Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2017 14(3): 532-541. **OPEN ACCESS**

Growing corn and soybean in solid and intercroppinig systems under different levels of irrigation water

Abd El-Alim Abdel-Rhman Metwally[1], Sayed Ahmed Safina[1], Rushdy EL-Killany[2] and Neama Abd El-Salheen Saleh[1]

[1]Agronomy Department, Faculty of Agriculture, Cairo University, Giza, **Egypt.**
[2]Soil Department, Faculty of Agriculture, Cairo University, Giza, **Egypt**

.
***Correspondence: drabdmetwally.agric@hotmail.com** **Accepted: 13** July 2017 **Published online: 26** Sep. 2017

Cultivated area of solid soybean in Egypt is very low under limited amount of irrigation water so intercropping soybean with corn was objected to increase its production under limited agricultural resources. Two experiments were conducted at Giza Agricultural Experiments and Research Station, Faculty of Agriculture, Cairo University, (Egypt) during the two successive seasons 2015 and 2016. The experiment included eighteen treatments which were the combinations between three applied irrigation water (75, 100 and 125% of the recommended water applied) and six cropping systems (50% soybean + 100% corn, 100% soybean + 100% corn, traditional solid corn, solid corn 'mixed system', traditional solid soybean and solid soybean 'mixed system'). The experimental design was split plot design with four replications. The data indicated that all the studied soybean characters were affected negatively by intercropping with corn. Increasing soybean plant density under intercropping systems from 50 to 100% of solid culture achieved high seed yield without reduction on corn grain yield. The interaction between levels of irrigation water and cropping systems did not affect soybean characters; meanwhile the reverse was true for corn crop. WUE was increased with decreasing irrigation water levels from 125 to 75% of the recommended irrigation water (8092 m^3/ha). It is be concluded that intercropping soybean with corn in beds 140 cm increased LER and WUE, as well as, total economic return than solid cultures under recommended level of applied irrigation water of solid crops

Keywords: Intercropping, Soybean, Corn, WUE, Net return.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] seed is used worldwide as a source of protein for livestock feed rations, as a source of cooking oil, and for many other purposes. However, it is not feasible to expand the area of soybean crop in Egypt because of high competition from the other summer crops like corn (*Zea mays* L.) and water scarcity. Several different cropping systems are followed in the Nile Valley and Delta areas of Egypt, depending on the soil type and crops; however, the low size of cultivated land per farmer and water deficit are the most problems associated with the cropping systems. There is a modern trend for growing crops on beds (100 – 140 cm width) according to population densities of field crops (wheat, corn, cotton, soybean, etc.) to save irrigation water by about 15% compared by traditional practice on ridges 60-70 cm in width (Abouelenein et al. 2009). There is a decline in area under soybean in Egypt, where it reached to about 7,812 ha in 2016, while, corn had about

4,877,829 ha in 2016 (Bulletin of Statistical Cost Production and Net Return, 2016). Consequently, there is the need to expand the scope of soybean cultivation through intercropping with corn plants. Intercropping soybean with corn increased each of land and net equivalent ratios (Metwally et al. 2008 and 2012 and Abdel-Wahab and Abd El-Rahman, 2016).

On the other hand, water is a primary limiting factor in Egyptian agriculture, various irrigation methods and cropping systems for increasing soybean production. Overall, irrigation significantly increased seed yield and number of seed per unit harvest area for all cultivars in most experiments (Heatherly, 1992). However, Morris and Garrity (1993) and Ouda et al. (2007) reported that increasing productivity of intercropped soybean and corn over the sole crop has been attributed to better use of water. Therefore, the objective of this investigation was to determine growth, yield and water use efficiency of different levels of irrigation water under modern solid and intercropping systems for increasing agricultural resources.

MATERIALS AND METHODS

A two-year study was carried out at Giza Agricultural Experiments and Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt during two successive summer seasons (2015 and 2016). The main factors were three levels of applied irrigation water (6069, 8092 and 10115 m^3/ha) and six cropping systems of solid and intercropping corn and soybean. Eighteen treatments were the combinations of the previous factors (Figure 1) as follows:

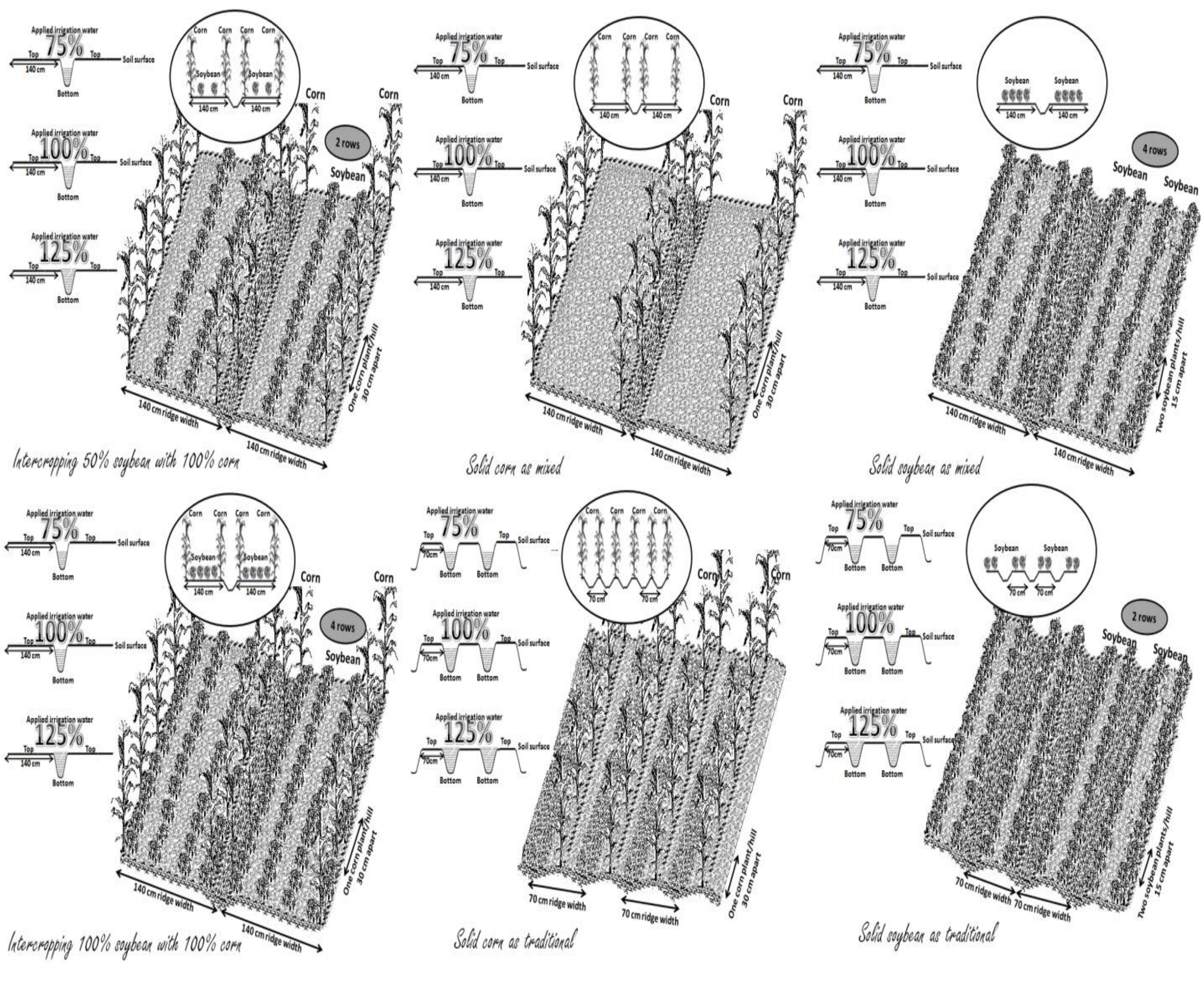

Figure 1. Intercropping soybean with corn and solid cultures of both crops.

Intercropping systems

Corn plants were grown in both sides of beds 140 cm width by growing two plants/hill distanced 50 cm apart, meanwhile two rows of soybean were grown in the middle of the bed (2 plants/hill distanced 15 cm apart). This pattern was expressed as 50% soybean + 100% corn plants (Inter1). As that of pattern (Inter1) but four rows of soybean were grown in the middle of the bed (2 plants /hill distanced 15 cm apart. This pattern was expressed as 100% soybean + 100% corn plants (Inter2). This pattern had the recommended total plant densities of solid corn and soybean.

Solid systems.

Solid systems as mixed.
Solid systems as traditional.

The studied characters:

A. Soybean characters: ten guarded plants at harvest were chosen at random from each sub plot to determine number of pods per plant, seed index, seed yield per plant (g) and harvest index 'HI' (%).HI = Economic yield/biological yield x 100 according to Clipson et al. (1994). Soybean seed yield per ha (ton) were determined from seed weight of each sub plot and converted to ton per ha.

B. Corn characters:

Ten plants at harvest were taken at random from each sub plot to determine plant dry weight, ear weight and grain yield per plant (g). Corn grain yield per ha (ton) were determined from grain weight of each sub plot and converted to ton per ha.

C. Irrigation water use efficiency (IWUE):

IWUE values were calculated according to Bhattarai *et al*. (2006) as follow: IWUE = (Ey/ Ir). Where IWUE is irrigation water use efficiency (kg/m^3), Ey is the economical yield (kg/ha) and Ir is the amount of applied irrigation water (m^3).

D. Farmer's benefit

It was calculated by determining the total costs and net return of intercropping cultures as compared to recommended sole culture as follows:

Total return of intercropping cultures = Price of soybean yield + price of corn yield (American Dollars $), to calculate the total return, the average of soybean (240 US $/ton of seeds) and corn (127 US $/ton of grains) prices were used by Bulletin of Statistical Cost Production and Net Return (2016).

Net return = Total return – (fixed costs + variable costs according to cropping systems and irrigation

Water requirements.

Statistical analysis was carried out according with (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5 per cent level of probability to compare differences between the means (Gomez and Gomez, 1984).

RESULTS AND DISSCUSSION

Soybean characters

Effect of applied irrigation water

Seed yield per plant, seed yield per ha and HI were not affected significantly by levels of applied irrigation water but the converse was true with number of pods per plant and seed index (Table 1).The lowest application water level reduced pod number and seed index. Shortage in applied irrigation water by 25% than recommended applied irrigation water did not reduce accumulation of dry matter in different organs of the plant during the early vegetative and development growth stages and consequently, yield of the crop. These results could be due to plant hormones played a major role to tolerate water shortage during germination and the early growth stages. These results are in accordance with those obtained by Aiken and Lamm (2012) who reported that the crop canopy shades soil and reduces evaporative water losses. Also, soybean has tap roots and torrent to drought than corn. Moreover, Shariatmadari et al. (2017) concluded that priming with appropriate concentration of gibberellin plays an important role in the induction of tolerance to drought and overcome limitations created by the environmental stress. Increasing applied irrigation water to 25% over that of recommended applied irrigation water did not increase soybean yield. The highest applied irrigation water may have cooler canopy temperatures and retain moisture longer which increased the probability of foliage disease problems compared to others. Excessive irrigation water during the vegetative stage stimulates vegetative growth and dry matter and increase potentiality for lodging and may be increasing fungal diseases without an increase in yield (Kranz and Benham, 2003).

Table 1. Soybean characters as affected by applied irrigation water, cropping systems and their interactions combined data across 2015 and 2016.

Cropping systems	Applied irrigation water	Seed yield/plant (g)	No. pods /plant	Seed index (g)	Seed yield/ha (ton)	HI (%)
Intercropping systems 50% soybean+100% corn (Inter 1)	75%	7.6	25.9	16.0	1.14	33.3
	100%	9.1	31.3	17.6	1.41	33.5
	125%	10.4	33.3	21.9	1.36	34.1
Mean		9.0	30.2	18.5	1.30	33.6
100% soybean+ 100% corn (Inter 2)	75%	5.4	21.8	15.6	1.34	24.6
	100%	6.8	23.2	16.5	1.64	28.9
	125%	6.3	23.1	20.1	1.64	30.3
Mean		6.2	22.7	17.4	1.54	27.9
Solid soybean (mixed system)	75%	14.4	38.8	17.9	2.99	35.8
	100%	15.4	45.3	17.0	3.07	31.9
	125%	15.1	42.8	18.9	3.07	32.3
Mean		15.0	42.3	17.9	3.04	33.3
Traditional solid soybean	75%	15.1	36.7	19.8	3.16	32.9
	100%	14.4	40.8	14.9	3.23	28.6
	125%	14.4	40.9	18.5	3.23	31.0
Mean		14.6	39.5	17.7	3.21	30.8
Average of applied irrigation water	75%	10.6	30.8	17.3	2.16	31.6
	100%	11.4	35.2	16.5	2.34	30.7
	125%	11.6	35.0	19.8	2.33	31.9
L.S.D.0.05 Applied irrigation water		N.S.	3.1	1.9	N.S.	N.S.
L.S.D.0.05 cropping systems		2.5	6.5	1.1	0.16	4.5
L.S.D.0.05 Interaction		N.S.	N.S.	N.S.	N.S.	N.S.

75% = 6069 m^3/ha, 100% = 8092 m^3/ha, 125% = 10115 m^3/ha

Effect of cropping systems

Seed yield and number of pods per plant, seed index, seed yield per ha and HI was affected significantly by cropping systems (Table 1). It was easy from above results to mention that the improvement of planting method from ridges to beds in intercropping systems enhanced efficiency of the photosynthetic rate of soybean leaves, which enhanced the biological characters of soybean. These differences depending on number of soybean plants per ha and shading effects by adjacent corn plants in intercropping systems. Traditional solid soybean culture had the highest values ($P \leq 0.05$) of number of pods and seed yields per plant and per ha as compared to those of intercropping systems. In general, intercropping soybean with corn decreased ($P \leq 0.05$) seed yields per plant and per ha by about 47.94 and 55.76%, respectively, as compared with those of traditional solid system (Table 1).

These results could be due to the adverse shading effects of adjacent corn plants which increase inter and intra-specific competition between plants as compared with those of traditional solid culture, especially, during reproductive and seed filling stages (Metwally et al. 2012). Also, soybean plants of intercropping system which have low density (50% soybean) achieved higher pod number and seed yield per plant than that of intercropping system which have 100% soybean. Conversely, increasing soybean plant density per unit area from 50 to 100% increased significantly seed yield per ha under intercropping conditions. The converse was true for decreasing plant density of soybean where it gave more space to increase solar radiation penetration between soybean plants. These results are in the same context of those obtained by Metwally et al. (2012) and Abdel-Wahab and Abd El-Rahman (2016).

Effect of the interaction between applied irrigation water and cropping systems

The interaction between applied irrigation water levels and cropping systems did not affect significantly all the studied soybean characters in the combined data across the two seasons (Table 1).These data showed that each of the two factors act independently ($P > 0.05$) on previous characters, as well as, cropping systems had higher effects on soybean productivity.

B. Corn characters

Effect of applied irrigation water

Plant dry weight, ear weight, grain yields per plant and per ha were affected significantly by applied irrigation water in the combined data across the two seasons (Table 2). The highest applied irrigation water caused significant increments ($P \leq 0.05$) in plant dry weight, grain yields per plant and per ha as compared with those of the other levels. The highest applied irrigation water increased plant dry weight, grain yields per plant and per ha by 20.15, 11.82 and 14.26 %, respectively, as compared to those of the lowest applied irrigation water.

It is known that the oxygen created by plants comes from the water it uses rather than from the CO_2 (Wittwer, 1992). Accordingly, it is expected that the excess irrigation water treatment (125%) enhanced efficiency of photosynthetic process of the plant especially corn which has high water requirements (Igbadun et al. 2008) and thereby more dry matter accumulation in the different organs of the plant.

Effect of cropping systems

Plant dry weight, ear weight, grain yields per plant and per ha were not affected significantly by cropping systems (Table 2). Obviously, the yielding ability of corn crop was not ($P > 0.05$) likely to be much affected by cropping systems. These data suggest that corn plant had high ability for convert more solar energy to chemical energy and more translocation of photosynthesis metabolites to the ears under the studied cropping systems. These results are in agreement with those obtained by (Metwally, 1999 and Undie et al. 2012) who indicated that intercropping soybean with corn had no significant reduction in grain yield of corn.

Effect of the interaction between applied irrigation water and cropping systems

Applied irrigation water x cropping systems affected significantly all the studied corn characters in the combined data across the two seasons (Table 2). Intercropping soybean with corn under application high level of water (125%) produced higher ear weight and grain yield of corn per plant as compared with solid corn plantings. This may be attributed to wide spacing between corn plants in beds than those on traditional solid planting on ridges (70cm).

Table 2. Corn characters as affected by applied irrigation water, cropping systems and their interaction, combined data across 2015 and 2016.

Cropping systems	Applied irrigation water	Plant dry weight (g)	Ear weight (g)	Corn grain yield/plant (g)	Corn grain yield/ha(ton)
Intercropping systems 50% soybean + 100% corn (Inter 1)	**75%**	376	235	205	6.83
	100%	369	261	215	7.36
	125%	400	273	241	7.76
Mean		**381**	**256**	**220**	**7.33**
100% soybean + 100% corn (Inter 2)	**75%**	365	239	202	6.66
	100%	480	263	210	7.16
	125%	483	230	230	7.56
Mean		**442**	**244**	**214**	**7.13**
Solid corn (mixed system)	**75%**	384	222	195	6.66
	100%	442	229	208	7.49
	125%	443	216	216	7.66
Mean		**423**	**222**	**206**	**7.26**
Tradition solid corn	**75%**	445	244	209	6.79
	100%	511	220	220	7.59
	125%	561	221	221	7.73
Mean		**505**	**228**	**217**	**7.36**
Average of applied irrigation water	**75%**	**392**	**235**	**203**	**6.73**
	100%	**450**	**243**	**213**	**7.39**
	125%	**471**	**235**	**227**	**7.69**
L.S.D.0.05 Applied irrigation water		**38.8**	**13.4**	**10.1**	**0.76**
L.S.D.0.05 Cropping systems		**50.7**	**N.S.**	**N.S.**	**N.S.**
L.S.D.0.05 Interaction		**57.0**	**35.0**	**12.0**	**0.69**

75% = 6069 m^3/ha, 100% = 8092 m^3/ha, 125% = 10115 m^3/ha

It is obvious that efficiency of photosynthetic process of the intercropped corn plant was enhanced with increasing applied irrigation water up to 125% of the recommended applied irrigation water. These results show that increase in surface absorbing sunlight and decreased evaporation rate from soil surface compared with the others (Andrade *et al*., 2002). Increasing irrigation water level from 6069 to 10115 m^3/ha had significant increments on ear weight and grain yield per plant under intercropping systems more than that of traditional solid planting. This may be due to wide spaces of beds furnished more light penetration between corn plants under intercropping (140 cm per bed) than that of traditional solid system (70 cm per ridge). Also, there were positive effects between corn plant and adjacent soybean plants due to beneficial effects of soybean residues under intercropping culture (Metwally et al. 2008 and El-Shamy et al. 2015). Accordingly, intercropping soybean with corn increased light intensity and CO_2 concentrations around corn canopy and thereby this biological situation reflected on the developing ears

C. Water use efficiency (WUE)

Effect of applied irrigation water

WUE of economic yield was affected significantly by applied irrigation water, meanwhile WUE of biological yield was not affected (Figure 3). The lowest applied irrigation water caused significant increments *($P \leq 0.05$)* in WUE of economic yield as compared to those of the other treatments. However, there were no significant differences between 100% and 125% of applied irrigation water treatments. The highest applied irrigation water decreased WUE of economic yield by about 50% as compared to the lowest applied irrigation water.

Effect of cropping systems

Intercropping soybean with corn increased WUE of economic yield by 16.94% as compared to traditional solid plantings of corn (Figure 3). Also, intercropping soybean with corn increased WUE of biological yield by 9.33% as compared to traditional solid plantings of corn. With respect to intercropping patterns, increasing soybean plant density from 50% to 100% did not affect negatively WUE of economic yield (Figure 3).

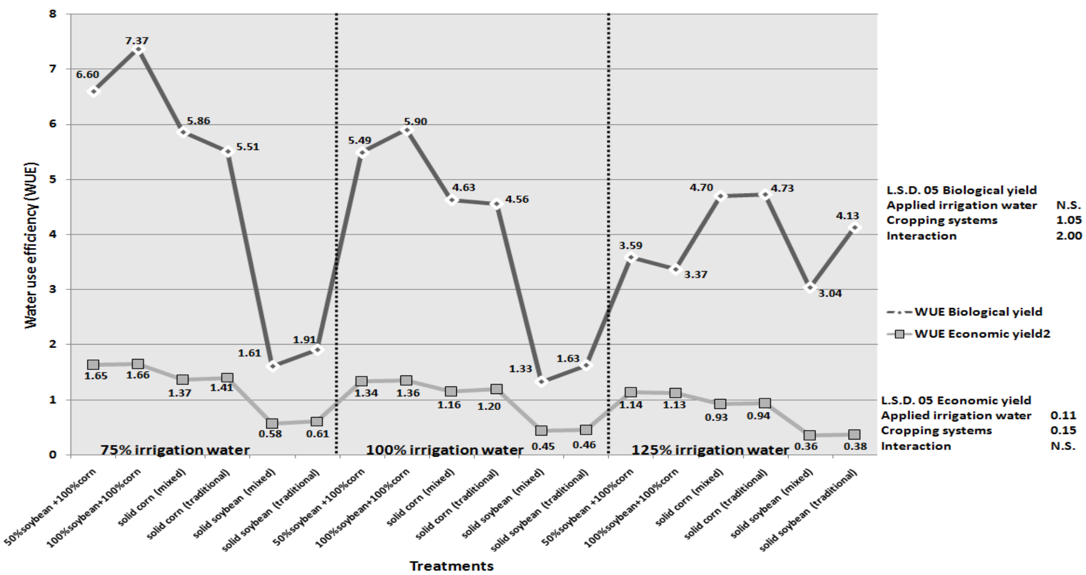

Figure 3. Effect of applied irrigation water, cropping systems and their interaction on water use efficiency (WUE), combined data across 2015 and 2016.

Table 3. Financial return as affected by applied irrigation water levels, cropping systems and their interaction, combined data across 2015 and 2016.

Cropping systems	Applied irrigation water	Financial return (US$)			Costs (US$)	Net (US$)
		Soybean	Corn	Total		
Intercropping systems 50% soybean + 100% corn (Inter 1)	75%	273.6	867.41	1141.01	801.57	339.44
	100%	338.4	934.72	1273.12	816.54	456.58
	125%	326.4	985.52	1311.92	831.52	480.40
Mean		312.00	930.91	1242.91	816.54	425.47
100% soybean + 100% corn (Inter 2)	75%	321.6	845.82	1167.42	817.57	349.85
	100%	393.6	909.32	1302.92	832.54	470.38
	125%	393.6	960.12	1353.72	847.52	506.20
Mean		369.6	905.51	1275.11	832.54	442.14
Average of intercropping	75%	297.60	856.61	1154.21	809.57	344.64
	100%	366.00	922.02	1288.02	824.54	463.48
	125%	360.00	972.82	1332.82	839.52	493.30
Mean		341.20	917.15	1258.35	824.54	433.80
Solid corn (mixed system)	75%	----	845.82	845.82	681.57	164.25
	100%	---	951.23	951.23	696.54	254.69
	125%	---	972.82	972.82	711.52	261.30
Mean		---	923.29	923.29	596.55	226.74
Traditional solid corn	75%	---	862.33	862.33	681.57	180.76
	100%	---	963.93	963.93	696.54	267.39
	125%	---	981.71	981.71	711.52	270.19
Mean		---	935.99	935.99	696.55	239.44
Average of solid corn	75%	---	854.07	854.07	681.57	172.50
	100%	---	957.58	957.58	696.54	261.04
	125%	---	977.26	977.26	711.52	265.74
Mean			929.63	929.63	696.54	233.09
Solid soybean (mixed system)	75%	717.60	---	717.60	491.60	225.99
	100%	736.80	---	736.80	505.61	231.18
	125%	736.80	---	736.80	519.50	217.29
Mean		730.4	---	730.40	505.57	224.82
Traditional solid soybean	75%	758.40	---	758.40	491.60	266.79
	100%	775.20	---	775.20	505.61	269.58
	125%	775.20	---	775.20	519.50	255.69
Mean		769.60	---	769.60	505.57	264.02

Average of solid soybean	75%	738.00	---	738.00	491.60	246.39
	100%	756.00	---	756.00	505.61	250.38
	125%	756.00	---	756.00	519.50	236.49
Mean		750.00	---	750.00	505.57	244.42

Prices of main products are that of 2016: US$ 127 for ton of corn; US$ 240 for ton of soybean.
75% = 6069 m^3/ha, 100% = 8092 m^3/ha, 125% = 10115 m^3/ha

These results indicate that corn plants may grow larger and they may use more water and high CO_2 concentration as a result of intercropping with the C_3 plants. Despite WUE of C_4 crops often being higher than that of C_3 crops (Gowik and Westhoff, 2011), water availability still dictates the maximum yields achievable by the C_4 crop (Ings et al. 2013).

Effect of the interaction between applied irrigation water and cropping systems

WUE of biological yield was affected significantly by the interaction between applied irrigation water and cropping systems, meanwhile WUE of economic yield was not affected (Figure 3). Intercropping soybean with corn with the application of 75% of recommended applied irrigation water achieved the highest WUE of biological yield than other solid plantings.

D. Farmer's benefit

The financial return of intercropped soybean with corn plants as compared with solid cultures of both crops is shown in Table (3). It is noticed that modifying solid corn planting method from ridge (70 cm width) to beds (140 cm width) decreased net return by 5.30% than that traditional solid culture of corn. Also, modifying solid soybean planting method from ridge to beds decreased net return by 14.84% compared to traditional solid culture of soybean. Conversely, intercropping cultures increased net return by about 81.17 and 64.30% as compared with corn and soybean traditional solid cultures, respectively. Also, intercropping cultures increased net return by about 91.32 and 92.95% as compared with mixed (beds) solid cultures of corn and soybean, respectively**.**In general, increasing levels of applied irrigation water increased net return of intercropping culture of corn and soybean, as well as, solid corn, but it is not occurred with solid soybean. Net return of intercropping soybean with corn was varied between treatments from US$ 339.44 per ha by intercropping 50% soybean with 100% corn that received 75% of applied irrigation water to US$ 506.20 per ha by intercropping 100% soybean with 100% corn received high level of applied irrigation water. Intercropping soybean with corn achieved the highest financial value under traditional applied irrigation water of corn (100%). In other words, modifying corn planting method from ridge to beds with growing 100% soybean (inter 2) in the middle corn bed saved 25% of applied irrigation water and doubled net return compared to traditional solid planting of corn. These results suggest that intercropping soybean with corn in the same bed (140 cm width) achieved high WUE and net return than solid corn for farmers. These findings are parallel with those obtained by Ouda et al. (2007), Metwally et al. (2009) and Abdel-Wahab and Abd El-Rahman (2016) who found that intercropping soybean with corn is more profitable than solid corn culture.

CONCLUSION

Corn characters were affected more than soybean by reducing irrigation water level than recommended one .Intercropping soybean with corn did not need more applied irrigation water than solid plantings and increased agro – economic feasibility. It can be concluded that applied irrigation water of 6069 to 8092 m^3/ha was suitable applied irrigation water requirements for productivity, WUE and net return under solid and intercropping cultures in beds 140 cm width under Egyptian conditions.

.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest".

ACKNOWLEGEMENT

The authors are grateful for Cairo University, Faculty of Agriculture, Agronomy department and Agriculture Research Center for financial support to carry out this study

AUTHOR CONTRIBUTIONS

Author METWALLY designed the study, wrote the protocol, facilitated the implementation of this study and overcome any problems, provided the scientific and technical support to carry out these trials, and reviewed the final manuscript.

Authors SAFINA and El-KILLANY performed the statistical analysis, help the analyses of the study, wrote the results, managed the literature searches, discussed the results.

Author SALEH carried out the field experiments, follow up the growth, development and harvest the tested field crops, and recorded and analysis the data of tested field crops and wrote the manuscript.

REFERENCES

Abdel-Wahab TI, Abd El-Rahman RA, 2016. Response of some soybean cultivars to low light intensity under different intercropping patterns with maize. Int J Appl Agric Sci 2 (2): 21 – 31.

Abouelenein R, Oweis T, El Sherif M, Awad H, Foaad F, Abd El Hafez S, Hammam A, Karajeh F, Karo M, Linda A, 2009. Improving wheat water productivity under different methods of irrigation management and nitrogen fertilizer rates. Egypt J Appl Sci 24 (12A): 417–431.

Aiken R, Lamm F, 2012. Irrigation guidelines for oilseed crops in the U.S. Central Great Plains. Kansas State Northwest Research – Extension Center, Kansas, pp. 14 – 24.

Andrade FH, Echarte L, Rizzalli R, Della Maggiora A, Casanovas M, 2002. Kernel number predication in maize under nitrogen or water stress. Crop Sci 42: 1173 – 1179.

Bhattarai SP, Pendergast L, Midmore DJ, 2006. Root aeration improves yield and water use efficiency of tomato in heavy clay and saline soils. Sci Hortic 108: 278 – 88.

Bulletin of Statistical Cost Production and Net Return, 2012. Summer and Nili Field Crops and Vegetables and Fruit, Agriculture Statistics and Economic Sector, Ministry of Egyptian Agriculture and Land Reclamation, Part (2), August 2016.

Clipson NJW, Edwards SJ, Hall JF Leach CK, Rayns FW, Weston GD, 1994. Crop Productivity. Published on Behalf of: Open Univ. and Univ. Greenwish (Formerly Thames Polytechnic), Avery Hill Road, Eltham, London SE92HB, 5 p.

El-Shamy Moshira A, Abdel-Wahab TI, Abdel-Wahab ShI, Ragheb SB, 2015. Advantages of intercropping soybean with maize under two maize plant distributions and three mineral nitrogen fertilizer rates. Adv. Biosci. and Bioeng. 3 (4):30 – 48.

Freed RD, 1991. MSTATC Microcomputer Statistical Program. Michigan State University, East Lansing, Michigan, USA.

Gomez KA, Gomez AA, 1984. Statistical Procedures for Agricultural Research, 2nd ed. John Willey and Sons, Toronto, ON, Canada.

Gowik U, Westhoff P, 2011. The path from C3 to C4 photosynthesis. Plant Physiol 155: 56–63.

Heatherly LG, 1992. Drought stress and irrigation effects on germination of harvested soybean seed. Crop Sci 33(4), 777-781.

Igbadun HE, Salim BA, Tarimo AKPR, Mahoo HF, 2008. Effects of deficit irrigation scheduling on yields and soil water balance of irrigated maize. Irrigation Sci 27 (1): 11–23.

Ings Jennifer, Mur LAJ, Robson PRH, Bosch M, 2013. Physiological and growth responses to water deficit in the bioenergy crop *Miscanthus* x *giganteus*. Frontiers in Plant Sci 4, Article 468: 1 – 12.

Kranz B, Benham B, 2003. Does irrigation improve soybean yields?. Nebraska Univ., Nebraska, pp. 8 – 17.

Metwally AA, 1999. Intensive copping system in the battle against food crises. In: Proc. 1st Conf. in Recent technologies, Fac. Agric., Cairo Univ., 27- 29 November, 11: 333 – 341, Egypt.

Metwally AA, Shafik MM, Fayez M, Safina SA, 2008. Performance of inoculated some soybean varieties under intercropping and solid plantings. The 1st Int. Conf., on Environmental Studies and Research "Natural resources & Sustainable Development", 7 – 9 April, Minufiya Univ., P. 81.

Metwally AA, Shafik MM, El-Habbak KE, Abdel-Wahab ShI, 2009. Step forward for increasing intercropped soybean yield with maize. The 4th Conf., Recent Technologies in Agric., 3 – 5 Nov. Cairo Univ., 2: 256 – 269.

Metwally AA, Shafik MM, El-Habbak KE, Abdel-Wahab ShI, 2012. Yield and soybean characters under some intercropping patterns with corn. Soybean Res 10: 24 – 42.

Morris RA, Garrity DP, 1993. Resource capture and utilization in intercropping: water. Field Crops Res 34:303-317.

Ouda SA, Mesiry TEl, Abdallah EF, Gaballah MS, 2007. Effect of water stress on the yield of soybean and maize grown under different intercropping patterns. Aust J Basic and Appl Sci 1(4): 578–85.

Shariatmadari MH, Parsa M, Nezami A, Kafi M, 2017. Effects of hormonal priming with gibberellic acid on emergence, growth and yield of chickpea under drought stress. Bioscience Res 14(1): 34-41.

Undie UL, Uwah DF, Attoe EE, 2012. Growth and development of late season maize/soybean intercropping in response to nitrogen and crop arrangement in the forest agro-ecology of South Southern Nigeria. Int J Agric Res 7(1): 1

Wittwer SH, 1992. Flower power: rising carbon dioxide is great for plants. Policy Review (Fall 1992), pp. 4 – 10.