Association between cultivar performance for economic and morphologic traits and agrometeorological factors in Bulgarian pepper (*Capsicum annuum* L.)

Correlaciones entre factores agrometeorológicos y caracteres de valor económico y morfológico en cultivares Búlgaros de pimentón (*Capsicum annuum* L.)

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Received: 05/19/2009
First review received: 11/22/2009
First reviewing ending: 07/08/2009
Accepted: 12/05/2009

ABSTRACT

Comparative cultivar trials were carried out for a long period (1984-2000) at the experimental field at "Maritsa" Vegetable Crops Research Institute, Plovdiv. Seven Bulgarian pepper (*Capsicum annuum* L.) cultivars with different fruit shape: 'Sivriya 600', 'Hebar', 'Stryama', 'Kurtovska kapiya 1619', 'Sofiyska kapiya', 'Kalinkov 800/7' and 'Maritsa' were studied on phenological development. A solid data base for morphological and economical important characters, valuable meteorological factors along the interphase periods of cultivar development was constructed. The aim of the research was to establish relationship between important agrometeorological factors and morphological and economical value characters. Twenty four high correlations ($r > \pm 0.70$) were determined for the investigated period and most of them (80%) was negative. In most of the established high dependencies (75% of the cases) the pericarp thickness and fruit weight were in close relation with agrometeorological factors. Negative correlation between the pericarp thickness and rainfalls during the whole harvesting period was found in 'Sofiyska kapiya', 'Maritsa' and 'Kalinkov 800/7'. Positive correlation ($r > 0.70$) was determined between the fruit weight and the active temperatures (air temperature which is above 10 ºC) from transplanting to first harvesting in 'Hebar', 'Sivriya 600' and 'Sofiyska kapiya'.

Key words: *Capsicum annuum*, climate, environment, fruit weight, correlation coefficients.

RESUMEN

Se realizaron ensayos comparativos de cultivares durante un largo período (1984-2000) en el campo experimental del Maritsa" Vegetable Crops Research Institute, Plovdiv Instituto de Investigación de Cultivos Vegetales "Maritsa", Plovdiv. Se estudiaron siete cultivares Búlgaros de pimentón con diferentes formas del fruto: 'Sivriya 600', 'Hebar', 'Stryama', 'Kurtovska kapiya 1619', 'Sofiyska kapiya' 'Kalinkov 800/7' y 'Maritsa' en relación al desarrollo fenológico. Se construyó una base de datos sólida para caracteres morfológicos y de importancia económica y factores meteorológicos importantes a lo largo de los períodos de interfases del desarrollo de los cultivares. El objetivo de la investigación fue establecer las relaciones entre factores agrometeorológicos importantes y caracteres morfológicos y económicos. Se determinaron en total 24 correlaciones altas ($r > \pm 0{,}70$) para el período investigado y la parte predominante de ellos (80%) fue negativa. En la mayoría de las altas dependencias establecidas (75% de los casos), el grosor del pericarpio y peso de frutos estuvieron en estrecha relación con los factores agrometeorológicos. Se encontró una correlación negativa entre el grosor de pericarpio y la cantidad de lluvia durante todo el periodo de cosecha en 'Sofiyska kapiya', 'Maritsa' y 'Kalinkov 800/7'. Se determinó una correlación positiva ($r > 0{,}70$) entre el peso de frutos y las temperaturas activas (temperatura del aire la cual está por encima de 10 ºC) desde el transplante a la primera cosecha en 'Hebar', 'Sivriya 600' y 'Sofiyska kapiya'.

Palabras clave: *Capsicum annuum*, pimentón, clima, ambiente, peso del fruto, coeficientes de correlación.

INTRODUCTION

Climate change propelled by over exploitation of natural resources and greater industrialization, besides other, does affect crop phenology as well. Plants, like other biological systems, do respond to the changes occurring in their micro and macro climatic regimes. In order to arrive at the optimum environmental parameters for enhanced crop productivity, the differential response of crop cultivars to fluctuating climate is imperative and an important researchable issue. In pepper a number of studies have been conducted that have revealed significant effect of climatic factors on crop growth (Carrilo *et al*., 1991; Stofella *et al*., 1995; Lohithasiva *et al*., 1999; Torodova *et al*., 2004).

However, the present level of knowledge, especially in Bulgaria, about the differential response of the cultivars to agrometeorological factors is limited. More detail information in this direction is developed in red pepper for grinding (Todorova, 2000; Cholakov *et al*., 2001, 2002). This situation has an important bearing on the cultivar adoption by the farmers as the information database regarding location specificity of cultivars. Correlations between yield, quality, resistance, plant and fruit morphology characters are investigated (Nacheva, 2003; Antonova, 2007) but the relationship of morphological and economically important characters towards the agrometeorological factors is limited at present. The objective was to assess the relationship of yield and other quantitative traits with agrometeorological factors affecting crop growth in pepper.

MATERIALS AND METHODS

The investigations were conducted during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria. The experiment was laid on completely randomized block design with four replications and fifty plants each in every replication. Data for seven pepper cultivars with different fruit shape – 'Sivriya 600', 'Hebar', 'Stryama', 'Maritsa', 'Kalinkov 800/7', 'Kurtovska kapiya 1619' and 'Sofiyska kapiya' were collected and analyzed. The following characters were investigated: standard yield (kg/da) and non standard yield (kg/da); morphological traits: plant height (cm), stem height (cm), fruit length (cm), diameter at the base (cm), number of locules and fruit weight (g). The pericarp thickness (mm) and usable fruit part (%) were also evaluated.

Ten agrometeorological factors (independent variables) were determined:

The sum of active temperatures (air temperature which is above 10 ºC) for the periods:

1. Transplanting to first harvesting
1. The whole harvesting period
2. Transplanting to the last harvesting

The sum of rainfalls from the periods:

3. Transplanting to first harvesting
4. The whole harvesting period
5. Transplanting to the last harvesting

The average twenty four-hour temperatures of the air for the periods:

6. Transplanting to first harvest
7. The whole harvesting period
8. Transplanting to the last harvesting
9. Set to the biometric analysis

The values of each independent variable were determined for every cultivar during the particular years of the studied. Methods used in design and analysis of the phenological data are given in our previous investigation (Cholakov and Todorov, 2007). The database consisted of morphological, economic and agrometeorological information for the cultivars under study. Correlation analysis was used for searching statistical dependencies between investigated characters (Lidanski, 1988).

RESULTS AND DISCUSSION

Data from the analysis of the morphological and economically important characters of the cultivars and their relationships with the agrometeorological factors during the investigation period are performed in Tables 1-7. Slight or non-essential dependencies, with correlation coefficient $r < \pm 0.30$ were not included. The total number of the cases with $r \geq \pm 0.30$ between the morphological and economic characters and environmental factors was 256. Proven correlations were determined in all of the investigated cultivars, 108 in $r > r_{0.05}$ and 54 in $r > r_{0.01}$. Most of them were negative. The greatest number of the significant relationships (in $r > r_{0.05}$) was established in 'Sofiyska kapiya' (28) followed by 'Kalinkov 800/7' (22) (Tables 4 and 6). In 'Stryama' and 'Kurtovska kapiya 1619' there was no strong relation between studied agrometeorological factors and morphological and economic characters (Tables 2 and 3). The largest number of cases with strongly expressed correlation ($r > \pm 0.70$) was established in cultivars 'Sofiyska kapiya' and 'Sivriya 600' with 10 and 6 dependencies, respectively (Table 4 and 7).

In most of the established strong dependencies (75 %) the pericarp thickness and fruit weight are in close relation with agrometeorologic factors. Strong positive correlation ($r > 0.70$) is found out between the fruit weight and the sum of active temperatures from transplanting to first harvesting in 'Hebar', 'Sofiyska kapiya' and 'Sivriya 600' (Tables 1, 4 and 7). Significant negative relationship between the fruit weight and the sum of active temperatures for whole

harvesting period is established in these cultivars as in 'Sofiyska kapiya' this correlation is very strong (r = - 0.85). There is also very strong negative relation between the standard yield and rainfalls amount from transplanting to the last harvesting in 'Sofiyska kapiya' (r = - 0.92). Buszowska and Bednarek (2005) established no relation between the sum of effective air temperatures in the selected months and the whole period of sweet pepper cultivation and the magnitude of the total yield and the marketable yield. However, an important and positive correlation between the sum of effective air temperatures of the June-September period and the early marketable yield is proved.

Positive and strong correlation (r > 0.70) is ascertained between the pericarp thickness and sum of active temperatures from transplanting to first harvesting in 'Sofiyska kapiya' and 'Sivriya 600' (Tables 4 and 7). Negative strong correlation (r from - 0.80 to -0.93) between the pericarp thickness and sum of active temperatures for the whole harvesting period is determined in these two cultivars.

Table 1. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Hebar' with conic shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield				-0.33						
Nonstandard yield	-0.34	0.30		-0.44			0.41	0.43	0.40	
Fruit weight	0.71	-0.61	-0.41		-0.42		0.54	-0.55		
Pericarp thickness					-0.63	-0.55				
Usable fruit part										
Plant height			0.34							
Stem height				-0.53	-0.71	-0.68				
Fruit length										
Fruit diameter		-0.30	-0.36						-0.33	
Locules	-0.64	-0.66	-0.61	0.32			0.43	-0.81		0.45

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

Table 2. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Stryama' with conic shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield			-0.34	0.38		0.30		-0.41	-0.36	
Nonstandard yield										
Fruit weight		-0.30	0.58					-0.31	0.36	0.43
Pericarp thickness		-0.34	-0.37	-0.39		-0.44	0.37	-0.41	0.40	
Usable fruit part										
Plant height	-0.34	0.60						0.33		
Stem height										
Fruit length										
Fruit diameter								0.30		-0.40
Locules		-0.41	-0.41	-0.45			-0.38		-0.34	0.42

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

Proved significant ($r > r_{0.01}$) negative correlation between the pericarp thickness and rainfalls amount for the whole harvesting period in four cultivars is established and it is strong in 'Sofiyska kapiya', 'Maritsa' and 'Kalinkov 800/7' (Tables 4, 5 and 6). In 'Sofiyska kapiya' and 'Kalinkov 800/7' the sum of rainfalls from the transplanting date to the last harvesting exerts an influence on the pericarp thickness with r = - 0.76 and r = - 0.89, respectively.

Strong negative relationships are also found out between: the stem length and the rainfalls sum during the harvesting (r = - 0.71) and number of locules/fruit and average twenty-four-hour temperature for the harvesting period (r = - 0.81) in 'Hebar' (Table 1); fruit length and average twenty-four-hour temperature from transplanting to the date of biometric analysis (r = - 0.82) in 'Sofiyska kapiya' (Table 4); between plant height and average twenty-four-hour temperature from transplanting to the first harvesting (r = - 0.72) in 'Maritsa' (Table 5).

Table 3. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Kurtovska kapiya 1619' with kapiya shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield			-0.31		0.54	0.42		-0.32		
Nonstandard yield	-0.32							0.33		0.38
Fruit weight	0.47	-0.36		0.44	0.47	0.51		-0.51	-0.49	
Pericarp thickness	0.53	-0.61	-0.35				0.32			0.48
Usable fruit part										
Plant height		0.39								
Stem height						-0.49				
Fruit length					0.56	0.52		-0.35	-0.57	
Fruit diameter	0.61	-0.42					-0.54		-0.42	
Locules	0.39	-0.42	-0.44	0.30	-0.60			-0.35		

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

Table 4. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Sofiyska kapiya' with kapiya shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield	0.52	-0.62				-0.92				
Nonstandard yield			-0.63	0.68	-0.67		-0.73			
Fruit weight	0.71	-0.85	0.30		-0.68	0.68	0.45	-0.46		-0.75
Pericarp thickness	0.76	-0.93			-0.78	-0.76	0.30		-0.34	-0.53
Usable fruit part			0.37					0.42		0.40
Plant height	0.47		0.36							
Stem height			-0.34							
Fruit length							0.49		-0.31	-0.82
Fruit diameter		-0.43	-0.68			-0.54	-0.66	-0.58	-0.57	
Locules			0.48				-0.69	0.47	0.56	0.50

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

Table 5. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Maritsa' with dolma shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield			-0.53						0.39	0.46
Nonstandard yield	-0.35			-0.59		-0.48	-0.31	0.55	0.35	0.46
Fruit weight	0.33	-0.42	-0.34						-0.36	
Pericarp thickness	0.44	-0.44			-0.78	-0.55				-0.41
Usable fruit part	-0.33	0.38			0.61					0.57
Plant height	0.33	0.43	0.40				-0.72			
Stem height	-0.62	0.62		-0.57			-0.49	0.38		
Fruit length										
Fruit diameter										
Locules			0.32					-0.37		0.38

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

Table 6. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Kalinkov 800/7' with dolma shape of the fruit during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield	0.57	-0.51		0.59				-0.54	-0.61	
Nonstandard yield				-0.66	-0.68	-0.69			0.59	
Fruit weight				-0.45	-0.61	-0.58				-0.31
Pericarp thickness			-0.35	-0.85	-0.81	-0.89				
Usable fruit part	-0.57	0.43	-0.42	-0.51			0.31	0.53	0.66	0.38
Plant height			-0.50						-0.59	
Stem height							-0.52			
Fruit length								-0.31		-0.56
Fruit diameter				-0.35	-0.43	-0.43				
Locules	0.40	-0.40					-0.42		-0.37	0.30

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

CONCLUSIONS

For the investigated period totally twenty four strong correlations ($r > \pm 0.70$) are determined and the predominant part of them (80 % approximtely) is negative. In most of the established strong dependencies (75 % of the cases) the pericarp thickness and fruit weight are in close relation with agrometeorologic factors. Strong negative correlation ($r > -0.70$) between the pericarp thickness and sum of the rainfalls for the whole harvesting period is established in 'Sofiyska kapiya', 'Maritsa' and 'Kalinkov 800/7'. Strong positive correlation ($r > 0.70$) is determined between the fruit weight and the sum of the active temperatures from transplanting to first harvesting in 'Hebar', 'Sivriya 600' and 'Sofiyska kapiya'.

Table 7. Correlation coefficient (r) in Bulgarian pepper (*Capsicum annuum* L.) cv. 'Sivriya 600' during 1984-2000 at the "Maritsa" Vegetable Crops Research Institute, Plovdiv, Bulgaria.

	Act Tem TFH	Act Tem WHP	Act Tem TLH	Rainfall TFH	Rainfall WHP	Rainfall TLH	24h Tem TFH	24h Tem WHP	24h Tem TLH	24h Tem SMA
Standard yield		-0.36		0.40			0.35	-0.32	-0.40	0.40
Nonstandard yield										
Fruit weight	0.72	-0.65	-0.46	-0.36	-0.77	-0.75	0.32			
Pericarp thickness	0.71	-0.80	-0.79		-0.45		0.68	-0.63		0.31
Usable fruit part			-0.33		0.46	0.47		-0.49	-0.40	
Plant height		0.49	0.49				-0.61	0.49		
Stem height					-0.42	-0.41				
Fruit length	0.35				-0.42	-0.49			-0.36	-0.39
Fruit diameter	0.51	-0.55	-0.53		-0.41		0.33			0.37
Locules	0.35				-0.42	-0.39				

$r_{0.05} = 0.482$; $r_{0.01} = 0.606$. Cells without r values for $r < \pm 0.30$

Act Tem: Sum of the active temperatures (air temperature which is above 10 ºC); Rainfall: sum of rainfalls; 24h Tem: Average 24-hour temperatures of the air; TFH: Period from transplanting to first harvesting; WHP: Period for the whole harvesting period (I); TLH: Period from transplanting to the last harvesting; SMA: Period from set to the biometric analysis

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