РАСТЕНИЯ ОТ ВИГНА (*VIGNA UNGUICULATA* L.) В УСЛОВИЯ НА ПОЧВЕНО ЗАСУШАВАНЕ
CHANGES IN THE LEAF GAS EXCHANGE, LEAF WATER POTENTIAL AND SEED YIELD OF COWPEA PLANTS (*VIGNA UNGUICULATA* L.) UNDER SOIL DROUGHT CONDITIONS

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Резюме

Вигната (*Vigna unguiculata* L.) е една от обещаващите бобови култури. Местните видове от тази култура традиционно се отглеждат в южните части на България. Тя има висока толерантност към засушаване. Поради това е перспективна култура за отглеждане при неполивни условия.

Целта на това проучване е да се анализира ефектът на естествено почвено засушаване върху листния газообмен, водния потенциал и добив от семена на растения от вигна (*V. unguiculata* L.). Четирите генотипа са оценени при условия на естествено засушаване и поливни условия.

Abstract

Cowpea (*Vigna unguiculata L.*) is one of the promising legume crops, landraces of which have been traditionally grown in the southern parts of Bulgaria. It is highly tolerant to dry conditions. Therefore it is a promising crop for growing under non-irrigation conditions.

The objective of this study was to analyze the effect of natural drought on the leaf gas exchange, leaf water potential and seed yield of cowpea plants (*V. unguiculata L.*). The four genotypes were evaluated in a natural drought-stressed and non-stressed environment.

Ключови думи: вигна (*V. unguiculata* L.), почвено засушаване, листен газообмен, воден потенциал, добив от семена.
Key words: cowpea (*V. unguiculata* L.), soil drought, leaf gas exchange, leaf water potential, seed yield.

INTRODUCTION

Cowpea (*V. unguiculata* L.) is a leguminous plant which according to its area of distribution occupies the second place after beans. In most countries it is grown for seeds but the leaves and the green beans, as well as the whole plants can also be used for fodder (Laghetti et al., 1990). In Bulgaria it is mostly grown in the southern parts of the country where it is known under various names: papuda, cowpea, bebridga, roglyo, etc.

At the Institute of Vegetable Genetic Resources (IVGR) a collection of 300 Cowpea samples of various geographic origins is maintained and assessed. The results show great genetic diversity of the tested samples both as regards to the vegetable habitus and to the morphology of the seed material (Stoilova, 1998; Stoilova, 2000; Stoilova et al., 2003). Biochemical studies show high nutrition value, determined by the high protein content in the seeds as well as content of irreplaceable amino acids. The quantity of raw protein reported in the studied samples of the Cowpea collection is within the range of 19.6%-26.81% (Sabeva and Stoilova, 2008). The content of lysine in the seeds is about 6.6-8.1g and methionine is 1.5-2.3g (Nielsen et al., 1997; Olabosi, 2007).

In search of new alternative solutions taking into consideration the climatic changes (drought, warming, change in the duration of the seasons), modification of the crop structure and their grain content, depending on their reaction to abiotic stress factors becomes necessary. There are many literature data confirming the Cowpea tolerance to drought as well as its high nutrition qualities (Hall et al., 1997; Watanabe et al., 1997; Berova et al., 2001a, Berova et al., 2001b). Due to that reason it is a perspective crop for growing under no irrigation conditions.

Since the information in this aspect is scarce, the objective of the conducted survey was using the parameters of the leaf gas exchange and the yield elements to study the reaction of several Cowpea samples to natural soil drought.

MATERIALS AND METHODS

Four samples of Cowpea (*V.unguiculata* L.) were tested – two of local origin, one of which was assumed to be a standard (Catalogue number A4E007-St-1) and A8E-0542 and two samples of foreign origin, catalogue numbers 87-52 and 95-045 respectively (IITA International Institute of Tropical Agriculture, Nigeria). The seeds from the selected samples were provided from the collection of the Institute of Genetic Resources in Sadovo. The morphological specification and phonological observations were made in accordance with the international Cowpea Descriptor (Cowpea Descriptor, 1983).

The experiment was carried out in the period 2009-2010. The experiment was set under the block method in three repetitions and 14 m^2 size of the experimental plot. The plants were divided into two groups: with optimal irrigation regime and subject to natural drought. The parameters of the leaf gas exchange were determined using the portable photosynthetic system LCpro+ (ADC, England), between 10 and 12 h, with light intensity 1500-1800 $\mu mol\ m^{-2}\ s^{-1}$. The water potential of the leaves was reported using pressure chamber EL 540-305 (ELE-International Ltd, Hemel Hempstead, England) – Turner, 1988. The last completely developed leaves were used for the analyses.

Parallel to that the changes of the meteorological elements during Cowpea vegetation were traced. The air temperature and the quantity of rainfalls were taken as main climatic factors, on the basis of which the main agrometeorological indices were determined. The Hydrothermal coefficient (Selyaninov's HTC, Kuzmova, 2003) was used for specification of the drought, which is a complex index for characterization of the temperature and humidity conditions. The average annual values of the studied parameters adopted for climatic standard (Climatic reference of Bulgaria, volumes 2, 3 and 6) were taken as a basis in the comparative analysis.

The plant productivity was reported at the end of vegetation, on the basis of the beans and seeds formed therein. The latter were measured and weighed and the productivity was calculated for the experimental plot and the obtained quantity was re-calculated for productivity per da respectively.

The results were statistically processed. The authenticity of the differences was determined according to the *t* criterion of *Student*.

RESULTS

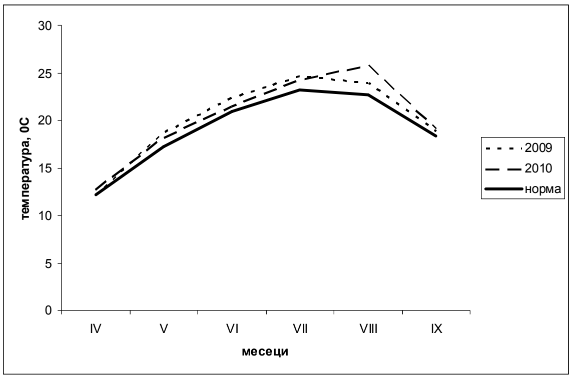
The main agrometeorological indices for the development of Cowpea during the experimental period are represented on Fig. 1-6.

In general, both experimental years turned to be drier and warmer than normal, which corresponds to the global tendencies. The whole period from April to September both in 2009 and 2010 was characterized by temperatures above the normal and monthly sums of the rainfalls below the normal. An exception for both years was July which was characterized by rainfalls above the normal and in 2010 they exceeded the norm by 2.5 times and were of flood type.

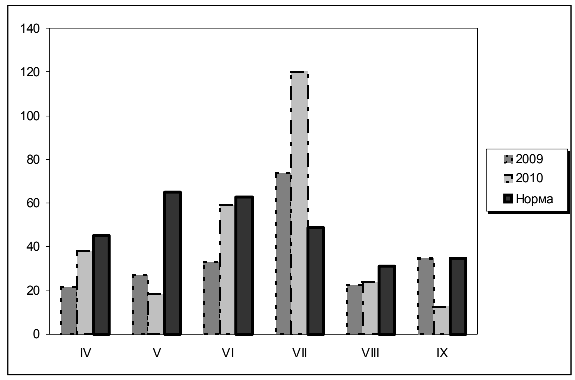
In both experimental years during the vegetation period of the Cowpea considerable increase was observed in both the maximum and the minimum air temperatures but the increase in the minimum temperatures was much bigger than in the maximum. At the same time, there were considerable differences in the agrometeorological conditions for the Cowpea during both experimental years, which were related to the relevant air humidity but which reflected on the conditions of humidification and the number of dry days. 2009 was characterized by considerably low relative air humidity, in contrast to 2010, and the number of dry days for the period April – September was 24, which is 8 times more, compared to 2010 (only 3 dry days).

Moreover, in 2009 20 of these days were extremely unfavorable for the development of Vigna, since the low relative air humidity (below 30%) was combined with high temperatures exceeding 25°C. In the presence of wind, such days are considered to have dry wind, which strengthens the negative effect of the drought. 2009 turned to be an extremely dry year and the whole period from April to September was dry and in May, June and August in the region of Sadovo continued drought was observed. The number of days with maximum temperatures exceeding 30°C was 64, nine of which were characterized by temperatures higher than 35°C. In July 2009 an absolute maximum of the air temperature was recorded – 39.5°C which almost reached the absolute temperature record for the region (39.8°C).

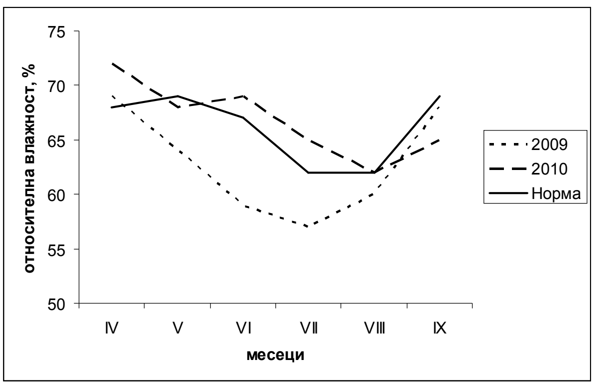
Table 1 presents data reflecting the changes in the leaf gas exchange in the leaves of the plants subjected to soil drought. In the plants of the four samples drought leads to different modifications. They are more considerable in August. The intensity of the net photosynthesis in the plants from Sample 95-045 was reduced by 37%, in A8E-0542 by 24% and in 87-52 – by 22%. P_N in the standard plants, ST-1 was at the control level in June and showed inconsiderable reduction in August (by 5.8%). These modifications can be compared to the changes in the stomatal conductance (g_s) and transpiration intensity (E). The presented data shows that to a large extent photosynthesis inhibition is connected with stomatal



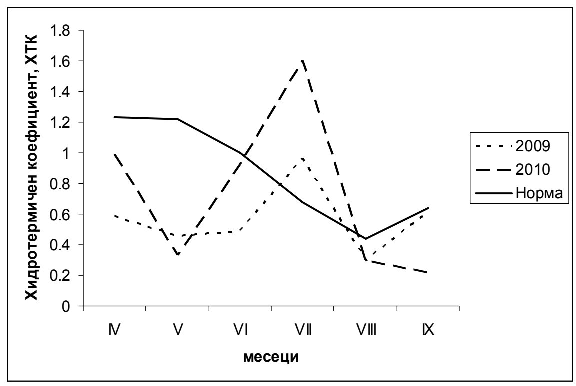
Фиг. 1. *Средна месечна температура на въздуха през вегетационния период на вигната*
Fig. 1. *Average monthly air temperature during the vegetation period of the Cowpea*



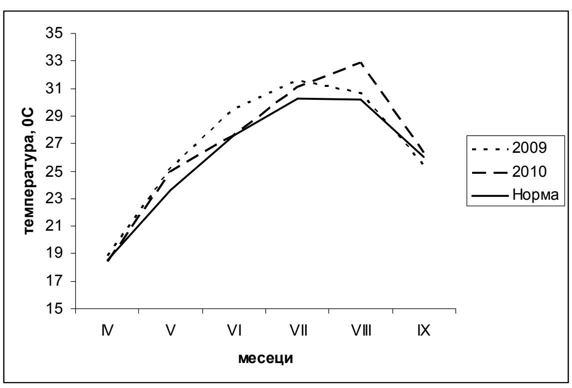
Фиг. 2. *Месечна сума на валежите през вегетационния период на вигната*
Fig. 2. *Monthly amount of rainfalls during the vegetation period of the Cowpea*



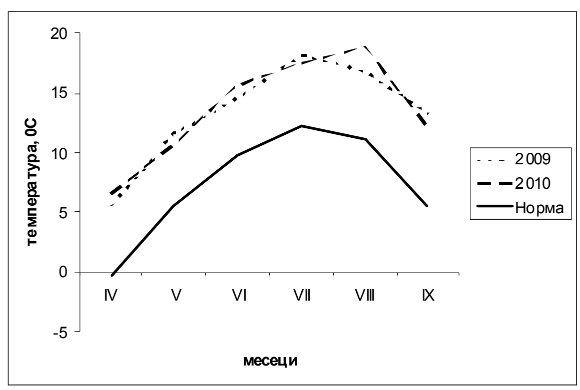
Фиг. 3. *Относителна влажност на въздуха през вегетационния период на вигната*
Fig. 3. *Relative air humidity during the vegetation period of the Cowpea*



Фиг. 4. *Хидротермичен коефициент (ХТК) през вегетационния период на вигната*
Fig. 4. *Hydrothermal coefficient (HTC) during the vegetation period of the Cowpea*



Фиг. 5*. Средни максимални температури на въздуха през вегетационния период на вигната*
Fig. 5. *Average maximum air temperatures during the vegetation period of the Cowpea*



Фиг. 6. *Средни минимални температури на въздуха през вегетационния период на вигната*
Fig. 6. *Average minimum air temperatures during the vegetation period of the Cowpea*

Таблица 1. Влияние на почвеното засушаване върху листния газообмен и водния потенциал на растения от вигна; P_N – скорост на фотосинтезата (µmol CO_2 m^{-2} s^{-1}); E – интензивност на транспирацията (mmol m^{-2} s^{-1}), g_s – устична проводимост (mol m^{-2} s^{-1}), Ψ_{leaf} – воден потенциал на листата (MPa); VI – Юни; VIII – Август

Table 1. Influence of soil drought on the leaf gas exchange and water potential of Vigna plants; P_N – intensity of photosynthesis (µmol CO_2 m^{-2} s^{-1}); E – transpiration intensity (mmol m^{-2} s^{-1}), g_s – stomatal conductance (mol m^{-2} s^{-1}), Ψ_{leaf} – leaf water potential (MPa); VI – June; VIII – August

	Control (irrigation)				Dried up (no irrigation)			
	P_N	g_s	E	Ψ_{leaf}	P_N	g_s	E	Ψ_{leaf}
ST-1								
VI	9.17 ± 0.11	0.20 ± 0.003	3.46 ± 0.03	-4.2 ±0.06	9.11 ± 0.09	0.09 ± 0.002	2.77 ± 0.12	-7.2 ±0.09
VIII	17.01 ± 0.22	0.17 ± 0.001	2.75 ± 0.09	-6.2 ±0.02	16.02 ± 0.24	0.09 ± 0.004	2.24 ± 0.10	-9.0 ±0.10
87-52								
VI	15.07 ± 0.36	0.09 ± 0.001	2.78 ± 0.10	-4.0 ±0.04	15.00 ± 0.16	0.06 ± 0.001	2.49 ± 0.14	-6.7 ±0.11
VIII	17.42 ± 0.24	0.21 ± 0.005	3.01 ± 0.08	-6.1 ±0.05	13.64 ± 0.10	0.07 ± 0.002	2.67 ± 0.009	-9.9 ±0.008
95-045								
VI	12.11 ± 0.21	0.08 ± 0.001	2.05 ± 0.02	-4.2 ±0.01	10.57 ± 0.19	0.02 ± 0.001	2.01 ± 0.12	-5.9 ±0.04
VIII	20.54 ± 0.20	0.12 ± 0.002	2.40 ± 0.09	-7.2 ±0.03	12.93 ±0.08	0.04 ± 0.002	1.85 ± 0.05	-9.9 ±0.05
A8E-0542								
VI	15.25 ± 0.19	0.08 ± 0.001	2.56 ± 0.09	-4.7 ±0.02	12.25 ±0.12	0.04 ± 0.001	2.21 ± 0.07	-5.4 ±0.07
VIII	15.90 ± 0.18	0.09 ± 0.001	3.74 ± 0.11	-6.4 ±0.02	12.08 ±0.14	0.04 ± 0.001	2.54 ± 0.12	-7.7 ±0.06

limitation. Fast loss of water in the leaf tissues causes hydropassive closing of the stomata and limits the access of CO_2 to the mesophyll cells as a result of which the photosynthesis intensity decreases.

The results show that the leaf water potential, which is a main thermodynamic value of water exchange, decreases during vegetation in the four Cowpea samples. Changes in Ψ_{leaf} most probably result from some structural and functional modifications ensuring plant's adaptation to drought (Paleg et al., 1984).

As seen from Table 2, in the tested samples under no irrigation vegetation is shorter by 6-9 days and they enter the last phase – maturing earlier, when compared to the plants grown under irrigation conditions. The samples of local origin have a shorter vegetation period; they begin to flower 18-20 days after germination and ripen for 80-82 days under non-irrigation conditions, while samples of foreign origin ripen for a longer period of time, 88 days respectively.

Table 3 reflects some of the morphological indices reported at the end of vegetation. The obtained results show that the bean sizes, length, width and thickness respectively, indicate almost identical values irrespective of the manner of growing. A change in a positive direction is observed in the number of beans and seeds from one plant in favour of the experiment under irrigation conditions. In the samples 95-045 and A8E-0542 there is considerable difference in the parameter "weight of 100 seeds". In a comparative aspect the lowest yield, compared with the plants grown under irrigation conditions is formed by the dried up plants from sample 95-045 and the highest yield – by the standard ST-1.

CONCLUSIONS

1. The dynamics of the changes in the parameters of the leaf gas exchange of plants from the studied Cowpea samples, subjected to drought, is different. In a comparative aspect the parameters of the plants from sample 95-045 are the lowest and those of sample ST-1 are the highest.

2. Phenological observations show considerable differences between the samples of local and foreign origin. Plants grown under non-irrigation conditions are characterized by shorter (6-9 days) vegetation and they enter the ripening phase earlier compared with those grown under irrigation conditions.

3. Productivity of the samples determined by the elements of the yield – number of beans and seeds in one plant, as well as their weight, reported under irrigation and non-irrigation conditions give us a reason to conclude that under

Таблица 2. Фенологични наблюдения на образци от вигна, отглеждани при поливни условия и при естествено засушаване; DFL – дни до цъфтежа; DurFL – продължителност на цъфтежа; DM – дни до зрелостта
Table 2. Phenological observations of Cowpea samples grown under irrigation conditions and natural drought. DFL – days to flowering; DurFL – duration of flowering; DM – days to maturity

	Control (irrigation)			Dried up (no irrigation)		
	DFL	Dur.FL	DM	DFL	Dur.FL	DM
ST-1	54±3	24±2	88±4	50±4	18±1	80±4
87-52	58±3	29±2	94±4	54±5	21±1	88±3
95-045	57±2	26±3	94±4	55±3	22±2	88±3
A8E-0542	51±3	24±3	90±4	49±3	20±4	82±3

Таблица 3. Морфологични наблюдения и добив (kg da^{-1}) на образци от вигна, отглеждани при поливни условия и при естествено засушаване
Table 3. Morphological observations and yield (kg da^{-1}) of Cowpea samples grown under irrigation conditions and natural drought

	H*	Ns/pod/pl	Pod/width	Pod/length	Thicknes s/pod	Ns/seed/pl	W100 Seeds	Yield
ST-1								
Control Irrigation	60±3.4	21±0.8	0.7±0.09	16.2±0.22	0.6±0.02	92.2±1.2	21.9±1.5	327.1±12
No irrigation	39±1.2	13.4±0.4	0.9±0.03	15.2±0.20	0.6±0.03	72.4±2.8	21.6±1.0	92.8±14
87-52								
Control Irrigation	65±23	48.6±2.1	0.6±0.04	13.1±0.19	0.5±0.03	152.4±2.1	14.5±1.6	324.4±21
No irrigation	50±2.6	8±0.2	0.7±0.04	12.8±0.26	0.5±0.01	122.6±3.6	14±1.9	68.0±10
95-045								
Control Irrigation	83±3.0	25.6±2.4	0.9±0.05	15.5±0.21	0.7±0.02	173.8±2.8	26.8±2.8	316.5±24
No irrigation	67±1.9	12±1.0	0.9±0.04	14.5±0.15	0.6±0.05	97.6±2.0	24.5±2.0	46.4±9
A8E-0542								
Control Irrigation	55±3.8	20.2±1.7	0.7±0.01	14.6±0.16	0.6±0.01	138.6±3.8	16.5±1.8	298.0±11
No irrigation	39±3.2	16±0.10	0.8±0.02	14.4±0.12	0.6±0.01	62.4±4.1	13.3±1.1	71.2±8

**H/pl – plant's height (cm); Ns/pod/pl – number of beans on one plant; Pod/width - ширина на боба (cm); Pod/length – bean's length (cm); Thickness/p – bean's thickness (cm); Ns/seed/pl – number of seeds per plant; W100 Seeds – weight of 100 seeds (g)*

irrigation conditions the number of beans and seeds per plant is bigger which contributes to the increase in the yield.

4. In a comparative aspect the lowest yield, compared with the plants grown under irrigation conditions is given by the dried up plants from sample 95-045 and the highest yield – by the plants from ST-1.

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ACKNOWLEDGEMENTS

We thank the Bulgarian National Science Fund, Project № DO 02-88/2008 for the financial support.

Статията е приета на 20.12.2011 г.
Рецензент – доц. д-р Калин Иванов