

EFFECT OF THE COMPOSITION OF SEEDLINGS MIXTURE ON THE PHYSIOLOGICAL BEHAVIOUR AND PHOTOSYNTHETIC PRODUCTIVITY OF TOMATO PLANTS

Nikolina G. Shopova, Dimitar T. Cholakov, Dimka I. Haytova

Agriculture University – Plovdiv

Abstract

The purpose of this investigation was to be established the influence of the components of the seedling mixture on the physiological behaviors and the photosynthetic productivity of tomato plants, during the vegetative growth stage after planting, under the conditions of late field production.

The variants with additives of different components of organic and organo-mineral origin to the standard peat-pearlitic mixture and peat-pearlitic mixture with adsorbent (TPSA) were tested. It was found that the using of a peat-pearlitic mixture with adsorbent + additive was a precondition for a greater physiological potential of the plants during the vegetative growth stage. The parameters of the leaf gas exchange, biological yield and the photosynthetic productivity reached their highest values in the use of TPSA and the addition of organic fertilizer Boneprot 2%.

Key words: tomato seedlings, seedlings mixture, biological yield, net photosynthetic productivity, leaf gas exchange, plastid pigments

1. INTRODUCTION

The use of high quality seedlings is essential for realizing the biological potential of plants in the field production of tomatoes and receiving good economic results (Markovic, et.al. 1997). Growing seedlings in containers is a progressive technological options, which becomes ever more categorically in the field production of vegetables. Cultivation of high quality seedlings requires compliance with several main technological elements, one of which is the composition of the culture mixture (Murtazov, 1980). In the Republic of Bulgaria research on issues related to the composition of the culture mixture in container growing of tomato seedlings is limited (Simidchiev and Kanazirska, 1986), and for late field production of tomatoes absence. There is no scientific information on the changes in the physiological status of the plants during the growing season, depending on the composition of seedlings mixture, used for growing seedlings. Unclear are a number of important issues relating to optimizing the composition of the seedling mixture in accordance with the requirements of the young plants through the use of substrates and supplements and their effects on photosynthetic productivity of tomato plants during the growing season and on certain physiological indicators pertaining to the amount of synthesized economically valuable phytomass.

The aim of the investigation was to establish the influence of the components of the culture mixture in late field tomato production, with a container growing of seedlings on physiological events, and the intensity of the photosynthetic productivity of plants.

2. MATERIAL AND METHODS

The experimental work was done during the 2011-2012 period with tomato cultivar Opal F₁. The sowing of seeds were done in the period June 2 - 3 in Styrofoam containers with 66 cells providing nutritional area per seedlings plant of 28 cm². For growing seedlings was used standard peat-pearlitic mixture in the ratio 3: 1 by volume, and the same peat-pearlitic mixture with adsorbent Fiba sorb, with the inclusion of additives with organic and organo-mineral origin. Examined the following variants:- peat-pearlitic mixture (TPC) – control, peat-pearlitic mixture with adsorbent Fiba sorb (TPSA), TPS Lumbrikal +10%, TPCA +10% Lumbrikal, TPS +3% sea sapropels, TPSA +3% sea sapropels, TPS Boneprot +2%, TPSA +2% Boneprot. Lumbrikalat is a product from the processing of manure and other organic waste from California red worm (*Lubricus rubellus* and *Eisenia foetida*) and consists of their excrement. Boneprotat (Arkobaleno, Italy) - is completely organic product based manure from chicken, beef, horse, rabbit origin. Sea sapropels were formed over a period of time from

dead organic matter and mineral residues of various marine organisms, sediment on the seabed. Physiological measurements were carried out on the 20th, 40th and 60th day after planting.

The study target was the leaf gas exchange featuring the photosynthetic rate, transpiration intensity and stomatal conductance determined by means of the photosynthetic system LCA-4 (ADC, England). The photosynthetic pigments were extracted with the help of 80% acetone. Using a spectrophotometer Helios, the extinction of the extract was measured, by applying the method of Pochinok (1976). The biological yield, composed of stems, leaves and fruits, was determined by drying at 105°C till reaching the constant weight. Based on the results of the biometric measurements, the chemical and physiological analyses, some indexes related to the photosynthetic productivity of the plants were determined, such as: 1. Photosynthetic potential– according to Nichiporovich (1961); 2. Net photosynthetic productivity, calculated by using the classic formula of Briggs et.al. (1920); 3. Economic photosynthetic productivity according to Vasev (1977); 4. Coefficient of economic efficiency, representing the correlation between the dry fruits mass and the biological yield; 5. Coefficient of biomass efficiency, representing the average daily increase of the dry matter of the fruit of kg/da dimensions. The mathematical processing of the data was done by using standard software SPSS – Duncan's Multiple Range Test (Duncan, 1955) and BIOSTAT.

3. RESULTS AND DISCUSSION

The crucial element underlying the productivity of a particular crop is the rate of phytomass accumulation. The photosynthetic activity of the leaves is the main source of accumulation of organic matter in the plant organism or for the formation of the so-called biological yield (Barnes, 1977). The tested variants differed in many of the main productivity elements (Table.1). There were differences in the accumulation of the overall as well as of the economically important phytomass. The values of the determined indicators and coefficients outlined advantage for variants, in which for the production of seedlings was used peat-pearlitic mixture with adsorbent. The comparison of average results show that in these variants the biological yield and dry fruits yield increased compared to the control with 10.6 to 19.6% for the first indicator and with 9.6 to 18.1% for second. The maximal values for both were report in variants TPSA + Boneprot, followed by variants TPSA + Lumbrikal.

Table 1. Photosynthetic productivity indexes of one plant during the growing season, average for the period 2012-2013

Variant №	Content of seedling mixture	Biological yield		Dry phytomass of the fruits, g		Coefficient of economic efficiency	Coefficient of biomass efficiency
		(g)	% to the control	(g)	% to the control		
1	TPS (K)	199,52	100,0	100,31	100,0	0,50	0,95
2	TPSA	220,62	110,6	109,96	109,6	0,50	1,04
3	TPS+L	208,01	104,3	104,81	104,5	0,50	0,99
4	TPSA+L	225,10	112,8	116,20	115,8	0,52	1,10
5	TPS+SS	214,49	107,5	104,99	104,7	0,49	0,99
6	TPSA+SS	223,65	112,1	112,28	111,9	0,50	1,06
7	TPS+B	221,78	111,2	113,43	113,1	0,51	1,07
8	TPSA+B	238,53	119,6	118,44	118,1	0,50	1,12

Investigated variants are not significantly different by a factor of economic efficiency (0.49 to 0.52), but nevertheless it should be noted that the highest values refer to variant TPSA + Lumbrikal. This indicates that the balance of the photosynthetic apparatus and accumulation organs of replacement nutrients in plants of this variant is similar to the highest level to the optimum. The evidence of greater biological potency and quality

distribution of digest in plants at variants with Boneprot and Lumbrikal added to TPSA, are the high values of the coefficient of efficiency of biomass - 1.12 and 1.10 respectively, which show the average daily increase the dry matter of the fruit for 1 da test plot. The noted is important criteria in evaluating not only biological but also the physiological potential of plants than those variants. The plants of the variants with absorbent have a greater photosynthetic capacity throughout the growing period. An important indicator of which depends on the total productivity of photosynthesis is photosynthetic potential. It characterizes the photosynthetic capacity of the crop for the vegetative period or interval of time. In support of this statement are higher values of photosynthetic potential (Table 2). As can be seen from the results they are 2.3 to 6.5% higher in compared to variants without absorbent. The largest photosynthetic potential of plants is variants with Boneprot and Lumbrikal added to TPSA. The increase relative to control is respectively 8.6% and 8.1%.

The studied variants differ from the control and to quantity of dry phytomass synthesized per unit photosynthetic potential, representing pure productivity of photosynthesis. At all variants was established increase in the values of this indicator. The relative growth compared to the control is from 1.4 to 10.1% and was greatest in variants TPSA +Boneprot. The net productivity of photosynthesis is greater in variants with absorbent, such as for the both with the same additive or non-additive increase was 3.5 to 5.3%.

Table 2. Photosynthetic productivity indexes of one plant during the growing season, average for the period 2012-2013

Variant №	Content of seedling mixture	Photosynthetic potential		Net photosynthetic productivity		Economic photosynthetic productivity	
		(m ²)	% to the control	(g/m ² /24h)	% to the control	(g/m ² /24h)	% to the control
1	TPS (K)	24,49	100,0	8,15	100,0	4,09	100,0
2	TPSA	26,08	106,5	8,44	103,6	4,22	103,1
3	TPS+L	25,18	102,8	8,26	101,4	4,16	101,8
4	TPSA+L	26,39	108,1	8,53	104,7	4,40	107,6
5	TPS+SS	25,17	102,7	8,52	104,5	4,17	102,0
6	TPSA+SS	25,71	105,0	8,69	108,0	4,42	108,0
7	TPS+B	25,96	106,0	8,54	104,8	4,37	106,8
8	TPSA+B	26,59	108,6	8,97	110,1	4,45	108,9

The noted trends are observed in terms of economic productivity index of photosynthesis. In accordance with the increased productivity of photosynthetic apparatus are the results of measurements of leaf gas exchange. Dynamics in the level of leaf gas exchange is essential for the physiological status of plants and has a directly related to photosynthetic productivity of the experimental plants. The use of additives as components of standard peat-pearlitic mixture has a positive effect on leaf gas exchange.

On the 20th day after planting dynamics in the level of leaf gas exchange is better express in 2013 (Table 3). This year the measured values of the rate of photosynthesis, transpiration intensity and stomatal conductivity are higher compared to 2012. This gives grounds to be noted that in 2013 the plants has better leaf gas exchange, which is closely related to that recorded in the same year greater economic productivity. For both years, the indicators determining the leaf gas exchange has a lowest value at the control. Statistical significance of differences with control and between variants with the same additive or without the addition is better for the intensity of transpiration and stomatal conductivity, with a few exceptions for the first indicator in 2013 for Boneprot and second indicator in 2012 for Boneprot and sea sapropels. Similar trends there are about of the rate of photosynthesis. Average for the two-year period, the rate of net photosynthesis was highest in variants TPSA + Boneprot. High and very close are the reported for this index values for variants № 4, 6 and 7. The performed mathematical processing shows that in both years the differences between these four variants are unproven. In the same variants is recorded intensive transpiration and better stomatal conductivity in comparison

with others. Therefore, the plants from these variants are more intense leaf gas exchange, which is one reason for the higher rate of net photosynthesis. Despite the absence of statistical significance of the difference for the some of the variants for both indexes, the highest values were measured in variant TPSA + Boneprot.

Table 3. Leaf gas exchange per plant on 20-th day after planting

Variant №	Content of seedling mixture	Rate of photosynthesis			Transpiration intensity			Stomatal conductivity		
		2012	2013	Average for 2 years	2012	2013	Average for 2 years	2012	2013	Average for 2 years
1	TPS (K)	10,81 b	17,42 d	14,12	2,23f	2,41 g	2,32	0,05 c	0,07 g	0,06
2	TPSA	12,24 ab	19,16 cd	15,70	2,45e	3,10 d	2,78	0,06 b	0,10 f	0,08
3	TPS+L	13,50 a	18,63 cd	16,07	2,78d	2,93 e	2,86	0,06 b	0,13 d	0,10
4	TPSA+L	14,11 a	21,30 ab	17,71	3,15ab	3,50 b	3,33	0,07 a	0,15 c	0,11
5	TPS+SS	12,37 ab	20,43 bc	16,40	2,79d	2,75 f	2,77	0,06 b	0,11 e	0,08
6	TPSA+SS	13,08 a	21,21 ab	17,15	2,97c	3,39 c	3,18	0,06 b	0,15 c	0,11
7	TPS+B	12,81 ab	22,75 ab	17,78	3,08b	3,71 a	3,40	0,07 a	0,16 b	0,11
8	TPSA+B	13,55 a	23,14 a	18,35	3,21 a	3,81 a	3,51	0,07 a	0,17 a	0,12
Legend: a,b,c.. Duncan's multiple range test (P<0.05)										

On the 40th day after planting leaf gas exchange was more dynamic in 2013 (Table 4). The stomatal conductivity and greater intensity of transpiration the rate of net photosynthesis was greater compared to 2012. All studied variants outweigh the control by the rate of photosynthesis with a well warranted provided the differences in 2012 in 2013, the reported values for variants № 3 and 5, although higher, did not differ statistically significantly from the control. Average for the two, values of this index are the highest in variants TPSA + Boneprot and differences in by years are statistics significant. The both variants with the same additive or without additive, the averages values are higher when there is absorbent. The differences in 2013 have a good statistical significant and very well warranted. In 2012, the gap has warranted only variants of couples with and without the addition Boneprot. Superiority of the variants with absorbent in physiological aspect is very well express by the indicators of transpiration intensity and stomatal conductivity.

Table 4. Leaf gas exchange per plant on 40-th day after planting

Variant №	Content of seedling mixture	Rate of photosynthesis			Transpiration intensity			Stomatal conductivity		
		2012	2013	Average for 2 years	2012	2013	Average for 2 years	2012	2013	Average for 2 years
1	TPS (K)	9,74 c	18,02 de	13,88	1,87 e	2,32 e	2,10	0,04 c	0,09 f	0,065
2	TPSA	12,32 b	19,99cde	16,16	2,00 e	2,71 f	2,36	0,07 e	0,12 e	0,095
3	TPS+L	12,96 b	18,33 e	15,65	2,13 d	2,62 d	2,38	0,06 d	0,13 d	0,095
4	TPSA+L	13,27 b	21,20 b	17,24	2,79 b	3,02 c	2,90	0,08 b	0,16 b	0,120
5	TPS+SS	12,16 b	18,91 de	15,54	2,30 c	2,01 f	2,16	0,05 e	0,12 e	0,085
6	TPSA+SS	12,93 b	20,54 bc	16,74	2,26 c	3,12 c	2,69	0,08 b	0,13 d	0,105

7	TPS+B	13,48 b	21,36 b	17,42	2,68 b	3,54 b	3,11	0,08 b	0,15 c	0,115
8	TPSA+B	15,16 a	23,61a	19,39	2,90 a	3,85 a	3,38	0,09 a	0,18 a	0,135
Legend: a,b,c.. Duncan's multiple range test (P<0.05)										

The differences with the variants without absorbent are statistically significant, except the established in 2012 for the intensity of transpiration in variants of both without addition and adding sea sapropels. The averages values for both indexes are highest in variant TPSA + Boneprot and differences with others are statistic significant.

In the third measurement of the 60-day (table 5) after planting is retained a dynamic flow of the leaf gas exchange in 2013. Average for the two years period the highest rate of net photosynthesis was measured at variants TPSA + Boneprot, followed by variants № № 4 and 7, where the reported values are very close, but deference are not statistic significant. The greatest intensity of transpiration was reported in variant TPSA + Boneprot , and the smallest - in TPSA + Lumbrikal.

Table 5. Leaf gas exchange per plant on 60-th day after planting

Variant №	Content of seedling mixture	Rate of photosynthesis			Transpiration intensity			Stomatal conductivity		
		2012	2013	Average for 2 years	2012	2013	Average for 2 years	2012	2013	Average for 2 years
1	TPS (K)	8,21 e	19,61 b	13,91	1,99 f	2,24 e	2,12	0,04 c	0,10 e	0,07
2	TPSA	11,95 d	19,71 b	15,83	2,47 c	2,48 d	2,48	0,05 b	0,12 c	0,09
3	TPS+L	12,34d	21,17 ab	16,76	2,64bc	2,71 c	2,68	0,06 a	0,12 c	0,09
4	TPSA+L	14,89bc	22,55 a	18,72	2,72 b	2,80bc	2,76	0,06 a	0,15 a	0,11
5	TPS+SS	12,99 cd	19,90 b	16,45	2,41 c	2,48 d	2,45	0,05 b	0,11 d	0,08
6	TPSA+SS	13,83bcd	19,88 b	16,86	2,76 b	2,94 b	2,85	0,06 a	0,13 b	0,09
7	TPS+B	15,75 b	22,15 a	18,95	3,23 a	2,87 b	3,05	0,06 a	0,15 a	0,11
8	TPSA+B	18,39 a	22,60 a	20,50	3,49 a	3,20 a	3,35	0,06 a	0,15 a	0,11
Legend: a,b,c.. Duncan's multiple range test (P<0.05)										

The special literature there is different views on the relationship between photosynthetic activity and content of photosynthetic pigments. There are publications about the lack of a linear relationship between the two factors, but there are others in which it is claimed that higher total chlorophyll content is one of the main factors that affect the intensity of photosynthesis and biological productivity of higher plants (Planchon, 1976; Sestak, 1986; Berova and Karanastidis, 2008).

The results of the assays, performed on 20-th day after sowing (Table 6) show that the composition of the seedling mixture influence on the contents of photosynthetic pigments. In all variants of the three quantities of pigment is greater in comparison with the control, the increase being from 1.8 to 13.6% with for chlorophyll a, and with 2.6 to 10.3% for the chlorophyll b and 2.4 -14.3% for carotenoids.

Stands out the variants TPSA + Lumbrikal in which the pigments content is the highest. Of the both with the same additive or without additive, the measured concentration of the three pigments is greater in the variants with absorbent. The increase for chlorophyll a (11,8%), for chlorophyll b (7,7%) and carotenoids (9,5%) is highest in variants with Lumbrikal. The content of green pigments (a + b), and the total content of photosynthetic pigments (a + b + c) is the highest in the variant TPSA + Lumbrikal. The increase, compared the control is by 12.8% in the first group and by 13.1% for the second group. The ratio between chlorophyll a and chlorophyll b, which for the experiment varies from 2.80-2.91, does not change significantly.

Table 6. Plastid pigment content on 20-th day after planting

Variant №	Content of seedling mixture	Plastid pigment , mg/g fresh mass										
		Chl. <i>a</i>		Chl. <i>b</i>		carotenoides <i>c</i>		<i>a+b</i>		<i>a+b+c</i>		<i>a/b</i>
		(mg)	%	(mg)	%	(mg)	%	(mg)	%	(mg)	%	
1	TPS (K)	1,10	100,0	0,39	100,0	0,42	100,0	1,49	100,0	1,91	100,0	2.92
2	TPSA	1,12	101,8	0,39	100,0	0,43	102,4	1,51	101,3	1,94	101,6	2.87
3	TPS+L	1,12	101,8	0,40	102,6	0,44	104,8	1,52	102,0	1,96	102,6	2.80
4	TPSA+L	1,25	113,6	0,43	110,3	0,48	114,3	1,68	112,8	2,16	113,1	2.91
5	TPS+SS	1,16	105,5	0,40	102,6	0,45	107,1	1,56	104,7	2,00	104,7	2.88
6	TPSA+SS	1,21	110,0	0,42	107,7	0,44	104,8	1,63	109,4	2,08	108,9	2.90
7	TPS+B	1,15	104,5	0,40	102,6	0,43	102,4	1,55	104,0	1,98	103,7	2.88
8	TPSA+B	1,20	109,1	0,42	107,7	0,46	109,5	1,62	108,7	2,08	108,9	2.86

Naturally (Nikolov, 1981; Bjorkman, 1981), on the 40th day after planting (Table 7), the content of photosynthetic pigments in all variants was higher, compared with those reported for 20 days. At this stage of development of the plants, the content of all three pigments was lowest at the control and there was equalization between control and the variant TPS + Lumbrikal. The reported concentrations for each of the three pigments are highest in variants TPSA + Boneprot. The tendency for higher pigments content at the all variants with adsorbent from variants with the same additive or without additive was no changes.

Table 7. Plastid pigment content on 40-th day after planting

Variant №	Content of seedling mixture	Plastid pigment , mg/g fresh mass										
		Chl. a		Chl. b		carotenoides c		a+b		a+b+c		a/b
		(mg)	%	(mg)	%	(mg)	%	(mg)	%	(mg)	%	
1	TPS (K)	1,25	100,0	0,45	100,0	0,46	100,0	1,70	100,0	2,16	100,0	2,78
2	TPSA	1,28	102,4	0,46	102,2	0,49	106,5	1,74	102,4	2,23	103,2	2,78
3	TPS+L	1,25	100,0	0,45	100,0	0,46	100,0	1,70	100,0	2,16	100,0	2,78
4	TPSA+L	1,31	104,8	0,46	102,2	0,51	110,9	1,77	104,1	2,28	105,6	2,85
5	TPS+SS	1,31	104,8	0,46	102,2	0,50	108,7	1,80	105,9	2,30	106,5	2,83
6	TPSA+SS	1,33	106,4	0,47	104,4	0,48	104,3	1,77	104,1	2,25	104,2	2,85
7	TPS+B	1,29	103,2	0,46	102,2	0,47	102,2	1,75	102,9	2,22	102,8	2,80
8	TPSA+B	1,38	110,4	0,49	108,9	0,53	115,2	1,87	110,0	2,40	111,1	2,82

The differences are greatest in the variants of the couple with Boneprot, and the increase in variant with adsorbent is 7.2% for chlorophyll a, 6.7% for chlorophyll b and 13.0% for carotenoids. This variant has the highest total content of the green pigment (a + b), and the total content of photosynthetic pigments (a + b + c), with an increase compared to the control, accordingly by 10.0% and 11.1%. There is no significantly change on the ratio of two green pigment (a / b).

The content of photosynthetic pigments on the 60th day after planting decreases and is very close to this reported on 20th day (Table 8). The difference between control and the examination variants increased. The tendency

established on the 20th and 40th day, for the variants with the same additive or without additive is reserved. Comparison of the results for the green pigment (a + b) and the total content of photosynthetic pigments shows that the increase for the first group compared to the control is from 5.5 to 17% and the second - from 5.9 to 17.6%. The highest values were recorded at the both groups of pigments in variants TPSA + Boneprot, followed by TPS + Boneprot. In this variants was the greatest effect from the participation of the absorbent in the composition of peat-pearlite mixture, expressed with an increase of 4.1% for the group (a + b) and 4.2% for the group (a + b + c). The ratio of the green pigment (a / b), is in the range 2.79 to 3.03. These values are very close to the reported on the 20th and 40th day after planting.

Table 8. Plastid pigment content on 60-th day after planting

Variant №	Content of seedling mixture	Plastid pigment , mg/g fresh mass										
		Chl. <i>a</i>		Chl. <i>b</i>		carotenoides <i>c</i>		<i>a+b</i>		<i>a+b+c</i>		<i>a/b</i>
		(mg)	%	(mg)	%	(mg)	%	(mg)	%	(mg)	%	
1	TPS (K)	1,09	100,0	0,37	100,0	0,41	100,0	1,46	100,0	1,87	100,0	2,95
2	TPSA	1,16	106,4	0,40	108,1	0,44	107,3	1,56	106,8	2,00	107,0	2,90
3	TPS+L	1,14	104,6	0,40	108,1	0,44	107,3	1,54	105,5	1,98	105,9	2,85
4	TPSA+L	1,17	107,3	0,42	113,5	0,45	109,8	1,59	108,9	2,04	109,1	2,79
5	TPS+SS	1,16	106,4	0,38	102,7	0,45	109,8	1,54	105,5	1,99	106,4	3,05
6	TPSA+SS	1,18	108,3	0,39	105,4	0,45	109,8	1,57	107,5	2,02	108	3,03
7	TPS+B	1,23	112,8	0,42	113,5	0,47	114,6	1,65	113,0	2,12	113,4	2,93
8	TPSA+B	1,27	116,5	0,44	118,9	0,49	119,5	1,71	117,1	2,20	117,6	2,89

4. CONCLUSIONS

The composition of seedlings, used for container growing seedlings for later field production of tomatoes effects on the physiological potential and on the productivity of the photosynthetic apparatus of the plants during the growing season.

Using 20-25 day seedlings grown in containers with 66 cells and the pearlitic-peat mixture with absorbent and the products tested as additives increases the photosynthetic biological potential, yield of plants and the content of photosynthetic pigments in the growing period and improves leaf gas exchange.

The physiological potential of plants is greatest in variant TPSA + Boneprot. There is the greatest rate and economic productivity of photosynthesis. There are most effective distribution of synthesis organic substances for growth and formation of plant organs, including the reproductive.

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