CONTEMPORARY AGRICULTURE / *SAVREMENA POLJOPRIVREDA* 62(3-4)168-176, 2013.
UDC: 63(497.1)-“540-2” ISSN 0350-1205

UDC: 627.13:631.559

EFFECT OF WATER STRESS ON THE YIELD OF COWPEA (*Vigna unguiculata* L. Walp.) IN TEMPERATE CLIMATIC CONDITIONS

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SUMMARY: Today, cowpea has remained a rather neglected and underutilized crop in Serbian agriculture. Due to its multipurpose nature, cowpea could be reintroduced into the agriculture of Serbia and other southeast European regions. To get more information about that possibility an experiment was carried out in field conditions under both rainfed (non-irrigated) and irrigated (well-watered) conditions in Novi Sad (45°20' N latitude, 19°51'E longitude, 84 m above sea level) in the years of 2011 and 2012. The experiments were arranged in completely randomized design with three replications. Overhead sprinkler irrigation system was used. Two different genotypes of cowpea (G_1 and G_2) were studied. To estimate the sensitivity of cowpea to water stress drought tolerance indices were estimated. The plant seed yield of cowpea was significantly higher in irrigation (10.33 g plant^{-1}) than in rainfed (4.35 g plant^{-1}) conditions. Determined drought tolerance indexes revealed that genotype G_1 was more tolerant to drought stress than genotype G_2. To obtain more information on behavior of these two cowpea genotypes under stress conditions, comprehensive and comparative studies, including new cowpea genotypes should be carried out. Obtained results could be used in breeding programs to make cultivars which will enable this crop to be grown in large area in the region of Serbia.

***Key words**: cowpea, water stress, yield.*

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp.) is an important source of protein and one of the most drought-resistant food legumes that widely grown in the semiarid regions where drought is a major production constraint (Ehlers and Hall, 1997,

Original scientific paper / *Originalni naučni rad*
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Dadson et al., 2005). In Serbia cowpea occupies rather neglected area (Mikić, et al, 2010).

Prevaling climate in the region is continental with four marked season. Drought is a regular phenomenon. It appears almost every year influencing the yield of growing plants. In dry years, yields are reduced by 52-76% in relation to the average yields obtained in the region. It means that in the variable climatic conditions of Serbia, in which summers are semi-arid to semi-humid, high and stable yields of growing plants can reliably be obtained only by supplementing crop water requirement through irrigation. Only optimum conditions permit the plants to use water according to their needs (Bošnjak, 2001).

Drought tolerance is defined as the ability of plants to live, grows, and yields satisfactorily with limited soil water supply or under periodic water deficiencies (Ashley, 1993). In cowpea cultivation, the most sensitive stages to water deficit or water stress are just prior to and during bloom (Davis et al., 1991), seed filling stage (Cordeiro et al., 1998) and vegetative stage, followed by the flowering and fruiting stages (Carvalho et al., 2000). To develop specific cowpea genotypes with special focus on irrigated conditions for different environments and social conditions is necessary (Santos et al., 2000). There is a need for cowpea cultivars that more tolerant to water deficit or more efficient in water use (Anyia and Herzog, 2004).

The aim of research was to obtain initial results on the possibility of cowpea growing in climatic conditions of Serbia region. Results of the effect of water stress on yield of cowpea will be used in breeding programs to develop cultivars resistant to stressful environmental conditions, as well as more efficient in wat

MATERIAL AND METHODS

The experiments were conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in Novi Sad (N 45°20`, E 19°51`) on the calcareous chernozem soil on the loess terrace, during 2011-2012 years. The experiment included irrigated (well-watered) and non-irrigated (rainfed) treatment. The experiments were established in completely randomized design with three replications and adapted to technical specifications of the sprinkling irrigation system. Two different genotypes of cowpea (G_1 and G_2) were grown. The size of the experimental unit was 3 m^2. The row spacing between and within the rows were 0.5 and 0.05 m respectively. Seed sowing was performed by hand on May 20, 2011 and May 9, 2012, respectively. Genotypes G_1 and G_2 were harvested on August 22 and 28, 2011 and on August 20 and 29, 2012 respectively. Irrigation was scheduled on the basis on water balance method and every day calculation of the status of readily available water in the soil layer of 0.5 m. Daily water used on evapotranspiration was calculated using hydrophytothermic index which had been estimated at 0.16 for soybean in the climate of Vojvodina (Bošnjak, 1983). Hydrophytothermic index of 0.16 for soybean was used because the value for cowpea has not been determined yet, as well as cowpea is similar to soybean. To estimate the sensitivity of cowpea genotypes to water stress, drought tolerance indices such as Stress Tolerance (TOL), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI), Stress Index (SI), Stress Tolerance Index (STI), Harmonic Mean (HM), Yield Index (YI) and Yield Stability Index (YSI)) were estimated for each cowpea genotype based on seed yield (g $plant^{-1}$) under stress and non-stress environment.

TOL = Yp – Ys (Rosielle and Hamblin, 1981)
MP = (Yp + Ys) /2 (Rosielle and Hamblin, 1981)
GMP = $(Yp * Ys)^{1/2}$ (Fernandez, 1992)
SSI = [(1 – (Ys / Yp)] (Fischer and Maurer, 1978)
SI = 1 – (Ỹs / Ỹp) (Fischer and Maurer, 1978)
STI = (Yp * Ys) / (Ỹp) 2 (Fernandez, 1992)
HAM = [2 * (Yp * Ys)] / (yp + Ys) (Kristin et al., 1997)
YI = Ys / Ỹs (Lin et al., 1986)
YSI = Ys / Yp (Bouslama and Schapaugh, 1984)

Yp and Ys: Seed yield of each genotype under non-stress and stress conditions, respectively.
Ỹp and Ỹs: Mean seed yield of all genotypes under non-stress and stress conditions, respectively

Data reported for yield of cowpea were assessed by analyses of variance (ANOVA) and Fisher's LSD test was used for any significant differences at the $P< 0.05$ and $P< 0.01$ levels between the means. All the analyses were conducted using software package statistics 8.0 series 608c (StatSoft Inc. USA).

RESULTS AND DISUSSION

Monthly values of water stress during growing season of cowpea were calculated by water balance method (Tab. 1 and 2).

Table 1. Water balance of cowpea – 2011

	May	June	July	August	Growing season
t	20.6	21.0	22.3	22.9	21.7
hfti	0.11	0.17	0.18	0.17	0.16
ETm (mm)	25	107	124	86-109	G_1 342- G_2 365
P (mm)	22	32	61	2	117
Δ	-3	-57	0	0	
r (mm)	60	57	0	0	
ETa (mm)	25	89	61	2	177
m (mm)	0	18	63	84-107	165-188
v (mm)	0	0	0	0	0

Table 2. Water balance of cowpea – 2012

	May	June	July	August	Growing season
t	16.2	23.1	25.3	23.9-24.9	23.5
hfti	0.11	0.17	0.18	0.17	0.16
ETm (mm)	40	118	140	84-123	G_1 382- G_2 421
P (mm)	45	22	31	0	98
Δ	+5	-60	0	0	
r (mm)	60	60	0	0	
ETa (mm)	40	82	31	0	153
m (mm)	0	36	109	84-123	229-268
v (mm)	5	0	0	0	0

t – mean monthly air temperature (^{o}C); hfti – hydrophitothermic coefficient (mm/^{o}C); ETm - the maximum evapotranspiration – irrigated (mm); P – monthly rainfall sum (mm); Δ ± – difference in rainfall (P) and ETm represents deficit or suficit after consuming or filling the reserve of readil available water; ETa - the actual evapotranspiration - rainfed (mm); d – deficit of readily available water (mm); s – suficit (mm).

The period under study (2011-2012) had varying weather conditions. This was especially true of the amount and distribution of precipitation. The growing seasons (May/August) of 2011 and 2012 had the rainfall amounts of 117 mm and 98 mm respectively, which are 155.8 and 174.0 mm less than the long term average (272.8 mm) (Fig. 1, Tab. 1 and 2). Both years were very droughty and unfavorable for plant production. In both years drought stress started in June and lasted to the and of the season. Less favorable year for cowpea production was 2012 with total deficit of readily available water from 229 - 268 mm for G_1 and G_2 respectively (Tab. 2). In 2011 total deficit of readily available water was 165 - 188 mm for G_1 and G_2 respectively (Tab. 1).

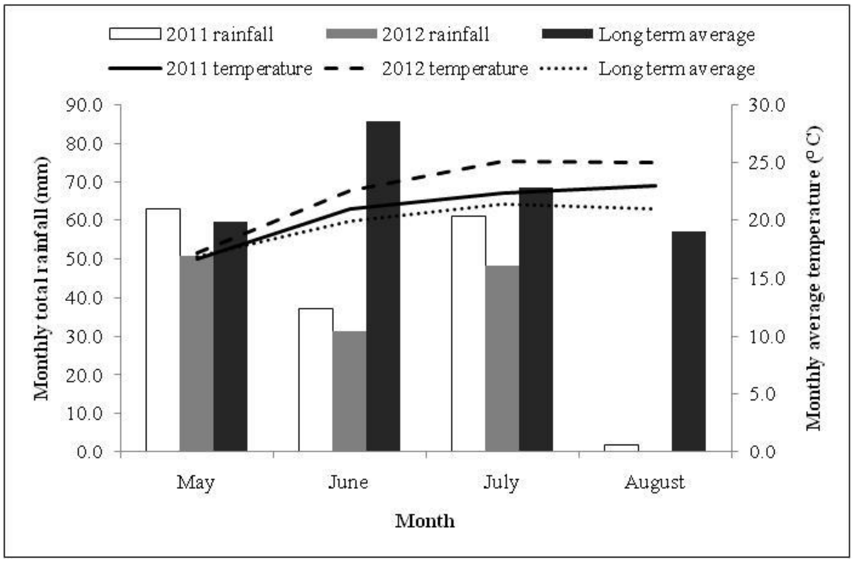

Fig. 1. Monthly average air temperatures (°C), monthly total rainfall (mm) in both years (2011 and 2012) in the cowpea growing season and long term average (1963-2010) (Rimski Šančevi, 1963-2009)

Not just a small amount of rainfall, but also their uneven distribution (Fig. 1) caused the need for irrigation. It was added 90 mm and 180 mm of water by irrigation in 2011 and 2012 respectively (Tab. 1). Given data indicate that climatic patterns in Serbia are changeable and long-term predictions of precipitation are not possible. That confirm supplementary character of irrigation in the region, i.e. rainfall can affect the soil water regime and irrigation schedule of growing plants (Pejić et al., 2012).

Table 3. Irrigation schedules and irrigation water applied

Year	Irrigation water applied (mm)			Irrigation water applied in the season (mm)
	Month			
	June	July	August	
2011	30 mm – 30 June	60 mm – 24 July	-	90
2012	30 mm – 18 June 60 mm – 25 June	60 mm – 11 July	30 mm – 4 August	180

Several studies conducted for a wide range of environments have demonstrated that cowpea yield increases with irrigation (Peksen, 2007, Abayomy and Abidoye, 2009). In the study period, on average, the yield of cowpea was significantly higher in irrigated (10.33 g plant^{-1}) than in rainfed conditions (4.35 g plant^{-1}) (Table 3). The average yield decrease of cowpea due to water stress was in average 5.98 g plant^{-1}, ranging from 9.74 g plant^{-1} in year 2012 which was unfavorable for cowpea production to 5.95 g plant^{-1} in 2011 which had slightly better conditions for cowpea production. Yield of cowpea (g plant^{-1}) obtained in the study both for irrigated and rainfed conditions are consistent with results reported by Peksen (2013) who found the yield of cowpea (Cv. Karagoz-86, Samsun, Turkey) for irrigated and rainfed conditions of 9.73 and 4.64 g plant^{-1} respectively.

Table 3. Yield of cowpea (g plant^{-1}) in irrigated and rainfed conditions

Genotype (C)	Irrigated	Year (A)		Average	
	Rainfed (B)	2011	2012	(BC)	(B)
G_1	I	9.72	15.28	12.5	10.33
	R	3.77	5.54	4.65	4.35
Average (AC)		6.74	10.41		
G_2	I	7.56	8.75	8.16	
	R	3.15	4.93	4.04	
Average (AC)		5.36	6.84	Average (C)	
Average (AB)	I	8.64	12.01	8.58	
	R	3.46	5.23	6.1	
Average (A)		6.05	8.62		
				7.34	

LSD	A	B	C	AB	AC	BC	ABC
0.01	0.5333	0.6237	1.038	1.0703	1.7812	1.7812	3.9691
0.05	0.3805	0.4449	0.7404	0.7065	1.1758	1.1758	2.1623

Water is vital for plant growth, development and productivity. Permanent or temporary water deficit stress limits the growth and the performance of the cultivated plants more than any other environmental factor (Lobato et al., 2008, Shao et al., 2009). Aranus et al. (2003) reported that, among the environmental factors affecting crops, the water input, expressed as the sum of rainfall and irrigation during the growing period, explained the large part of the yield variability.

Cowpea is usually better adapted to drought, high temperatures and other biotic stresses compared with other crop plant species. Because of that it is primarily grown in drier regions of the world where is one of the most drought-resistant food legumes (Dadson et al, 2005). Cowpeas are grown under both irrigated and rainfed conditions. The crop responds positively to irrigation, but will also produce well under dry land conditions. The effect of drought stress on the yield of cowpea depends on genotype, intensity and duration of stress and the growth stage exposed to water stress. In both years the yield of cowpea was significantly influences by water stress (Tab. 3) which clearly indicates that high and stable production of this plant in the region is only possible by supplementing crop water requirement through irrigation.

Determined drought tolerance indexes (Tab. 4) reveled that G_1 genotype was more tolerant to drought stress than that G_2 genotype. To obtain more information on behavior of these two genotypes under different stress conditions, comprehensive studies, should be carried out. Results of the study should be used in breeding programs to develop cultivars that suit to temperate climatic conditions of the Serbia region.

Table 4 Drought tolerance indices over two years in cowpea under irrigated and rainfed conditions

Year	Genotype	Y_{irr}	Y_d	TOL	MP	GMP	SSI	STI	HAM	YI	YSI
2011	G_1	9.72	3.77	5.95	6.74	18.87	0.61	0.49	5.43	1.08	0.39
	G_2	7.56	3.15	4.41	5.36	7.56	0.58	0.32	4.44	0.91	0.42
2012	G_1	15.28	5.54	10.41	9.17	9.2	0.64	0.58	8.13	1.05	0.36
	G_2	8.75	4.93	6.84	6.14	6.57	0.44	0.3	6.31	0.94	0.56
Average	G_1	12.5	4.66	8.18	7.96	14.04	0.62	0.54	6.78	1.06	0.39
	G_2	8.16	4.04	5.62	5.75	7.07	0.51	0.44	5.38	0.92	0.49

CONCLUSION

Very high seed yield loses due to water deficit or drought stress may occur in cowpea cultivation under rainfed conditions. Study results revealed that high and stable production of cowpea in the region is only possible by supplementing crop water requirement through irrigation. Nevertheless, G_1 genotype was more tolerant to drought stress than that G_2 genotype, some more cowpea genotypes should be investigated in order to get cultivars resistant to stressful environmental conditions, as well as more efficient in water use.

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EFEKAT VODNOG STRESA NA PRINOS VIGNE (*Vigna unguiculata* L. Walp.) U UMERENIM KLIMATSKIM USLOVIMA

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Izvod

U poljoprivredi Srbije vigna se gaji na zanemarljivo malim površinama. Zbog višenamenske upotrebe vigna bi mogla da zauzme značajnije površine u poljoprivredi Srbije i području jugoistočne Evrope. Za dobijanje više informacija o mogućnosti gajenja vigne na ovim prostorima obavljena su eksperimentalna istraživanja u poljskim uslovima sa i bez navodnjavanja (Novi Sad, 45°20' N, 19°51'E, 84 m nadmorske visine) u periodu 2011/2012 godine. Ogled je postavljen po randomiziranom rasporedu parcela u tri ponavljanja. Navodnjavanje je obavljeno sistemom za navodnjavanje kišenjem. U ogledu su bila zastupljena dva genotipa (G_1 and G_2). Osetljivost genotipova vigne na vodni stres utvrdjena je obračunom indeksa suše. Prinos vigne je bio signifikantno veći u uslovima navodnjavanja (10,33 g biljci^{-1}) u odnosu na varijantu bez navodnjavanja (4,35 g biljci^{-1}). Utvrdjeni indeksi suše ukazuju veću otpornost na vodni stres genotipa G_1 u odnosu na genotip G_2. Za dobijanje više informacija o osetljivosti ispitivanih genotipova na vodni stres, opsežnija istraživanja, uključujući i druge genotipove su neophodna. Dobijeni rezultati će biti korišćeni u oplemenjivačkim programima za dobijanje sorata koje će omogućiti da ova biljna vrsta zauzme veće površine u Srbiji.

Ključne reči: vigna, vodni stres, prinos.

Received / *Primljen*: 29.08.2013.
Accepted / *Prihvaćen*: 16.10.2013.