Impact of biofertilisers and agrometeorological conditions on phenological growth of pepper (*Capsicum annuum* L.) in organic agriculture

Влияние на биоторовете и агрометеорологичните условия върху фенологичното развитие на пипер (*Capsicum annuum* L.) при биологично земеделие

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Abstract

The pepper has a relatively large share in the general structure of the vegetable production in Bulgaria. The objective of this research was to investigate the influence of biofertiliser Emosan (HemoZym NK, Hemozym Bio N_5) in combination with biofertilisers Lumbrical and Boneprot, as well as the influence of certain agrometeorological conditions on the phenological growth of pepper cv. 'Sofiiska Kapiya'. This experiment was carried out in 2009 – 2011 on the experimental fields of the Agroecological Centre at the Agricultural University Plovdiv (Bulgaria). The pepper was grown using existing technology for mid-early field production, according to the principles of organic agriculture. The agroclimatic characteristics were taken on the basis of data of twenty-four-hour performance of meteorological factors. In the three years of the experiment the temperature conditions during the period of active vegetation of the pepper (June - July - August) were above the average, which was in conjunction with the global trends. The application of biofertiliser Emosan, in combination with basic fertilization with biofertilisers Boneprot and Lumbrical and under the impact of suitable agrometeorological conditions, had a positive impact on the pepper plants. Pepper plants showed earlier entry into the main phenophases under field conditions of organic farming.

Keywords: agrometeorological conditions, biofertilisers, *Capsicum annuum* L., organic agriculture, phenological growth, vegetable crops

Резюме

В общата структура на зеленчуковите култури у нас относителният дял на пипера е голям. Целта на настоящото проучване е да се установи влиянието на биотор Емосан (HemoZym NK, Hemozym Bio N_5) в съчетание с биоторовете Лумбрикал и Бонепрот, както и влиянието на агрометеорологичните условия върху фенологичното развитие на пипер от сорт Софийска капия. Експериментът се изведе през периода 2009 - 2011г. на Учебно-опитното поле към Агроекологичния център на Аграрен университет Пловдив (България). Пиперът се отгледа по технология за средноранно полско производство, според принципите на биологичното земеделие. Агроклиматичната характеристика е изготвена въз основа на данните за денонощния ход на основните метеорологични фактори. През експерименталните години температурните условия през периода на активната вегетация на пипера (юни - юли - август) са над нормалните температури, което е в съответствие с глобалните тенденции. Внасянето на биотор Емосан комбиниран с основно торене от биоторовете Бонепрот и Лумбрикал и под влияние на подходящите агрометеорологични условия има положително въздействие върху по - ранното встъпване в основните фенофази от развитието на пипера, отгледан при полски условия на биопроизводство.

Ключови думи: агрометеорологични условия, *Capsicum annuum* L., биологично земеделие, биоторове, зеленчукови култури, фенологично развитие

Подробно резюме

Непикираният разсад се отгледа в полиетиленова оранжерия на Агроекологичния център, като са използвани семена, които отговарят на изискванията за приложение в биологичното земеделие. Сеитбата на семената се извърши в срок, съобразно изискванията за средноранно производство за пипер през третото десетдневие на месец март. Опитът се изведе в 4 повторения с площ 1 m^2 на повторение. След оразмеряване на вариантите са внесени като основно торене фоновете-Бонепрот и Лумбрикал ($g*m^2$), като дозите на биоторовете са според препоръките на фирмите вносители и производители. През периода на разсадопроизводството са положени оптимални грижи-поливане, проветряване, редовно отстраняване на плевелите и биологична борба срещу вредителите. При полски условия (през втората половина на месец май) засаждането на разсада се извърши на висока равна леха, при схема 120+60x15 cm, като опитът е изведен по метода на дългите парцели, в четири повторения, с големина на отчетната площ 9.6 m^2. Преди засаждане на разсада на полето с инкорпориране са внесени в почвата локално (редово), като основно фоново торене биоторовете Бонепрот и Лумбрикал в две концентрации - оптимална (70 kg*da при фон Бонепрот и 400 L*da при фон Лумбрикал) и редуцирана с 50 %. Биотор Емосан е внесен почвено, разтвор в концентрация 15 L* da, преди сеитба на семената, а подхранването с него е трикратно-в края на разсадния период, а при полски условия (във фенофаза бутонизация и след формиран масов завръз). Определи се настъпването на фенофазите (в дни): от сеитбата за фенофаза поникване и от поникването за фенофазите–котиледони, кръстосване, бутонизация, цъфтеж, техническа зрелост и ботаническа зрелост. Началото на всяка фенофаза се определи при 10 %, а масовото встъпване е при 75 % от наблюдаваните растения. Наблюденията през вегетационния период са

извършени върху 10 предварително маркирани растения. През вегетационните 2009 - 2011г. са направени фенологични наблюдения върху настъпването на отделните фенофази (таблици 1, 2 и 3). Агрометеорологичните условия през месец септември са свързани с нахлуване на по - хладен въздух и по - чести превалявания, които се оказват подходящи и създават условия за осигуряване на плавен процес на узряване на плодовете, като масовото настъпване на фенофазата е свързано със започване на беритбите. Приложените биоторове оказват положително влияние върху натрупването на хранителни вещества, което се отразява и върху по - бързото узряване на плодовете на пипера. През трите години температурните условия са над нормалните. Най-големи са отклоненията през месец август на 2010 г. (3.1°C над нормата) и месец юли на 2011г. (2.2 °C над нормата). Най-слабо е отклонението през юни 2010г. едва 0.5°C над нормата, което съвпада с фенофаза бутонизация, което обуславя и по-високия реализиран добив. Температурите през останалите месеци за трите експериментални години са в интервал от 1.0 °C до 1.5 °C над нормата. Внасянето на биотор Емосан комбиниран с основно торене, като фон от биоторовете Бонепрот и Лумбрикал и под влияние на подходящите агрометеорологични условия има положително въздействие върху по-ранното встъпване в основните фенофази от развитието на пипера, отгледан при полски условия на биопроизводство.

Introduction

The agroclimatic resources of Bulgaria are determined by its geographic location, the relief and the influence of nearby sea-basins i.e. the Mediterranean Sea and the Black Sea. With respect to the climate, Plovdiv is a part of the Transitional continental climatic subregion of Bulgaria to the European continental climatic region and a climatic region of East - Middle Bulgaria (Ahmed, 2004). Plovdiv was more resistance to the sum of precipitation and more sensitive to the sum of temperature (Popova, et al., 2010).

The pepper has a relatively large share in the general structure of the vegetable production in Bulgaria (Sourlekov and Rankov, 1977). The pepper in Bulgaria is the second most significant vegetable culture from an economic point of view. Pepper production uses mostly local varieties registered by Bulgarian selection scientists (Cholakov and Todorov, 1989; Cholakov, et al., 1996). Todorov, et al. (1985) specify that over 98% of the area under pepper in Bulgaria is occupied by Bulgarian varieties, thus proving the contribution of the Bulgarian genetic selection.

There are recommendations to use the Bulgarian varieties for organic production (Antonova, et al., 2012) as most adapted to local agroecological conditions. Cholakov and Todorov (2007) point out that the phenological responses of most of the pepper varieties grown in Bulgaria are not been sufficiently investigated.

Plants, like other biological systems, do respond to the changes occurring in their micro and macro climatic regimes. In order to determine the optimum environmental parameters for enhanced crop productivity, there is a need to determine different response of crop cultivars to fluctuating climate conditions (Todorova, et al., 2009). The pepper has high requirements towards the growth factors i.e. temperature, light, humidity, soil, nutritional substances and the preceding crop (Veselinov, et al., 1984).

Under Bulgarian climatic conditions the pepper is an annual plant (Kartalov, et al., 1990).

The research (Vlahova, et al.,2014) has proven the biofertiliser application as an effective measure in organic agriculture, as well as a reliable reserve of nutritional substances for the soil. The survey results by Shopova (2014) show that the composition of the seedling mixture and the composition components included in it and being of an organic or organo-mineral origin have a positive influence on the occurrence of the main phenophases and the length of the main sub-periods of the development of tomato plants. Boteva and Georgieva (2013) have found that the use of seeds treated with the biofertiliser Baikal has been characterized with the shortening of the phenophases for the pepper of the variety of Kurtovska Kapiya 1619.

Objectives

The objective of this research was to investigate the influence of biofertiliser Emosan (HemoZym NK, Hemozym Bio N_5) in combination with biofertilisers Lumbrical and Boneprot, as well as the influence of certain agrometeorological conditions on the phenological growth of pepper cv. 'Sofiiska Kapiya'.

Materials and Methods

This experiment was carried out in 2009-2011 in a polyethylene greenhouse and on the experimental fields situated on the territory of a certified organic farm of the Agroecological Centre at the Agricultural University of Plovdiv, Bulgaria.

Vegetable tested

The pepper is a tropic plant and optimum temperature for pepper growth is 18-25 ºC (Murtazov, et al.,1984). It has also specific requirements towards the intensity and duration of sun radiation and is a plant of the short day (10-12 hours) (Kartalov, et al., 1990). Due to its shallow root system the pepper is quite demanding when it comes to humidity. The pre-irrigation humidity until the beginning of the fruitfulness phenophase is maintained at levels of approximately 70 % of the maximum soil water capacity and during the fruitfulness phenophase 80–85 % of the maximum soil water capacity (Murtazov, et al., 1984). The pepper was grown using existing technology for mid-early field production, according to the principles of organic agriculture (Panayotov, et al., 2007).

Agrotechnology

The unpricked- out seedlings were grown in the polyethylene greenhouse of the Agroecological Center by using seeds, which were in conformity with the requirements for application in organic agriculture (Regulation (EEC) No. 889/2008).

The seed-bed location in the greenhouse was consistent with the crops from the preceding period of seedling production upon observed rotation. Sowing of pepper seeds took place in time according to the requirements for mid-early pepper production during the third decade of March. The experiment was carried out in 4 replications on an area of 1 m^2 per replication. After sizing the variants, Boneprot and Lumbrical ($g*m^2$) were applied as basic fertilisation. During the period of seedling production, all the required agro-technical practices were undertaken, i.e. watering, ventilation, regular cleaning of weeds and biological pest control (Vlahova, 2013 a).

Under field conditions (during the second half of May), the seedling transplanting was completed on a high-flat seed-bed, at the following scheme: 120+60x15 cm. The experiment was done according to the method of long plots, in 4 replications, with a size of the reporting area of 9.6 m^2.

Fertilization

Selected biofertilisers were applied in doses recommended by the manufacturing companies.

Seedling growing (green-house)

The biofertilisers Boneprot and Lumbrical were applied into the soil through incorporation prior to the time of seeding in two concentrations, i.e. an optimum of 70 kg*da for basic fertilisation with Boneprot next of 400 L*da for basic fertilisation with Lumbrical and reduced concentration i.e. 50 % from the optimum. The biofertiliser Emosan was applied twice into the soil in a form of solution, i.e. before seeding time and in the end of the seedling period) in the concentration of 15 L*da.

Field growing

The biofertilisers Boneprot and Lumbrical were applied on field plots locally (in the crop rows), into the soil via incorporation before transplanting the seedlings on the field. They were applied as basic fertilization in two concentrations, i.e. optimum of 70 kg*da for the basic fertilisation Boneprot, next of 400 L*da for the basic fertilisation Lumbrical and reduced concentration i.e. 50 % from the optimum. The biofertiliser Emosan was applied twice during vegetation as vegetative feeding (at the flower bud phenophase and after a formed mass fruitset phenophase) in concentration of 15 L*da (Vlahova, 2013 a).

Treatments:

1. Control (non - fertilised)
2. Basic fertilisation with Boneprot (optimum concentration)
3. Basic fertilisation with Boneprot (50 %) + Emosan
4. Basic fertilisation with Lumbrical (optimum concentration)
5. Basic fertilisation with Lumbrical (50 %) + Emosan

Characteristics of the biofertilizers included into the study

This study included biofertilisers–Boneprot, Lumbrical and Emosan, the active ingredients of which are included in the list of permitted substances for maintaining soil fertility according to Regulation (EEC) No. 889/2008 incl. Annex 1.

Boneprot (Arkobaleno, Italy) is a pellet organic fertiliser, and has following composition: organic nitrogen (N)- 4.5 %; phosphorus anhydride (P_2O_5) total- 3.5 %; potassium (K_2O)- 3.5 %; organic carbon (C) of biological origin 30 %; humification rate (HR)-10-13 %; degree of humification (DH) 40- 42 %; humidity 13-15 %; pH of 6 -8 (pH in H_2O). Boneprot is an entirely organic fertiliser consisting mainly of cattle manure.

Lumbrical (private producer from village Kostievo, Plovdiv region, Bulgaria) is a product obtained from processing of natural manure and other organic waste by Californian red worms (*Lumbricus rubellus* and *Eisenia foetida*) and consists of their excrements. The commercial product has humidity of 45 - 55 % and organic substance content of 45- 50 %. Ammonium nitrogen (NH_4N)- 33.0 ppm; nitrate nitrogen (NO_3N)- 30.5 ppm; P_2O_5- 1410 ppm; K_2O- 1910 ppm and MgO- 1.8 %. It contains useful microflora 2x10^{12} pce*g, humic and fulvic acids, nutritional substances. The product has a pH of 6.5- 7.0 (pH in H_2O).

Emosan, HemoZym NK, Hemozym Bio N_5 (Arkobaleno, Italy) contains total nitrogen (N)- 5 %; organic nitrogen (N)- 5 %; organic carbon (C) of biological origin- 14 %; protein- 34 p/p; humidity- 65 p/p; K- 0.4 p/p; P- 0.06 p/p; pH 7.0- 10.0.

Study parameters

Meteorological parameters and agroclimatic characteristics

The agroclimatic characteristics were taken on the basis of data of twenty-four-hour performance of meteorological factors (air temperature (°C), rainfall (mm), relative humidity (%) detected by the Synoptic Station at NIMH Plovdiv (Research and Experimental Field at the Agricultural University of Plovdiv). The climatic norms by periods of ten days were determined based on data from Agroclimatic Manual of the Republic of Bulgaria (1960). The hydrothermal coefficient (HTC) was used to characterize the conditions of humidification, as this is a complex parameter for characterization of the temperature and humidity conditions of the environment (Selyaninov, cited by Kouzmova, 2003).

Phenological characteristics

The occurrence of the phenophase was determined (in days): from the sowing for the sprouting phenophase and from the sprouting for the phenophases- cotyledons, first true leaf, flower bud, flowering, ripening, and botanical maturity. The beginning of each phenophase was determined at 10 % of - and the mass entry was at 75 % of all plants under observation. During the vegetation period 10 pre - marked plants were subject to the observations in the field condition (Ganeva, 1984).

Results and Discussion

Phenological characteristics of the pepper during the period 2009 - 2011

During the vegetation years 2009- 2011 there were phenological observations carried out on the separate phenophases (Tables 1, 2 and 3), but agrometeorological conditions during the experimental period are presented on the Tables 4, 5 and 6. The agrometeorological conditions in the period before sowing during the three experimental years were suitable for sowing in- time and had the following characteristics - temperature of 12.8 °C (2009), 13.7 °C (2010), 11.5 °C (2011), and relative humidity of 52 % (2009), 68 % (2010), and 83 % (2011).

The beginning of the *sprouting* phenophase took place on the 10^{th} day the earliest, when the biofertiliser Emosan on both basic fertilisations was applied into soil as the average air temperature before the occurrence of the phenophase was 12.5 °C (2009), 10.7 °C (2010), 11.3 °C (2011), and the relative humidity was 67 % (2009), 73 % (2010), 68 % (2011). During the 3-year study period the phenophase took place on the 11^{th} day for plants from the variants characterized with the optimum concentration of Boneprot and Lumbrical. During the experimental period this phenophase occurred at latest with the plants from the control variant. The same sequence was shown upon the mass spread of the phenophase.

During the period of three years the entry into the *cotyledons* phenophase was reported on the 10th day for the plants of a variant with the biofertiliser Emosan on both basic fertilisations, as well as for the plants of the variant on the basic fertilisation Lumbrical applied in an optimum concentration as the temperature in the days before the occurrence of the phenophase was 12.1 °C (2009), 11.7 °C (2010), 12.7 °C (2011), and the relative humidity was 71 % (2009), 69 % (2010), 59 % (2011), as their average values were similar and favourable for the growth of the seedlings.

Table 1. Duration of the different phenophases of pepper (in days) in 2009

Таблица 1. Продължителност на отделните фенофази при пипер (в дни) през 2009

Treatments /variants/	From sowing		From sprouting											
	to sprouting		to cotyledons		to first true leaf		to flower bud		to flowering		to ripening		to botanical maturity	
	b	m	b	m	b	m	b	m	b	m	b	m	b	m
Control	12	16	11	15	23	29	60	64	66	71	100	113	125	137
Boneprot (opt.)	11	14	11	14	23	28	58	63	65	70	99	112	122	134
Boneprot (50 %) + Emosan	10	13	10	13	20	25	58	62	63	67	96	108	117	129
Lumbrical (opt.)	11	14	10	14	21	26	58	63	65	68	98	110	121	134
Lumbrical (50 %) + Emosan	10	13	10	13	20	25	58	62	63	67	96	108	118	130

b - beginning; m - mass

The beginning of the *first true leaf* phenophase occurred for the variant with the biofertiliser Emosan on both basic fertilisations on the 20th day the earliest within the 3-year study period as the agrometeorological conditions before the occurrence of the phenophase were following-average temperature of 14.2 °C (2009), 13.2 °C (2010), 10.8 °C (2011) and average relative humidity 67 % (2009), 79 % (2010), and 62 % (2011). The phenophase occurred last with the plants from the control variant on the 23rd day (2009, 2010 and 2011), where no fertilization was applied.

In the days before pricking off during the three years of growth, the average temperatures were favourable for the adaptation of the seedlings. The pepper seedlings pricking off of to a permanent location took place under suitable agrometeorological conditions, i.e. temperature was 21.1 °C (2009), 17.5 °C (2010), 17.8 °C (2011), and the relative humidity was 61 % (2009), 63 % (2010),72 % (2011) respectively. The relatively constant temperatures in the periods of ten days after pricking off created conditions for adaptation and favourite root development under field conditions.

It was found that the plants entered the *flower bud* phenophase on the 58th day the earliest (2009) for all variants, except for the control. For the plants of the variant fed with Emosan on both basic fertilisations it happened on the 63rd day in 2010 and on 64th day in 2011 as the temperatures before the occurrence of the phenophase were

23.3 °C (2009), 20.0 °C (2010), 24.5 °C (2011), and the relative humidity was 52 % (2009), 75 % (2010) and 71 % (2011). The applied biofertilisers stimulated the plants to enter earlier the flower bud phenophase in comparison with the control plants. The positive effect of the biofertiliser Emosan applied on both basic fertilisations also affected the earlier entry into the beginning of the flower bud phenophase, which was found in 2010 and in 2011. June had favourable agrometeorological conditions as it was very warm and humid month, which was beneficial to the development of pepper plants for entering the stage of mass flower bud.

Table 2. Duration of the different phenophases of pepper (in days) in 2010

Таблица 2. Продължителност на отделните фенофази при пипер (в дни) през 2010

Treatments /variants/	From sowing		From sprouting											
	to sprouting		to cotyledons		to first true leaf		to flower bud		to flowering		to ripening		to botanical maturity	
	b	m	b	m	b	m	b	m	b	m	b	m	b	m
Control	12	16	11	14	23	30	67	72	74	79	110	125	135	149
Boneprot (opt.)	11	15	10	13	22	28	65	71	72	77	107	121	130	143
Boneprot (50 %) + Emosan	10	13	10	13	20	25	63	68	70	74	104	117	127	140
Lumbrical (opt.)	11	14	10	13	22	28	64	70	72	76	106	120	130	144
Lumbrical (50 %) + Emosan	10	13	10	13	20	25	63	68	70	74	104	118	127	140

b - beginning; m - mass

It was found that the *flowering* phenophase took place the earliest for the plants from a variant treated with Emosan on both basic fertilisations on the 63rd day in 2009, and on the 70th day in 2010 and 2011 as the average temperature in the days before the occurrence of the phenophase was 23.2 °C (2009), 21.5 °C (2010), and 22.6 °C (2011), and the relative humidity was 51 % (2009), 69 % (2010), 65 % (2011). The earlier occurrence was due to the implemented vegetative feeding with the liquid biofertilizer Emosan at the flower bud phenophase, which additionally added nutritional substances valuable for the plants. This early entrance into the flowering phenophase confirmed the efficiency of applied biofertiliser Emosan in combination with both basic fertilisations, thus having an effect on the earlier mass entry in to the phenophase and confirmed during the three vegetation years. It is clear that the agrometeorological conditions during the vegetation period of the pepper plants are crucial for optimal pepper growth.

The *ripening* phenophase occurred the earliest for those plants fed with Emosan on both basic fertilisations, i.e. on the 96th day in 2009 and on the 104th day in 2010. During the period before the occurrence of the phenophase the average temperature was 23.3 °C (2009), 23.1 °C (2010), the average relative humidity was 62 % (2009) and 65 % (2010), and the total rainfall amount was 99.2 mm (2009) and 29.0 mm (2010), which had a positive influence on fruit ripening. In 2011, the earliest entrance in the ripening phenophase took place on the 103rd day for the plants fed with Emosan on the basic fertilisation Lumbrical, and a day later on the combined variant on the basic fertilisation Boneprot. In the days before, the average temperature was 23.5 °C (2011), the average relative humidity was 56 % and the total rainfall amount was 16.5 mm. The favourable agrometeorological conditions, together with the required irrigation norm and the more frequent entrenchment for the purpose of aeration of the pepper root system, all created preconditions for the earlier entry of the crop in the ripening phenophase.

Table 3. Duration of the different phenophases of pepper (in days) in 2011

Таблица 3. Продължителност на отделните фенофази при пипер (в дни) през 2011

Treatments /variants/	From sowing		From sprouting											
	to sprouting		to cotyledons		to first true leaf		to flower bud		to flowering		to ripening		to botanical maturity	
	b	m	b	m	b	m	b	m	b	m	b	m	b	m
Control	13	18	11	15	23	29	67	73	75	80	110	125	135	149
Boneprot (opt.)	11	15	10	14	22	28	67	72	74	79	108	121	132	145
Boneprot (50 %) + Emosan	10	13	10	13	20	25	64	68	70	75	104	117	127	141
Lumbrical (opt.)	11	15	10	14	22	28	65	71	73	78	107	122	131	145
Lumbrical (50 %) + Emosan	10	13	10	13	20	25	64	68	70	75	103	116	126	139

b - beginning; m - mass

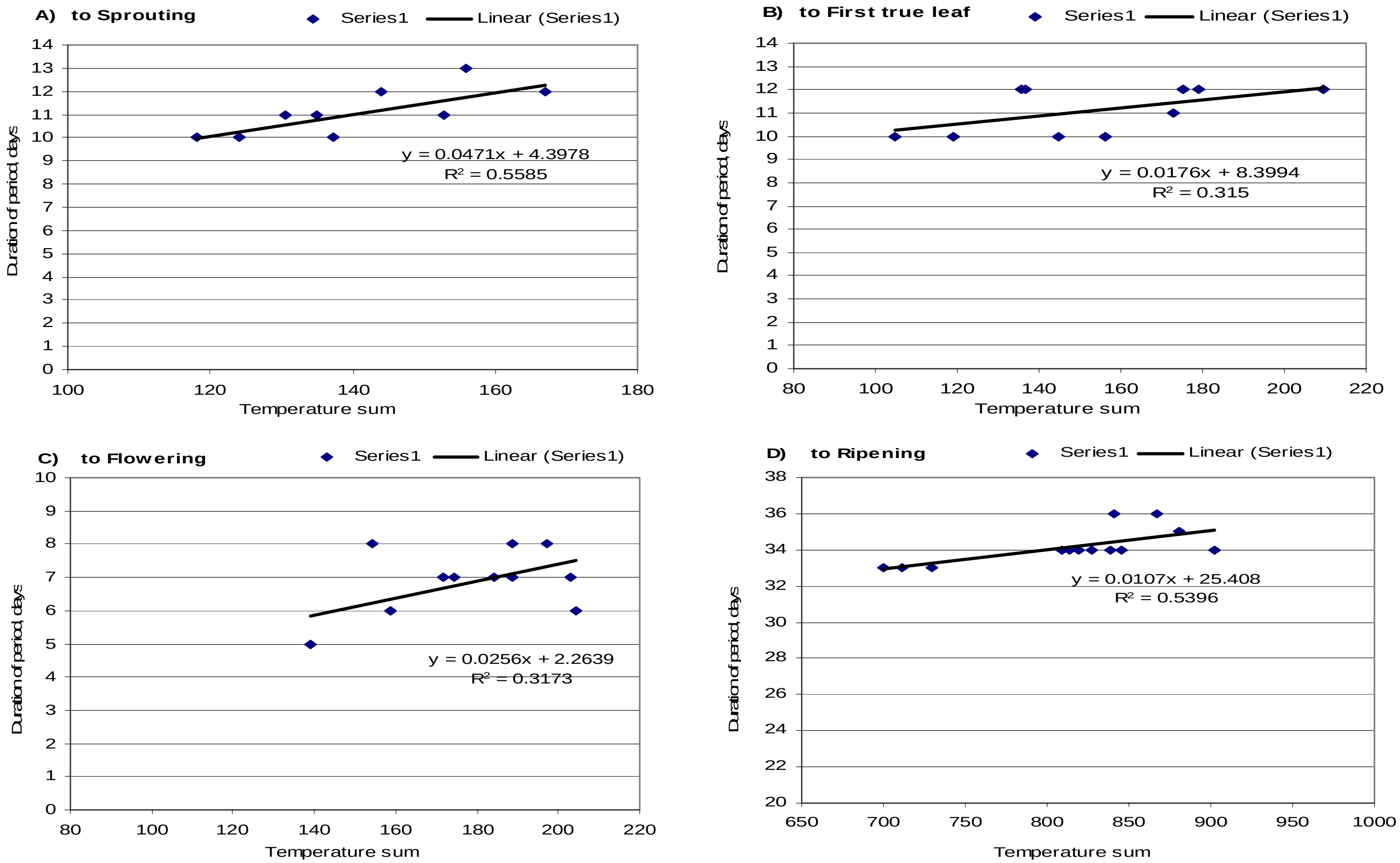
It was found that the *botanical maturity* phenophase took place the earliest on the 117th day for the plants of the variant fed with Emosan on the basic fertilisation Boneprot (2009), on the 127th day for Emosan on the both basic fertilisations (2010), and on the 126th day for Emosan on the basic fertilisation with Lumbrical (2011) as the agrometeorological conditions before the occurrence of the phenophase were following-average temperature 25.0 °C (2009), 25.4 °C (2010), 24.8 °C (2011), average relative humidity 56 % (2009), 67 % (2010), 63 % (2011) and the total rainfall amount was 22.4 mm (2009), 116.5 mm (2010) and 11.7 mm (2011). The 3-year study found that there was an earlier entry in the beginning of pepper phenophases as well as an earlier entry in the mass botanical maturity for the variant fed with Emosan in the phenophase formed mass fruitset applied on both basic fertilisations- Boneprot and Lumbrical, as the average air temperatures were typical for the summer month of August, i.e. the average monthly temperatures were 23.9 °C (2009), 25.8 °C (2010), and 23.7 °C (2011), and the relative humidity was 60 % (2009), 62 % (2010), and 64 % (2011). The agrometeorological conditions in September are characterized with the entry of cooler air and more frequent rainfall, which turn out to be suitable and created conditions for ensuring a smooth process of fruit ripening. The mass entry into the phenophase is connected with the starting of the harvest. The applied biofertilisers has positive impact on the accumulation of nutritional substances, which itself influenced the quick fruit ripening of pepper.

In the three years of the experiment the temperature conditions during the period of active vegetation of the pepper (June - July - August) were above the average temperatures, which was in conjunction with the global trends. The largest diversions were reported in August 2010 (3.1 °C above the norm) and in July 2011 (2.2 °C above the norm). The lowest diversion was in June 2010 only 0.5 °C above the norm, which coincided with the flower bud phenophase, which also determined the obtained higher yields. The temperatures during the other months in the three experimental years were within the range of 1.0 °C to 1.5 °C above the average (Table 7). The conditions for humidification were extremely dynamic and varied during the individual phenophases of pepper development throughout the experiment. The data obtained in 2009 for the hydrothermal coefficient (HTC) showed that there was a drought period at HTC < 1 in June (1.00), July (0.68), and September (0.64), and a dry period at HTC < 0.5 in August (0.44) (Vlahova, 2013 b). The data obtained in 2010 for HTC showed that there were drought periods reported at HTC < 1 in June (0.92), and a dry period at HTC < 0.5 in May (0.33), August (0.30), and September (0.22). In 2011 a drought period at HTC < 1 was reported in May (0.77), July (0.53), and August (0.93), and a dry period at HTC < 0.5 in June (0.22) and September (0.05) (Vlahova, 2012). The above conditions determined the need for soil watering in conformity with the phenological growth of pepper as well as with the specific agrometeorological conditions.

Vlahova and Popov (2014) point out that the highest standard yield in all three experimental years was shown by the variant fed with the biofertiliser Emosan on the basic fertilisation Lumbrical, i.e. 1541 kg/da (2009), 2258 kg/da (2010), and 2006 kg/da (2011). A high yield was reported upon the additional feeding with the biofertiliser Emosan on the basic fertilisation Boneprot, i.e 1512 kg/da (2009), 2184 kg/da (2010) and 1900 kg/da (2011). The results showed that fertilisation with liquid biofertiliser Emosan on basic application of solid Boneprot or Lumbrical improve the soil nutrient conditions which reflects in improved feeding regime of pepper plants. This reflects in improved (higher) yields and productivity of plants. The findings provide grounds for suggesting the studied biofertilisers as an effective agro-technical solution in organic production of pepper.

During the experimental period, upon comparison of the combined variants on both basic fertilisations, a positive effect on the quality of the fruits was reported after application of the biofertiliser Emosan on the Lumbrical basic fertilisation, as it increased the values of the dry matter (2009, 2010, 2011), total sugars (2009, 2010) and vitamin C (2010, 2011), thus confirming this combination as successful for application in the organic pepper production (Vlahova and Popov, 2013).

For a large part of the agricultural crops dependency has been established between the time of occurrence of the separate phenophases (as of the beginning of the vegetation period), and the respective temperature sum (Kornov, 2012; Kirchev et al., 2014). Similar dependencies have been also determined in connection with the duration of the phenophase, depending on the temperature sum. Regarding the conditions of the experiment, the results of which are the subject of the present paper, there is a significant linear dependency concerning only the period until sprouting and occurrence of the ripening, at values of the coefficient of determination, respectively R^2=0.56 and R^2=0.54 (Figure 1- A); and Figure 4- D). As for the first true leaf and flowering phenophase, the connection is poor to moderate at R^2=0.32 (Figure 2- B) and Figure 3- C). In the remaining phases the connection is poor or practically missing.



Figures 1- 4. Dependency between the Duration of period- Sprouting- A); First true leaf-B); Flowering-C); Ripening- D) and Temperature sum

Фигури 1-4. Зависимост между продължителността на периода- Поникване- A); Кръстосване- B); Цъфтеж- C); Техническа зрялост- D) и температурната сума

Conclusions

The application of biofertiliser Emosan, in combination with basic fertilization with biofertilisers Boneprot and Lumbrical and under the impact of suitable agrometeorological conditions, had a positive impact on the pepper plants. Pepper plants showed earlier entry into the main phenophases under field conditions of organic farming. The results shown by biofertiliser combinations provide grounds for recommending these in organic agriculture mid-early pepper production. The global climate changes start impacting vegetable production. The study showed that dry periods during the 3-year study forced adaptation of pepper growth. These dry agroecological conditions determine the need for adaptive soil watering in conformity with the phenological growth of pepper as well as with the specific agrometeorological conditions.

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Table 4. Agrometeorological parameters (2009)

Таблица 4. Агрометеорологични показатели (2009)

Variants		from sowing	from sprouting					
		to sprouting	to cotyledons	to first true leaf	to flower bud	to flowering	to ripening	to botanical maturity
Control	∑ t [(1)]	167.05	145	209.5	303.8	204.2	902.3	681.5
	Aver. t [(2)]	12.9	12.2	15.0	23.4	22.7	23.7	24.3
	Aver.RH [(3)]	68	71	64	51	56	60	58
	∑ Rainfall[(4)]	*	*	*	3.9	3.20	99.2	22.4
	mm /day[(5)]	*	*	*	0.30	0.36	2.76	0.80
Boneprot (opt.)	∑ t [(1)]	152.80	145	209.5	256	184	827	583.9
	Aver. t [(2)]	12.7	12.2	15.0	23.3	23.0	23.6	24.3
	Aver.RH [(3)]	66	71	64	52	53	61	58
	∑ Rainfall[(4)]	*	*	*	3.9	3.2	99.0	22.4
	mm /day[(5)]	*	*	*	0.35	0.40	2.83	0.93
Boneprot (50 %) + Emosan	∑ t [(1)]	137.3	132.9	156	256	139	699.8	550.0
	Aver. t [(2)]	12.5	12.1	14.2	23.3	23.2	23.3	25.0
	Aver.RH [(3)]	67	71	67	52	51	62	56
	∑ Rainfall[(4)]	*	*	*	3.9	3.2	99.2	22.4
	mm /day[(5)]	*	*	*	0.35	0.53	3.31	1.02
Lumbrical (opt.)	∑ t [(1)]	152.8	132.9	172.8	256	184	711.5	594.2
	Aver. t [(2)]	12.7	12.1	14.4	23.3	23.0	23.7	24.8
	Aver.RH [(3)]	66	71	66	52	53	61	57
	∑ Rainfall[(4)]	*	*	*	3.9	3.2	99.2	22.4
	mm /day[(5)]	*	*	*	0.35	0.40	3.20	0.93
Lumbrical (50 %) + Emosan	∑ t [(1)]	137.3	132.9	156	256	139	699.8	572.6
	Aver. t [(2)]	12.5	12.1	14.2	23.3	23.2	23.3	24.9
	Aver.RH [(3)]	67	71	67	52	51	62	56
	∑ Rainfall[(4)]	*	*	*	3.9	3.2	99.2	22.4
	mm /day[(5)]	*	*	*	0.35	0.53	3.31	0.97

(1) Temperature sum, ∑ t °C; (2) Average temperature, Aver. Temp.°C; (3) Average relative humidity, Aver.RH (%); (4) Rainfall sum, ∑ Rainfall (mm); (5) Rainfall mm/per day, mm /per day.

* Rainfalls has not been reported because seedlings have been grown in a greenhouse

Table 5. Agrometeorological parameters (2010)

Таблица 5. Агрометеорологични показатели (2010)

Variants		from sowing	from sprouting					
		to sprouting	to cotyledons	to first true leaf	to flower bud	to flowering	to ripening	to botanical maturity
Control	∑ t (1)	144.0	93.8	178.9	347.1	203.1	867.6	636.6
	Aver. t (2)	11.1	11.7	13.8	20.4	25.4	23.4	25.5
	Aver.RH (3)	72	76	74	73	66	64	66
	∑ Rainfall(4)	*	*	*	47.2	6.2	29.0	123.8
	mm /day(5)	*	*	*	2.78	0.78	0.78	4.95
Boneprot (opt.)	∑ t (1)	130.5	93.4	175.4	258.6	188.6	840.4	632.3
	Aver. t (2)	10.9	11.6	13.5	19.9	23.6	23.3	25.3
	Aver.RH (3)	72	70	77	74	65	64	67
	∑ Rainfall(4)	*	*	*	47.2	0	29.7	126.5
	mm /day(5)	*	*	*	3.63	0	0.83	5.06
Boneprot (50 %) + Emosan	∑ t (1)	118.0	93.6	144.8	219.5	171.6	808.9	607.8
	Aver. t (2)	10.7	11.7	13.2	20.0	21.5	23.1	25.4
	Aver.RH (3)	73	69	79	75	69	65	67
	∑ Rainfall(4)	*	*	*	12.2	36.6	29.0	116.5
	mm /day(5)	*	*	*	1.11	4.58	0.83	4.85
Lumbrical (opt.)	∑ t (1)	130.5	93.4	175.4	219.3	188.6	813.4	632.3
	Aver. t (2)	10.9	11.6	13.5	19.9	23.6	23.2	25.3
	Aver.RH (3)	72	70	77	75	65	65	67
	∑ Rainfall(4)	*	*	*	12.3	0	29.0	126.5
	mm /day(5)	*	*	*	1.12	0	0.83	5.06
Lumbrical (50 %) + Emosan	∑ t (1)	118.0	93.6	144.8	219.5	171.6	808.9	607.8
	Aver. t (2)	10.7	11.7	13.2	20.0	21.5	23.1	25.4
	Aver.RH (3)	73	69	79	75	69	65	67
	∑ Rainfall(4)	*	*	*	12.2	36.6	29.0	116.5
	mm /day(5)	*	*	*	1.11	4.58	0.83	4.85

(1) Temperature sum, ∑ t °C; (2) Average temperature, Aver. Temp.°C; (3) Average relative humidity, Aver.RH (%); (4) Rainfall sum, ∑ Rainfall (mm); (5) Rainfall mm/per day, mm /per day.

* Rainfalls has not been reported because seedlings have been grown in a greenhouse

Table 6. Agrometeorological parameters (2011)

Таблица 6. Агрометеорологични показатели (2011)

Variants		from sowing	from sprouting					
		to sprouting	to cotyledons	to first true leaf	to flower bud	to flowering	to ripening	to botanical maturity
Control	∑ t (1)	156.0	151.8	136.5	405.9	197.0	880.5	2578
	Aver. t (2)	11.1	12.7	10.5	23.9	21.9	24.5	23.4
	Aver.RH (3)	68	56	68	68	64	56	66
	∑ Rainfall(4)	*	*	*	7.5	7.9	38.6	49.8
	mm /day(5)	*	*	*	0.44	0.88	1.07	4.5
Boneprot (opt.)	∑ t (1)	134.9	140	123.5	358.4	174.4	845.7	256.5
	Aver. t (2)	11.2	12.7	10.3	23.9	21.8	24.2	23.3
	Aver.RH (3)	68	59	63	70	65	56	69
	∑ Rainfall(4)	*	*	*	6.9	7.9	37.9	65.0
	mm /day(5)	*	*	*	0.46	0.99	1.08	5.9
Boneprot (50 %) + Emosan	∑ t (1)	124.1	140	119.2	269.1	158.5	819	271.4
	Aver. t (2)	11.3	12.7	10.8	24.5	22.6	23.4	24.7
	Aver.RH (3)	68	59	62	71	65	57	64
	∑ Rainfall(4)	*	*	*	6.9	5.9	17.2	22.2
	mm /day(5)	*	*	*	0.63	0.84	0.49	2.02
Lumbrical (opt.)	∑ t (1)	134.9	140	123.5	313.1	154.1	839	237.5
	Aver. t (2)	11.2	12.7	10.3	24.1	22.0	24.0	23.8
	Aver.RH (3)	68	59	63	70	64	57	69
	∑ Rainfall(4)	*	*	*	6.9	5.3	40.5	18.7
	mm /day(5)	*	*	*	0.53	0.76	1.16	1.87
Lumbrical (50 %) + Emosan	∑ t (1)	124.1	140	119.2	269.1	158.5	729.7	272.8
	Aver. t (2)	11.3	12.7	10.8	24.5	22.6	23.5	24.8
	Aver.RH (3)	68	59	62	71	65	56	63
	∑ Rainfall(4)	*	*	*	6.9	5.9	16.5	11.7
	mm /day(5)	*	*	*	0.63	0.84	0.53	1.06

(1) Temperature sum, ∑ t °C; (2) Average temperature, Aver. Temp.°C; (3) Average relative humidity, Aver.RH (%); (4) Rainfall sum, ∑ Rainfall (mm); (5) Rainfall mm/per day, mm /per day.

* Rainfalls has not been reported because seedlings have been grown in a greenhouse

Table 7. Major agrometeorological parameters in Plovdiv, Bulgaria (2009 - 2011)

Таблица 7. Главни агрометеорологични показатели в Пловдив, България (2009-2011)

Years	Months	Average Monthly					
		Air Temperature (°C)	Humidity (%)	Sum of rainfall (mm)	Min t (°C)	Max t (°C)	HTC
2009	March	7.3	68.1	53.5	2.5	12.3	0.80
	April	12.1	69	21.5	5.2	18.8	1.23
	May	18.7	64	26.9	11.6	25.2	1.22
	June	22.4	59	32.8	14.5	29.5	1.00
	July	24.6	57	73.5	18.1	31.6	0.68
	August	23.9	60	22.4	16.8	30.7	0.44
	September	18.9	68	34.6	13.2	25.4	0.64
	October	13.4	78	85.6	8.9	19.0	1.10
2010	March	6.9	72	72.4	1.4	12.2	0.66
	April	12.7	72	37.9	6.5	18.4	0.99
	May	18.1	68	18.7	10.7	25.0	0.33
	June	21.4	69	59.1	15.6	27.6	0.92
	July	24.2	65	120.0	17.5	31.1	1.60
	August	25.8	62	23.8	18.9	32.9	0.30
	September	19.1	65	12.7	12.1	26.3	0.22
	October	10.8	85	119.1	6.8	15.5	3.56
2011	March	6.9	74	74.4	1.5	12.6	0.40
	April	11.8	64	18.8	6.1	17.4	0.53
	May	17.1	72	40.8	10.7	23.2	0.77
	June	22.4	61	14.6	15.5	28.3	0.22
	July	25.4	57	41.5	17.6	32.4	0.53
	August	23.7	64	68.4	16.7	31.0	0.93
	September	21.2	63	3.4	13.5	29.5	0.05
	October	11.6	72	70.4	6.2	18.1	1.96