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EFFECTS OF ORGANIC INPUTS APPLICATION ON YIELD AND QUALITATIVE PARAMETERS OF TOMATOES AND PEPPERS

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Abstract

The new regulation of organic cultivation starting 2022, and The Action plan for organic production in the EU, have as main aim the extinction of organically cultivated surfaces and to ensure trackability of products in a manner that will allow the significant decrease of the negative agricultural impact on environment and in human health. Due to the restrictions on organic foods, not many inputs as fertilizers or growth promoters are available for organic vegetable application. Products of natural origin are used in horticultural crops as a stimulator of the growth and development of plants. The present study was conducted in frame of a project developed in ADER program. In frame of the project research aims to identify, evaluate, tase, develop and validate methods for the analysis of nutrients and contaminants from inputs usable in organic farming. The project strategy includes application of two organic inputs in condition of certified organic field at SCDL Bacau on three important vegetable species: tomatoes, peppers, and cucumbers. The work presents the developed protocols in terms of application to highlight the potential of products to enhance quality and yield parameters, for two of three species, namely solanaceous. Assessment of total dry matter, total soluble solids, carotenes, lycopene, chlorophylls, and xanthophylls content and yield potential were accomplished. Application of these inputs may contribute to enhanced growth, yield, and resistance against specific pathogens, as well as the positive impact of content and activity of certain bioactive compounds.

Key words*: solanaceous, vegetables, ecological inputs, quality.*

INTRODUCTION

According to the Food and Agriculture Organization (FAO), sustainable agriculture is the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of environment and conserving natural resources.

Organic farming is the essential substitute to traditional cultivation for promoting or restoring biodiversity in agricultural landscapes (Tscharntke et al., 2021). To support the long-term cultivation of the plants, soil fertility must be maintained and improved. The use of chemical fertilizers is prohibited in organic farming. Thus, to maintain soil fertility, it is necessary to replace inputs with specific management practices by cultivating legumes, green manures or deep-rooted plants in a multiannual rotation program, incorporating natural fertilizers resulting from animal husbandry and other organic matter. from organic farming within the permissible limits specified by EU regulations. (Reganold et al., 2016; Meemken et al., 2018)

In organic farming the use of any substance obtained by chemical synthesis processes is prohibited and it is desired to reduce to a minimum any use of inputs from farms (these are allowed only exceptionally and under the control of inspection bodies). In order not to have any doubts about the inputs that can be used in organic farming in the European Union, the Commission has drawn up a list of fertilizers and amendments authorized under Regulations (EEC) No. 2092/91 and (EC) no. 834/2007, (CE) nr.889 / 2008, (CE) nr.848 / 2018 and (CEE) nr. 2164/2019. Organic fertilizers are an alternative to synthetic fertilizers and provide the nutritional requirements for healthy plant growth, micronutrients metals such as iron, zinc, manganese and copper. (Souri, 2016; Souri et al., 2018; Laily et al., 2021).

Organic farming will face a shortage of fertilizers due to climatic conditions that cause rapid mineralization of soil organic matter. Foliar fertilizers are used to support and supplement the needs of microelement plants. Thus, nutrients can be absorbed by plants through the leaves, which is influenced by

various factors as plant type, time and type of application, temperature, weather, etc., and the effects are visible shortly after application.

Sweet peppers (*Capsicum annuum*) are consumed for its high nutritional value (vitamin A, C, folate and macro elements: phosphorus, calcium, potassium) (Apostol et al., 2020; Guilherme et al., 2020; Silva et al., 2021). A two-year study at the Research Institute of Vegetable Crops at Skierniewice, Polonia showed that organic fruits of peppers had a higher average fruit weight, less wastes and more intensive redness as compared to conventional fruits. Meantime, organic pepper containned more ascorbic acid, β-carotene, soluble phenols and total flavonoids (Szafirowska et al., 2009).

The yield and quality of tomato are the subject of significant influence of fertilization method (Hasnain, 2020). In an open field experiment, (Bilalis et al. 2018) obtained the highest lycopene content through the application of seaweed compost compared with tomatoes managed with inorganic fertilizer. The same study shows a significantly higher total soluble solids and total solids to titratable acidity on tomatoes grown organically (Bilalis et al.,). Hasnain, 2020 stated that the screening of literature allows to classify the developed studies as follows: the most fertilization studies of tomato have generally only evaluated the effects on plants (Ravindran et al., 2019) or soil quality (He, 2016), solely. There are also studies focused on evaluation of both the plants and soil quality but only a limited number of parameters were the subject of investigations (Muchanga et al., 2020)

Exploring and understanding both the effects of fertilizer and application time, ration, as well as detecting the effects facilitate comprehensive evaluations of soil and plant and ensures significant support for production practice for the technologies of sustainable agriculture practice. More detailed work is mandatory necessary and should be explored to improve the development of sustainable agriculture.

MATERIALS AND METHODS

Legislation frame and place of experiment: the experimental device was developed in accordance with the provisions of EC Regulation 834/2007, Regulation (EC) no. 889/2008 and Regulation (EC) no. 848/2018 on organic farming. The experiment was performed in research field of the S.C.D.L. Bacău, in the polygon of ecological agriculture on an evolved medium alluvial soil, with a loam-sandy texture, the pH value was between 6.2-6.8, with a humus content of 2 -2.6%. The landfill is in interfluve of Bistriţa - Siret on an evolved alluvial land. Cultivation techniques are those adopted in the conditions of organic farming, in accordance with the regulations in force. The seedlings were produced in separate enclosures, in the greenhouse, under the conditions imposed by the regulations for organic farming. *Solanaceae* seedlings were produced in nutrient cubes and alveolar palettes. For weed control mulching with black polyethylene foil was applied and manually works if the case. The control of diseases and pests was done only with admitted products: against diseases: copper products - Boille Bordellaise - sulfur microns; for pests control Oleorgan, Lima Ko, Konflic, nettle macerate. The planting was fulfilled in the optimal period for the Bacău area on May 14, according to specific planting schemes devoted to the ecological culture of vegetables.

Applied inputs for impact evaluation: Treatments using Codamix and Ecoaminoalga plus (two fertilizers approved for organic farming) were applied to test the effectiveness on two vegetable species: peppers and tomatoes *Management of products* application based on protocols developed by SCDL and presented at section of results.

Biological material selected for this study was represented tomatoes and peppers patented varieties of SCDL Bacau: DarianaBac - sweet pepper and Bacuni - tomato variety.

DarianaBac - sweet pepper is an early variety, with a vegetation period of maximum 120 days until the first harvest. The plant has an average vigor. The plants have 50% erect port and 50% of plants are horizontal. Color of fruits is yellow, with green nuances at technological maturity and bright red at physiological maturity. Shape is trapeze in longitudinal section. Length of fruits is 9,5-11,5 cm and diameter is 7,5-8 cm. Number of lobs 3-4. Pulp's thickness - 7,5-8,5 mm. Average weight of fruit - 80-120 g.

Unibac is a mid-early variety of tomatoes. The plants have determined growth and the robustly

is medium. The plant's height is 60-75 cm. The fruits are spherical-flattened shaped, red-brick colored at physiological maturity. The average weight of fruits is 70-90 g, and the number of seed lodge is four to five, and firmness is good. Over 65% from the entire production is included in I and extra quality. Yield destination is fresh consumption and canning.

Average yield potential of variety is 80-100 t ha^{-1}. Climatic data were registered during entire period of vegetation for each experimental crop. Starting one week before the first treatment and up to four weeks after the last treatment, the following data were daily recorded: average, minimum and maximum temperature (°C); precipitation (quantity in mm). Any meteorological event that could influenced the quality and persistence of the treatments or their results (prolonged periods of drought, heavy rains, excessively low temperatures, etc.) were noted. For each species the values for are displayed in Table 1 and Table 2.

Table 1. Climatic data registered during experimental period of pepper

pepper	Air Temperature (◦C)		Solar Radiation (W/m2)		Air Relative Humidity (%)		Wind Speed (m/s)		Soil Temperature (◦C)		Daily evapo transpiration (ET0) (mm)	
	avg		avg		avg		avg		avg		avg	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Ist treatment	12,76	20,69	275	265	51,21	57,30	2,0	1,7	15,5	17,3	4,2	4,6
IInd treatment	22,87	25,77	258	272	73,84	78,10	0,4	0,8	23,9	24,8	4,3	4,0
IIIrd treatment	22,82	21,44	266	279	73,29	68,68	0,6	0,8	22,3	23,3	4,5	4,1

Table 2. Climatic data registered during experimental period of tomatoes

tomatoes	Air Temperature (◦C)		Solar Radiation (W/m2)		Air Relative Humidity (%)		Wind Speed (m/s)		Soil Temperature (◦C)		Daily evapo transpiration (ET0) (mm)	
	avg		avg		avg		avg		avg		avg	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Ist treatment	12,76	20,69	275	265	51,21	57,30	2,0	1,7	15,5	17,3	4,2	4,6
IInd treatment	17,48	18,22	280	238	61,99	65,95	0,9	0,7	15,7	17,3	4,3	4,2
IIIrd treatment	20,79	25,77	188	272	89,72	78,10	0,5	0,8	22,5	24,8	3,3	4,0

Table 3a. Soil characteristics of pepper experimental device

Assessed parameter	clayey cambic chernozem soil (values at 0,20 m deep)
ph	6,7
Humus content	2,3 (%)
Azot (%)	0,120
P mobil (ppm)	125
P mobil (ppm) corrected	115
K mobil (ppm)	200
Cu (mg/ kg)	31,6
Zn (mg/ kg)	68
Fe (%)	2,13
Mn (mg/ kg)	788
Ca (mg/ kg)	1105
Mg (mg/ kg)	4355
S-SO4	10

Table 3b. Soil characteristics of tomatoes experimental device

Assessed parameter	clayey cambic chernozem soil (values at deep of)	
	0,20 m	0,40 m
ph	6,62	6,19
Humus content	2 (%)	1,8
Azot (%)	0,110	0,110
P mobil (ppm)	138	82
P mobil (ppm) corrected	127	82
K mobil (ppm)	185	115
Cu (mg/ kg)	31,6	
Zn (mg/ kg)	68	
Fe (%)	2,13	
Mn (mg/ kg)	788	
Ca (mg/ kg)	1105	
Mg (mg/ kg)	4355	
S-SO4	10	

Soil investigations
The investigated parameters reflect their values at 20 cm deep, respectively 40 cm as presented in Table 3a and Table 3b
Plant investigation
Morphological investigations: size, number of inflorescences, foliage color, vigor, shape, appearance, color.
Biological and phenological observations: date of sowing, number of days till emergence, number of days till appearance of true leaves, number of days till appearance of the first flowers, number of days till first fruits development, date of first and last harvest. The quality of the tomato and peppers genotypes cultivated in organic conditions under application of organic inputs was assessed by determining the total soluble solids (TSS), dry matter (DM), carotene, lycopene carotene, lycopene. The fruits collected from each variant at physiological stage of maturity.
The total soluble solids content (TSS) was quantified using a handheld high precision portable refractometer. The samples were previously homogenized in a homogenizer. The results are expressed in ◦Brix, according to 932.12 methods (AOAC, 2005) Two measurements were performed for each homogenate sample and the results were expressed in ◦Brix.
The dry matter content (DM) was determined by drying fresh homogenized samples in a forced air drying oven (Biobase,) at 103 ± 2°C for 24 h until a constant mass was obtained (AOAC, 2000). The content was expressed in %. Differences from 100% was represented by water content. The mineral quantity was assessed my measurements and report to 100% from fresh weight of material, after calcination at 1000°C.
Antioxidants as β-carotene and lycopene from peppers and tomatoes fruits treated were extracted using petroleum ether and the quantitative dosing was performed spectrophotometric at different wavelengths respectively 452 nm for β-carotene and 472 nm for lycopene using spectrophotometer, against them blank represented by petroleum ether (Dobrin, 2019).
Statistical Analysis The results were reported as means ± standard errors. The ANOVA test was used to highlight the statistical significance among genotype characteristics and crop system differences. Where the differences were significant, Duncan's test ($p < 0.05$) multiple comparison tests was used.

RESULTS AND DISCUSSIONS

The results are presented for each investigated species, to highlight the best influence in terms of yield and quality following the application of two organic fertilizers at different moments during vegetation period.
The applied scheme for evaluation of inputs influence on pepper and tomatoes plants was based on a protocol special developed for these investigations. The protocol includes planting scheme, number and moments of treatments application, investigations to be followed. The protocol is the subject of a separate publication, here a synthesis is provided to follow up the experiment.
The experimental device for each crop was linear with three variants, displayed in three replicates: unfertilized control, and F1, F2 (two different foliar fertilization variants). Treatments were applied in three moments during vegetation cycle starting in third decade of May, continuing at interval of one month for the second application and another month for the third one. Method of organic fertilizer administration was leaf spray, concentration per application dose 2.5 liters/ ha/ treatment, concentration solution 0.25% Amount of solution applied/ ha: 1000 liters.
Capsicum annuum species under the influence of organic fertilizer application
The analyses of data registered in 2020 experimental year showed the influence of foliar application on earliness (Table 4).

Table 4. Phenological investigation of pepper, 2020-2021

Experimental variant 2020	Days to emergence	Seedling age (days)	Days till starting flowering	Days till fruit development	Days till first harvest 2020
A-VMt	5.67±0.33a	70.33±0.33a	98.00±0.57a	103.33±0.33a	174.00±1.00a
A-VF1	5.67±0.33a	70.33±0.33a	95.33±0.33a	100.33±0.88a	165.67±1.85a
A-VF2	6.00±0.0a	70.00±0.0a	95.33±0.88a	100.67±1.20a	167.00±3.46a

Tukey P < 0.05: Mean±Std. erro

Experimental variant 2021	Days to emergence	Seedling age (days)	Days till starting flowering	Days till fruit development	Days till first harvest
A-VMt	5.33±0.33a	69.67±0.33a	108.67±0.33a	115.00±0.57a	179.33±1.20a
A-VF1	5.00±0.0a	70.00±0.0a	104.67±0.88b	110.67±0.88b	173.33±0.66b
A-VF2	5.00±0.0a	70.00±0.0a	106.00±0.57ab	111.67±0.88ab	175.33±0.33b

Tukey P < 0.05: Mean±Std.error

The date of the first harvest varied depending on the fertilization variant: A-VF1, A-VF2 were early comparing the control variant. It is observed that variant A-VF1, A-VF2 the fruits reached the technological maturity faster compared to the control variant. Date of last harvest was 08.10.2020. The total number of harvested fruits per plant was 5 to 8.

The evolution of the sweet pepper Dariana Bac variety, for 2021 was slightly delayed compared to the average of recent years due to the low temperature conditions in the early stages of plant growth and development (Table 4). The date of the first harvest varied depending on the fertilization variant: The fruits in A-VF1 variant were harvested after 173.33±0.66 days from emergence and fruits from A-VF2 after 175.33±0.33. Same influence as in 2020 was confirmed in 2021, in all fruits of A-VF1 variant reached the technological maturity faster compared to the control variant. In A-VF2 variant the fruits reached the technological maturity faster compared to the control variant. Date of the last harvest 01.10.2021, was due to the first frost, total number of harvested fruits per plant being 3 to 6.

Related the influence of organic fertilizer application on yield we observed that both experimental years the values registered by control variant was lower compared to the fertilized variants. The best results were found in A-V1F2 which had a production of over 36.5 t/ha and in A-V2F2 - 32.9 t/ha.

Another sequence of our investigation was to analyse the influence of the application of two variants of foliar fertilization on some physiological parameters of fruits *Capsicum annum* L. var. *grossum* Sendt.

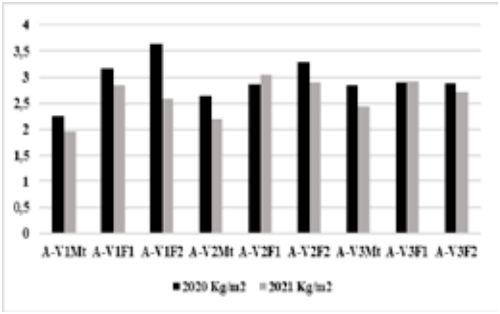

Figure 1. Influence of organic fertilizer application on peppers yield in 2020 and 2021

The total dry matter is composed of both organic and inorganic compounds, soluble or insoluble, and may be a quality indicator for peppers. The analysis of the peppers from the experimental variants was performed during the maturity period. The control variant had substantially equal values in three replicates, with an average of 9.54% Compared to the control, the application of the first fertilization variant led to higher accumulations. Compared to the control, the application of the first fertilization variant led to higher accumulations 9.60%, and the second fertilization variant, reported to the control, led to the highest accumulations of soluble dry matter 9,71%.

The soluble dry matter (TSS) is one of the most accessible and important indicators in estimation of quality, the soluble dry matter being composed mainly of soluble carbohydrates (glucose, fructose and sucrose), along with which are organic acids, amino acids and minerals.

The fertilization treatments lead to accumulation in peppers fruits of high TSS content (Table 5).

Table 5. Physiological investigations of peppers fruits

Peppers	DM	Water %	Minerals%	TSS Brix	Caroten mg 100g-1	Lycopene mg 100g-1
A-Mt	9.54±0.38a	90.45±0.38a	0.68±0.237a	6.59±0.11b	7.95±0.73ab	5.01±0.56ab
A-F1	9.60±0.51a	90.39±0.51a	0.46±0.012a	7.61±0.13a	7.14±0.24b	4.05±0.20b
A-F2	9.71±0.33a	90.28±0.33a	0.70±0.106a	7.48±0.34ab	11.15±1.05a	7.76±1.23a

Lycopene, the main red pigment in pepper fruits, shows a quantitative increase during the ripening period. Differences between lycopene levels can occur as results of different influences as variety, sampling method, preparation, method of determination, natural fruit variation, fertilization, agro-climatic conditions, soil properties, solar radiation, geographical origin, and post-harvest conditions. According to Igbokwe et al. (Igbokwe, 2013), the content of lycopene in red peppers can have values nine times more than green peppers. There are studies that report double the amount of lycopene in the red areas compared to the green ones. After integration of two experimental years, we can preliminarily conclude the positive influence of the two fertilizers in the case of yield, accumulations of total dry matter, soluble dry matter, partially carotene and lycopene.

Lycopersicum esculentum species under the influence of organic fertilizer application

Similar protocol including the linear experimental device, three replicates, application of two products in three phases during vegetation period was applied in case of tomatoes in purpose of evaluation the influence of organic fertilization on phenology and in the quality of tomatoes fruits.

Method of administration: leaf spray Concentration / application dose: application dose 2.5 liters / ha / treatment, concentration solution 0.25%.

Observations before applying the first treatment (plants with minimum 8 true leaves) and after applying the treatments. Efficacity was assessed by observations, measurements, and investigations before the first treatment and after each treatment. From the observations undertaken on the fertilized variants, in 2020, we conclude on the following aspects: there is difference related the number of inflorescences (8-11) in case of organic fertilizer application and (7-9) in control variant.

The height of the plant under organic fertilization reached (65-80 cm) compared to the control variant where the values of plants height ranged from 55-70 cm. During 2021, the number of developed inflorescences was (10-11) and the height of the plant (65-85 cm) in treated variants against control variant were number of inflorescences was 8-10 and plant height 60-75 cm. By visually assessment of foliage color was estimated as dark green, at all treated variants compared to the control which was green.

The beginning of maturation varied depending on the fertilization variant. The application of organic fertilizer conducted to an early fruit maturation (Table 6).

During 2021 experiments (Table 7) we observed that the beginning of maturation varied depending on the fertilization variant. In the control variant there were observed delays compared to the variants where organic fertilizer was applied.

It is observed that in variant T-VF1, in all replicates, and variant T-VF2 in two of three replicates, the beginning of maturation was achieved faster compared to the control variant.

Table 6. Phenological investigations of tomatoes, subject of treatments with two different organic fertilizers in 2020

Varianta	Days to emergence (days) 2020	Seedling age (days) 2020	Days till starting flowering 2020	Days till fruit development 2020	Days till harvest 2020
T-VMt	3.33±0.33a	47.67±0.33a	70.67±0.33a	78.67±0.33a	118.33±0.88a
T-VF1	4.33±0.66a	46.67±0.66a	69.33±0.33a	76.33±0.33a	103.33±9.68a
T-VF2	4.00±0.57a	47.00±0.57a	69.89±0.35a	76.67±0.88a	115.00±1.00a

Table 7. Phenological investigations of tomatoes, subject of treatments with two different organic fertilizers in 2021

Varianta	Days to emergence (days) 2021	Seedling age (days) 2021	Days till starting flowering 2021	Days till fruit development 2021	Days till harvest 2021
T-VMt	5.00±0.0a	45.00±0.0a	68.00±0.0a	75.67±0.33a	115.33±0.33a
T-VF1	4.67±0.33a	45.44±0.33a	66.67±0.33a	73.67±0.33b	100.67±9.83a
T-VF2	4.67±0.33a	45.33±0.33a	67.00±0.57a	74.33±0.33ab	111.67±0.33a

From the production point of view (Figure 2) in 2020 the T-VF1 fertilization variant stands out, which had an increase in production compared to the control variant of over 1.5 kg/m^2. T-V2F1 had a production of over 7.1 kg/m^2, and T-V3F1 - 6.91 kg/m^2.

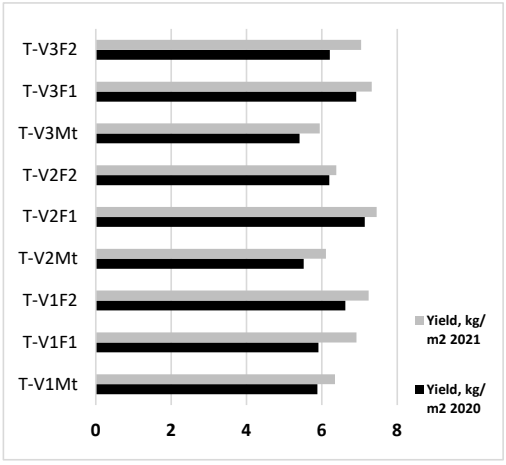

Figure 2 Influence of organic fertilizer application on tomatoes yield in 2020 and 2021

During experimental year of 2021, the T-VF1 fertilization had an increase in production compared to the control variant of over 1.34 kg/m^2. T-V2F1 had a production of over 7.45 kg/m^2. T-V3F1 obtained 7.32 kg/ m^2.

In both years, the average weight of the fruit was positively influenced by the application organic fertilizers against the control. According to our investigations in control variant the fruit weight varied from 56-70 g; T-VF1: 70-90 g/fruit; T-VF2: 65-85 g. during the first experimental year and a similar tendency was observed in the second experimental year, when fruits of control variant weighed 60-70 g; those from T-VF1: 70-85 g; and the fruits of T-VF2: 70-80 g.

Organic tomatoes were evaluated in terms of quality at harvest, in the ripening stage.

The fruits were harvested at the (6) stage of maturity, having an average diameter of 68.39 mm and an average height of 46.32 mm. The fruits were harvested by hand from each variant, the average samples on each repetition to correspond to the uniformity of size and maturity.

The analysis of tomatoes from the experimental variants was performed during the maturity period and highlighted a superior level of accumulation of total dry matter in variants where the fertilizer was applied, 5.35% and 5,72%, against control variant 5,19%. Same positive influence was observed in case of TSS accumulation, both treated variants, having superior accumulation comparing control (Table 8).

Table 8. Phisiological investigation of tomatoes

Varianta	DM %	Water %	Mineralse %	TSS Brix	Caroten mg 100g-1	Lycopene mg 100g-1
T-Mt	5.19±0.51a	94.81±0.51a	0.50±0.018b	4.33±0.15a	4.40±0.20a	3.50±0.17b
T-F1	5.35±0.47a	94.64±0.47a	0.57±0.006a	4.81±0.09a	4.62±0.26a	4.39±0.20ab
T-F2	5.72±0.25a	94.28±0.25a	0.55±0.010ab	4.82±0.10a	4.83±0.22a	4.69±0.37a

Regarding the influence of the fertilization variants, we found that both variants in the three repetitions allowed significantly higher accumulations of carotene and lycopene, compared to the control variants. Carotene and lycopene are the main pigments that give the specific color for tomato fruits, depending on variety, maturation phase, phytosanitary condition. They play an important role in determining the degree of ripeness and for assessing the commercial quality of tomatoes fruits. The synthesis of carotene and lycopene takes place simultaneously with the biodegradation of chlorophyll in tomato fruits.

The carotene and lycopene content represents an indicator for the degree of maturity and quality of the fruit. The color fruit playing a key role in consumer acceptance. Regarding the influence of the fertilization variants, we found that both variants in the three repetitions allowed significantly higher accumulations of carotene and lycopene, compared to the control variants.

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CONCLUSIONS

Related the influence of organic fertilizer application on pepper: after integration of two experimental years, we can preliminarily conclude the positive influence of the two fertilizers in the case of peppers yield, earliness, accumulations of total dry matter, soluble dry matter, partially carotene and lycopene.

Related the influence of organic fertilizer application on tomatoes - the application of organic fertilizer conducted to an early tomatoes fruit maturation. The positive influence of the two fertilizers is found even after the second season of experimentation, so we can conclude in the case of accumulations of total dry matter, soluble dry matter, carotene and lycopene that they were superior compared to the control. Related the influence of organic fertilizer application on yield we observed that both experimental years the values registered by control variant was lower compared to the fertilized variants.

The presented data are preliminary results of the major study, and more investigations will continue. The general objective of the research is to identify, evaluate, test, develop and validate the methods for the analysis of nutrients and contaminants from inputs usable in organic farming.

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