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Impact of Foliar Spraying with Antioxidant and Intercropping Pattern of Maize and Soybean on Yields and its Attributes

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ABSTRACT

In order to study the effect of foliar spray by antioxidant (salicylic and ascorbic acids) and intercropping patterns on the production of both maize and soybean. Two field experiments were conducted at Agronomy Department Farm, Agriculture Faculty, Assiut University, Assiut, Egypt during 2016 and 2017 seasons. Two factors were studied, the first one was foliar application of Antioxidant compounds (control, ascorbic acid at 200 ppm, salicylic acid at 200 ppm and ascorbic acid + salicylic acid at 200 ppm). Four intercropping patterns were used (maize-soybean 2:2, maize-soybean 2:1, sole maize and sole soybean) as a second factor. The obtained results showed that: The results indicated that foliar spraying with antioxidant and intercropping patterns enhanced significantly all traits in this study except plant height of maize in both seasons. Thus, the highest values of measured traits where observed from plants which sprayed with salicylic acid at rate of 200 ppm of the two crops in the two successful seasons. Maximum yield and its attributes of maize were produced from the sole maize sown followed by the intercropping pattern of 2:1 of maize and soybean in both seasons. In addition, maximum soybean yield and its related traits were produced from the sole sown followed by the intercropping pattern 2:2 of maize and soybean in both seasons. It could be concluded that intercropping pattern 2:2 of maize and soybean with foliar spraying salicylic acid at rate of 200 ppm recorded the maximum of land equivalent ratio (LER) and monetary advantage index (MAI) of the unit area under Assiut Government condition.

Keywords: Maize, Soybean, Intercropping Patterns, Ascorbic and Salicylic Acid.

INTRODUCTION

Intercropping is an important agronomic strategy that involves the growing of two or more crops on the same site of soil (Katyayan, 2005), maximizes production as well as resource utilization per unit area, provide 15–20% of food supply to the world (Lithourgidis *et al.,* 2011). Also it has ecological and biological advantages over sole cropping (He *et al.,* 2012 and Waktola *et al.,* 2014). Cereal–legume (maize-soybean) intercropping is a maintainable land management practice (Regehr *et al.,* 2015). Additionally, it helps to sustain and expand the soil fertility because leguminous crops like soybean accumulate nitrogen from 80 to 350 kg/ha (Mobasser *et al.,* 2014). El-Edward *et al.* (1985) found that weight of 100-grain, grain yield and LER, increased when soybean was intercropped with maize. Metwally *et al.* (2005) and Aziz *et al.* (2012) concluded that intercropping with 2-row maize: 2-row soybean give higher yield, LER and net return than other intercropping patterns. The maize yield and its components was decreased under maize-soybean intercropped as compared with sole maize (Abou-Keriasha *et al.* 2012 and Abrar *et al.* 2016). However, Abrar *et al.* 2016 illustrated that the maximum seed yield and its components of soybean were higher in sole compared with different intensities of intercropping, thus, the maximum seed yield of soybean (1.20 t/ha) was recorded in sole soybean crop followed by 2 row maize: 2 rows soybean (0.46 t/ha). While, the minimum seed yield (0.34 t/ha) was recorded in case of double row maize: one row of soybean. Hamd Alla *et al.* (2014) found tallest maize plants under intercropping system as compared with sole maize.

Salicylic acid (SA), a naturally plant hormone, turns as an endogenous signal molecule responsible for inducing a biotic stress tolerance in plants (Gunes *et al*., 2007). Exogenous application of salicylic acid may be contributed in physiological processes, such as stomatal conductance, menerals uptake, membrane activity and photosynthesis hence affected growth Borsani *et al*. (2001), and he add that spraying of salicylic acid affected the nutrient balances in the plant as reported by. Ascorbic acid (AS) is considered as the most famous growth regulators under abiotic stress conditions (Conklin, 2001). Not only AS acts as an antioxidant, but also the cellular levels of AS are correlated with the activation of complex biological defense mechanisms (Conklin and Barth, 2004). Furthermore, experimental studies on dissimilar crops have shown that foliar application of AS may reduce drought stress effects leading to an increment of growth and yield (Salama, 2009).

Therefore, the objective of this research was aimed to estimate the effect of antioxidant foliar application and intercropping patterns on maize and soybean yields and other yields related characters.

MATERIALS AND METHODS

Experimental site

Current study was conducted at Agronomy Department Farm, Faculty of Agriculture, Assiut University, Egypt lat. (27° 18' N, long. 31° 16' and alt. 53 m a.s.l.) during 2016 and 2017. The preceding crop was wheat in both seasons. The soil properties of experimental site are shown in Table 1.

Table 1. Some physical and chemical properties of representative soil samples of the experimental site before sowing (0-30 cm depth) for the two growth seasons.

Soil property	2016 season*	2017 season*
Particle - size distribution		
Silt (%)	26.4	26.3
Sand (%)	24.3	25.2
Clay (%)	49.3	48.5
Texture	Clay	Clay
Organic matter (%)	1.70	1.75
Field capacity (%)	42.8	43.2
EC (1:1 extract) (dS m^{-1})	0.77	0.73
pH (1:1 suspension)	8.2	8.3
Total nitrogen (%)	0.72	0.69
$CaCO_3$ (%)	3.5	3.6
KCl-extractable N (mg kg^{-1})	42.23	41.26
$NaHCO_3$-extractable P (mg kg^{-1})	4.32	4.72
NH_4OAC-extractable K (mg kg^{-1})	48.11	51.20

*** Each value represents the mean of three replications.**

Experimental design and treatments: -

Field experiments were laid out in randomized complete block design (RCBD) using strip plot arrangement with three replications. The first variable was four foliar application treatments of Antioxidant compounds (control,

ascorbic acid, salicylic acid and ascorbic acid + salicylic acid), which occupied in horizontal plots. Three equal foliar applications 10 days interval with antioxidant started at 20 days after sowing of maize by the following treatments:

1- Control (sprayed with water).
2- Ascorbic acid (200 ppm).
3- Salicylic acid (200 ppm).
4- Ascorbic acid + Salicylic acid (200 ppm).

While the second variable was intercropping patterns, which allocated in vertical plots. The intercropping patterns were as follows:

1- 2 maize : 2 soybean: Two maize ridges alternating with another two ridges of soybean. Maize was grown in one row/ridge (70 cm width) with leaving two plants/hill spaced at 40 cm. Soybean seeds were drilled in two row/ridge, in two plants/hill spaced at 15 cm.
2- 2 maize : 1 soybean: Two maize ridges alternating with another one of soybean. Maize was grown in one row/ridge (70 cm width) with leaving two plants/hill spaced at 40 cm. Soybean seeds were drilled in two row/ridge, in two plants/hill spaced at 15 cm.
3- Sole maize: Maize was grown in one row/ridge (70 cm width) and thinned to one plant/hill, 30 cm apart between hills.
4- Sole soybean**:** Soybean seeds were drilled in two row/ridge, in two plants/hill spaced at 15 cm.

The experimental unite area was 10.5 m^2. Seeds of the early – maturing soybean variety Giza 111 were inoculated with *Bradyrhizobium japonicum* and Arabic gum was used as a sticking agent. Soybean seeds were sown on 11th and 14th May in 2016 and 2017 seasons, respectively. Meanwhile, maize hybrid Giza 128 (white single cross) was sown 15 days later. Soybean plants were harvested on 14th and 16th September in 2016 and 2017 seasons, respectively. Maize plants were harvested on 19th and 21th September in 2016 and 2017, respectively. Cultural management, disease and pest control programs for maize and soybean crops were followed as recommended by the Egyptian Ministry of Agriculture.

Crop yield determination

Maize traits:

At maturity, ten guarded plants of maize from each experimental unit were taken randomly and the plant height (cm), number of rows/ear and weight of 100 kernels (g) were measured and the all harvested plants from each experimental unit were used to determine the grain yield (kg/fed) after adjustment the grains moisture to 15.5%.

Soybean traits:

At maturity, ten guarded plants of soybean from each experimental unit were taken randomly and the plant height (cm), number of seed/plant and weight of 100 seed (g) were measured and the all harvested plants from each experimental unit were used to determine the seed yield (ton/fed).

Competitive relationships

Land equivalent ratio (LER)

Defined as the ratio of area needed under sole cropping to intercropping system at the same management level to gain an equivalent yield (Willey, 1979). It is calculated as follows:

$$\mathbf{LER} = (\mathbf{Y_{ab}/Y_{aa}}) + (\mathbf{Y_{ba}/Y_{bb}})$$

Where Y_{aa} = Pure stand yield of crop (a); Y_{bb} = Pure stand yield of crop (b); Y_{ab} = Intercrop yield of crop a and Y_{ba} = Intercrop yield of crop b.

Monetary advantage index (MAI)

Suggests that the economic assessment should be in terms of the value of land saved, this could probably be most assessed on the basis of the rentable of this land. MAI was calculated according to the formula, suggested by (Willey, 1979):

$$\mathbf{MAI} = \frac{\mathbf{Value\ of\ combined\ intercrops} \times \mathbf{LER} - \mathbf{1}}{\mathbf{LER}}$$

In Egyptian pound maize price was 2.45 L.E./kg for grain yield and soybean was 4388 L.E./ton for seed yield of the two seasons (Bulletin of Statistical Cost Production and Net Return, 2017).

Statistical analysis:

Collected data were analyzed by MSTAT-C (1991) software package according to Gomez and Gomez (1984). Means were compared using revised Least Significant Difference (RLSD) at 5% level of significant (Steel and Torrie, 1981).

RESULTS AND DISCUSSION

Effect of antioxidants on yields and its attributes of maize and soybean.

Concerning, maize traits results presented in Table 2 showed that foliar spray of maize plants by salicylic and /or ascorbic acid enhanced significantly all studied traits except plant height in both seasons as compared to the control treatment. Thus, the highest number of rows/ear (13.2 and 13.8), weight of 100 kernels (39.8 and 40.8 g) and grain yield (2489.5 and 2643.9 kg/fed) in the first and second seasons, respectively were obtained from sown maize plants which were sprayed by 200 ppm of salicylic acid (SA). These findings are in harmony with those obtained by Borsani *et al.* (2001), Khan *et al.* (2003), Gunes *et al.* (2007), Tufail *et al.* (2013) Said and Abd El-Moneem (2016) and Ahmad *et al.* (2018).

Table 2. Effect of antioxidant foliar spraying on yield and its attributes traits of maize during 2016 and 2017 seasons

Antioxidant	Plant height (cm)	Number of rows/ear	Weight of 100 kernels (g)	Grain yield (kg/fed)
		Season 2016		
Control	203.2	12.6	38.3	2213.4
Ascorbic acid at 200 ppm	200.8	12.9	39.0	2394.8
Salicylic acid at 200 ppm	204.8	13.2	39.8	2489.5
Ascorbic + Salicylic acids at 200 ppm	206.0	12.8	38.6	2298.7
F test	NS	**	**	**
Rev L.S.D 0.05	-	0.2	0.3	49.8
		Season 2017		
Control	203.0	13.1	39.4	2371.0
Ascorbic acid at 200 ppm	204.1	13.6	40.1	2551.2
Salicylic acid at 200 ppm	205.9	13.8	40.8	2643.9
Ascorbic + Salicylic acids at 200 ppm	204.6	13.4	39.7	2456.4
F test	NS	**	**	**
Rev L.S.D 0.05	-	0.2	0.5	109.8

NS and ** means not significant, significant at 0.05 and 0.01 probability, respectively.

Regarding soybean traits, results presented in Table 3 revealed that the investigated foliar spraying with salicylic and /or ascorbic acid at rate of 200 ppm had significant effects on all studied traits in both seasons. Thus, tallest plants (108.5 and 116.7 cm), higher number of seed/plant (87.3 and 94.0), heaviest 100 seed (17.9 and 20.1 g) and higher seed yield (0.726 and 0.755 ton/fed) in both seasons, respectively, were obtained from soybean plants which were spraying by 200 ppm of salicylic acid (SA). These findings are in harmony with those obtained by Jaiswal *et al.* (2014).

The previous results could be attributed to the fact that SA enhances growth vigor of plants and increased plant growth due to exogenous application of salicylic acid may be contributed in physiological processes, such as stomatal conductance, minerals uptake, membrane activity and photosynthesis hence affected growth as reported by Borsani *et al.* (2001).

Table 3. Effect of antioxidant foliar spraying on yield and its attributes traits of soybean during 2016 and 2017 seasons

Antioxidant	Plant height (cm)	Number of seed/plant	Weight of 100 seed (g)	Seed yield (ton/fed)
		Season 2016		
Control	96.5	83.7	16.6	0.661
Ascorbic acid at 200 ppm	104.7	86.2	17.7	0.706
Salicylic acid at 200 ppm	108.5	87.3	17.9	0.726
Ascorbic + Salicylic acids at 200 ppm	97.5	85.1	17.1	0.692
F test	**	**	*	**
Rev L.S.D 0.05	3.0	0.8	0.9	0.014
		Season 2017		
Control	103.5	89.9	18.7	0.706
Ascorbic acid at 200 ppm	112.6	92.7	19.9	0.735
Salicylic acid at 200 ppm	116.7	94.0	20.1	0.755
Ascorbic + Salicylic acids at 200 ppm	105.0	91.6	19.3	0.720
F test	**	**	*	*
Rev L.S.D 0.05	3.6	1.0	0.9	0.031

*** and ** means significant at 0.05 and 0.01 probability, respectively.**

Effect of intercropping patterns on yields and its attributes of maize and soybean.

Results presented in Table 4 showed that intercropping patterns had a significant effect on all studied traits in both seasons except plant height in the first season. The tallest maize plants produced from intercropping pattern of 2:2 followed by pattern of 2:1 in both seasons. Intercropping patterns 2:2 and 2:1 had the tallest plants compared with sole in both season, those may be due to competition of associated crops for intercepted the light intensity compared with sole maize. Similar results were observed by Hamd Alla *et al.* (2014). Maximum number of row/ear, 100 grain weight and grain yields of maize were produced from the sole maize followed by the pattern 2:1. While, the lowest values of previous traits were obtained from the pattern 2:2. The highest maize grain yield in sole and 2:1 pattern may be due to higher population. These results are agreement with those obtained by Abou-Keriasha *et al.* (2012) and Abrar *et al.* (2016).

Table 4. Effect of intercropping patterns on yield and its attributes traits of maize during 2016 and 2017 seasons.

Intercropping patterns	Plant height (cm)	Number of rows/ear	Weight of 100 kernels (g)	Grain yield (kg/ fed)
		Season 2016		
2:1	203.6	12.8	38.5	2332.1
2:2	204.9	12.3	37.8	2009.1
Sole	202.6	13.4	40.5	2706.1
F test	NS	**	**	**
Rev L.S.D $_{0.05}$	-	0.4	0.5	132.0
		Season 2017		
2:1	203.7	13.4	39.7	2499.7
2:2	207.6	12.9	38.7	2140.8
Sole	201.8	14.1	41.6	2876.3
F test	**	**	**	**
Rev L.S.D $_{0.05}$	0.4	0.5	0.6	122.7

NS and ** means not significant, significant at 0.05 and 0.01 probability, respectively.

Results presented in Table 5 cleared that the different intensities of intercropping affected significantly yield and its attributes of soybean in both seasons. Intercropping patterns 2:2 and 2:1 give the tallest plants compared with sole in both seasons. Those results may be due to competition of associated crops for intercepted the light intensity compared with sole maize. Maximum seed numbers/plant, weight of 100 seed and seed yield per feddan of soybean were recorded in sole soybean crop followed by pattern 2:2. Otherwise, the minimum seed numbers/plant, weight of 100 seed and seed yield per feddan were recorded in case of intercropping at 2:1 pattern. The reduction occurs in yield and its attributes may be due to the shading from top of maize plants to top of intercropped soybean which in turn decreased interception of solar radiation. Similar findings were obtained by Metwally *et al.* (2009), Abou-Keriasha *et al.* (2012) and Abrar *et al.* (2016).

Table 5. Effect of intercropping patterns on yield and its attributes traits of soybean during 2016 and 2017 seasons

Intercropping patterns	Plant height (cm)	Number of seed/ plant	Weight of 100 seed (g)	Seed yield (ton/fed)
		Season 2016		
2:1	101.4	79.9	16.4	0.350
2:2	106.4	86.1	17.1	0.715
Sole	97.6	90.7	18.5	1.023
F test	**	**	**	**
Rev L.S.D $_{0.05}$	2.2	0.9	0.7	0.033
		Season 2017		
2:1	109.1	86.1	18.5	0.361
2:2	114.1	92.5	19.2	0.736
Sole	105.1	97.6	20.8	1.090
F test	**	**	**	**
Rev L.S.D $_{0.05}$	1.6	1.1	0.6	0.081

**** means significant at 0.05 and 0.01 probability, respectively.**

Effect of the interaction between antioxidants and intercropping patterns on yields and its attributes of maize and soybean.

The results presented in Table 6 revealed that the interaction between antioxidants foliar spray and intercropping pattern couldn't exhibit any significant differences in all traits except weight of 100 kernels of maize in both seasons as well as seed yield (ton/fad) of soybean in the first season only. Thus, the highest of 100 kernel weight

of maize (42.2 and 43.1 g) in the first and second season, respectively. which produced from sole maize plants foliar spraying with 200 ppm of salicylic acid. Meantime, the highest seed yield of soybean (1.048 ton/fed) in the first season was attended to sole soybean plants with foliar spraying with 200 ppm of salicylic acid. These results are in harmony with those detected by Zilic *et al.* (2010) and Dragicevic *et al.* (2017).

Table 6. Effect of the interaction between antioxidant foliar spraying and intercropping patterns on maize and soybean during 2016 and 2017 seasons for significant traits only.

Characters	Weight of 100 kernels (g) of maize			Seed yield (ton/fed) of soybean		
Intercropping patterns Antioxidant	2:1	2:2	Sole maize	2:1	2:2	Sole soybean
		Season 2016				
Control	38.4	37.1	39.6	0.317	0.671	0.996
Ascorbic acid at 200 ppm	38.6	38.0	40.4	0.363	0.724	1.032
Salicylic acid at 200 ppm	38.9	38.5	42.2	0.369	0.759	1.048
Ascorbic + Salicylic acids at 200 ppm	38.4	37.6	39.8	0.351	0.708	1.018
F test		**			**	
Rev L.S.D $_{0.05}$		0.5			0.13	
		Season 2017				
Control	39.4	38.1	40.7	0.351	0.708	1.060
Ascorbic acid at 200 ppm	39.8	39.1	41.6	0.366	0.739	1.099
Salicylic acid at 200 ppm	40.0	39.2	43.1	0.373	0.776	1.117
Ascorbic + Salicylic acids at 200 ppm	39.5	38.7	41.0	0.354	0.722	1.084
F test		*			NS	
Rev L.S.D $_{0.05}$		0.7			-	

NS, * and ** means not significant, significant at 0.05 and 0.01 probability, respectively.

Effect of antioxidants and intercropping patterns on Land equivalent ratio (LER) and Monetary advantage index (MAI) of maize and soybean.

Land equivalent ratio (LER)

Results presented in Table 7 revealed that land equivalent ratio (LER) values were greater than one in both seasons. Here too, it could be concluded that actual productivity was higher than the expected productivity. The results also showed that maize was superior of soybean in the antioxidant treatments and intercropping patterns. The SA and intercropping pattern of 2:2 give higher relative yields of maize (RY_m) and relative yields of soybean (RY_s) compared with the other treatments studied. The highest LER (1.48 and 1.46) in the two respective seasons were observed when salicylic acid was spraying on intercropping pattern 2:2 plants. Similar results in this respect were observed by of Metwally *et al.* (2005), Aziz *et al.* (2012), Abou-Keriasha *et al.* (2012) and Hamd Alla *et al.* (2014).

Monetary advantage index (MAI)

Monetary advantage index (MAI) is considered an indicator of the economic feasibility of antioxidant and intercropping patterns, results recorded in Table 7 showed that the highest MAI values of 2663.98 and 2697.14 were obtained from foliar spraying salicylic acid at 200 ppm with intercropping pattern of 2:2 in first and second seasons, respectively. These MAI values were positive due to LER which were greater than one. The previous results are in same line with those obtained by Abou-Keriasha *et al.* (2012) and Hamd Alla *et al.* (2014) who's stated that economic benefit expressed with the higher MAI values in intercropping.

Table 7. Effect of antioxidants and intercropping patterns on Land equivalent ratio (LER) and Monetary advantage index (MAI) of maize and soybean during 2016 and 2017.

Characters	Relative yield		LER	Relative yield		LER	MAI	
	Maize	Soybean		Maize	Soybean			
Intercropping patterns Antioxidant	2:1			2:2			2:1	2:2
			Season 2016					
Control	0.89	0.32	1.21	0.76	0.67	1.43	1186.85	2284.11
Ascorbic acid at 200 ppm	0.85	0.35	1.20	0.73	0.70	1.43	1217.96	2477.00
Salicylic acid at 200 ppm	0.88	0.35	1.23	0.76	0.72	1.48	1341.09	2663.98
Ascorbic + Salicylic acids at 200 ppm	0.84	0.35	1.18	0.73	0.70	1.42	1174.31	2449.95
			Season 2017					
Control	0.89	0.33	1.22	0.75	0.67	1.42	1363.18	2391.28
Ascorbic acid at 200 ppm	0.86	0.33	1.19	0.74	0.67	1.41	1237.09	2489.83
Salicylic acid at 200 ppm	0.88	0.33	1.22	0.76	0.69	1.46	1367.50	2697.14
Ascorbic + Salicylic acids at 200 ppm	0.85	0.33	1.18	0.73	0.67	1.39	1185.71	2439.04

CONCLUSION

From the obtained results, it could be recommended that maximum land equivalent ratio and monetary advantage index were produced from intercropping pattern of 2:2 of maize and soybean plants which were sprayed with salicylic acid at rate of 200 ppm.

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تأثير الرش الورقي بمضادات الأكسدة ونظم تحميل الذرة الشامية وفول الصويا على المحصول ومكوناته

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أجريت تجربة حقلية بمزرعة قسم المحاصيل، كلية الزراعة بجامعة أسيوط خلال الموسمين 2016 و2017 بهدف دراسة تأثير الرش الورقي بمضادات الأكسدة ونظم تحميل الذرة الشامية وفول الصويا على المحصول ومكوناته. تمت دراسة عاملين، كان العامل الأول هو الرش بمضادات الاكسدة (كنترول، حامض الاسكوربيك بتركيز 200 جزء في المليون، حامض السلسليك بتركيز 200 جزء في المليون، الاسكوربيك +السلسليك بتركيز 200 جزء في المليون) وأربعة نظم التحميل (2:2، 1:2، الزراعة المنفردة من الذرة الشامية والزراعة المنفردة من فول الصويا) كعامل ثاني. وأشارت النتائج الي:1- تأثرت جميع الصفات التي تم دراستها تأثرت معنويا بالرش بمضادات الاكسدة ونظم التحميل المختلفة لمحصولي الذرة الشامية وفول الصويا ما عدا ارتفاع النبات في محصول الذرة الشامية خلال موسمي الدراسة.2- لقد سجل الرش بحامض السلسليك بتركيز 200 جزء في المليون اعلي المتوسطات للصفات تحت الدراسة لكلا المحصولين.3- أظهرت النتائج ان اعلي محصول ومكونات المحصول في حالة الزراعة المنفردة للذرة الشامية يليها نظام تحميل 1:2 بينما أعطت الزراعة المنفردة اعلي محصول ومكوناته يليها نظام 2:2 في فول الصويا خلال موسمي الزراعة. توصي الدراسة بتحميل الذرة الشامية وفول الصويا بنظام 2:2 والرش الورقي بحامض السلسليك بتركيز 200 جزء في المليون حيث سجل اعلي معدل استغلال الأرض والعائد الاقتصادي من وحدة المساحة تحت ظروف محافظة أسيوط.