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CHICKPEA YIELDS AND WATER USE EFFICIENCY DEPENDING ON CULTIVATION TECHNOLOGY ELEMENTS AND IRRIGATION

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Abstract

The paper presents the results of the field experiments dedicated to investigation of chickpea reaction on cultivation technology elements in the South of Ukraine. The study was carried out during 2012-2014 on the dark-chestnut soil in the semi-arid climate conditions. The design of the study included research of the crop reaction on the following agrotechnological factors: plowing depth (20-22, 28-30 cm), fertilization dose (N_0P_0; $N_{45}P_{45}$; $N_{90}P_{90}$), plants population (50, 100, 150 plants per m^2), and humidification conditions (sprinkler irrigation applied or not). The study was conducted in four replications by the split plot design method with the crop variety Rosanna of Kabuli type. Chickpea yielding data were processed by ANOVA procedure, the differences obtained in the experiments are significant and reliable at the probability level of 95%. The results of the experiments testify that the best crop productivity could be obtained at the irrigated variants with the highest fertilization dosage, the maximum plants population, and plowing at the depth of 28-30 cm - 3600 kg per ha. However, the best water resource use efficiency was obtained at the variants with plowing at the depth of 20-22 cm - 36.66 kg per mm. Absence of water supply by irrigation also worsened the water use efficiency and productivity of the crop. Mineral fertilizers and optimum plants population significantly enhanced the crop water use efficiency and productivity both at the irrigated and non-irrigated conditions.

Key words*: chickpea, irrigation, mineral fertilizer, plant population, plowing, water use efficiency, yield.*

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a well-known leguminous crop traditionally cultivated in the countries of the Asian region, e.g. India, Turkey, which nowadays has its value increasing throughout the world, and is growing in a number of European countries, Australia and the USA (Saxena and Singh, 1987). It is believed to come from south-eastern Turkey and the neighboring part of Syria (Singh, 1997). Later on, the crop spread to the modern areas of its cultivation.

Chickpea together with other pulses is a valuable source of plant protein. It is a source of high-qualitative protein, vitamins and mineral compounds that makes it an irreplaceable component of diet for many people (Wood and Grusak, 2007). Besides, forage cultivars of chickpea could be used for obtaining a high-qualitative fodder for non-ruminant and ruminant animals (Ribeiro and Melo, 1990). Chickpea is an important and very prospective leguminous crop in combating the problem of starving, which is on the table for the regions with steep increasing population and lack of protein supply like Sub-Saharian Africa (Myers and Kent, 2001). The crop is prospective for the developing regions of the world because of its comparatively low cultivation and biological requirements, especially, not bad drought (Varshney et al., 2014) and heat stress (Devasirvatham et al., 2012) tolerance.

However, chickpea is an interesting crop not only for the developing African countries and the Asiatic region. It is an important niche crop in Europe and the USA. So, we need a scientifically based rational agrotechnology to be developed to support efficient chickpea production in the above-mentioned regions. There is an evident lack of studying chickpea cultivation technologies in the European region, so, this gap should be filled in the nearest future.

We know from the previously conducted studies that chickpea reacts negatively on water stress (Behboudian et al., 2001). And this reaction depends on the cultivation peculiarities, environmental conditions and variety of the crop (Fukai and Hammer, 1995; Gupta et al., 2000; Mafakheri et al., 2010). It is also a wide-known fact that modern agriculture, especially, in the arid and semi-arid regions of the world, suffers from the lack of qualitative fresh water (Rijsberman, 2006). Therefore, modern cultivation technologies have to be water-efficient. The goal of our field study was to discover the best agrotechnological options for chickpea production (including tillage, plants population, fertilization etc.) in the European semi-arid climatic zone of southern Ukraine to obtain the highest grain yield of the crop at the most efficient water use.

MATERIALS AND METHODS

Field trials in regard to the chickpea cultivation technology were conducted during 2012-2014 at the irrigated lands of Cooperative Farm "Radianska Zemlia", which was a basic experimental farm of Kherson State Agrarian University. The experimental plots were located at the latitude 46°43′N, longitude 32°17′E, and were elevated to 42 m above the sea level. The field experiments were conducted in four replications by using the randomized split plot design method. The study was dedicated to evaluation of the following cultivation technology elements:

- A - plowing depth: A1 - plowing at the depth of 20-22 cm; A2 - plowing at the depth of 28-30 cm;
- B - mineral fertilizers' application doses: B1 - N_0P_0; B2 - $N_{45}P_{45}$; B3 - $N_{90}P_{90}$;
- C - plants population: C1 - 50 plants per m^2; C2 - 100 plants per m^2; C3 - 150 plants per m^2;
- D - irrigation management: D1 - no irrigation applied (rain-fed conditions); D2 - irrigated conditions.

Climate of the zone of experiments conduction is characterized as comparatively dry and hot, with the average annual air temperature of 9.8°C that has a tendency to further increase (Lykhovyd, 2018).

According to the data provided by Kherson regional hydrometeorological center, total rainfall amounts in the zone average to 441 mm, while evapotranspiration reaches 1000 mm. The main meteorological indexes for the period of chickpea vegetation in the experiments are given in the Table 1.

Table 1. Meteorological indexes during the period of chickpea vegetation in the field experiments

2012		2013		2014		Months
AT, °C	PA, mm	AT, °C	PA, mm	AT, °C	PA, mm	
2.5	25.6	3.1	38.8	7.4	32.0	March
13.2	5.9	11.9	3.7	11.5	29.5	April
20.8	39.6	20.7	0.3	18.0	38.2	May
23.4	20.1	23.0	79.1	20.8	64.4	June
26.6	40.2	23.2	44.1	25.1	19.4	July
23.6	79.2	24.2	12.4	24.5	20.7	August

Note: AT - air temperature; PA - precipitation amounts.

The soil of the experimental plots was represented by the dark-chestnut middle-loamy slightly saline soil with the humus content of 2.5%. The soil pH is neutral in the layer 0-50 cm. Bulk density of the soil layer 0-50 cm is 1.29 g/cm^3. The soil has low content of available nitrogen, moderately high content of mobile phosphorus, and very high content of exchangeable potassium. The soil has moderate natural fertility, which is limited mainly by nitrogen content.

Chickpea cultivation technology in the experiments was based on the generally accepted recommendations for the crop cultivation in the South of Ukraine. Rosanna variety was used in the experimental work. This variety belongs to Kabuli type of chickpea, has round, yellowish, smooth seeds with 1000 seeds weight of 290-310 g. Protein content is 25-26%. Rosanna is a middle-ripening, lodging-resistant variety.

The previous crop was winter wheat. The soil was prepared by carrying out double harrowing at the depths of 6-8 and 10-12 cm, which was followed by plowing with accordance to the experimental design. Mineral fertilizers (in the form of ammonium nitrate and super phosphate) were applied in pre-plowing period by the means of a seed drill with accordance to the experimental design. Cultivator tillage at the depth of 12-14 cm was also conducted as a measure of weed management. An early-spring dragging was conducted to level the soil surface. Pre-sowing cultivator tillage was conducted at a depth of 5-7 cm. Chickpea was sown by the means of a seed drill John Deere 740A on 28th of March in 2012, 4th of April in 2013 and 23rd of March in 2014. The seeds were dressed by the active nitrogen-fixation bacteria in advance. The crop was rolled after sowing. Gezaguard 500 FW herbicide (the active substance is prometryn, 500 g/l) was used in the dose of 3.0 l per ha in the pre-emergence period to control weeds. Nurell D insecticide (the active substances include chlorpyrifos, 500 g/l and cypermethrin, 50 g/l) was used at the beginning of the flowering stage to control insects.

Soil moisture in the 0-50 cm soil layer was kept up at the level of 75% of the water-holding capacity by the means of Kuban irrigation machine. The soil moisture control was performed by using the gravimetric method (Reynolds, 1970). Irrigation water from the Ingulets irrigation system was applied to the field in the following amounts: three times at the rate of 45 mm in 2012; once at the rate of 50 mm in 2013; twice at the rate of 50 mm in 2014. The water of the system is unfavorable for irrigation because of high content of dissoluble salts (1549.67 ± 69.01 mg/l), sodium adsorption ration (5.03 ± 0.75 meq/l), Kelly ratio of 0.99 ± 0.16 meq/l, permeability index of 1.26 ± 0.05 meq/l, and toxic sodium content (49.77 ± 3.61%) (Lykhovyd and Kozlenko, 2018; Lavrenko et al., 2018). Such type of water is limited suitable for irrigation, may lead to soil crusting, salinization, alkalinization, deterioration of biological properties, etc. (Lykhovyd and Lavrenko, 2017).

Chickpea yield was evaluated by the results of entire harvesting of the experimental plots by using the self-propelled harvester CLAAS Lexion. The yield was recalculated to the basic moisture (14%). Harvesting of chickpea was carried out on 18th of July in 2012, on 22nd of July in 2013, on 13th of July in 2014 under the rain-fed conditions; under the irrigated conditions: on 3rd of August in 2012, on 6th of August in 2013, on 31st of July in 2014.

Yield data of chickpea were processed by the standard procedure of ANOVA within MS Excel software. Significance of the differences was proved for the reliability level of 95% (LSD_{05}). Water use efficiency (WUE) of chickpea was determined as a relation of yield to the water amounts consumed by the crop during the vegetative period in kg/mm (Garcia y Garcia et al., 2009).

RESULTS AND DISCUSSIONS

The results of the study are given in the Tables 2 and 3. It was found out that the highest grain productivity was provided by chickpea plants cultivated under the irrigated conditions. Irrigation increased yield of the crop by more than 80%. Also, it was proved that plowing at the depth of 28-30 cm is slightly better than at the depth of 20-22 cm (by 2.33%). This fact could be put upon the better soil water consumption by chickpea plants with better root distribution through the soil profile. It is also evident that chickpea grain yield increase with the increase of the crop density from 50 to 150 plants per m^2 both at the rain-fed and irrigated variants of the experiment (average chickpea grain yield enhancement due to the increase of plants population was 24.75%). Considerable chickpea productivity improvement was connected with application of mineral fertilizers that provided 27.68% growth of grain yield (while comparing the variants with no fertilizers and the maximum fertilizers' application dose). The best yielding performance of chickpea was obtained on the variants with plowing at the depth of 28-30 cm, mineral fertilizers' application dose $N_{90}P_{90}$, plants population 150 plants/m^2, and irrigation applied - 3600 kg/ha.

The similar tendency has been discovered while the evaluation of chickpea WUE. It was determined that mineral fertilizers, increased plants population and irrigation significantly increased the index. Irrigation increased WUE of chickpea more than two times. However, the contrary tendency was discovered in regard to the effect of plowing depth on the crop WUE. Increased plowing depth led to decrease of WUE by 0.56%. This is the fact that made us think that the out pay of yield at the variants with deeper plowing is not worth that amounts of water that are used by the crop on these variants.

Table 2. Chickpea yield depending on cultivation technology elements (kg/ha) (average for the period 2012-2014)

Plowing depth	Mineral fertilizers application dose	Plants population		
		50 plants/m^2	100 plants/m^2	150 plants/m^2
Rain-fed conditions (no irrigation)				
A1 (20-22 cm)	B1	1260	1480	1550
	B2	1410	1680	1770
	B3	1520	1800	1900
A2 (28-30 cm)	B1	1280	1500	1600
	B2	1440	1720	1830
	B3	1560	1850	1980
Irrigation				
A1 (20-22 cm)	B1	2180	2480	2700
	B2	2660	3020	3310
	B3	2830	3240	3530
A2 (28-30 cm)	B1	2220	2530	2740
	B2	2710	3100	3380
	B3	2890	3330	3600

Note: The LSD_{05} for factors A, D – 0.035-0.048; B, C – 0.043-0.059; interactions AD – 0.050-0.068; BD, CD, AB, AC – 0.061-0.083; BC – 0.075-0.102; ABD, ACD – 0.086-0.118; BCD, ABC – 0.106-0.144; ABCD – 0.150-0.204. All the differences between the studied variants are significant.

Table 3. Chickpea WUE depending on cultivation technology elements (kg/mm) (average for the period 2012-2014)

Plowing depth	Mineral fertilizers application dose	Plants population		
		50 plants/m^2	100 plants/m^2	150 plants/m^2
Rain-fed conditions (no irrigation)				
A1 (20-22 cm)	B1	8.81	11.24	11.79
	B2	10.48	13.94	14.65
	B3	11.89	15.67	16.31
A2 (28-30 cm)	B1	8.47	10.76	11.83
	B2	10.21	13.75	14.99
	B3	11.74	15.57	17.00
Irrigation				
A1 (20-22 cm)	B1	15.53	19.50	22.28
	B2	22.64	28.46	32.61
	B3	25.16	31.95	36.66
A2 (28-30 cm)	B1	15.57	19.36	22.13
	B2	22.43	28.41	32.41
	B3	24.68	31.96	36.36

Previously conducted studies proved that chickpea water use and water use efficiency are strongly dependent on the water supply of the crop, and on the peculiarities of rainfall distribution if we are talking about the rain-fed conditions (Zhang et al., 2000). Singh and Rama (1989) also reported about the response of chickpea to the water stress. This is in strong agreement with the results of our study that testify about significant WUE improvement of chickpea related to irrigation. Bhattarai et al. (2008) reported about the effect of the irrigation management practice and scheduling on the WUE of chickpea. Strong et al. (1997) also found out a strong correlation between chickpea yield, WUE and water supply.

However, in some environmental conditions, irrigation can result in worse WUE of the crop if it is sown in inappropriate time (Oweis et al., 2004).

The fact that additional supply with mineral nutrition improves chickpea yield and WUE was reported by Khan et al. (2003), Singh and Bhushan (1980), Parihar (1990). Besides, soil nitrogen level together with fertilization, cultivar and *Rhizobial* inoculation of seeds was also proved to be a factor of WUE index changes (Gan et al., 2010). All these scientific results are in agreement with ours. However, we think that chickpea reaction on fertilization management has not yet sufficiently studied in semi-arid climatic conditions both at the irrigated and non-irrigated conditions.

Chickpea response on the tillage practice is studied insufficiently. There is a study related to investigation of chickpea reaction to three tillage practices (no-till, minimum tillage and conventional tillage), however, it was conducted only in the rain-fed conditions, which is not the best option for chickpea cultivation in the arid and semi-arid climate (Rathore et al., 1998). Another study claimed about higher WU of chickpea under the no-till option comparatively to conventional tillage (Fernandez-Garcia et al., 2013).

Leach and Beech (1988) reported about slight affection of plant density and inter-row spacing on chickpea productivity and WUE. They also claimed about considerable differences in radiation use efficiency by the crop in dependence on different sowing patterns. Bahr (2007) has also claimed about significant differences in yielding patterns and productivity of chickpea due to the different plants population. And the fact of different crop productivity is always closely connected with the fact of different WUE of the crop, as it was proved by the results of our scientific experiments. Plants population effects on the crop yield was also studied by Jettner et al. (1999), and Gan et al. (2003).

Besides the studied factors, there are other factors that affect WUE of chickpea plants, for example, variety, sowing time, etc. (Brown et al., 1989). Therefore, further investigations in this field are required to provide concerned agricultural producers with scientifically substantiated comprehensive recommendations on chickpea water-saving and efficient cultivation technology.

CONCLUSIONS

The best WUE of chickpea in the experiments was provided by the variant with the crop cultivation by plowing at the depth of 20-22 cm, fertilization dose $N_{90}P_{90}$, plants population of 150 plants per m^2 at the irrigated conditions (36.66 kg per mm), while the maximum grain yield was obtained under the plowing at the depth of 28-30 cm with the same other options (3600 kg per ha). Therefore, we see that deeper plowing increases yield but has a negative effect on WUE. Rain-fed chickpea provided less yield under comparatively low WUE. Application of mineral fertilizers at the optimum plant population significantly improved chickpea productivity and WUE.

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