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Original scientific paper

RESPONSE OF COWPEA GENOTYPES TO WATER STRESS IN TEMPERATE CLIMATIC CONDITIONS

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Mitigation of global climate change impact on the agricultural production is the major priorities in future research. Cowpea as a drought tolerant plant is interesting for growing in semi-arid climate of the Vojvodina region. The effect of water stress on yield of cultivated plants can be obtained by calculating the yield response factor (K_y) which represents the ratio between the relative evapotranspiration deficit ($1-ET_a/ET_m$) and the relative decline in yield ($1-Y_a/Y_m$). The values of K_y ranged from 0.91 to 1.17 for genotype G_1 and G_2 respectively. Genotype G_1, with a value lower than 1 of Ky, shows a good tolerance to water deficit, on the contrary, genotype G_2, with a greater Ky than 1, expresses some sensitivity to water stress. Obtained results will be used in breeding programs to develop cowpea cultivars tolerant to stressful conditions, primarily to water stress, as well as more productive in water use.

Keywords: cowpea (*Vigna unguiculata* (L.) Walp.), water stress, yield, irrigation

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is ranked third among legumes in world production and was grown on 10.7 million ha in 2004 (DUZDEMIR *et al*., 2009). In Serbia cowpea occupies rather neglected area (MIKIĆ *et al*., 2010). It is one of the most drought-resistant food legumes suitable for growing in the semiarid regions where drought is a major production constraint (EHLERS and HALL, 1997; DADSON *et al*., 2005; PEJIĆ *et al*., 2013). As a drought tolerant plant cowpea is interesting for growing in semiarid climate of the Vojvodina region where drought appears almost every year (BOŠNJAK, 2001). Cowpeas are grown under both irrigated and non-

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irrigated regimens (PEKSEN, 2007). In the region, high and stable yields of growing plants can reliably be obtained only by supplementing crop water requirement through irrigation (PEJIĆ *et al.*, 2011a). One of the prerequisites for successful cultivation of cowpea in the region is the existence of cultivars tolerant to water stress. Therefore it is necessary to focus breeding research towards the creation of genotypes suitable for growing in these conditions (PEJIĆ *et al.*, 2013)

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). 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 (MARTINS *et al.*, 2003). 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; ABDELSHAKOOR and FAISAL, 2010). There is a need for cowpea cultivars that are more tolerant to water deficit or more efficient in water use (ANYIA and HERZOG, 2004; BASTOS *et al.*, 2011).

The response of yield to water supply can be quantified through the yield response factor (K_y) which relates relative yield decrease to relative evapotranspiration deficit (DOORENBOS and KASSAM, 1979). A larger K_y value indicates greater yield losses due to water deficit. The accuracy of K_y depends on having a sufficient range and number of values for yield (Y) and evapotranspiration (ET), and assumes that the relationships between Y and ET are linear over this range. VAUX and PRUITT (1983) suggest that it is highly important to know not only the K_y values from the literature but also those determined for a particular crop species under a specific set of climatic and soil conditions. This is because K_y may be affected by other factors besides soil water deficiency, namely by soil properties, climate (environmental requirements in terms of evapotranspiration, PETCU *et al.*, 2009), growing season length, irrigation methods and programs (UCAN and GENCOCLAN, 2004) and inadequacies of production technology. Water deficit effect on crops yield can be presented in two ways, for individual growth periods or for the total growing season. KOBOSSI and KAVEH (2010) suggested K_y values for the total growing period instead for individual growth stages as the decrease in yield due to water stress during specific periods, such as vegetative and ripening periods, is relatively small compared with the yield formation period, which is relatively large.

The aim of this research was to get initial information of how the plants of cowpea react to water stress as well as on irrigation. Obtained results will be used in breeding programs to develop cultivars tolerant to stressful environmental conditions, as well as more efficient in water use that could be successfully grown in the Vojvodina region, but also for the whole region around this area, that is, Serbia as well as neighboring countries.

MATERIALS AND METHODS

The experiments were conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in Novi Sad (N 45°19`, E 19°50`) 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. Genotype G_1 is lower in growth and has shorter growing season, contrary, genotype G_2 is more robust and has longer growing season. 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. Genotype 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 coefficient of 0.16 for soybean was used because the value for cowpea has not been determined yet, as well as cowpea plants are similar to soybean.

The effect of water stress (K_y), for the growing season, on cowpea yield was determined using the Stewart's model (STEWART *et al*., 1977) as follows:

$$\left(1-\frac{Y_a}{Y_m}\right)=K_y\left(1-\frac{ET_a}{ET_m}\right)$$

Where:

Y_a = the actual harvested yield (non-irrigated, g $plant^{-1}$), Y_m = the maximum harvested yield (under irrigation, non limiting conditions, g $plant^{-1}$), K_y = the yield response factor, ET_a = the actual evapotranspiration (mm) corresponding to Y_a, ET_m = the maximum evapotranspiration (mm) corresponding to Y_m, $(1–ET_a/ET_m)$ = the relative evapotranspiration deficit, and $(1–Y_a/Y_m)$ = the relative yield decrease I = irrigation water applied (mm)

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 $P< 0.05$ levels between the means. The relationship between crop yield and water used by evapotranspiration was evaluated using regression analysis. All the analyses were conducted using software package statistics 8.0 series 608c (StatSoft Inc. USA).

RESULTS AND DISCUSSION

Monthly values of water stress during growing season of cowpea were calculated by water balance method (Table 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
d (mm)	0	18	63	84-107	165-188
s (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
d (mm)	0	36	109	84-123	229-268
s (mm)	5	0	0	0	0

t – mean monthly air temperature (ºC), hfti – hydrophitothermic coefficient, 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 readily 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) (Figure 1). Both years were very droughty and unfavorable for plant production. Less favorable year for cowpea production was 2012 with deficit of readily available water in the growing season from 229 to 268 mm for G_1 and G_2 respectively (Tab. 2). In 2011 deficit of readily available water in growing season ranged from 165 to 188 mm for G_1 and G_2 respectively (Tab. 1).

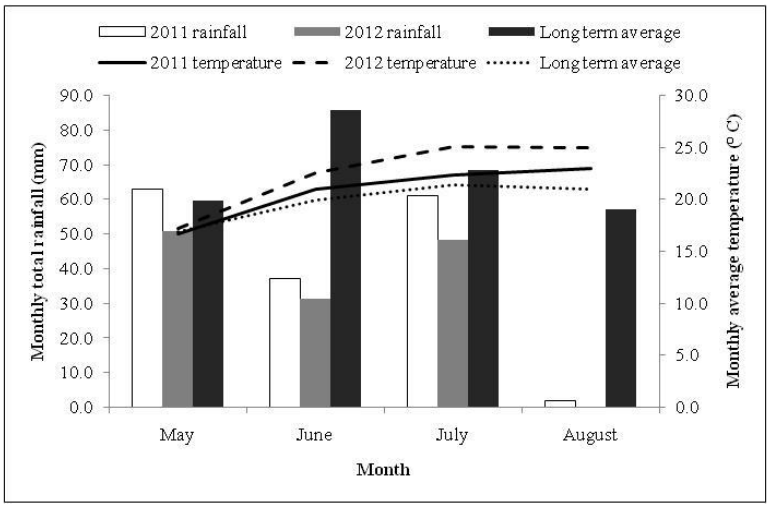

Figure. 1 Monthly average air temperatures (ºC), monthly total rainfall (mm) in the cowpea growing season and long term average (1963-2010, MS Rimski Šančevi)

To maintain the optimum soil moisture it was added 90 mm and 180 mm of water by irrigation in 2011 and 2012 respectively (Table 3). 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*., 2011a,b).

Table 3. Irrigation schedules and irrigation water applied

Year	Irrigation water applied (mm)			Irrigation water applied in the season (mm)
	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

Evapotranspiration rate of cowpea in irrigation conditions (ET_m) ranged from 342 to382 mm and 365-421 mm and in the rainfed conditions (ET_a) in the interval from 177 to 153 mm for G_1 and G_2 respectively (Table 1 and 2). Obtained ET_m values for cowpea are lower than those of 450-480 mm determined for soybean, as similar legume crop (BOŠNJAK, 1996; PEJIĆ *et al*., 2011a). The main reason for that is shorter growing period of cowpea. The relationship between cowpea yield (g plant^{-1}) and seasonal crop water use (ET mm) for studied period was linear (R^2 = 0.607, P < 0.05, Figure 2). PEJIĆ *et al*., (2011a) also reported linear relationship between yield and seasonal evapotranspiration of soybean (R^2 = 0.689, P < 0.05) for the Vojvodina region.

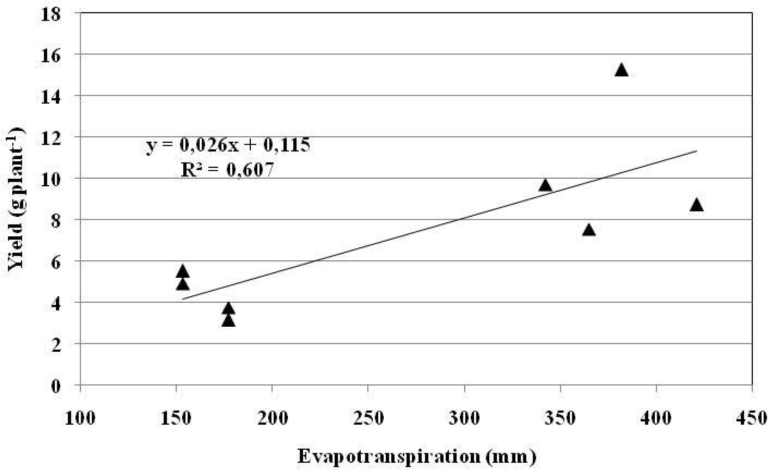

Figure 2 Relationship between crop evapotranspiration and yield of cowpea

Several studies conducted for a wide range of environments have demonstrated that cowpea yield increases with irrigation (PEKSEN, 2007; ABAYOMY and ABIDOYE, 2009; DUZDEMIR *et al*., 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}) (Figure 3). The average yield decrease 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, 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. Our results are in agreement with DUZDEMIR *et al*., (2009) who obtained 9.40 g of seed per plant^{-1} in conditions of complete water application. Obtained results confirm that continuous water supply is necessary 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.

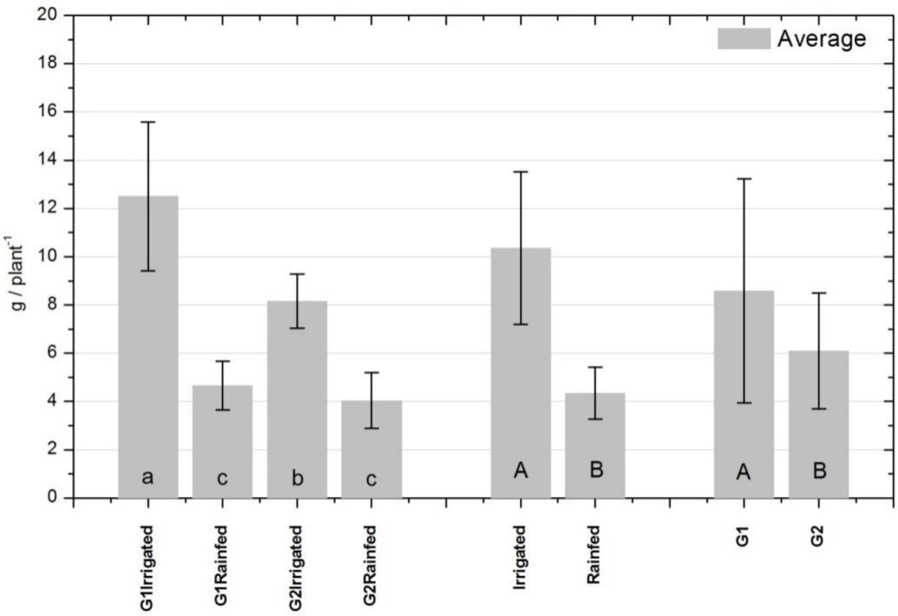

Figure 3 Yield of different cowpea genotypes (g plant^{-1}) in irrigated and rainfed conditions (Column marked with the different letters within treatments differ significantly at P≤0.05; Error bars indicate standard deviation)

The crop yield response factor (K_y) gives an indication of whether the crop is tolerant to water stress. For $K_y \leq$, 1 the plant is tolerant, for $K_y \geq 1$, the plant is sensitive to water stress. The values of K_y ranged from 0.91 to 1.17 for genotype G_1 and G_2 respectively (Table 4 and 5). In fact, genotype G_1, with a value lower than 1 of Ky, shows a good tolerance to water deficit, on the contrary genotype G_2, with a greater Ky than 1, expresses some sensitivity to water stress. Obtained results indicate that some more cowpea genotypes should be tested in order to get cultivars tolerance to water deficit. BASTOS *et al.* (2011) stressed that the selection of drought tolerance genotypes of cowpea is very important especially in arid regions or sites with irregular rain distribution. Determined values of K_y of cowpea in our experiments are consistent with results reported by DUZDEMIR *et al.* (2009), who obtained K_y of 0.92 for climatic conditions of Turkey as well with results obtained by SEPASKHAH and ILAMPOUR (1996) who detected 1.01 K_y for cowpea grown in Iran.

Table 4. Genotype 1 (G_1) actual and maximum evapotranspiration (ET_a, ET_m, mm), actual and maximum harvested yield (Y_a, Y_m, g plant^{-1}), relative evapotranspiration deficit ($1-ET_a/ET_m$), relative yield decrease ($1-Y_a/Y_m$), irrigation water applied (I, mm), yield response factor (K_y)

Year	ET_m	ET_a	$1-ET_a/ET_m$	Y_m	Y_a	$1-Y_a/Y_m$	I	K_y
2011	342	177	0.48	9.72	3.77	0.61	90	1.27
2012	382	153	0.60	15.28	5.54	0.64	180	1.07
2011/12	362	165	0.54	12.50	4.65	0.62	135	1.17

Table 5. Genotype 2 (G_2) actual and maximum evapotranspiration (ET_a, ET_m, mm), actual and maximum harvested yield (Y_a, Y_m, g plant^{-1}), relative evapotranspiration deficit ($1-ET_a/ET_m$), relative yield decrease ($1-Y_a/Y_m$), irrigation water applied (I, mm), yield response factor (K_y)

Year	ET_m	ET_a	$1-ET_a/ET_m$	Y_m	Y_a	$1-Y_a/Y_m$	I	K_y
2011	365	177	0.52	7.56	3.15	0.58	90	1.12
2012	421	153	0.64	8.75	4.93	0.44	180	0.69
2011/12	393	165	0.58	8.16	4.04	0.51	135	0.91

CONCLUSIONS

Based on the obtained results it can be concluded that the yield of cowpea was significantly higher in irrigated (10.33 g plant^{-1}) than in rainfed conditions (4.35 g plant^{-1}). The results revealed that high and stable production of cowpea in the region is only possible by supplementing crop water requirements trough irrigation. Evapotranspiration rate in irrigation conditions (ET_m) from 342 to 421 mm could be considered as cowpea water requirements in climate conditions of the Vojvodina region. The values of K_y ranged from 0.91 to 1.17 for genotype G_1 and G_2 respectively. Genotype G_1, with a value lower than 1 of K_y, is a good tolerant to water deficit, but genotype G_2, with a greater K_y than 1, expresses some sensitivity to water stress. The determined values of K_y could be used as a good platform for cowpea growers in the Vojvodina region, but also for the whole region around this area, that is, Serbia as well as neighboring countries. Nevertheless, of the results obtained in this research, some more cowpea genotypes should be tested in order to get cultivars tolerant to stressful environmental conditions as well as more efficient in water use.

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OSETLJIVOST GENOTIPOVA VIGNE NA VODNI STRES U UMERENIM KLIMATSKIM USLOVIMA

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Izvod

Ublažavanje uticaja globalnih klimatskih promena na poljoprivrednu proizvodnju imaju poseban značaj u budućim istraživanjima. Vigna kao biljna vrsta otporna je interesantna za gajenje u semi-aridnim klimatskim uslovima Vojvodine. Efekat vodnog stresa na prinos gajenih biljaka može se dobiti obračunom koeficijenta opadanja prinosa (K_y) koji predstavlja odnos izmedju i relativnog deficita evapotranspiracije ($1–ET_a/ET_m$) i relativnog opadanja prinosa ($1–Y_a/Y_m$). Vrednosti K_y za genotipove vigne G_1 i G_2 bile su u intervalu od 0,91 do 1,17. Genotip G_1 sa vrednošću K_y manjom od 1 pokazuje dobru otpornost na vodni stress, a genotip G_2 sa vrednošću K_y većom od 1 pokazuje odredjenu osetljivost na deficit vode. Dobijeni rezultati biće korišćeni u oplemenjivačkom radu za dobijanje sorata tolerantnih na stresne uslove sredine, pre svega vodni stres, a takodje i mnogo produktivnije u pogledu iskorišćenosti vode.

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