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INFLUENCE OF SOME CROPPING SYSTEMS AND MINERAL NITROGEN FERTILIZER LEVELS ON WHEAT PRODUCTIVITY AND ITS ATTRIBUTES UNDER SANDY SOIL CONDITIONS

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ABSTRACT

Two field experiments were carried out at Ismailia Agricultural Experiments and Research Station, A.R.C., El- Ismailia governorate, Egypt, during 2015 and 2016 seasons to increase wheat productivity and profitability with reducing N input after intercropping system of maize with peanut, as well as, cultures of sole maize and peanut under sandy soil conditions. Three cropping systems of summer crops (intercropping maize with peanut, sole maize and sole peanut) and three N fertilizer levels for wheat (low '214.2', medium '261.8' and high '309.4' kg N ha^{-1}) were tested. A split plot design with three replications was used. Cropping systems of summer crops were randomly assigned to the main plots, meanwhile N fertilizer levels of wheat were allotted in subplots. The results showed that cropping systems of summer crops had significant effect on all studied wheat traits except 1000 – grain weight in the two seasons. Intercropping system (maize + peanut) increased significantly plant height, number of spikes per m^2, number of grains spike^{-1}, grains weight spike^{-1} and grain yield ha^{-1} compared with those after cultures of sole maize or sole peanut. Mineral N fertilizer levels affected significantly all the studied wheat traits in the two seasons except 1000 – grain weight in the 1st season only. The medium and the highest mineral N fertilizer levels had similar effect on grain weight spike^{-1}, 1000 – grain weight and grain yield ha^{-1}. The interaction between cropping systems of summer crops and mineral N fertilizer levels affected significantly 1000 – grain weight and grain yield ha^{-1} in the 1st season and grains weight spike^{-1} and grain yield ha^{-1} in the 2nd season. The cropping system (maize + peanut / wheat) with application of medium mineral N fertilizer levels for wheat plants recorded the highest productivity and net return per year compared to the conventional system (peanut/ wheat) with the application of high mineral N fertilizer levels for wheat plants.

It can be concluded that wheat plants that received 261.8 kg N ha^{-1} in the winter after the intercrops (maize + peanut) in the summer decreased mineral N inputs for the following wheat plants by 15.3% in the winter and increased net return by about US$ 80 ha^{-1} in both the years compared to the conventional cropping system (peanut/wheat) with the application of 309.4 g N ha^{-1} for wheat plants.

(Key words: Intercropping, maize, peanut, wheat, N fertilizer, financial return)

INTRODUCTION

In Egypt, wheat (*Triticum aestivum* L.) is the most important cereal crop as it is the staple food of the Egyptian people, but the gap between wheat consumption and production is continuously increasing due to steady increase in the human population with limited cultivated area. Wheat grain yield is primarily nitrogen (N) – limited under production system, especially Subba-Rao (1980) predicted the requirements for mineral N fertilizer increased during forty years ago. In this concern, Behera (1995) reported that application of 100% of the recommended mineral N fertilizer (120 kg ha^{-1}) for wheat recorded higher grain and straw yields than the 50% of the recommended mineral N fertilizer.

Although crop productivity can be enhanced by nitrogen (N) fertilization and diverse/complex cropping systems, these practices may strongly interact and impact soil properties differently (Russell *et al.*, 2006). It is known that crop residue is a good source of nutrients in many agro – ecosystems for sustainable crop production and environment (Blanco – Canqui and Lal, 2009), while organic N fertilizers must be converted, or mineralized, by microbes to nitrate and ammonium compounds (Moore *et al.*, 2009). In Egypt, intensive cropping system (peanut/Egyptian clover-one cut/wheat) increased total and net returns as compared with the conventional cropping system; peanut/ wheat (Abdel-Galil *et al.*, 2015).

Accordingly, these observations led to integration of crop sequence of peanut (*Arachis hypogaea* L.) and

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maize (*Zea mays* L.) either by grown together in intercropping or grown in sole cultures in summer season and their interaction on the following crop at winter season. Hence, there is an urgent need to maximize the efficient use of cropping systems for achieving high wheat grain yield without excessive use of mineral N. The present study was therefore,conducted to increase wheat productivity and profitability with reducing N input after intercropping system of maize with peanut, as well as, cultures of sole maize and peanut under sandy soil conditions.

MATERIALS AND METHODS

Two field experiments were carried out at Ismailia Agricultural Experiments and Research Station, A.R.C., Ismailia governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m a.s.l.), Egypt during 2015/16 and 2016/17 seasons to increase wheat productivity and profitability with reducing N input after intercropping system of maize with peanut, as well as, cultures of sole maize and peanut under sandy soil conditions. Chemical analysis of the soil (0 – 60 cm) was done by Water, Soil and Environment Research Institute, ARC (Table 1) according to methods of Jackson (1958) and Chapman and Pratt (1961).

Table 1. Chemical properties of Ismailia site after harvested summer crops

Chemical soil properties	Cropping systems of summer crops		
	Peanut + maize	Maize	Peanut
$CaCO_3$ (%)	1.26	1.70	1.70
Organic matter (%)	1.09	0.85	0.92
pH	7.65	7.94	7.26
Available N (mg 100 g^{-1})	3.02	2.16	2.91
Available P (mg 100 g^{-1})	1.89	1.45	1.74
Available K (mg 100 g^{-1})	14.02	12.10	14.00
Available Ca (mg 100 g^{-1})	65.00	44.20	62.10
Available Mg (mg 100 g^{-1})	13.55	11.40	14.00
Available Fe (ppm)	5.50	4.10	5.10
Available Mn (ppm)	3.10	3.20	4.00
Available Zn (ppm)	0.80	0.60	0.50

The treatments were the combinations of three cropping systems of summer crops (intercropping maize with peanut, as well as, cultures of sole maize and peanut). Three N fertilizer levels for wheat (low '214.2', medium '261.8' and high '309.4' kg N ha^{-1}) were added, high level of N was the recommended one under sandy soil in Egypt. Peanut cv. Ismailia 1 'semi – erect' and maize cv. S.C. 168 were sown on May 26th and 30th at 2015 and 2016 seasons, respectively. Wheat cultivar cv. Sakha 94 was sown on 20th and 25th November at 2015 and 2016 winter seasons. Sprinkler irrigation was the irrigation system. Calcium super phosphate (15.5% P_2O_5) at the rate of 476 kg ha^{-1} was applied during soil preparation for planting maize and peanut in the summer season and peanut seeds were inoculated by *Bradyrhizobium* before seeding it. Sole maize was conducted by planting maize in ridges 60 cm width and left one plant per hill spaced at 35 cm after thinning. Also, sole peanut was conducted by planting peanut in ridges 60 cm width and left one plant $hill^{-1}$ spaced at 10 cm after thinning. Meanwhile, intercropping culture was conducted by planting maize in middle of beds 120 cm width and left two plants $hill^{-1}$ spaced at 35 cm after thinning, peanut was planted in both sides of maize beds and left one plant $hill^{-1}$ spaced at 10 cm after thinning. Calcium sulfate at rate of 1190 kg ha^{-1} was applied for peanut after 35-40 days from peanut planting. Potassium sulfate (48% K_2O) at a rate of 240 kg ha^{-1} was added in two equal doses at sowing and after 30 days. Mineral N fertilization was applied to maize plants by the rate of 480 kg ha^{-1} as ammonium sulfate (20.6% N) in three equal doses at 15, 30 and 45 days after planting. Mineral N fertilization was applied to peanut plants by the rate of 35.7 kg N ha^{-1} as ammonium sulfate (20.6% N) at 15 days after planting. In the two winter seasons, calcium super phosphate (15.5% P_2O_5) at rate of 476 kg ha^{-1} was applied during soil preparation for planting wheat. Potassium sulfate (48% K_2O) at a rate of 240 $kgha^{-1}$ was added in two equal doses at sowing and after 30 days. Wheat grains were drilled at the rate of 166.6 kg ha^{-1} in 6 rows on bed with120 cm width. All agronomic practices were carried out according to technical recommendations of groundnut at Ismailia Governorate. At harvest, the following traits were measured on ten guarded plants according to the intercropping system from each plot: Plant height (cm), number of spikes per m^2, number of grains $spike^{-1}$, grains weight $spike^{-1}$ (g) and 1000

– grain weight (g). Grain yield ha^{-1} (t) was recorded on the basis of experimental plot area by harvesting of all plants of each plot. A split plot design was used with three replications. Cropping systems of summer crops were randomly assigned to the main plots, meanwhile N fertilizer levels of wheat were allotted in subplots. Each plot contained 12 ridges (4.0 m in length, 0.6 m in width). In case of beds, plot contained 6 beds (4.0 m in length, 1.2 m in width) the plot area was 28.8 m^2.

Peanut pods, maize grains and wheat grains prices presented by (Anonymous, 2016 and 2017) were used. Net return year^{-1} was calculated as follows: Net return year^{-1} = total costs – total return according to cropping systems of summer crops + N fertilizer levels of wheat.

Analysis of variance was performed using MSTATC statistical package (Freed, 1991). Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Cropping systems of summer crops

Data in table 2 shows that plant height, number of spikes per m^2, number of grains spike^{-1}, grains weight spike^{-1} and grain yield ha^{-1} were affected significantly by cropping systems of summer crops in the two growing seasons, meanwhile 1000 – grain weight was not affected. Intercropping system (maize + peanut) caused higher values of wheat for plant height, number of spikes per m^2, number of grains spike^{-1}, grains weight spike^{-1} and grain yield ha^{-1} in comparison with those followed maize. It is important to mention that there were no significant differences between preceded peanut and maize on wheat grain yield and its attributes except grain yield ha^{-1} in the 2nd season.

Intercropping system (maize + peanut) increased significantly grains weight spike^{-1} by 10.71 and 9.71% in the 1st and 2nd seasons, respectively, as compared with those followed maize. Also, grain yield ha^{-1} was increased by 10.85 and 11.25% in the 1st and 2nd seasons, respectively, as compared with those followed maize. These results could be due to different effects on the chemical and physical soil properties which reflected on the studied wheat traits later (Table 1). Soil after maize had lower nutrients than those of the harvested intercrops. It seems that roots variation of the intercrops (maize + peanut) changed three dimensions of the experiential soil (from the top to the bottom of the soil profile, from north to south and east to west); and it is apt to suggest that soil structure and porosity was improved than the roots of sole crops. Accordingly, variation between root system morphology and its distribution of the intercrops was biological tool in determining the magnitude of below-ground biological soil interactions than roots of sole maize or peanut. So, it is expected that intercropping maize with peanut altered the dynamics of organic matter turnover and the rate of nutrient cycling within the experimental soil through soil biological activity (Tian *et al*., 1993) and availability of soil nutrients (Asghar *et al*., 2006) before wheat sowing.

Mineral N fertilizer levels on wheat

Data in table 2 shows that plant height, number of spikes per m^2, number of grains spike^{-1}, grains weight spike^{-1},, 1000 – grain weight and grain yield ha^{-1} were affected significantly by N fertilizer levels in the two growing seasons, meanwhile 1000 – grain weight in the 2nd season was not affected. The highest N fertilizer level (309.4 kg ha^{-1}) gave higher values of plant height, number of spikes per m^2, number of grains spike^{-1}, grains weight spike^{-1} and grain yield ha^{-1} (t) in comparison with those of other lower ones. In general, there were no significant differences between medium (261.8 kg N ha^{-1}) and high N fertilize levels (309.4 kg N ha^{-1}) for grains spike^{-1} and grain yield ha^{-1} in the two seasons. This may be due to the residual effects of preceding crops (mixed and pure stand of peanut). It seems that low N fertilizer level (214.2 kg N ha^{-1}) had negative effects on studied wheat traits at harvest, whereas N deficiency decreased spikelet number and delayed time of double row and terminal spikelet (Longnecker *et al*., 1993). Conversely, wheat plants that received 309.4 or 261.8 kg N ha^{-1} had higher values of grains weight spike^{-1}, 1000 – grain weight and grain yield ha^{-1}. This could be justified with logic that N availability satisfied wheat requirement for growth and development, which enabled the plant to produce more dry matter accumulation.. These data attributed to the adequate mineral N level (261.8 kg N ha^{-1}), which might facilitate the tillering ability of the plants, resulting in greater spike population (Jan and Khan, 2000). It is known that assimilates availability from flag leaf developed under high N supply determined the number of fertile florets at anthesis and in turn final grain number and that would be key trait to improve wheat yield without changing the anthesis date (Kumari, 2011).

The interaction between cropping systems of summer crops and mineral N fertilizer levels on wheat

Data in table 2 shows that cropping systems of summer crops x mineral N fertilizer levels affected significantly grain yield ha^{-1} in the first and second seasons. These results revealed that wheat plants that followed intercropping system (maize + peanut) and received 309.4 or 261.8 kg N ha^{-1} had the highest grains weight spike^{-1}, 1000 – grain weight and grain yield ha^{-1} compared with the other treatments. It seems that this improvement had a great ecological importance. It is expected that if such improvement continues unabated year after year, the overall situation will improve considerably within a few years. The intercrops had positive effects on the chemical soil properties which interacted with the adequate mineral N level to increase available soil major nutrients (Table 1) that reflected on the studied wheat traits later compared with the others (Table 2). It is evident from the data that the intercrops (maize + peanut) could be played a major role in improvement of nutritional status of the experimental soil than they grown alone.

Table 2. Effect of cropping systems of summer crops, N fertilizer levels and their interaction on wheat grain yield and its attributes in the two seasons

Cropping systems	N fertilizer level for wheat	Pant height (cm)	Number of spikes/m^{-2}	Number of grains spike^{-1}	Grains weight spike^{-1} (g)	1000 - grains weight (g)	Grain yield (t ha^{-1})
First season							
Peanut + maize	214.2 kg N ha^{-1}	82.60	329.66	38.31	1.77	40.32	6.22
	261.8 kg N ha^{-1}	84.50	335.00	41.28	1.87	42.46	6.66
	309.4 kg N ha^{-1}	88.56	338.33	42.92	1.95	42.72	7.05
	Mean	85.22	334.33	40.84	1.86	41.83	6.64
Maize	214.2 kg N ha^{-1}	73.76	326.66	36.94	1.59	38.66	5.65
	261.8 kg N ha^{-1}	77.00	333.00	39.95	1.72	39.75	6.11
	309.4 kg N ha^{-1}	83.23	335.66	40.80	1.74	41.29	6.22
	Mean	78.00	331.77	39.23	1.68	39.90	5.99
Peanut	214.2 kg N ha^{-1}	75.76	324.33	37.23	1.69	39.63	5.94
	261.8 kg N ha^{-1}	81.50	333.00	40.72	1.80	41.41	6.35
	309.4 kg N ha^{-1}	84.60	335.00	41.67	1.84	42.19	6.49
	Mean	80.62	330.77	39.87	1.78	41.08	6.26
Average of N fertilizer	214.2 kg N ha^{-1}	77.37	326.88	37.49	1.68	39.53	5.93
	261.8 kg N ha^{-1}	81.00	333.66	40.65	1.79	41.21	6.37
	309.4 kg N ha^{-1}	85.46	336.33	41.80	1.84	42.06	6.59
L.S.D. 0.05 Cropping systems		3.90	2.47	0.95	0.16	–	0.39
L.S.D. 0.05 N fertilizer levels		2.33	2.87	0.58	0.07	0.88	0.25
L.S.D. Interaction		-	-	-	-	1.82	0.42
Second season							
Peanut + maize	214.2 kg N ha^{-1}	89.83	341.33	40.88	1.81	42.44	5.84
	261.8 kg N ha^{-1}	91.90	345.33	44.12	1.92	44.77	6.24
	309.4 kg N ha^{-1}	94.76	351.00	45.50	2.03	45.91	6.60
	Mean	92.16	345.88	43.50	1.92	44.37	6.23
Maize	214.2 kg N ha^{-1}	84.86	338.00	39.43	1.67	40.86	5.21
	261.8 kg N ha^{-1}	87.90	341.66	42.19	1.78	41.76	5.77
	309.4 kg N ha^{-1}	91.06	343.66	42.27	1.80	42.76	5.83
	Mean	87.94	341.11	41.29	1.75	41.80	5.60
Peanut	214.2 kg N ha^{-1}	85.80	337.66	40.03	1.75	41.88	6.18
	261.8 kg N ha^{-1}	89.46	344.00	42.36	1.84	43.68	5.53
	309.4 kg N ha^{-1}	91.70	347.00	42.66	1.87	41.78	6.02
	Mean	88.98	342.88	41.68	1.82	42.45	5.91
Average of N fertilizer	214.2 kg N ha^{-1}	86.83	339.00	40.11	1.74	41.73	5.74
	261.8 kg N ha^{-1}	89.75	343.66	42.89	1.85	43.40	5.85
	309.4 kg N ha^{-1}	92.51	347.22	43.48	1.90	43.48	6.15
L.S.D. 0.05 Cropping systems		2.98	4.49	1.32	0.11	N.S.	0.49
L.S.D. 0.05 N fertilizer levels		0.74	2.80	0.71	0.06	N.S.	0.31
L.S.D. Interaction		-	-	-	0.12	-	0.54

Table 3. Financial return of cropping systems of summer crops and mineral N fertilizer levels on wheat in the two seasons

Cropping systems	N fertilizer level for wheat	Yield (t ha^{-1}) of cropping systems		Financial return (US$ ha^{-1})			
		Summer crops	Wheat	Summer crops	Wheat	Total	Net year^{-1}
			First season				
Peanut + maize	214.2 kg N ha^{-1}	1.78 (peanut) +	6.22	808 (peanut)	855	2035	1540
	261.8 kg N ha^{-1}	3.24 (maize)	6.66	+ 372 (maize)	916	2096	1573
	309.4 kg N ha^{-1}		7.05		970	2150	1598
	Mean	**1.78 + 3.24**	**6.64**	**808 + 372**	**913**	**2093**	**1570**
Maize	214.2 kg N ha^{-1}	4.97	5.65	571	777	1348	1072
	261.8 kg N ha^{-1}		6.11		840	1411	1074
	309.4 kg N ha^{-1}		6.22		855	1426	1028
	Mean	**4.97**	**5.99**	**571**	**824**	**1395**	**1058**
Peanut	214.2 kg N ha^{-1}	2.53	5.94	**1148**	817	1965	1470
	261.8 kg N ha^{-1}		6.35		873	2021	1498
	309.4 kg N ha^{-1}		6.49		893	2041	1489
	Mean	**2.53**	**6.26**	**1148**	**861**	**2145**	**1485**
Second season							
Peanut + maize	214.2 kg N ha^{-1}	1.66 (peanut)	5.84	753 (peanut)	803	1914	1419
	261.8 kg N ha^{-1}	+ 3.12 (maize)	6.24	+ 358 (maize)	858	1969	1446
	309.4 kg N ha^{-1}		6.60		908	2019	1467
	Mean	**1.66 + 3.12**	**6.23**	753 + 358	**856**	**1967**	**1444**
Maize	214.2 kg N ha^{-1}	4.78	5.21	549	716	1265	989
	261.8 kg N ha^{-1}		5.77		793	1342	1005
	309.4 kg N ha^{-1}		5.83		802	1351	953
	Mean	**4.78**	**5.60**	**549**	**770**	**1319**	**982**
Peanut	214.2 kg N ha^{-1}	2.40	6.18	1089	850	1939	1444
	261.8 kg N ha^{-1}		5.53		760	1849	1326
	309.4 kg N ha^{-1}		6.02		828	1917	1365
	Mean	**2.40**	**5.91**	**1089**	**812**	**2037**	**1378**

Prices of main products are US$ 137.6 ha^{-1} for ton of wheat grains, US$ 454.0 ha^{-1} for ton of peanut pods and US$ 115.0 ha^{-1}for ton of maize grains

Financial return

Data in table 3 showed financial return of cropping systems of summer crops and mineral N fertilizer levels on wheat in the two seasons. Net return was varied between treatments from US$ 1028 ha^{-1} (wheat plants that received 309.4 kg N ha^{-1} that followed maize) to US$ 1598 ha^{-1} (wheat plants that received 309.4 kg N ha^{-1} that followed the intercrops 'maize + peanut') in the first year. Also, net return was varied between treatments from US$ 953 ha^{-1} (wheat plants that received 309.4 kg N ha^{-1} that followed maize) to US$ 1467 year (wheat plants that received 309.4 kg N ha^{-1} that followed intercrops 'maize + peanut') in the second one.

It is important to mention that wheat plants that received 261.8 kg N ha^{-1} that followed the intercrops 'maize + peanut' recorded the highest net return (US$ 1573 ha^{-1} in the first year and US$ 1446 ha^{-1} in the second one) compared to the others. It is noticed that net return reached maximum values by intercropping maize with peanut in the summer and growing wheat that received 261.8 kg N ha^{-1} in the following winter. Similar results were obtained by Abdel-Galil *et al.* (2015) who found that intensive cropping system by using the local cultivar of peanut (Ismailia 1) was more profitable for Egyptian farmers through increasing the followed wheat productivity.

It can be concluded that wheat plants that received 261.8 kg N ha^{-1} in the winter after the intercrops (maize + peanut) in the summer decreased mineral N inputs for the following wheat plants by 15.3% in the winter and increased net return by about US$ 80 ha^{-1} in both years compared to the conventional cropping system (peanut/wheat) with application of 309.4 g N ha^{-1} for wheat plants.

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