Agronomy

Impact of crop sequence and nitrogen fertilization levels on wheat (*Triticum aestivum* L.) productivity in Egypt

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ABSTRACT

Crop intensification of traditional wheat crop sequence by the inclusion of legumes (as intercrops or catch crops) is a suitable procedure to increase land productivity. An experiment was carried out at Kafr El-Hamam Agriculture Research Station, Sharkia Governorate, Egypt. A split-plot design was used in three replicates to compare the effect of 6 crop sequences (S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat) and 3 nitrogen fertilization levels for wheat (50, 70 or 90 kg N /fad.) on soil content of available NPK, wheat productivity and farmer's net income. The results can be summarized as follows: Legumes as preceding crops increased the soil content of available NPK. The inclusion of legumes in crop sequence significantly increased grain yield as compared with cereal crops. Where, the highest grain yield (2.86 ton/fad.) with S5 treatment in the first season and (3.04 ton/fad.) by S4 treatment in the second season, respectively. Application of 70 kg N/fad significantly increased grain yield and its components of wheat. The interaction of cropping sequence S5 and S4 treatments along with 70kg N/fad level significantly had the highest yield and its components of wheat in two seasons. Replacing traditional cropping sequence maize/wheat (S1) with S4 or S5 treatments significantly increased cereal units and net income. Therefore, it can be recommended to grow fahl berseem following maize monoculture (S2) or maize intercropping with cowpea (S4) and soybean (S5) to increase available NPK in the soil, wheat grain yield, values of total cereal units and net income.

Keywords: Legumes, cereals, NPK, cereal units.

INTRODUCTION

Currently, the agricultural sector in Egypt is facing many challenges that affect crop production and increase the demand for food crops to achieve food security for the increasing numbers of population. Cereals are the main staple food globally and wheat is the most important one. Wheat represents the main source of carbohydrates and the main component in the Egyptian diet as well wheat straw is used to feed livestock. In 2020, wheat is grown on about 3.4 million fad of land with an average yield was about 2.7 ton/fad (the highest in Africa). However, Egypt is the world's largest wheat-importing country, which is about 53% of total supply (Bulletin, 2020) and mainly depends on imported wheat.

In light of the repercussions of the Coronavirus disease and the Ukraine/Russia war and their impacts on the grain supply and the cost of food production in Egypt, increasing local production has become imperative. The supply of wheat from local sources can be increased by one or more of the following practices: (1) increasing wheat area; (2) increasing productivity per unit; and (3) reducing food loss and waste. Wheat cultivation is difficult to expand due to limited arable land, scarcity of water, and increased production costs. As a result, increasing the productivity of land unit area may be the best option at this point.

In Egypt, maize-wheat sequential is the prevailing cropping sequence, and this combination rapidly depletes soil fertility. Changing two crops pattern per year to three or four crops can play a potential role in achieving the country's food security, with the inclusion of legume crops as precursor crops and/or intercrops. The conventional monoculture of maize, maize + soybean (intercropping) had a significant advantage in yield, economy, land utilization ratio and reducing soil nitrate nitrogen (N) accumulation, as well as a better residual effect on the subsequent wheat (Zhang *et al.,* 2015). Also, inclusion of three crops (faham berseem, pea, fodder maize) in the Egyptian crop structure will certainly increase the cereal units, net incomes, and cropping index (CI) of cropping sequence compared to maize-wheat prevailing cropping sequence (El-Mehy *et al.,* 2016). The sequence of corn-clover-wheat produced higher grain and straw yield when compared to the sequence of corn-fallow-wheat (Gad *et al.,* 2018). Clover as a preceding crop left a good residual effect on the wheat plant which gave the highest yield and its components compared to fodder maize and follow (Abd Allah *et al.,* 2020).

In general, arranging cereal-legume crops in an appropriate sequence allows them to use the available resources more efficiently (Negash *et al.,* 2018; Voisin *et al.,* 2018), higher overall productivity and quality (Mohammed and Chen, 2018), improve soil fertility and reduce nitrate leaching (Dogan and Bilgili 2010; Sainju *et al.,* 2015), increased water productivity (Zohry and Ouda, 2018), better control of pests and diseases (Jalli *et al.,* 2021) and greater economic profitability (Zhang et al., 2015, Mohammed and Chen, 2018). Wheat grain yield was the highest following alfalfa, and it was 33% lower following wheat (Ercoli *et al.,* 2014).

In a cropping sequence, wheat after grain legumes was more efficient in N uptake and use than after cereals (Espinoza *et al.,* 2015). The pulse system increased total grain production by 35.5 over the summer fallow system (Gan *et al.,* 2015).

Optimized cropping sequences and nutrient management are the most important agronomic factors for maximizing the yield potential of wheat cropping systems. Under Egyptian agricultural conditions, N is regarded as the most important factor in wheat production (FAO, 2005). Nitrogen is one of the most important elements of plant nutrition, which often to a great extent determines not only wheat yield level but also grain quality. Therefore, it is important to evaluate the use of high nitrogen fertilizer rates because unsuitable nitrogen doses lead to increased nitrate leaching (Huang *et al.,* 2018). Litke et al. (2018) confirmed a significant increase in wheat yield until the nitrogen fertilizer rate of 180 kg /ha. The highest wheat grain yield was obtained from the sequence of corn-clover-wheat when received the highest nitrogen rate 93.75 kg N/fad (Gad *et al.,* 2018). Cropping sequences combined with adequate mineral N fertilizer, resulted in stable wheat yields and reduced yield risk (Macholdt *et al.,* 2020). The effect of nitrogen fertilizer on wheat yields has been extensively studied, but with the adoption of high-yielding varieties, the effect of nitrogen fertilization is changing as well. Therefore, there is an urgent need to maximize the efficient use of N elements without excessive use of mineral N fertilizer through suitable cropping sequences. Thus, the main purpose of this experiment was to compare different crop sequences, including legume versus cereal crops, to their effects on soil available NPK, wheat yield, cereal units, and farmer's net income.

MATERIALS AND METHODS

An experiment was conducted during the period from summer growing season of 2018 to winter growing season of 2019/2020 seasons at Kafr El-Hamam Agriculture Research Station, Sharkia Governorate, Egypt, (Lat. 30 º 44′ 22″ N, Long 30º 58 ′09″ E) to investigate the effect of six crop sequences on growth, yield and its components of wheat (cv. Misr 1) which was fertilized with 3 nitrogen fertilization levels (50, 70 or 90 kg N /fad). Soil samples (0-30cm layer) were collected from the experimental site and analyzed for physical and chemical characteristics, at the beginning of the study according to Black (1965) as shown in Table (1). Available N and K % were determined using the standard method outlined by Jackson (1973) and available P% was determined calorimetrically according to Murphy and Riley (1962).

Table 1: physical and chemical properties of experimental Site in 2018/2019 and 2019/2020 seasons.

Soil properties / Season	Sand (%)	Silt (%)	Clay (%)	Texture	EC (dS/m)	pH	Available (mg/kg)		
							N	P	K
2018/2019	27.5	29.6	42.9	Clay loam	1.30	7.6	40.9	9.5	365
2019/2020	25.9	30.7	43.4		1.29	7.8	43.2	10.3	420

Soil analysis was carried out at the Central Fertility Laboratory (ARC)

The experiment included 18 treatments arranged in a split-plot design with three replications. Cropping sequences treatments were allocated in the main plots and nitrogen levels were arranged in the 1st order sub-plot. Each plot comprised 8 ridges, 70 cm in width and 3.0 m in length (plot area=16.8 m2).

Cropping sequences were: maize (Zea mays L.) /wheat (*Triticum aestivum* L.) (S1), maize/ clover (Fahl) (Egyption clover L.)/wheat (S2), maize/silage maize (Zea mays L.)/wheat (S3), intercropping cowpea Vigna unguiculata (L.) with maize/ clover (Fahl)/wheat (S4), intercropping soybean with maize/ clover (Fahl) /wheat (S5) and intercropping soybean (Glycine max L.) with maize/ wheat (S6) while, mineral nitrogen fertilizer levels of wheat were 50 kg N/fad. (N1), 70 kg N/fad. Nitrogen fertilizer, nitrate ammonium (33.5%), was split into two equal doses; the first dose was applied to the soil at the 1st irrigation, and the second one was applied at the 2nd irrigation. The cultivars used were hybrid maize (SC 130), soybean (cv. Giza 111), cowpea (cv. local), clover (cv. Fahl), silage maize (pioneer 2066), and wheat (cv. Masr 1). The source of seeds for all crops was the Agricultural Research Center, except for silage maize, which was brought in from Pioneer Company (Egypt). Planting maize at 0.25 cm between hills and 0.70 cm between ridges is recommended. Cowpea was intercropped with maize on the other side of the same ridge in hills at 20 cm apart and 2 plants per hill (50% of the recommendation), meanwhile soybean was planted in a ridge alternated with maize 2:2 (by drilling it in one row at 5 cm apart between plants). Silage maize was sown in ridges 70 cm apart in hills 20 cm apart (plant/hill), while clover (fahl) seeds were distributed in all plots using the broadcast method. Wheat seeds were sown on ridges at a rate of 50 kg per field in three rows per ridge (zigzag shape), and wheat was grown on the same ridges as maize with minimal tillage. Overall, all crop production cultural practices were implemented as recommended. The planting and harvesting dates of crops in both seasons are presented in **Table 2**.

Table 2: Sowing and harvesting dates of all crops in 2018/2019 and 2019/2020 seasons.

Crop type	First season (2018/2019)		Second season (2019/2020)	
	Sowing date	Harvest date	Sowing date	Harvest date
Maize (*Zea mays* L.)	10-May, 2018	29- August, 2018	13- May,2019	31- August, 2019
Soybean (*Glycine max* L.)	14-May, 2018	5- September, 2018	16- May,2019	10- September, 2019
Cowpea *Vigna unguiculata* (L.)	10-May, 2018	7-Jule and 20-August, 2018	13- May, 2019	13-Jule and 25-August, 2019
Clover (Fahl) (*Egyption clover* L.)	6-Septemper, 2018	22- November, 2018	11- September, 2019	23- November, 2019
Silage maize (*Zea mays* L.)	6- September, 2018	22- November, 2018	11- September, 2019	25- November, 2019
Wheat (*Triticum aestivum* L.)	25-November, 2018	9- May, 2019	27-November, 2019	11- May, 2020

Data recorded:

The data recorded for summer crop (maize), intercropping crops (soybean and cowpea), catch crops (clover (fahl) and silage maize), and winter crop (wheat) characters were as follows: grain yield of maize, seed yield of soybean, fresh forage yield of cowpea (at 60 and 40 days for first and second cuts, respectively), fresh forage yield of clover (fahl) (at 70 days), and fresh forage yield of silage maize (at 77 days). The data were determined on a whole-plot basis, then they were transferred to tons or fads. At wheat harvest time, ten plants were randomly taken from the middle ridges of each plot to estimate plant height (cm), spike length (cm), spike weight (g), grain weight per spike (g), and 1000-grain weight (g). The number of spikes/m2 was estimated from m2. Grain and straw yields (fad) were recorded based on the experimental plot area by harvesting all plants from each plot and transferring them to tons (fad).

Cereal Units (CUs):

Cereal units' calculation was conducted for the whole year structure. Cereal units were proposed by Brockhaus (1962) to express agronomic gains from crops based on constituents of products either main-products or by-products. Cereal units for crops, estimated per 100 kg, as follow: Main-product of maize and wheat grain equal 1.0 unit, soybean seed equal 1.5 unit. While by-products of maize straw equal 0.15-unit, wheat and soybean straw were 0.25 unit, fahl berseem equal 0.14 unit, cowpea equal 0.12 unit and silage equal 0.11 unit.

Economic return:

The farmer's benefit was calculated by calculating each crop sequence's total returns, total costs (fixed + variable), and net returns. The prices and costs of various crops were presented in Egyptian pounds (L.E.) in the Bulletin of Statistical Information (2018-2019).The prices were as follows: 4407 and 920 L.E./ton for wheat grain and straw, 3047 and 756 L.E./ton for maize grain and straw, 6041 and 808 L.E./ton for seed and straw of soybean, and 300 L.E./ton of silage maize. There were 5669 and 2834 L.E. for clover and cowpea, respectively, on cut of fresh forage or fad. It is worth noting that cowpea plant density is half of what is recommended. Maize had a total production cost of 9877 L.E. per fad, while wheat had a total production cost of 11085, 11326, and 11564 L.E. per fad for N fertilization levels of 50, 70, and 90 kg N per fad, respectively. Soybean had a variable cost of 2022 L.E/fad, cowpea had a cost of 1500 L.E/fad, fahl berseem had a cost of 1233 L.E/fad, and silage maize had a cost of 1800 L.E/fad. Net return was calculated as follows: **Net return = total return - total costs**

Statistical analysis:

All the data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split plot design using MSTAT Computer software package. Least Significant difference (LSD) was used to test the differences between treatment means at 5% level of probability as described by (Gomez and Gomez, 1984).

RESULTS

I. Effect of the crop sequences treatments on soil content of available NPK:

Results in Table 3 show the soil content of available NPK (mg/kg) before wheat planting under different crop sequences. The results indicated that the soil content of available NPK (mg/kg) was higher in the second season compared to the first one. The highest value of soil content and available NPK was found when two-legume crop sequences were cultivated in S4 and S5, followed by one-legume crop sequences grown in S6 and S2, in both seasons. In the first and second seasons, respectively, the increases in soil available N (mg/kg) were 57.1 and 47.4% for S4, and 51.4 and 50.0% for S5, compared to the traditional crop sequence S1.crop sequence of one legume cultivation increased the soil content of available N compared to S1 by 28.6 and 26.32% in S2 and by 40.0 and 39.5% in S6, respectively, in the first and second seasons.

Table 3: Soil content of available NPK (ppm) before wheat planting in 2018/2019 and 2019/2020 seasons.

Crop sequence	1st season (2018/2019)			2nd season (2019/2020)		
	N	P	K	N	P	K
Maize/wheat (S1)	35	6.45	360	38	9.10	385
Maize/clover (fahl) /wheat (S2)	45	8.42	455	48	10.22	465
Maize/silage maize/wheat (S3)	25	4.22	344	30	7.72	374
Intercropping cowpea with maize/clover (fahl) /wheat (S4)	53	8.20	376	57	10.30	410
Intercropping soybean with maize/clover (fahl)/wheat (S5),	55	8.49	450	56	9.94	480
Intercropping soybean with maize/ wheat (S6)	49	7.44	470	53	10.49	490

II- Effect of crop sequences on yield and yield components of wheat:

Results in Table 4 confirm that wheat plant height significantly ($P \leq 0.05$) affected by crop sequence in the two growing seasons. Inclusion of legume crops (clover, cowpea, or soybean) in cropping sequences S2, S4, S5 and S6 increased height of wheat plants compared to wheat following cereal crops in S1 (maize) and/or S3 (silage/maize). The highest plants (111.6 and 114.9 cm) were produced by S5 and S4, while the shortest ones (107.6 and 110.6 cm) were recorded with S3 in the first and second season, respectively. Concerning yield components of wheat and spike characters, the results presented in Table 4 indicate that these traits were significantly affected (P 0.05) by crop sequence in both seasons. Planting wheat after a legume crop improved yield components as compared with planting wheat after maize (S1) or silage/maize (S3). The highest mean values of number of spikes/m2 were obtained by crop sequences S5 and S4 and number of grains per spike by S2 and S4 treatments in the two seasons, respectively. S5 obtained the heaviest grain weights of 1,000 in both seasons. Likewise, spike characters significantly increased when wheat was grown after legume crop sequences. where the highest values of spike length and grain weight/spike were produced after S5 and S4 in the first and second seasons, respectively. Contrary to expectations, the lowest values of wheat yield components and spike characters were produced following (maize/silage maize) S3 in both seasons, followed by S1 (maize/wheat). Results in Table 4 indicate that biological and grain yields of wheat were significantly (P 0.05) affected by crop sequence in both seasons. Biological and grain yield values followed the same trend for yield components of wheat. where the biological and grain yields of wheat following cereal crops were consistently less than wheat after legumes, with different N levels. Results in Figure 1 show that grain yield increased in cropping sequences S2, S4, S5, and S6 by 8.0, 20.0, 27.1, and 14.2 percent compared to traditional crop sequence S1 (maize/wheat) in the first season, corresponding to 7.9, 27.7, 21.0, and 14.7 percent in the second season, respectively. Whereas, growing maize or silage maize (S3) prior to wheat reduced the yield of wheat by 5.8 and 7.1% in the first and second seasons, respectively.

Table 4: Effect of crop sequences on yield and yield components of wheat in 2018/2019 and 2019/2020 seasons.

Trait crop sequence	Plant height (cm)	No. of spikes /m²	Spike length (cm)	Grain wt./ spike (g)	No. of grains /spike	Thousand grain weight (g)	Biological yield (ton/fad)	Grain yield (ton/fad)
1st season 2018/2019								
S1	109.0	396.7	12.57	2.49	51.37	50.88	5.64	2.25
S2	110.2	420.4	12.58	2.84	53.35	53.33	5.80	2.43
S3	107.6	358.4	12.16	2.14	47.53	47.55	5.46	2.12
S4	110.5	450.4	12.94	2.66	52.70	53.99	6.69	2.70
S5	111.6	451.4	12.99	2.76	52.11	54.99	6.40	2.86
S6	110.1	448.4	12.77	2.71	51.97	50.75	5.99	2.57
LSD at 5%	2.2	17.3	0.54	0.22	1.54	1.31	0.91	0.09
2nd season 2019/2020								
S1	112.7	416.4	14.55	2.73	51.50	48.47	6.10	2.38
S2	113.0	424.8	14.77	2.84	54.20	50.47	6.32	2.57
S3	110.6	390.7	14.33	2.24	47.70	45.02	6.17	2.21
S4	114.9	426.1	16.61	4.43	68.86	52.96	6.68	3.04
S5	114.8	416.0	15.27	3.74	60.90	53.23	6.72	2.88
S6	113.9	418.0	15.22	3.23	58.10	52.14	6.31	2.73
LSD at 5%	4.0	17.3	1.00	0.47	10.83	1.50	0.44	0.49

S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat.

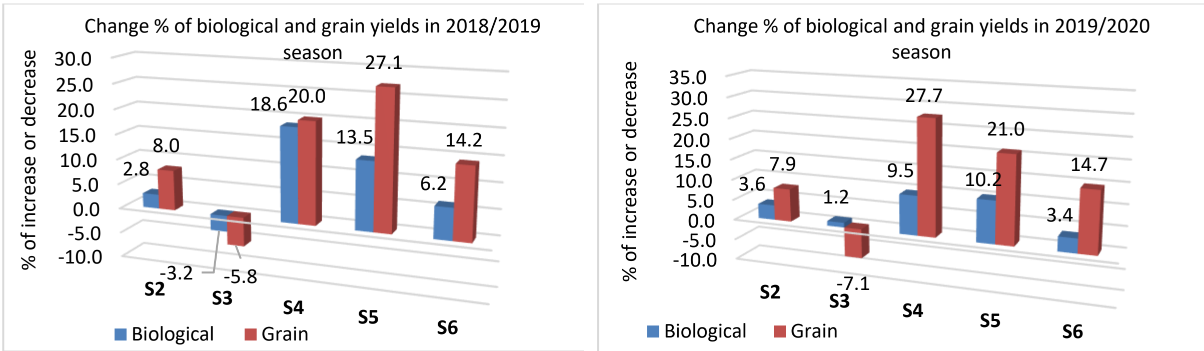

Fig. 1. Response of biological and grain yields o wheat to crop sequences in 2018/2019 and 2019/2020 seasons.

III. Effect of N fertilization levels on yield and yield components of wheat:

Significant (P≤ 0.05) increase in plant height of wheat plants owing to raise N fertilization levels from 50 up to 90 kg/fad in the two growing seasons as clear in Table (5). The values of plant height 111.2 and 115.3 cm were produced by application N3 in 2018/2019 and 2019/2020 season, respectively. Noteworthy is that there were insignificant differences between the N3 and N2 levels for plant height. On the other hand, application of 50 kg/fad recorded the lowest values of plant height in the two seasons.

Regarding yield components, results in Table 5 highlighted a significant (P 0.05) effect of N fertilization levels on yield components of wheat in the two growing seasons. In all crop sequences, application N2 levels had the highest values of number of spikes per m2, spike length, grain weight per spike, grain number per spike, and 1000-grain weight. However, there was no significant difference between the 70 and 90 kg N/F levels in the two growing seasons. Contrary to expectations, the lowest mean values of previous traits were produced with the lowest N levels (N1; 50 kg N/fad).

Table 5: Effect of N fertilization levels on yield and yield components of wheat in 2018/2019 and 2019/2020 seasons.

Trait Fertilization level of N	Plant height (cm)	No. of spikes/m^2	Spike length (cm)	Grain weight/spike (g)	No. of grains /spike	Thousand - Grain weight (g)	Biological yield (ton/fad)	Grain yield (ton/fad)
				1st season 2018/2019				
N1	108.2	386.0	12.15	2.36	49.85	48.66	5.60	2.14
N2	110.1	440.8	12.99	2.76	52.55	53.60	6.22	2.73
N3	111.2	436.1	12.87	2.67	52.10	53.38	6.16	2.59
LSD at 5%	1.8	10.4	0.47	0.11	1.15	0.87	0.47	0.06
				2nd season 2019/2020				
N1	110.4	395.6	14.22	2.70	49.16	47.34	6.02	2.33
N2	114.2	434.7	15.96	3.53	61.86	52.59	6.72	2.82
N3	115.3	415.7	15.19	3.38	59.62	51.14	6.41	2.77
LSD at 5%	2.2	9.5	0.57	0.50	7.18	0.90	0.44	0.26

Fertilization levels was N1: 50kg N/fad, N2: 70kg N/fad, N3: 90kg N/fad.

Wheat tended to significantly produce (P≤ 0.05) the greatest biological and grain yields when fertilized by medium N levels 70 kg/fad (N2) as shown in Table 5. While the lowest values of biological and grain yields were produced with N1 (50 kg N/fad.). The lowest N fertilization level of 50 kg N/fad significantly reduced grain yield of wheat compared to 70 and 90 kg N/fad by 21.6 and 17.4 % in 2018/2019 season and by 17.4 and 15.9 % in 2019/2020 season, respectively.

IV. Effect of interaction on yield and yield components of wheat:

Results in Table 6 confirm that plant height significantly affected by interaction between crop sequence and N level in both growing seasons. The highest mean value of plant height was obtained from S5 x N3 and S4 x N3. On the other hand, lowest value of plant height achieves with S3 x N1.

Yield and yield components were significantly affect by the interaction between crop sequences and N fertilization levels in the two seasons, as shown in Table 6. Crop sequences which include legume crops along with N2 produced the highest values of yield components, biological and grain yields. The highest values of biological yields (6.72 and 7.15 ton/fad.) and grain yields (3.23 and 3.22) were obtained with S5 x N2 and S4 x N2 in first and second season, respectively. While, biological and grain yields in cereal crop sequences increased with increasing N fertilization levels up to 90 kg N/fad, where the lowest values of yield and yield components were obtained by S3 x N1 in both seasons.

Table 6: Interaction effect of crop sequences and N fertilization levels on yield and yield components of wheat in 2018/2019 and 2019/2020 seasons.

Interaction		Plant height (cm)	No. of spikes/m²	Spike length (cm)	Grains weight/spike (g)	No. of grains /spike	Thousand - grain weight (g)	Biological yield (ton /fad)	Grain yield (ton /fad)
		1st season 2018/2019							
S1	N1	106.3	381.0	12.06	2.20	48.86	45.66	5.16	1.99
	N2	110.1	382.1	12.60	2.44	51.86	52.66	5.72	2.44
	N3	110.8	427.1	13.06	2.85	53.40	54.33	6.04	2.31
S2	N1	110.0	367.5	12.20	2.65	52.66	52.66	5.46	2.16
	N2	110.0	446.6	13.26	3.06	54.66	54.33	6.09	2.68
	N3	110.7	447.0	12.30	2.81	52.73	53.00	5.85	2.44
S3	N1	102.9	316.1	11.53	2.02	46.30	45.33	5.09	1.88
	N2	110.0	360.0	12.46	2.16	47.30	47.00	5.24	1.99
	N3	110.0	399.0	12.50	2.24	49.00	50.33	6.03	2.48
S4	N1	110.1	405.9	12.36	2.20	50.00	50.66	6.66	2.25
	N2	110.2	476.0	13.23	2.94	54.20	56.33	6.70	3.13
	N3	111.3	469.4	13.23	2.84	53.90	54.00	6.70	2.73
S5	N1	110.4	415.5	12.53	2.65	50.33	48.66	5.93	2.35
	N2	111.3	495.7	13.33	2.90	54.42	59.33	6.72	3.23
	N3	113.2	443.0	13.10	2.74	51.60	57.00	6.58	3.00
S6	N1	109.5	430.1	12.26	2.46	51.00	49.00	5.31	2.22
	N2	109.4	484.2	13.06	3.11	52.86	52.00	6.87	2.91
	N3	111.3	431.0	13.00	2.56	52.06	51.66	5.77	2.60
LSD at 5%		**4.5**	**25.6**	**1.16**	**0.27**	**2.80**	**2.13**	**1.17**	**0.13**
		2nd season 2019/2020							
S1	N1	109.0	408.0	13.66	2.24	41.30	45.02	5.92	2.17
	N2	114.6	432.0	15.66	3.30	56.60	53.37	6.31	2.48
	N3	114.6	409.3	14.33	2.65	56.60	47.04	6.07	2.51
S2	N1	111.3	406.6	14.33	2.40	41.60	44.00	6.09	2.39
	N2	112.3	458.0	15.33	3.16	65.00	54.24	6.66	2.53
	N3	115.6	410.0	14.66	2.96	56.00	52.69	6.20	2.79
S3	N1	105.6	364.0	13.00	1.95	39.80	43.62	5.83	1.71
	N2	112.3	398.0	14.33	2.23	51.30	45.66	6.18	2.35
	N3	114.0	410.3	15.66	2.56	52.00	45.71	6.51	2.59
S4	N1	112.0	407.3	15.00	3.90	65.50	52.64	6.04	2.74
	N2	115.6	438.6	18.33	4.75	70.60	53.28	7.15	3.22
	N3	117.3	432.6	16.50	4.65	70.50	53.10	6.85	3.18
S5	N1	112.0	396.0	14.33	2.90	58.00	50.32	6.20	2.58
	N2	116.6	450.0	16.50	4.28	65.00	55.98	7.28	3.15
	N3	116.0	402.0	15.00	4.05	59.70	53.29	6.69	2.91
S6	F1	113.0	392.0	15.00	2.83	48.70	48.23	6.04	2.38
	F2	114.3	432.0	15.66	3.46	62.60	55.83	6.72	3.18
	F3	114.6	430.0	15.00	3.42	62.90	52.17	6.17	2.67
LSD at 5%		**5.5**	**23.4**	**1.39**	**1.23**	**17.60**	**2.10**	**0.77**	**0.65**

S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat, N1: 50kg N/fad, N2: 70kg N/fad, N3: 90kg N/fad

V- Effect of crop sequences on productivity of each crop in crop sequences:

Results in Table 7 show yield of each crop in the different crop sequences. Maize grain and straw yields were clearly decreased when in intercropped with soybean in S5 and S6 compared to traditional crop sequence (S1). Whereas, reduction in grain and straw yields of maize were slight when intercropping with cowpea compared to S1. Results were true in both growing seasons. Yield of soybean did not differ in both sequences S5 and S5, where maize was the preceding crop in both sequences. Crop sequence obviously affected on fresh yield of clover (fahl) in both seasons. The highest forage yield was obtained by growing clover (fahl) following cowpea (S4), while the lowest yield was produced when growing clover (fahl) following maize (S2).

Table 7: Productivity of each crop of different crop sequences in 2018/2019 and 2019/2020 seasons.

Crop sequence	Maize yield (ton/fad)		Soybean yield (ton/fad)		Fresh forage yield (ton/fad)			Wheat yield (ton/fad)	
	Grain	Straw	Seed	Straw	cowpea	Clover(fahl)	Silage maize	Grain	Straw
	1st season 2018/2019								
S1	3.57	4.11	-	-	-	-	-	2.25	3.39
S2	3.53	4.05	-	-	-	11.50	-	2.43	3.37
S3	3.55	4.08	-	-	-	-	4.50	2.12	3.34
S4	3.35	3.78	-	-	7.90	12.00	-	2.70	3.99
S5	2.40	2.95	0.75	1.15	-	12.10	-	2.86	3.54
S6	2.44	2.93	0.77	1.25	-	-	-	2.57	3.42
	2nd season 2019/2020								
S1	3.56	4.09	-	-	-	-	-	2.38	3.72
S2	3.80	4.45	-	-	-	10.30	-	2.57	3.75
S3	3.80	4.56	-	-	-	-	5.10	2.21	3.96
S4	3.46	3.94	-	-	7.18	10.70	-	3.04	3.64
S5	2.48	3.05	0.75	1.20	-	10.10	-	2.88	3.84
S6	2.30	3.10	0.78	1.32	-	-	-	2.73	3.58

S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat

VI. Cereal units (CUs) of different crop sequences:

The results showed that the six sequences could be arranged in descending order according to their biological performance in increasing land use efficiency, expressed as CUs. The results in Table 8 show that the first three positions were recorded by crop sequences S4, S5 and S2, consecutively, which were including fahl berseem as a catch crop in the transition period between growing summer and winter crops.

Table 8: Cereal units (CUs) of each crop of different crop squences in 2018/2019 and 2019/2020 seasons.

	Maize (CUs/fad)		Soybean(CUs/fad)		Fresh forage yield (CUs/fad)			Wheat (CUs/fad)		Total CUs of each crop sequence
	Grain	Straw	Seed	Straw	cowpea	Clover (fahl)	Silage maize	Grain	Straw	
	1st season 2018/2019									
S1	35.70	6.17	-	-	-	-	-	22.50	8.48	72.84
S2	35.30	6.08	-	-	-	16.10	-	24.30	8.43	90.20
S3	35.50	6.12	-	-	-	-	4.95	21.20	8.35	76.12
S4	33.50	5.67	-	-	9.48	16.80	-	27.00	9.98	102.43
S5	24.00	4.43	11.25	2.88	-	16.94	-	28.60	8.85	96.94
S6	24.40	4.40	11.55	3.13	-	-	-	25.70	8.55	77.72
	2nd season 2019/2020									
S1	35.60	6.14	-	-	-	-	-	23.80	9.30	74.84
S2	38.00	6.83	-	-	-	14.42	-	25.70	9.38	94.32
S3	38.00	6.69	-	-	-	-	5.61	22.10	9.90	82.30
S4	34.60	5.91	-	-	8.62	14.98	-	30.40	9.10	103.61
S5	24.80	4.58	11.25	3.00	-	14.14	-	28.80	9.60	96.17
S6	25.30	4.65	11.70	3.30	-	-	-	27.30	8.95	81.20

S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat.

The inclusion of clover (fahl) as a catch crop before the wheat is an outstanding procedure to increase the CUs obtained in S2 by 23.8 and 26.0% compared to S1, respectively, in first and second seasons. Whereas, intercropping cowpea (in S4) or soybean (in S5) with maize before fahl berseem increased CUs by 40.6 and 38.5% by cowpea, and by 36.6 and 28.5 % by soybean in 2018/2019 and 2019/2020 season, respectively. On the other hand, the lowest value of cereal units were achieved by tradition cropping sequence S1 (maize/wheat), followed by cereal- sequence S3, it including (maize/silage/wheat) treatments, in both seasons.

VII- Economic evaluation:

Results in Table 9 show that cost of production, total and net return increased with increasing crop intensification from 2 up to 4 crops/year. Total cost values were increase as result of increasing N fertilization level of wheat, irrespective crop sequences. While total and net return increased by increasing wheat fertilization levels up to 70 kg N/fad under legume-sequences (S2, S4, S5 and S6). Whereas total and net return of cereal-sequences (S3) increased with raised N fertilization rate of wheat up to 90 kg N/fad. The highest total return were obtained by S5 with application wheat fertilization at 70 kg N/fad, followed by total return of S4 at the same N levels in both seasons. Likewise, the highest net return values were produced in S5 in first season and S4 in second season, when wheat received 70kg N/fad. It is worth noting that the variations in total and net income between S5 and S4 were slight and can be ignored. Further, net return increased in S2, S4, S5 and S6 by 90.5, 102.0, 99.2 and 11.0 % compared to S1 (maize/wheat), but it reduced in S3 by -6.9%, as average of both seasons. In contrast, the lowest total income were produced with S1 (maize/wheat). Whereas the lowest net income was attained by S3 in both seasons.

Table 9: Response of total and net income to crop sequences and N fertilization levels of wheat in 2018/2019 and 2019/2020 seasons.

Trait Treatment		Total cost L.E/fad	Total return L.E/fad	Net return L.E/fad	Total cost L.E/fad	Total return L.E/fad	Net return L.E/fad	Net return as average of both seasons
1st season 2018/2019					2nd season 2019/2020			
S1	N1	20962	25684	4722	20962	26968	6006	5364
	N2	21203	27769	6566	21203	28408	7205	6885
	N3	21441	27612	6171	21441	28290	6849	6510
S2	N1	22195	32055	9860	22195	34563	12368	11114
	N2	22436	34448	12012	22436	35578	13142	12577
	N3	22674	33391	10717	22674	36058	13384	12050
S3	N1	22762	26503	3741	22762	27899	5137	4439
	N2	23003	27024	4021	23003	30451	7448	5735
	N3	23241	29461	6220	23241	31592	8351	7286
S4	N1	23695	34142	10447	23695	35732	12037	11242
	N2	23936	37244	13308	23936	38429	14493	13900
	N3	24174	35851	11677	24174	38013	13839	12758
S5	N1	24217	34336	10119	24217	35747	11530	10824
	N2	24458	38131	13673	24458	38730	14272	13973
	N3	24696	37201	12505	24696	37349	12653	12579
S6	N1	22984	27950	4966	22984	29001	6017	5491
	N2	23225	31795	8570	23225	32415	9190	8880
	N3	23463	29699	6236	23463	30131	6668	6452

S1: maize/wheat, S2: maize/ clover (fahl) /wheat, S3: maize/silage/wheat, S4: intercropping maize + cowpea/ clover (fahl)/ wheat, S5: intercropping maize + soybean/ clover (fahl)/wheat, S6: maize + soybean/wheat, N1: 50kg N/fad, N2: 70kg N/fad, N3: 90kg N/fad. The prices were as follows: 4407 and 920L.E./ton for wheat grain and straw, 3047 and 756 L.E./ton for maize grain and straw, 6041 and 808 L.E./ton for seed and straw of soybean, 300 L.E./ton of silage maize. One cut of fresh forage/fad were 5669 and 2834L.E. for clover and cowpea, respectively. It is worth to noting that plant density of cowpea 50% of recommended.

DISCUSSION

The previous positive effect of legume crops on soil content of available NPK, yield and its components of wheat and cereal units, and net income might be attributed to the essential roles of legumes in stimulating soil fertility. The effects of the first growing season may still be in the soil during the second growing season, which is why it has more available NPK (mg/kg).Results confirm that the soil content of available N increased with the increasing number of legume crops in the cropping sequence. After a legume, more N may be available for the subsequent crop than after a cereal. This can be due to the absence of soil N depletion compared with a cereal grown without sufficient N input or reduced N immobilization of soil mineral N due to the lower C:N ratio of legume residues (Chen *et al.,* 2014; Ercoli *et al.,* 2014). Results are in line with Ouda et al. (2019) they found that the maximum value of soil nitrogen % was obtained from CS2 cultivation (cowpea/clover/wheat), as a result of the presence of cowpea and short-season clover in suggested crop sequence compared to CS1 (maize/clover/wheat) and CS3 (cowpea intercropped with maize/ clover/wheat). The same trend was observed for available P and K, where legume crops increase soil content of P and K for the subsequent cereal crop. Legumes-based sequences resulted in more available N, P and K in soil compared to their content at initiation of the study (Chandra, 2011). Legumes fix the atmospheric nitrogen and facilitate soil P and K circulation (Stagnari, 2017). Increasing wheat plant height may be due to the vital role of leguminous residual effect in enriching the soil with available NPK (Table, 3), which in turn increased meristematic activity and stimulation of cell elongation in wheat plants. Similar results were obtained by Dogan and Bilgili (2010), El-Mehy et al. (2016) and Gad et al. (2018). Likewise, positive role of legume crops on yield components of wheat could be attributed to after legume more N may be available for the subsequent crop than after a cereal (Table 3), especially 2-legume crop sequences S4 (cowpea intercropping with maize following by fahl berseem) and S5 (soybean intercropping with maize following by fahl berseem). On the other hand, residues effects of silage maize or maize has influenced negatively soil chemical properties and resulted in unfavorable environmental conditions of wheat plants for basic growth resources (Espinoza et al., 2015). The results coincide with that of Pagnani et al. (2019) residues obtained under wheat/wheat showed a higher thickness and weight than wheat/faba bean and were characterized by a greater percentage of hemicellulos, cellulose, and lignin, but with lower N content.

The enhancements in biological and grain yields after legume, were logical where yield components of wheat were increased following legume crops compared to cereal crops (maize or silage maize). This was in harmony with Zhang et al. (2015) they found that intercropping soybean with maize had better residual effect on the subsequent wheat compared with monoculture of maize. Gad et al. (2018) who found that the sequence of corn-clover-wheat produced highest yield and its components of wheat compared to the sequence of corn-fallow-wheat. Pagnani et al. (2019) found that wheat-faba bean sequence produce the highest grain yields, due to an increased number of spikes/ m^2, while the lowest grain yield was recorded under wheat-wheat. The superiority of grain and straw yields of wheat grown after clover may be attributed to the high values of most of yield components such as number of spikes/m2, number of grains/spike and 1000-grain weight (Abd Allah et al., 2020). Variation of wheat yield after different legume sequence could be attributed to legumes differing in the amount of biological N2 fixation. The amount of N2 fixed by legume is determined by the genetic potential, rhizobia, and symbiosis, as well as the ability of legumes to establish their symbiosis, which is influenced by the environment and management (Giller, 2001). Grain and biological yields of wheat were higher in S4 and S5 than yield in S2 and S6 as a result of growing a two-legume crop opposite one-legume crop before wheat. These results are consistent with Ouda et al. (2019) they note that wheat yield was increased by 30, 55, and 43% in the sequence maize/clover/wheat, cowpea/clover/wheat and maize + cowpea /clover/wheat, respectively compared to its value in the maize/wheat. The superiority of legume as preceding crops can be ascribed to low C/N ratio of legume stubble caused them to decompose rapidly, increasing the availability of nitrogen for the development of the next crop, which favored the wheat that followed in the rotation (Voisin et al., 2018).

Increasing nitrogen application is increasing cell division and elongation leads to an increase in plant height (Dogan and Bilgili, 2010). This finding was agreed with the result of (El-Mehy *et al.,* 2016 and Gad, 2018). Increased yield and yield components of wheat could be justified with logic that N availability satisfied wheat requirement for growth and development, which enabled the plant to produce a greater number of grains/spike (Chowdhury *et al.,* 2018). Probably, the lower values obtained from N3 compared to N2 could be due to the adverse effect of excessive N dressings on wheat grain formation, owing to increased lodged plants with increased N fertilization levels. Zhang et al. (2017) found that as nitrogen levels increased, the basal internodes became slender and fragile with the thick stem wall, while chemical components (lignin, cellulose, and silicon content) and the strength of the stem decreased gradually, which significantly increased the lodging risk. Another interpretation is that suitable N fertilizer application notably increased the non-structural carbohydrate (NSC) reserve stored in the stem pre-anthesis, which promoted the sink strength and grain filling rate of grain. Excess N fertilizer, on the other hand, significantly reduced NSC accumulation in the stem pre-anthesis and inhibited the sink strength and grain-filling rate of wheat grain.(Liang et al., 2017; Liu *et al.,* 2021). These results are in harmony with those obtained by Dogan and Bilgili (2010) and Gan et al. (2015). Mosanaei et al. (2017) stated that the highest yield components of wheat produce in the application of nitrogen fertilizers at the recommended rates and the lowest means were achieved in nitrogen rate of 15% higher than the recommended. Furthermore, increase biological and grain yields with N2 were attributed to the higher number of spikes/ m2, grain weight/spike, grains number /spike and 1000-grain weight in the N2 treatment. The results are in agreement with the results of Litke et al. (2018) stated that a significant average yield increase was observed until the nitrogen fertilizer rate N180, and any further increase of N rate (i.e. N210 and N240) did not give a significant increase of wheat yield. Chowdhury et al. (2018) found that all parameters of wheat were increased with increasing the N level up to N2 (160 kg/ ha), and further increase than that decreases these parameters. However, the reduction with N1 (50 kg N/fad.) may be due to the N availability did not satisfy wheat requirements for growth and development.

Concerning interaction, results indicated that cropping sequences combined with adequate mineral N fertilizer enhanced the growth, yield, and yield components of wheat plants. When wheat was preceded by legume crops, wheat characters increased with increasing N levels up to 70 kg N/fad. wheat plants respond to high N fertilization levels (90 kg N/ha) when wheat is sown after the cereal-crop sequence. These findings suggested that legume crops that fix N2 can benefit succeeding crops and reduce the need for mineral N fertilization.(Franke *et al.,* 2018; Gad *et al.,* 2018). Cropping sequences combined with adequate mineral N fertilizer, resulted in stable wheat yields while reducing yield risk (Macholdt et al., 2020). The variation in maize yield may be attributed to the plant density of maize being lower than recommended when maize intercropped with soybean (2 rows of maize: 2 rows of soybean), but it reached 100% of recommended when maize intercropping with cowpea.

This result in line with Abd-Rabboh et al. (2020) sole maize had the highest grain yield compared to intercropping culture. A substantial increase in fresh forage yield of clover (fahl) after the legume crop indicated the positive role of legume as the preceding crop. Results herein are in agree with those obtained by Zohry et al. (2017) stated that the highest yield of short season clover was obtained when cowpea preceded it in both growing seasons.

Alternation of a legume and wheat was merited for a higher yield and accumulated cereal units as well as increased total and net return. Intensifying the traditional crop sequences by the inclusion of cowpea or soybean (as intercrops) or fahl berseem or silage (as catch crops) is a good and rational procedure for wheat intensive land use. Results are in agree with those obtained by El-Mehy et al. (2014). Zohry et al. (2017) found that the highest values of cereal units were obtained in CS3 (cowpea then short-season clover before wheat). Like that, the inclusion of clover (fahl) in crop sequence following sole maize or intercropping with cowpea or soybean increased total and net income. Arranging cereal-legume crops in an appropriate sequence with applied the optimum N levels allows them to use the available resources more efficiently (Negash et al., 2018 and Voisin et al., 2018), and greater economic profitability (Zhang et al., 2015, Mohamed and Chen, 2018).

CONCLUSION

The current study demonstrates that diversifying cropping systems with legume crops can improve soil fertility by increasing soil content of available NPK, increasing wheat grain production ranging from 8.0 to 27.7 percent, cereal units of different crop sequences, and farmer net income, when compared to traditional crop sequence S1 (maize/wheat).In addition, results showed that applying 70 kg N/fad (N2) produced the highest wheat grain yield, cereal units, and net income compared to 50 and 90 kg N/fad (N3).Growing fahl berseem following maize monoculture (S2) or maize intercropping with cowpea (S4) and soybean (S5) increased soil content of available NPK, wheat grain yield, and values of total cereal units by 24.9, 39.5, and 32.6%, respectively, as well as net income by 90.5, 102.0, and 99.2%, respectively, over the crop sequence of maize and wheat, as the average of both seasons.

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تأثير التعاقب المحصولى ومستويات التسميد النيتروجينى على إنتاجية القمح في مصر

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يعد التكثيف المحصولى لتعاقب القمح السائد بإدراج محصول بقولى (كمحصول محمل أو محصول مؤقت) إجراء مناسب لزيادة انتاجيه الارض. لذا تم إجراء تجربة حقلية خلال موسمى الزراعة 2019/2018 و 2020/2019 في محطة البحوث الزراعية بكفر الحمام - محافظة الشرقية. حيث تم استخدام تصميم القطع المنشقة مره واحده في ثلاث مكررات لمقارنة تأثير 6 معاملات للتعاقبات المحصولية (S1: ذرة شامية / قمح ، S2: ذرة شاميه / برسيم فحل / قمح ، S3: ذرة شاميه / ذره سيلاج / قمح ، S4: تحميل لوبيا العلف مع الذرة الشاميه / برسيم فحل / قمح ، S5: تحميل فول الصويا مع الذرة الشاميه/ برسيم فحل / قمح ، S6: تحميل فول الصويا مع الذرة الشاميه/ قمح) وإضافة 3 مستويات من السماد النيتروجينى للقمح (50 ، 70 أو 90 كجم نتروجين / فدان) على محتوى التربة من NPK الميسر، محصول القمح ومكوناتة ، إجمالى وحدات الحبوب وصافي دخل المزراع. أظهرت النتائج أن التعاقبات المحصولية التى اشتملت على المحاصيل البقولية زادت من محتوى التربة من NPK الميسر. سجلت المحاصيل البقولية كمحصول سابق للقمح أعلى القيم من حاصل حبوب القمح /ف ومكوناتة معنويا مقارنة بتعاقب القمح مع المحاصيل النجيليه. حيث سجل أعلى محصول من حبوب القمح/ف (2.86 طن / فدان) مع S5 في الموسم الأول و (3.04 طن / فدان) مع S4 في الموسم الثاني، على التوالي. أدي إضافة 70 كجم نتروجين / فدان إلى زيادة محصول القمح ومكوناته مقارنة بمستوى التسميد النتروجينى 50 و 90 كجم نيتروجين / فدان. أظهر التفاعل بين التعاقب S4 أو S5 مع مستوى التسميد النتروجينى 70 كجم ن/ف تاثيرمعنوى، حيث حقق أعلى حاصل من القمح ومكوناته في كلا الموسمين. أدى استبدال التعاقب المحصولى التقليدى (ذرة / القمح، S1) بالتعاقب البقولي S4 و S5 إلى زيادة واضحة في إجمالى وحدات الحبوب/ف بنسبة 39.5 و 32.6%، وكذلك صافى الدخل بنسبة تصل إلى 102.2 و 99.2% ،على التوالي، كمتوسط الموسمين . **وعلى ذلك فإنه يمكن التوصية بزراعة البرسيم الفحل عقب الذرة الشامية المنفردة او المحملة مع لوبيا العلف أو فول الصويا لزيادة الميسر من النتروجين والفوسفور والبوتاسيوم بالتربة وزيادة محصول القمح وإجمالى وحدات الحبوب وبالإضافة إلى زيادة صافى دخل المزارع.**

الكلمات المفتاحية: البقوليات، الحبوب، التسميد، وحدة الحبوب