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Productivity of Intercropped Wheat with Faba Bean under Crop Sequences and Foliar Application of Humic Acid

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INTERCROPPING cereal-legume (wheat + faba bean) is essential to enhance productivity per unit area, land use efficiency and decreasing the gap between production and consumption in Egypt. Furthermore, we are trying to find the best concentration of humic acid foliar application which could improve the production of wheat and faba bean. A field experiment was set with a combination of five crop sequences and intercropping systems (clover/wheat; wheat + faba bean; clover/wheat + faba bean; sole wheat; sole faba bean) in addition to, three foliar application treatments of humic acid at the rate of control (0.0), 2.0 and 4.0g/L. Results show that foliar application of humic acid and intercropping systems affected significantly all traits of wheat and faba bean except number of branches/plant and plant height in the first season for faba bean. The highest mean values of yield and its components of wheat were obtained when wheat was sown after clover under foliar application with 4g/L humic acid as compared with sole wheat with no foliar application in both seasons. The 2g/L humic acid and wheat + faba bean give higher land equivalent ratio and the lowest values of aggressivity. whereas the highest mean values of area time equivalent ratio and monetary advantage index were obtained from 4g/L humic acid foliar application with clover/wheat + faba bean in both seasons.

Keywords: Intercropping, Sole cropping, Foliar application, Wheat, Faba bean.

Introduction

Wheat (*Triticum aestivum* L.) from cereals and faba bean (*Vicia faba* L.) from legumes are the most important two food crops in Egypt according to the consumed amount of them comparing to other crops. The daily meals of all Egyptian contain at least one product of the previous crops. Recently the gap between production and consumption of wheat reached dangerous level as it exceeded 50% (FAO 2017) and for faba bean production and consumption are almost equal. The problem of wheat production rose up when the Egyptian government tried to increase the cultivated area while in the same season it is competing with faba bean and forage crops in limited area so any increase in the area of wheat led to a decrease in the other winter crops.

In Egypt it important to increase the production of wheat to reduce the food gap resulting from the continuous increasing of the population which is duplicated in the last two decades. There are two main ways to overcome this problem. Increasing cropping area by land reclamation or using intercropping systems. However, land reclamation needs a lot of time, efforts and economically is an expensive way in addition to the limitation in water resources. The faster way is by using intercropping systems including catch crops such as Egyptian mono-cut clover (*Trifolium alexandrinum* L.) to adopt growing three crops per year, which will certainly help to maximize productivity per unit area, land use efficiency and increase net return for farmers without exhausting soil fertility or waste additional water resources (Hamd Alla et al., 2015).

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Intercropping cereal-legume has many advantages for greater growth and productivity of cereals as it leads to an increase in biomass and grain yield. Maize plants intercropped with cowpea exhibited the higher values of yield and yield components than the sole maize (Hamd Alla, et al., 2014) and the same trend was observed when intercropping durum wheat in faba bean (Li et al., 2007). Intercropping improving utilization of resources (water, land, nutrients and light) by 10–50 % over sole crop on the same piece of land expressed in land equivalent ratio (Willey, 1979).

The yield components of faba bean were decreased when intercropped with wheat. Intercropping faba bean with wheat (50% faba bean +100% wheat) increased land equivalent ratio and net returns compared to sole crops (Abdel-Wahab & Amal, 2016). Land equivalent ratio between cowpea and maize was 1.65, the monetary advantage Index was 2360.80 and the aggressivity maize was 0.45 and cowpea was -0.45 (Hamd Alla et al., 2014). Intercropping maize and soybean with foliar spraying of salicylic acid recorded the maximum land equivalent ratio and monetary advantage index (Said & Hamd-Alla, 2018).

In Egypt, faba bean intercropped with other winter crops such as (wheat, tomato, garlic, sugar beet, fennel and onion) is a good way for increasing the cultivated area of it helping to decrease the gap between production and consumption. Moreover, it will provide additional area for wheat production without noticeable reduction in faba bean production. Most of agricultural land in Egypt is alkaline, having a high pH which reduce the availability of plant nutrients leading to a decrease in productivity. In addition, the intensification system due to the limited agricultural area in Egypt coupled with micronutrient deficiencies led to low fertility soils with low organic matter. Humic acid (HA) plays an important role in improving plant growth as it could be utilized to address micronutrients deficiency in the alkaline soils. Affecting plant growth could be ascribed to an improve in physical properties (Chen & Aviad, 1990; Sharif et al., 2002; Ghada et al., 2018). Recently, as a modern fertilization strategy, the foliar spray with different molecules as humic acid has been introduced, as these organic substances did not have any bad effect on the environment (Senn, 1991; Jindo et al., 2012; Rosa et al., 2018).

Therefore, the present research was concerned with finding the best intercropping combination and to finding the best concentration of humic acid foliar application which can be used to improve the production of wheat and faba bean.

Materials and Methods

Experimental site

This work was carried out at Agronomy Department Farm, Faculty of Agriculture, Assiut University, Egypt during 2016/2017 and 2017/2018. The preceding crop was maize in both seasons. Soil properties of experimental site are shown in Table 1.

TABLE 1. Soil physical and chemical properties of representative soil samples (0–30cm depth) of the experimental soil.

Soil property	
Particle - size distribution	
Silt (%)	26.4
Sand (%)	24.3
Clay (%)	49.3
Texture	Clay
Organic matter (%)	1.70
Field capacity (%)	42.8
EC (dS m^{-1})	0.77
pH (1:1 suspension)	8.2
Total nitrogen (%)	0.72
$CaCO_3$ (%)	3.5

* Each value represents the mean of three replications.

Experimental design and treatments

A field experiment was carried out in a randomized complete block design using split block arrangement with three replications. The first variable was three foliar application treatments of humic acid in a solid form as potassium humate (85%) at the rate of control (0.0), 2.0 and 4.0g/L (480L/ha), which occupied in horizontal plots. Two equal foliar applications at 20 days interval sprayed with humic acid started 30 days after sowing of wheat.

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

1- Clover/wheat (C/W): Wheat was planted after cutting (removing clover from soil) in six rows (120cm width) at 15cm between rows and 20cm between hills (100% wheat).

2- Wheat + faba bean (W+B): Faba bean seeds were sown in both sides of ridge (120cm width) by growing two plants/hill distanced at 20cm, in the meantime six rows of wheat were grown in middle of the ridge at 15cm row spaces and 20cm between hills (50% faba bean + 100% wheat).

3- Clover/wheat + faba bean (C/W+B): With the same method as described at (1) and (2). (50% faba bean + 100% wheat).

4- Sole wheat (SW): Wheat grown in six rows (120 cm width) at 15cm between rows and 20cm between hills (100% wheat).

5- Sole faba bean (SB): Seeds were drilled in four rows (120cm width), with two plants/hill and 20cm between hills (100% faba bean).

The experimental unit area was 10.5 m^2 (3x3.5m). Mono-cut Egyptian clover Var. Fahl (Giza1) seeds were sown on 15th and 17th September in 2016 and 2017 seasons, respectively with seed rate 48kg/ha. Seeds of faba bean cultivar Giza 3 were inoculated with Rhizobium leguminosarum before sowing. Faba bean seeds were sown on 15th and 18th October in 2016 and 2017 seasons, respectively with seed rate 119kg/ha. Wheat cv. Gemmiza 11 was sown on 25th and 27th November in 2016 and 2017 seasons, respectively with seed rate wheat 80kg/ha. Calcium super phosphate (15.5% P_2O_5) at the rate of 476kg. ha^{-1}. and potassium sulfate (48.0% K_2O) at the rate of 119kg per ha. were applied during soil preparation in the two seasons for all crops. Mineral N fertilizer of faba bean was added at the rate of 47.6kg N/ ha as urea' 46.5% N" after 21 days from sowing under sole and intercropping. Mineral nitrogen fertilizer for sole wheat and intercropped at the rate of 388kg N/ha (100% recommended), of urea' 46.5% N' in three doses, after 21, 45 and 65 days from sowing. Egyptian clover Var. Fahl plants were cut on 19th and 21th November in 2016 and 2018 seasons, respectively. Faba bean plants were harvested on 1st and 4th April in 2017 and 2018 seasons, respectively. Finally, wheat plants were harvested on 7th and 10th May in 2017 and 2018, respectively. All other cultural practices for all crops were done following the recommendation of the Egyptian Ministry of Agriculture.

Crop yield determination

Egyptian clover Var. Fahl (Giza1) traits:

Clover (Fahl) fresh forage yield in ton/ha was assessed in the first and second seasons.

Faba bean traits

At harvest, ten guarded plants of faba bean from each experimental unit were taken randomly to determine plant height (cm), number of branches/ plant, number of pods/plant and weight of 100 seed (g). Finally, all plants from each experimental unit were harvested to determine the seed yield (kg/ha).

Wheat traits

At harvest, number of spikes/m^2 for each experimental unit was recorded then ten guarded stems were taken randomly from each experimental unit and the following traits were measured i.e. plant height (cm), grains number/ spike and 1000 grain weight (g). In addition, grain, straw and biological yields (kg/ha) were measured as all harvested plants from each experimental unit were weighted then threshed to assess grain and straw yields.

Intercropping indices

Land equivalent ratio (LER)

Defined as the ratio of area needed under sole crop to intercropping at the same conditions to gain an equivalent yield (Willey, 1979). LER was determined according to the following formula :

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

where Y_{aa}= Sole crop yield (a); Y_{bb}= Sole crop yield (b); Y_{ab}= Intercrop yield of crop a and Y_{ba}= Intercrop yield of crop b.

Area time equivalent ratio (ATER)

$$\frac{\{(L_a \times T_a) + (L_b \times T_b)\}}{T}$$

Area time land equivalent ratio (ATER) takes in to account the duration of crops and permits an evaluation of crops on yield per day basis. It is a modification of LER and expressed as below:

ATER= {(La × Ta) + (Lb × Tb)} (Hiebsch & Mccollum, 1987)

where L_a and L_b are the relative yield or partial LER of component crops 'a' and 'b'; T_a and T_b is the duration of component crops and T is the total duration of the crop sequences and intercropping system.

Aggressivity (A)

This parameter was used to determine the competitive relationship between two crops in a mixture as indicated by Mc-Gillichrist (1960). The aggressivity was calculated as: $AW= (Y_{IW}/Y_W \times Z_{IW}) - (Y_{IF}/Y_F \times Z_{IF})$, and $AF= (Y_{IF}/Y_F \times Z_{IF}) - (Y_{IW}/Y_W \times Z_{IW})$, where: Z_{IW}= Sown proportion of crop wheat (in wheat intercropping with faba bean); Z_{IF}= Sown proportion of crop faba bean (in faba bean intercropping with wheat).

Monetary advantage index (MAI)

However, none of the above competition indices provides any clear information on the economic advantage of the intercropping system. For this reason, the monetary advantage index (MAI) was calculated according to the formula, suggested by Willey (1979):

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

To calculate the monetary advantage index (MAI) (US$) were used: 250 US$/ton for wheat grains, 760US$/ton for faba bean seeds and 26.44US$/ton for fresh forage of clover, prices presented by (Egyptian Bulletin of Statistical Cost Production and Net Return, 2017).

Statistical analysis

Analysis of variance was carried out using SAS program version 9.2 (SAS, 2008) and Revised Least Significant Difference (R.LSD) at 5% level of probability was used to compared between means (Steel & Torrie, 1981).

Results and Discussion

Egyptian clover Var. Fahl (Giza1) yield

Data in Table 2 summarized the clover (Fahl) fresh forage yield in ton /ha during 2016/2017 and 2017/2018 growing seasons in the land which was occupied by the experiment and these data were used to calculate the area time equivalent ratio (ATER) and monetary advantage index (MAI).

TABLE 2. Mean values of clover (Fahl) fresh forage yield in ton/ha during 2016/2017 and 2017/2018 growing seasons.

Land of preceding treatment	Forage fresh yield ton/ha	
	2016/2017	2017/2018
Land of control humic C/W	41.17	50.33
Land of control humic C/W+B	38.64	45.99
Land of 2g/L humic C/W	42.68	52.85
Land of 2g/L humic C/W+B	37.52	45.85
Land of 4g/L humic C/W	40.62	48.72
Land of 4g/L humic C/W+B	39.57	47.85

Crop sequences and intercropping systems of wheat

Yield and its attributes

Results in Table 3 show that plant height, number of spikes/m^2, grains number/spike and 1000grain weight were affected significantly by crop sequences and intercropping systems in both seasons. C/W+B had the tallest plants (111.73 and 114.25cm) in the first and second seasons, respectively as compared with sole wheat which had the shortest plants (104.23 and 106.77cm) in the first and second seasons, respectively. On the other hand, C/W produced the maximum values of number of spikes/m^2, grains number/spike and 1000 grain weight followed by C/W+B then sole wheat in the first and second seasons. The lowest value in this respect was obtained from C/W in both growing seasons. The data showed that the average yields obtained were 7245.24, 6643.91, 6989.80 and 6833.24kg/ha. in 2016/2017 season for the crop sequences and intercropping systems of C/W, W+B, C/W+B and SW, respectively (Table 4). The corresponding means in 2017/2018 were 7545.79, 6857.97, 7226.08 and 7089.62kg/ha. in the same order. C/W intercropping system produced the heavier weight of straw and biological yields as compared with SW and W+B. wheat plant under crop sequences and intercropping systems was taller than that in the SW in both seasons, this may be due to competition between the two crops for light intensity interception, leading to an increase

of the height of wheat plants. Furthermore, crop sequences and intercropping systems produced the highest mean value of number of spikes/m^2, grains number/spike, 1000 grain weight, grain, straw and biological yields of wheat. This trend could be ascribed to the effect of planting wheat after a legume crop (clover) which produced the maximum yield and its attributes due to better nitrogen supply as compared with planting wheat after fallow. In addition, the increase in wheat yields under C/W treatment may be due to less weed competition as weeds were eliminated during clover cutting before planting wheat plants. These results are logic since plant height the main constituents of straw took the same trend as previously stated. The present results are in general accordance with those obtained by Li et al. (2007), Hamd Alla et al. (2014, 2015) and Abdel-Wahab & Amal (2016).

Humic acid foliar application of wheat

Yield and its attributes

Results presented in Table 3 indicate that humic acid as foliar application had significant effect on plant height, number of spikes /m^2, grains number/spike and 1000 grain weight in both seasons. Spraying humic acid with 4g/L exceeded the control and 2g/L treatments in all previous measured traits in this study. As the highest values were 113.64 cm for plant height, 76.06 for grains number/spike and 50.40 for 1000 grain weight in the second season, while, number of spikes/ m^2 had the highest recorded 380.00 in the same treatment in the first season. On the other hand, control treatment recorded the lowest values in the previous traits in the two growing seasons. Results in Table 4 show that grain, straw and biological yields /ha were affected significantly by humic acid foliar application in the two growing seasons. The highest average yields obtained were 7744.92, 12875.80 and 20620.71kg/ha for grain, straw and biological yields respectively, were obtained from spraying humic acid with 4g/L in 2016/2017 season. The corresponding means in 2017/2018 were 7965.27, 13049.54 and 21014.80kg/ha in the same order. The tallest wheat plants obtained from foliar application of humic acid with 4g/L in both seasons may be due to humic substances may contain hormone molecules in their structure or induce the production of endogenous hormones that affect plant physiological processes and growth (Jindo et al., 2012). In addition, foliar application of humic acid with 4g/L produced the highest mean value of number of spikes/m^2, grains number/spike, 1000 grain weight, grain, straw and biological yields of wheat. As, humic acid may influences respiration and photosynthesis, formation of complex with mineral ions, catalysis to enzymes, and stimulation of nucleic acid metabolism (Schnitzer & Khan, 1972).

Effect of interaction between crop sequences and intercropping systems with humic acid foliar application on wheat

The effect of interaction between crop sequences and intercropping systems with humic acid foliar application on wheat was not significant for all studied traits except plant height in the second season, in addition to, straw and biological yields in both seasons (Table 5). As the highest mean value of straw yield was obtained with C/W under foliar application with 4g/L humic acid with an increase about 37.00 and 36.16% in the first and second seasons respectively, as compared with sole sowing with no humic acid application (Fig.1). Finally, biological yield responds the same as straw yield with an increase about 35.23 and 24.40% in the first and second seasons respectively, as compared with sole sowing with no humic acid application (Fig. 2). Growing wheat after clover under foliar spray with 4g/L humic acid gave the highest straw and biological yields as the application of humic acid under this crop sequences may be increased the N uptake in higher amounts than other treatment combination which led to an increase in growth resulted in high straw and biological yields. These findings are in accordance with the study made by Rosa et al. (2018).

Faba bean

Crop sequences and intercropping systems

Yield and its attributes of faba bean

Data in Table 6 clarify that crop sequences and intercropping systems had a significant effect on all studied traits in both seasons except plant height and number of branches/plant in the first season. The tallest faba bean plants produced from the crop sequences and intercropping system of C/W+B followed by system of W+B in both seasons. The shortest plants in this regard were of SB. Also data in the same table show that the highest values of number of branches/plant, number of pods/plant, weight of 100 seed and seed yield/ha in favor of SB followed by W+B. The lowest values in this respect were obtained from the crop sequences and intercropping systems of C/W+B in the two growing seasons. The height plant of faba bean under crop sequences and intercropping system was more than that in the SB, these results may be due

to competition of associated crop for intercepted the light intensity. However, number of branches/ plant, number of pods/plant, weight of 100 seed and seed yield/ha of faba bean was decreased when intercropped with wheat compared with SB in the two growing seasons. This reduction under crop sequences and intercropping was ascribed to low plant density of faba bean (50% of monoculture) with the highest plant density of wheat (100%) which, probably reduced the interception of solar radiation by faba bean plants compared with the SB (100%). These findings are in agreement with those obtained by Abou-Keriasha et al. (2013), Hamd Alla et al. (2014), Abdel-Wahab & Amal (2016), Said & Hamd-Alla (2018) and Ghada et al. (2018).

Humic acid foliar application

Data in Table 6 show that humic acid foliar application had significant effect on all studied traits in both seasons except number of branches/ plant in second season only. The tallest faba bean plants produced from spraying humic acid with 4g/L in both seasons, while there is no significant difference between control and spraying humic acid with 2g/L. The highest values of number of pods/plant, weight of 100 seed and seed yield/ ha produced from spraying humic acid with 4g/L in both seasons. On the other hand, the lowest values in this respect were obtained from control treatment in the two growing seasons. Faba bean plant sprayed with humic acid with 4g/L was taller than the control. In the same trend, number of pods/plant, weight of 100 seed and seed yield/ha of faba bean were increased by sprayed humic acid as compared with the control in the two growing seasons. This increase might be due to enhancing the growth and development by increasing humic acid supply. Same results were reported by Sani (2014) as humic acid significantly affects plant growth and development. Beside, improving crop growth, humic acid increased nutrients uptake (Khan et al., 2018).

Effect of interaction between crop sequences and intercropping systems with humic acid foliar application on faba bean

Results in Table 7 revealed that the effect of interaction between crop sequences, intercropping systems and humic acid foliar application had no significant effect on all studied traits of faba bean except seed yield in both seasons. The lowest mean value of seed yield recorded under C/W+B treatment with no foliar application as compared with sole faba bean with no foliar application as the reduction reached about 69% as compared with sole faba bean with no foliar application in the first season (Fig. 3) this reduction is might be due to that faba bean was grown in 50% of its density as compared with sole treatment and this may be led to a big reduction in its yield in addition to the competition for light and nutrients. These finding are in accordance with the study made by Rosa et al. (2018).

Intercropping indices

Land equivalent ratio (LER)

Results presented in Table 8 demonstrated that land equivalent ratio (LER) values were greater than one in two growing seasons. Here too, it could be concluded that actual productivity was higher than the expected productivity. The results also found that wheat was superior to faba bean in the humic acid treatments and intercropping systems. The 2g/L humic acid and intercropping system of W+B give higher LER (1.37 and 1.38) in first and second seasons, respectively compared with the other treatments studied. The data on LER of different humic acid and intercropping systems indicated that LER values were greater than one in all treatments and it indicated the yield advantage over mono-cropping due to the better utilization of environmental resources for growth in both season. Values of partial LER of wheat were higher than the partial LER of faba bean. Abdel-Wahab & Amal (2016), reported that intercropping faba bean with wheat (50% faba bean +100% wheat) increased land equivalent ratio and net returns compared to sole crops.

Area time equivalent ratio (ATER)

The area time equivalent ratio provides a more realistic comparison of the yield advantage of intercropping over that of sole cropping that the land equivalent ratio as it considers variation in time taken by component crops of different intercropping systems. However, crop production is a function of both crop duration (time) and land area. The data regarding the ATER are presented in Table 8. In both the crop sequences and intercropping systems the area time equivalent ratio values were lesser than LER values indicating the over estimation of resource utilization contrary to land equivalent ratio. ATER values were lesser in C/W+B and in W+B than LER values indicating the over estimation of resource utilization contrary to land equivalent ratio. Higher value of area time equivalent ratio was observed in 4g/L humic with C/W+B crop sequences and intercropping system.

TABLE 3. Effect of crop sequences, intercropping systems and foliar application of humic acid on plant height, number of spikes/m², number of grains/spike and 1000 grain weight of wheat during 2016/2017 and 2017/2018 growing seasons.

Trait	Plant height (cm)		Number of spikes/m²		Number of grains/spike		1000 grain weight (g)	
Season	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**
Crop sequences and intercropping treatments								
SW	104.23	106.77	334.67	334.33	67.88	70.05	45.82	46.94
W+B	107.32	111.97	315.11	311.00	63.58	65.90	43.67	44.63
C/W	109.70	112.39	372.00	376.33	75.06	77.22	50.34	51.59
C/W+B	111.73	114.25	352.89	356.33	71.27	73.23	47.82	49.07
R. LSD $_{0.05}$	**0.85**	**2.32**	**17.39**	**9.90**	**2.30**	**0.98**	**2.03**	**0.96**
Foliar application of humic acid levels								
Control	104.70	109.71	293.00	298.00	64.59	67.00	44.01	44.90
2g/L Humic	108.16	110.68	358.00	356.50	69.66	71.74	47.56	48.88
4g/L Humic	111.88	113.64	380.00	379.00	74.09	76.06	49.17	50.40
R. LSD $_{0.05}$	**0.64**	**3.10**	**38.89**	**30.16**	**1.73**	**2.44**	**1.84**	**0.37**
CV%	0.72	1.90	2.96	2.92	3.63	1.14	4.16	1.90
Analysis of variance (Mean squares)								
Rep	24.56 **	0.31 ^{NS}	13249.33 **	10920.33 **	6.60 ^{NS}	12.20 **	13.89 ^{NS}	0.33 ^{NS}
Intercrop (I)	93.69 **	92.65 **	5352.74 **	7137.00 **	215.09 **	207.32 **	72.77 **	79.45 **
Error I	0.61	4.18	235.41	81.22	4.39	0.82	3.23	0.78
Humic (H)	154.87**	50.34 *	24556.00 **	20979.00 **	271.39 **	246.56 **	83.51 **	96.60 **
Error H	0.32	7.11	1117.33	672.33	2.22	4.42	2.51	0.1
I*H	1.23 ^{NS}	26.23 **	54.07 ^{NS}	87.00 ^{NS}	0.87 ^{NS}	0.85 ^{NS}	0.40 ^{NS}	0.70 ^{NS}
Error	0.61	4.49	103.41	101.22	6.37	0.67	3.82	0.83

*, ** and NS means significant (P≤0.05), highly significant (P≤0.01) and not significant (P>0.05), respectively.

TABLE 4. Effect of crop sequences, intercropping systems and foliar application of humic acid on grain, straw and biological yields kg/ha of wheat during 2016/2017 and 2017/2018 growing seasons.

Trait	Gran yield kg/ha		Straw yield kg/ha		Biological yield kg/ha	
Season	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**
Crop sequences and intercropping treatments						
SW	6833.24	7089.62	11320.33	11456.52	18153.58	18546.15
W+B	6643.9	6857.97	10997.71	11029.71	17641.61	17887.68
C/W	7245.24	7545.79	12367.53	12414.87	19612.78	19960.66
C/W+B	6989.79	7226.07	12081.93	12159.42	19071.73	19385.49
R. LSD $_{0.05}$	**184.77**	**135.06**	**492.50**	**313.00**	**491.56**	**179.58**
Foliar application of humic acid levels						
Control	6191.96	6448.61	10412.50	10406.55	16604.46	16855.16
2g/L Humic	6847.26	7125.72	11787.34	11839.31	18634.60	18965.03
4g/L Humic	7744.91	7965.26	12875.80	13049.54	20620.71	21014.80
R. LSD $_{0.05}$	**631.47**	**287.49**	**1876.90**	**1326.79**	**2089.17**	**1121.75**
CV%	2.32	1.78	2.3	1.45	1.52	1.44
Analysis of variance (Mean Squares)						
Rep	79744.05 ^{NS}	1378658.79 **	3504347.77 **	16722396.36 **	2554933.28 **	8498039.23 **
Intercrop (I)	582467.11 **	743389.72 **	3685699.20 **	3641114.08 **	7093397.00 **	7507827.53 **
Error I	26523.87	15120.64	187345.62	81207.36	200286.68	26730.1
Humic (H)	7293701.09 **	6927112.30 **	18285561.81 *	21005708.02 **	48392730.83 **	51911551.00 **
Error H	294553.21	61054.21	2602212.77	1300359.31	3224108.51	929514.4
I*H	25042.31 ^{NS}	36237.53 ^{NS}	364095.04 **	387352.44 **	497481.38 **	557651.20 **
Error	25886.94	16346.99	72441.38	29247.81	79756.4	74342.3

*, ** and NS means significant (P≤0.05), highly significant (P≤0.01) and not significant (P>0.05), respectively.

TABLE 5. Effect of the interaction between crop sequences and intercropping systems with foliar application of humic acid on plant height, straw and biological yields of wheat during 2016/2017 and 2017/2018 growing seasons.

Trait	Plant height (cm)				Straw yield (kg/ha)				Biological yield (kg/ha)			
	SW	W+B	C/W	C/W+B	SW	W+B	C/W	C/W+B	SW	W+B	C/W	C/W+B
Season 2016/2017												
Control	100.20	104.00	106.40	108.20	4277.30	4088.00	4622.70	4512.00	6833.30	6576.00	7384.00	7113.30
2g/L Humic	105.20	107.00	108.90	111.50	4906.70	4760.00	5106.70	5037.30	7756.00	7553.30	8097.30	7912.00
4g/L Humic	107.30	111.00	113.80	115.50	5085.30	5014.70	5860.00	5680.00	8293.30	8108.00	9240.70	9014.70
R. LSD $_{0.05}$	NS				502.83				514.20			
Season 2017/2018												
Control	102.90	115.20	110.00	110.90	4353.00	4027.00	4583.00	4527.00	7020.50	6626.50	7452.50	7228.50
2g/L Humic	107.90	109.60	111.70	113.60	4913.00	4793.00	5139.00	5053.00	7880.50	7690.50	8272.50	8030.50
4g/L Humic	109.60	111.10	115.60	118.30	5175.00	5083.00	5927.00	5747.00	8476.50	8230.50	9435.50	9176.50
R. LSD $_{0.05}$	3.85				291.52				486.24			

NS means not significant, significant at 0.05 probability.

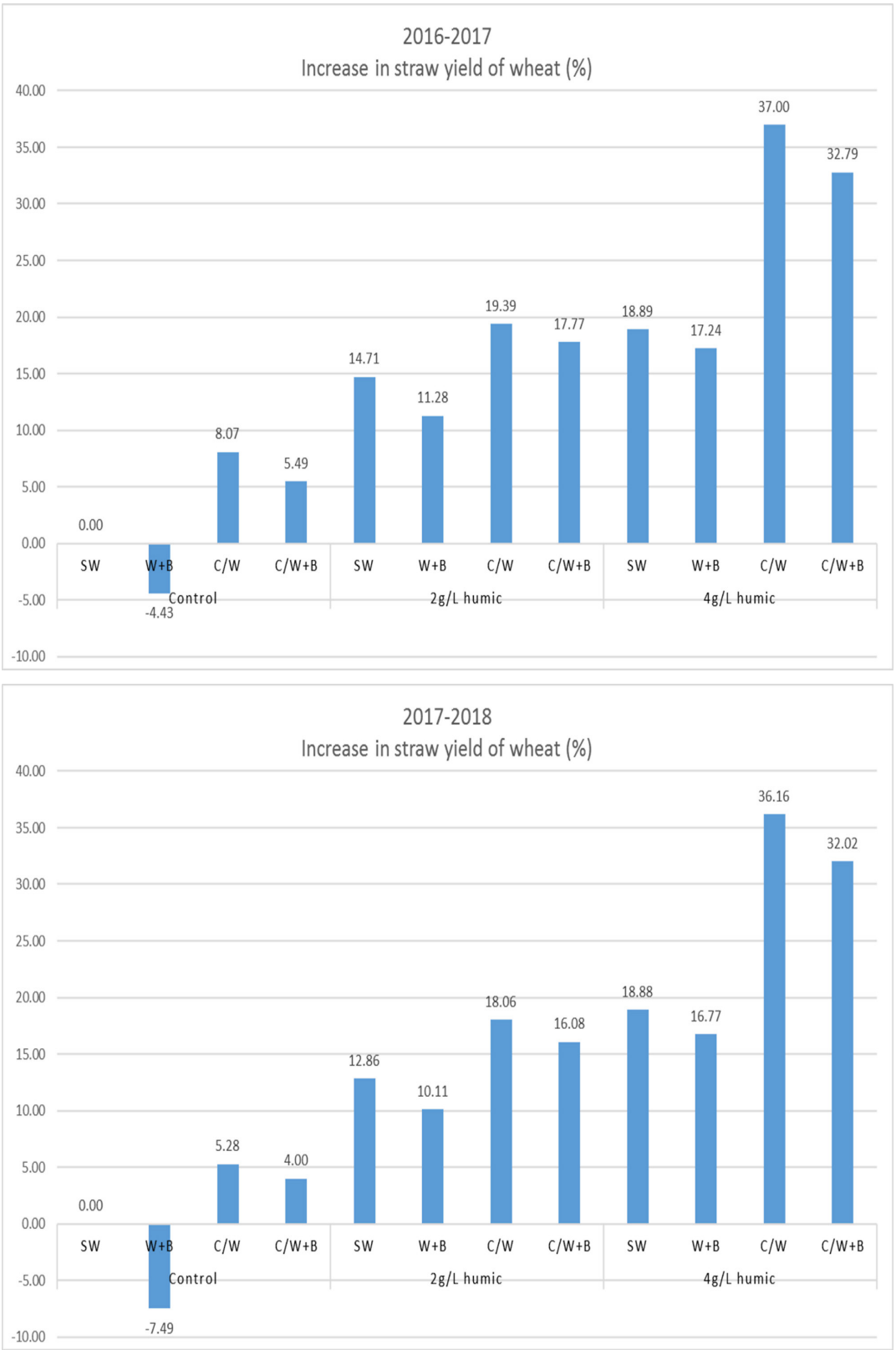

Fig.1. Increase in wheat straw yield (%) as compared with sole sowing with no humic acid application.

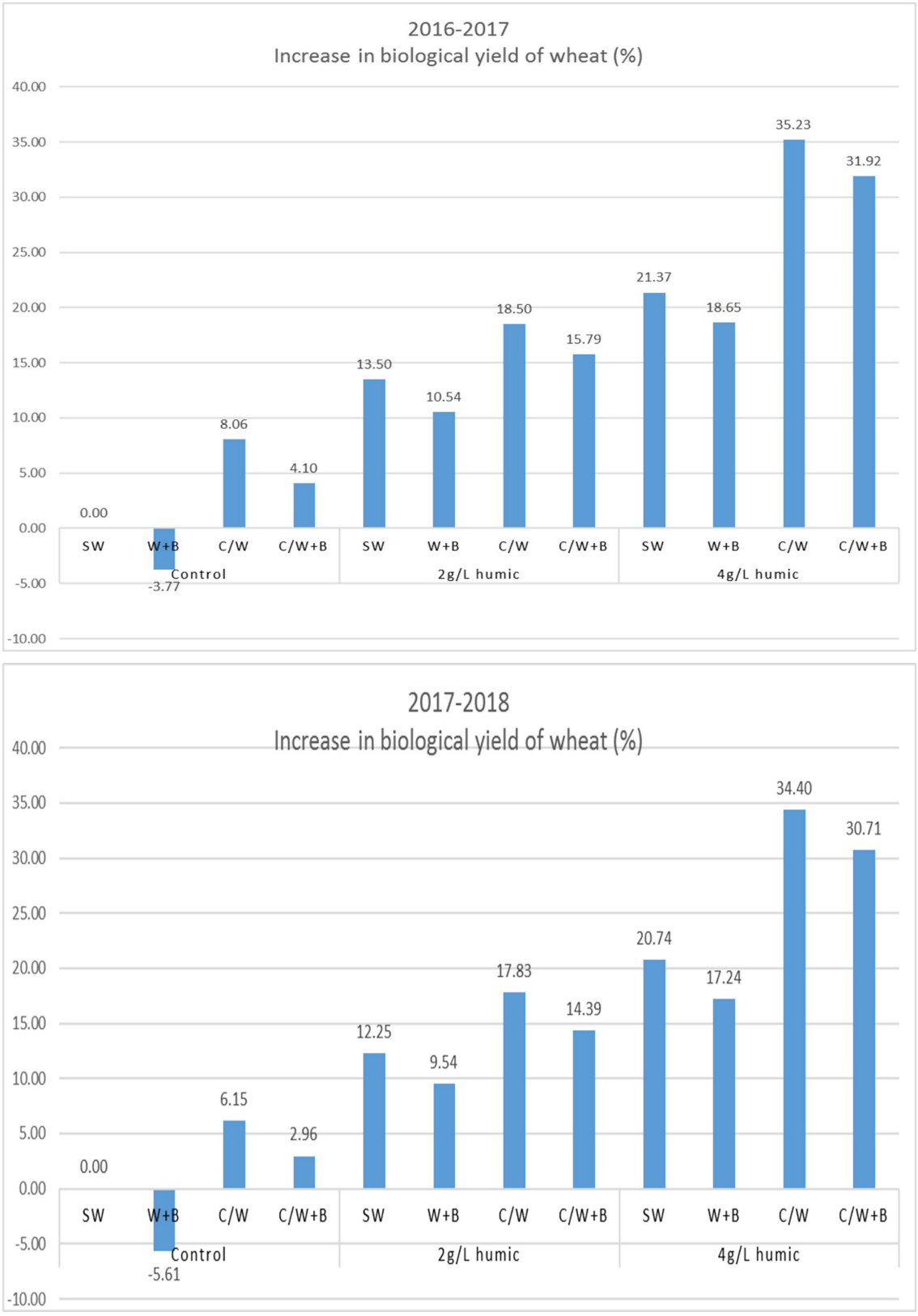

Fig. 2. Increase in wheat biological yield (%) as compared with sole sowing with no humic acid application.

TABLE 6. Effect of crop sequences, intercropping systems and foliar application of humic acid on yield and its attributes of faba bean during 2016/2017 and 2017/2018 growing seasons.

Trait	Plant height (cm)		Number of branches/ plant		Number of pods/plant		Weight of 100 seed (g)		Seed yield (kg/ha)	
Season	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**	**2016/2017**	**2017/2018**
Crop sequences and intercropping treatments										
SB	82.31	85.78	3.96	4.28	22.84	23.45	72.73	73.62	2257.48	2321.10
W+B	82.69	85.93	3.66	4.10	21.55	22.18	70.07	70.89	822.10	885.31
C/W+B	83.01	86.43	3.34	3.71	20.97	21.67	68.93	69.60	725.42	785.83
R. LSD $_{0.05}$	**NS**	**0.27**	**NS**	**0.23**	**0.83**	**0.10**	**2.79**	**0.36**	**78.33**	**81.63**
Foliar application of humic acid levels										
Control	81.91	85.46	3.40	3.82	20.68	21.42	68.26	68.97	1127.72	1191.38
2g/L Humic	82.31	85.75	3.59	3.93	21.82	22.45	70.04	70.79	1270.06	1342.68
4g/L Humic	83.79	86.93	3.96	4.34	22.86	23.43	73.43	74.35	1407.20	1458.18
R. LSD $_{0.05}$	**1.47**	**0.48**	**NS**	**NS**	**1.38**	**0.55**	**3.43**	**0.95**	**64.95**	**30.31**
CV%	0.67	0.40	9.45	7.84	1.47	1.54	2.67	1.92	5.36	1.27
Analysis of variance (Mean Squares)										
Rep	18.38 **	143.80 **	0.49 ^{NS}	2.04 **	2.69 *	8.58 **	9.97 ^{NS}	45.36 **	6947.95 ^{NS}	21926.40 ^{NS}
Intercrop (I)	1.12 ^{NS}	1.06 **	0.86 ^{NS}	0.76 **	8.24 **	7.53 **	34.16 *	37.95 **	6625174.75 **	6642547.70 **
Error I	0.57	0.04	0.22	0.03	0.38	0.01	4.33	0.08	3399.74	3692.86
Humic (H)	8.84 *	5.49 **	0.73 ^{NS}	0.69 ^{NS}	10.74 *	9.11 **	62.04 *	67.34 **	175763.49 **	161117.76 **
Error H	1.24	0.14	0.25	0.12	1.05	0.17	6.58	0.51	2337.09	509.42
I*H	0.02 ^{NS}	0.27 ^{NS}	0.02 ^{NS}	0.02 ^{NS}	0.29 ^{NS}	0.40 ^{NS}	0.99 ^{NS}	1.48 ^{NS}	33170.24 **	28922.63**
Error	0.31	0.12	0.12	0.1	0.1	0.12	3.56	1.87	4628.99	286.76

*, ** and NS means significant (P≤0.05), highly significant (P≤0.01) and not significant (P>0.05), respectively.

TABLE 7. Effect of the interaction between crop sequences and intercropping systems with foliar application of humic acid on seed yield of faba bean during 2016/2017 and 2017/2018 growing seasons.

Trait	Seed yield (kg/ha)					
	SB	W+B	C/W+B	SB	W+B	C/W+B
	Season 2016/2017			Season 2017/2018		
Control	855.67	303.33	262.50	883.00	331.00	287.75
2g/L Humic	924.33	358.37	318.23	959.50	388.50	344.45
4g/L Humic	1065.55	374.57	333.67	1083.25	396.45	358.35
R. LSD $_{0.05}$	**131.24**			**29.41**		

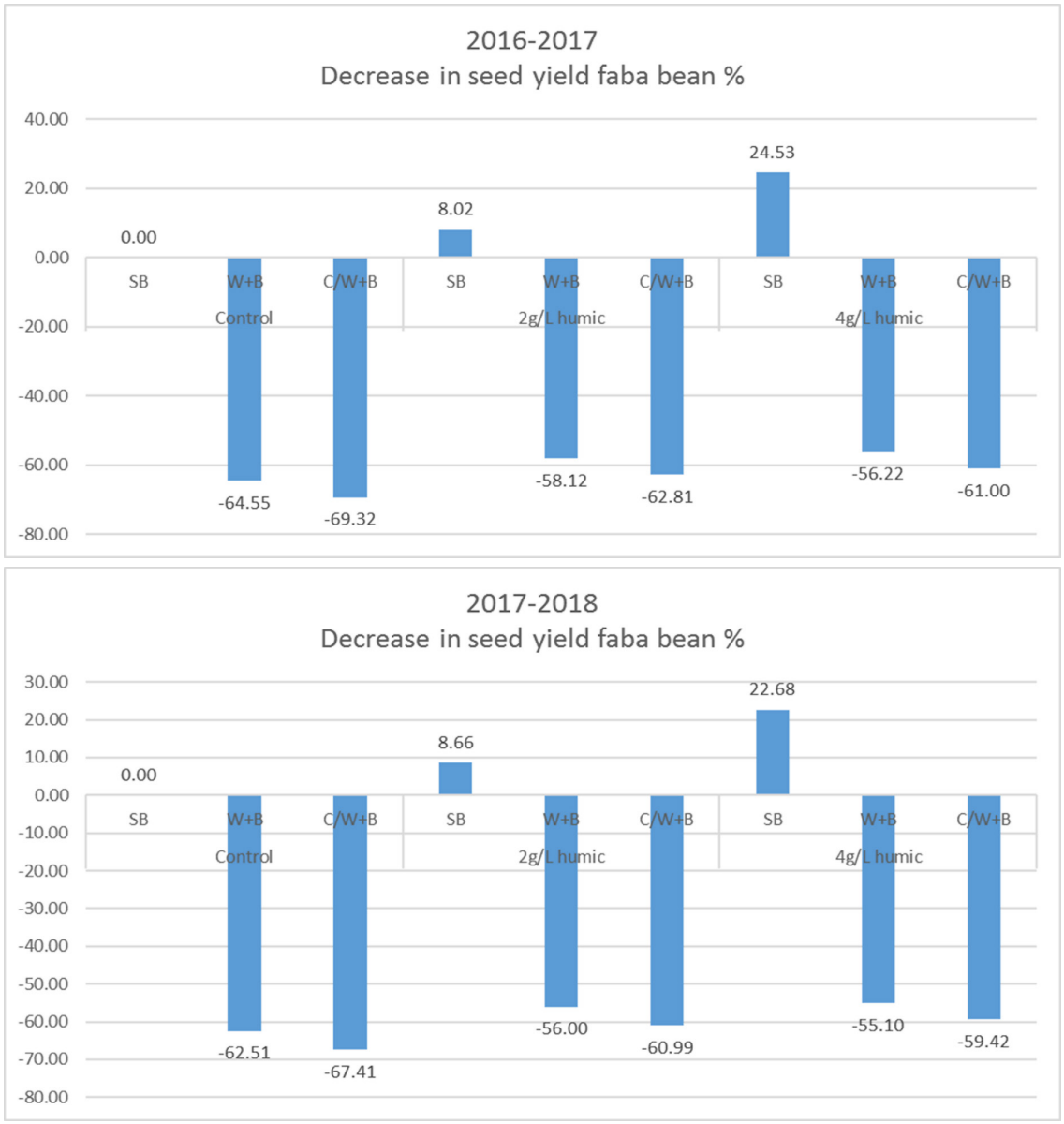

Fig. 3. Decrease in faba bean seed yield (%) as compared with sole sowing with no humic acid application.

TABLE 8. Effect of intercropping systems and foliar application of humic acid on land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity (A) and monetary advantage index (MAI) during 2016/2017 and 2017/2018 growing seasons.

Season	Characters	Relative yield			Relative yield			ATER		Aggressivity (A)				Monetary advantage index (MAI)	
	Intercropping systems Humic acid	C/W+B		LER	W+B		LER	C/W+B	W+B	C/W+B		W+B		C/W+B	W+B
		Wheat	Faba bean		Wheat	Faba bean				A_w	A_f	A_w	A_f		
Season 2016/2017	Control	1.02	0.31	1.32	0.97	0.35	1.33	1.19	0.93	0.40	-0.40	0.26	-0.26	745.82	501.03
	2g/L Humic	1.01	0.34	1.35	0.98	0.39	1.37	1.19	0.96	0.32	-0.32	0.20	-0.20	855.60	621.53
	4g/L Humic	1.04	0.31	1.35	0.96	0.35	1.32	1.22	0.92	0.41	-0.41	0.26	-0.26	947.35	604.32
Season 2017/2018	Control	1.01	0.33	1.34	0.97	0.37	1.35	1.19	0.95	0.36	-0.36	0.22	-0.22	845.87	555.47
	2g/L Humic	1.00	0.36	1.36	0.98	0.40	1.38	1.20	0.97	0.29	-0.29	0.17	-0.17	959.37	669.90
	4g/L Humic	1.04	0.33	1.37	0.95	0.37	1.32	1.23	0.93	0.38	-0.38	0.22	-0.22	1066.97	626.86

Aggressivity (A)

The data on aggressivity values are presented in Table 8. Aggressivity values of wheat were (0.41 and 0.38) higher in 4g/L humic acid and C/W+B as compared with the other treatments in first and second seasons, respectively. The results of aggressivity showed that wheat was the dominant species with positive values whereas faba bean was the dominated species with negative values in the humic acid and intercropping systems in both the growing seasons. Indicated that there was higher difference in competitive ability of wheat to faba bean where wheat was more competitive than faba bean. The greater the numerical value, the higher is the difference in competitive abilities and the higher the differences between the actual and the expected yields. Kumar (2008) also reported that negative values of aggressivity under intercrop showed that wheat was dominant and lentil and toria were the dominated crops in the systems.

Monetary Advantage Index (MAI)

Monetary advantage index (MAI) is presented in Table 8. MAI values were positive and revealed a definite yield advantage in both seasons. MAI values showed the economic advantage in 4g/L humic acid foliar application with intercropping systems as compared to the no foliar application with intercropping systems in 2016/2017 and 2017/2018. The highest MAI values of 947.35 and 1066.97 were obtained from 4g/L humic acid foliar application with C/W+B in the first and second seasons, respectively. Monetary advantage index (MAI) is considered an indicator of the economic feasibility of humic acid foliar application and intercropping systems. MAI values are based on the land equivalent ratio (LER). These MAI values were positive due to LER which were greater than one. Hamd Alla et al. 2014 who's stated that economic benefit expressed with the higher MAI values in intercropping, as reported by other studies (Hiebsch & Mccollum, 1987; Padhi, 2001; Ghosh, 2004; Shata et al., 2007; Takim, 2012; Hamdollah, 2012; Dube et al., 2014; Said & Hamd-Alla, 2018).

Conclusion

In developing countries where the production of crops is not sufficient for the consumption by human and animals, the application of the intercropping systems in order to increase the cropping area and net return for farmers could be a useful and fast solution. In Egypt as there is a competition between wheat and other crops during winter season because of limited land resources, intercropping systems will provide additional area for wheat production without noticeable reduction in faba bean production. The clover grown before wheat, lead to improves the fertility of the soil and help in weed control. From the obtained results, it could be recommended that the highest mean values of yield and its components of wheat were obtained when wheat was grown after clover under foliar application with 4g/L humic acid as compared with sole wheat with no foliar application in both seasons. The lowest mean value of yield and its components of faba bean recorded under clover/wheat + faba bean with no foliar application as the reduction was about 69% as compared with sole faba bean with no humic application in the first season. The 2g/L humic acid and wheat + faba bean gave the higher values land equivalent ratio. However, gave the lowest values aggressivity. The highest mean values of area time equivalent ratio, and monetary advantage index were obtained from 4g/L humic acid foliar application with clover/wheat + faba bean in both seasons.

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إنتاجية القمح المحمل مع الفول البلدي تحت التعاقب المحصولي والرش الورقي بحامض الهيوميك

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يعد تحميل الحبوب- البقول (القمح + الفول البلدي) ضرورية لتعزيز الإنتاجية لكل وحدة مساحة، وكفاءة استخدام الأراضي، وتقليل الفجوة بين الإنتاج والاستهلاك في مصر. بالإضافة إلى ذلك كنا نحاول أن نجد افضل تركيز لحامض الهيوميك لتحسين انتاجية القمح والفول. اشتملت التجربة الميدانية على مزج خمسة أنظمة من التعاقب المحصولي والتحميل (البرسيم/القمح؛ القمح + الفول البلدي؛ البرسيم/ القمح + الفول البلدي؛ القمح المنفرد؛ الفول البلدي المنفرد) بالإضافة إلى ثلاثة معاملات ت للرش الورقي بحامض الهيوميك بمعدل مقارنه (0.0)، 2.0 و4.0 جم/لتر. اظهرت النتائج أن الرش بحامض الهيوميك والتعاقب المحصولى والتحميل كان لهم تأثيرا معنويا على كل صفات القمح قيد الدراسة. اما في الفول فتأثرت جميع الصفات معنويا بجميع عوامل الدراسة عدا عدد الأفرع في كلا الموسمين بالنسبة لحامض الهيوميك وعدد الأفرع وطول النبات في الموسم الأول فقط بالنسبة للتعاقب المحصولى والتحميل. تم الحصول على أعلى قيم للمحصول ومكوناته من القمح عندما زرع القمح بعد البرسيم مع الرش الورقي بحامض الهيوميك 4 جم/ لتر مقارنة بالقمح المنفرد مع عدم استخدام الرش الورقي في كلا الموسمين. أعطي حامض الهيوميك 2 جم/ لتر والقمح + الفول البلدي أعلى معدل استغلال الأرض ومع ذلك، أعطي اقل قيم للعدوانية. وتم الحصول على أعلى قيم لنسبة المكافئ الأرضي لوحده الزمن، والعائد الاقتصادي من الرش الورقي بحامض الهيوميك 4 جم/لتر مع البرسيم/القمح + الفول البلدي في كلا الموسمين.