, in the autumn harvesting cycle, both the mulching with white film and the chemical fertilization determined good yield results, but the combination of the two factors led to the phenomenon of synergism, generating the highest yields. In the autumn harvesting cycle this species behaves well in the conditions of North-Eastern Romania, the results being comparable to those from other research.

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