

Influence of Conventional and Intensive Cropping Sequences on Wheat Productivity under Different Mineral Nitrogen Fertilizer Rates

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ABSTRACT

A two-year study was conducted at Sakha Research station, Agricultural Research Center (ARC), Kafr El-Shiekh governorate, Egypt during 2013/2014 and 2014/2015 to decrease mineral nitrogen (N) inputs of wheat crop. This study included two experiments each one contained 9 treatments, which were combinations of three cropping sequences (summer crop/Egyptian clover "fahl"/wheat, summer crop/fodder maize/wheat and summer crop/fallow/wheat) and three mineral N fertilizer rates (80 kg N/fad, 60 kg N/fad + ascobien and 40 kg N/fad + ascobien). A split plot design with three replications was used and combined analysis was done for the two experiments in each season. The results showed that there were clearly insignificant differences between rice and maize as a preceded summer crop on grain yield of wheat plants. The cropping sequence (maize or rice /Egyptian clover "fahl"/wheat) increased significantly all the studied wheat traits compared with the other cropping systems in the two seasons. There were insignificant differences between application of 80 kg N/fad and 60 kg N/fad + ascobien for grain yield/fad in the two seasons. The optimum grain yield/fad was obtained by growing Egyptian clover "fahl" during transition period between preceded maize or rice in the summer season and wheat that fertilized by 60 kg N/fad + ascobien in the winter season.

Keywords: Wheat, Maize, Rice, Egyptian clover, Cropping systems, N fertilizer.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop because it is the staple food of the Egyptian people. However, it is primarily nitrogen (N) – limited under production system in Egypt, Subba-Rao (1980) predicted the requirements for mineral N fertilizer will increase in the future. Now, the use of expensive chemical N fertilizers in Egypt is a limiting factor for the low-income farmers and increases the cost of crop production where prices of chemical N fertilizers during a few years have increased. With the current technology for fertilizer production and the inefficient methods employed for fertilizer application, both the economic and ecological costs of fertilizer usage will eventually become prohibitive (Dixon and Wheeler, 1986). However, N is the most important nutrient element required for crop production. N deficiency is one of the major yield limiting factors for cereals (Shah *et al.*, 2003). N is considered to be the most important factor in wheat production under Egyptian agricultural conditions (FAO, 2005).

Hence, there is an urgent need to maximize the efficient use of this element without excessive use of mineral N fertilizer by some agricultural practices through the suitable cropping sequences with using bio- fertilizers, which are natural, beneficial and ecologically friendly. Accordingly, the cropping system adopted by the farmer in these soils should

be physically viable, sustainable, less exhaustive acceptable to farming community. Mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to longer-term agroecosystem sustainability, up to societal and ecological benefits (Malezieux *et al.*, 2009). Generally, the conventional cropping sequence in these areas is double cropping system (two crops per year). However, the preceded summer crop as rice (*Oryza sativa* L.) promoted degradation and inefficient use of natural resources, particularly soils and water (Gupta and Seth, 2007). Also, Hamd-Alla *et al.* (2015) revealed that wheat yield was reduced after maize (*Zea mays* L.) harvest. Consequently, if Egyptian agricultural production must be intensified, ways of making maximum use of land must be pursued without soil degradation and pollution. This necessitates the inclusion of catch crop as fodder crop such as fodder maize or Egyptian clover (*Trifolium alexandrinum* L.) after summer crop harvest and before wheat sowing which leading to triple cropping sequences.

Moreover, bio- fertilizers are natural, beneficial and ecologically friendly. Ascorbic acid and citric acid and their salts are widely known for their role as chelators and acidulants (Oktar *et al.*, 2001 and Kim *et al.*, 2006). Accordingly, there is need to explore the possibilities of using the expanding native sources of plant nutrition by adding

antioxidants such as ascorbic acid which containing (25% ascorbic acid +13% citric acid) under such condition; especially the beneficial effects of ascorbic acid upon growth have been reported on wheat (Ahmed, 2015). Therefore, the objective of this investigation was to decrease mineral N inputs of wheat crop.

MATERIALS AND METHODS

A two-year study was carried out at Sakha Agricultural Experiments and Research Station, Agricultural Research Center (A.R.C.), Kafr El – Sheikh governorate (31°06'42"N, 30°56'45"E, 17 m a.s.l.), Egypt, during 2013/2014 and 2014/2015 to decrease mineral N inputs of wheat crop. The soil was clay textured. Chemical analysis of the soil (0 – 60 cm) was done by Water, Soil and Environment Research Institute, ARC (Table 1). Chemical analysis of the soil was determined using the methods described by Jackson (1958) and Chapman and Pratt (1961). This study included two experiments beginning with preceding summer crop (Rice or Maize), each experiment include 9 treatments which were the combinations of three cropping sequences (summer crop/Egyptian clover "fahl"/wheat, summer crop/fodder maize/wheat and summer crop/fallow/wheat) and three mineral N fertilizer rates (80 kg N/fad, 60 kg N/fad + ascorbic and 40 kg N/fad + ascorbic).

Cultivars of all the tested crops were as follows: rice cv. Sakha 106, maize cv. S.C.128, Egyptian clover cv. Gemmiza 1 'fahl – one cut' and wheat cv. Giza 168. Wheat plots were tilled in two tillages, then it was fertilized by phosphor and potassium in form of calcium superphosphate (P₂O₅, 15.5%) and potassium sulfate (48%), respectively. Nitrogen fertilization was split in the form of urea (46.5%) into two equal doses; the first dose was applied to the soil before the 1st irrigation and the second one was applied before the 2nd irrigation. Ascorbic was added as a foliar application in two equal doses after one and two months from wheat sowing (200 g Ascorbic acid/150 L water) for each dose. Furrow irrigation is the irrigation system in the area. Recommended cultural practices for growing all crops were implemented as provided by the Egyptian Ministry of Agriculture. Dates of sowing and harvesting of all the tested crops are presented in Table (2).

At 60 and 120 days from wheat sowing, the following traits were measured from each sub plot: Dry weight/m² (g) and leaf area index (LAI). Flag leaf area (cm²) was measured at 120 days from wheat sowing then calculated as a mean of ten flag leaves area from each sub plot. At harvest, the following traits were measured from each sub plot: plant height (cm), number of spikes/m², number of grains/spike. Grain yield/fad (ardab) was recorded on the basis of experimental plot area by harvesting all plants of each sub plot.

Table 1: Chemical properties of soil (0 - 60 cm depth) during different periods during the year.

Traits		Maize experiment	Rice experiment
Before planting the experiment	N (ppm)	20	20
	P (ppm)	36	36
	K (ppm)	656	656
After maize or rice harvesting	N (ppm)	32	26
	P (ppm)	51	43
	K (ppm)	704	684
After Egyptian clover cutting	N (ppm)	55	45
	P (ppm)	72	69
	K (ppm)	848	811
After fodder maize harvesting	N (ppm)	34	34
	P (ppm)	56	62
	K (ppm)	733	759

Table 2: Dates of sowing and harvesting of all the tested crops in the two seasons.

Crops	2014		2015	
	Sowing	Harvested	sowing	harvested
Rice	19 May	10 September	10 May	1 September
Maize	20 May	10 September	10 May	1 September
Forage berseem	20 September	24 November	11 September	13 November
Fodder Maize	20 September	24 November	11 September	13 November
Wheat	3 December	23 April	20 November	10 April

The treatments were assigned at random in each experiment in split plot design in three replications and a combined analysis for the two experiments was done in each season. Crop sequences (forage crops) were arranged at random in the main plots, whereas mineral N fertilizer rates were randomly allocated in sub plots. The sub plots area was 7 x 4 m. Data was statically analyzed according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

I. Growth characters:

Data in Tables 3 and 4 show that preceding crop had a significant effect on Dry weight (g/m^2) of wheat at 60 and 120 days and plant height in both seasons as well as flag leaf area (cm^2) at heading in the second season. Application of rice as preceding crop resulted in a significant increase in Dry weight (g/m^2) of wheat compared with maize in the two seasons. The inverse was true in flag leaf area and plant height. LAI did not significantly affected by preceding crop at the two sampling dates in both seasons. It is likely that residual effects of rice enhanced complementary positive interactions in soil than those of maize which reflected positively on different biological processes in the rhizosphere of wheat and in turn increased Dry weight per unit area. These results may be attributed to rice allowed the transport of oxygen into the rhizosphere thus providing a habitat for both aerobic and anaerobic bacteria involved in redox reactions of the C, N and S cycle (Sessitsch *et al.*, 2012). Meanwhile, maize is supportive for aerobic degradation of organic matter to CO_2 (Breidenbach *et al.*, 2017).

According to crop sequences data in table (3& 4) showed that there was a significant effect on all growth characters in both seasons. It seems that Egyptian clover gave the highest wheat dry weight/ m^2 , LAI, flag leave area and plant height compared with the others. These results may be due to the beneficial effect of decomposition of Egyptian clover residues that altered positively the dynamics of organic matter turnover and the rate of nutrient cycling within the soil. It is known that soil organic matter accumulation improve soil quality through its extensive impacts on soil physical, chemical and biological properties (Johnston *et al.*, 2009). Such effect was expected because of soil N availability was increased as result of a mix of living rhizobia and dead Egyptian clover roots in the experimental soil before wheat sowing (Table 1). Accordingly, the rate of photosynthesis which reflected positively on dry weight of whole plant could be maintained high during grain filling in later periods of senescence as a consequence of increase LAI. On the other hand, residues effects of fodder maize has influenced negatively soil chemical properties (Table 1) and resulted in unfavorable environmental conditions between wheat plants for basic growth resources.

The results show that the highest dry weight/ m^2 , LAI, flag leave area and plant height was obtained

with application of 80 kg N/fad followed 60 kg N/fad + ascobien (Table 3&4). It is important to mention that there were insignificant differences between the highest and the medium mineral N rate for LAI. Obviously, ascobien that is a simulative compound containing (13% ascorbic acid, 25% citric acid) enhanced cell division and enlargement which reflected positively on leaf area. Ascobien is a product of D-glucose metabolism which effected nutrition cycles activity in higher plants and plays an important role in the electron transport system (Helsper *et al.*, 1982). Thus, ascorbic +citric acids appeared to act in a concert which indicates a complete set of antioxidant defense system. These results are in harmony with those obtained by Abd-El-Hameed (2004), bakry (2013), El Tahan (2015) and Ahmed (2015). On other hand, application of 40 kg N/fad + ascobien recorded the lowest values for growth characters in the two seasons. These results may be due to N availability did not satisfy wheat requirement for growth and development.

II. Grain yield and its attributes:

Data in (Table 5) shows that preceding summer crop had a significant effect on number of grains/ m^2 , while number of grains/spike and grain yield (ardab/fed.) did not affect. Preceded maize crop caused significant decreases in number of spikes/ m^2 compared to those of preceded rice crop. Accordingly, it is expected that growth resources such as water and soil nutrients were more relatively absorbed and converted to crop biomass during growth and development stages of wheat plants that followed rice than wheat after maize harvest. It is known that the photosynthetic rate/unit area of leaf depends on the development and maintenance of the photosynthetic system (Farquhar *et al.*, 1980).

Cropping sequences affected significantly number of spikes/ m^2 , number of grains/spike and grain yield/fad in the two seasons except number of grains/spike in the first one (Table 4&5). Egyptian clover in the transition period gave the highest number of spikes/ m^2 , number of grains/spike and grain yield/fad compared with the others. These results probably due to the residual effects of Egyptian clover increased soil N, P and K availability (Table 1) for wheat growth and development that affected positively the yield attributes of wheat compared with the others. These results reveal that residual effects of Egyptian clover enhanced efficiency of photosynthetic process of wheat crop which reflected on yield attributes of wheat.

Mineral N fertilizer rate had significant effect on number of spikes/ m^2 , number of grains/spike and grain yield/fad in the two seasons (Table 4&5). Wheat plants which fertilized with 80 kgN/fad gave the highest values of number of spikes/ m^2 , number of grains/spike and grain yield/fad in the two seasons.

Table 3: Dry weight/plant (gm/m²) and Leaf area index (LAI) as affected by crop sequences and nitrogen fertilization in 2014 and 2015 seasons.

Factor	Dry weight (g/m ²)				LAI			
	2014		2015		2014		2015	
	Days after sowing							
	60	120	60	120	60	120	60	120
P.C (P)								
Rice	690 a	2483.6 a	796.4	2537.2 a	3.25	5.72	8.26	9.56
Maize	682.9 b	2142.2 b	768.1	2351.6 b	3.45	3.04	6.51	7.58
f-test	**	**	NS	**	NS	NS	NS	NS
Forage crop (F)								
Clover	708.9 a	2427.1 a	799.6 a	2530.9 a	3.65 a	5.21 a	7.23 a	9.18 a
Maize	671.5 b	2216.8 c	764.8 c	1359.6 c	3.16 b	4.14 b	6.22 b	7.93 b
Non	678.9 b	2294.8 b	782.3 b	2442.7 b	3.25 b	5.27 a	6.57 ab	8.6 a
f-test	**	**	**	**	**	**	**	**
N/fed. (N)								
80	731.3 a	2429.0 a	823.7 a	2523.3 a	3.96 a	5.47 a	8.87 a	8.5 a
60 + Ascobine	691.0 b	2333.2 b	775.6 b	2453.1 b	3.53 b	4.79 ab	6.91 ab	8.7 a
40 + Ascobine	637.1 c	2176.6 c	747.4 c	2356.8 c	2.57 c	4.36 b	6.39 b	7.7 b
f-test	**	**	**	**	**	**	**	**
Interaction								
P X F	**	**	**	**	*	**	**	**
P X N	N.S	**	N.S	**	**	**	**	*
F X N	N.S	**	**	*	**	*	NS	**
P X F X N	*	**	**	**	**	**	NS	**

*, ** and NS indicate P<0.05, P<0.01 and not significant, respectively. In each factor, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 4: Flag leaf area (cm²), Plant height (cm), Spike no./m² and grain no./spike as affected by crop sequences and nitrogen fertilization in 2014 and 2015 seasons.

Factor	Flag leave area (cm ²)		Plant height (cm)		Spikes No./m ²		Grains No./sike	
	2014		2015		2014		2015	
	Days after sowing							
	60	120	60	120	60	120	60	120
P.C (P)								
Rice	22.2	22.66 b	78.02 b	80.31 b	471.32 a	448.62 a	52.05	54.17
Maize	21.76	24.6 a	86.66 a	86.35 a	390.37 b	401.67 b	52.09	56.42
f-test	NS	**	**	**	**	**	NS	NS
Forage crop (F)								
Clover	23.88 a	25.32 a	84.85 a	85.74 a	500.2 a	502.76 a	53.48	57.45 a
Maize	21.08 b	22.52 b	80.54 c	81.78 b	382.59 c	354.86 c	51.63	54.48 b
Non	20.97 b	23.05 b	81.62 b	82.47 b	409.75 b	417.81 b	51.1	53.95 b
f-test	**	**	**	**	**	**	NS	**
N/fed. (N)								
80	24.55 a	26.21 a	85.33 a	85.85 a	472.18 a	482.98 a	54.35 a	58.39 a
60 + Ascobine	23.4 b	25.33 a	83.05 b	84.5 b	435.93 b	427.53 b	52.86 b	56.03 b
40 + Ascobine	17.98 c	19.35 b	78.64 c	79.65 c	384.42 c	364.91 c	48.99 c	51.47 c
f-test	**	**	**	**	**	**	**	**
Interaction								
P X F	**	**	**	**	**	**	N.S	**
P X N	**	*	**	**	**	N.S	N.S	N.S
F X N	N.S	N.S	N.S	*	*	N.S	**	**
P X F X N	**	*	**	**	**	**	N.S	**

*, ** and NS indicate P<0.05, P<0.01 and not significant, respectively. In each factor, means followed by a common letter are not significantly different at the 5% level by DMRT

Table 5: Grain yield (ardab/fed.) of wheat cv. Giza 168 as affected by crop sequences and nitrogen fertilization and their interactions in 2014 and 2015 seasons.

		2014				2015			
P.C	Forage	N. Fertilization			Mean	N. Fertilization			Mean
		80	60+	40+		80	60+	40+	
			Ascobine	Ascobine			Ascobine	Ascobine	
		Mean (P X F X N)			(P X F)	Mean (P X F X N)			(P X F)
Rice	Clover	19.84 a	19.57 a	16.67 bcd	18.69	21.5 a	21.45 a	17.46 f	20.14 A
	Maize	19.61 a	16.15 cd	16.76 bcd	17.51	20.27 abc	19.92 bc	17.25 f	19.15 B
	Non	18.58 ab	18.15 abc	13.46 e	16.73	20.68 ab	18.98 cde	15.72 g	18.46 C
Maize	Clover	20.25 a	20.18 a	14.93 de	18.45	21.08 ab	20.86 ab	18.07 ef	20 A
	Maize	19.18 a	18.6 ab	11.16 f	16.31	19.69 bcd	18.4def	12.2 h	16.76 D
	Non	19.54 a	18.73 ab	13.12 e	17.13	20.34 abc	19.91 bc	14.43 g	18.23 C
		Mean (P X N)			(P)	Mean (P X N)			(P)
Rice		19.34 a	17.96 b	15.63 c	17.64	20.82 a	20.12 ab	16.81 c	19.25
Maize		19.66 a	19.17 a	13.07 d	17.3	20.37 ab	19.72 b	14.9 d	18.33
		Mean (F X N)			(F)	Mean (F X N)			(F)
	Clover	20.04	19.87	15.8	18.57 A	21.29 a	21.16 a	17.76 d	20.07 A
	Maize	19.4	17.38	13.96	16.91 B	19.98 bc	19.16 c	14.73 e	18.34 B
	Non	19.06	18.44	13.29	16.93 B	20.51 ab	19.44 c	15.07 e	17.95 B
	Mean (N)	19.5 A	18.56 B	14.35 C		20.59 A	19.92 B	15.85 C	

Means followed by a common letter are not significantly different at the 5% level by DMRT.

These results probably due to the adequate mineral N rate (80 kg N/fad) facilitated the tillering ability of the plants and resulted in greater spike population (Jan and Khan, 2000). On other hand, application of 40 kg N/fad + ascobien recorded the lowest number of spikes/m², number of grains/spike and grain yield/fad in the two seasons (Table 4). These results may be due to the shortage of N-availability for wheat growth and development, which affected negatively the plant to produce more number of grains/spike. 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). Similar results were obtained by El-Hag (2012) who found that increase in mineral N rate resulted in reduction in mortality of tillers which reflected on number of tillers from the main stem.

All the interactions affected significantly most the studied wheat traits in both seasons (Table 3, 4&5).

The interactions of grain yield (ardab/fed.):

Interaction between preceded summer crops and cropping sequences

Grain yield/fad was affected significantly by the interaction between preceded summer crops and cropping sequences in the two seasons (Table 5). With regardless to the summer crop, growing Egyptian clover in the transition period achieved the highest grain yield/fad compared with the others. These results may be due to growing Egyptian clover in the transition period improved soil nutrient dynamics after summer maize or rice harvest. So, it may be possible that residual effects of Egyptian clover disrupted soil aggregates and increased

aeration for wheat growth and development compared with others. These results show that each of these two factors act dependently on grain yield/fad.

Interaction between preceded summer crops and mineral N fertilizer rates

Grain yield/fad was affected significantly by the interaction between preceded summer crops and mineral N fertilizer rates in the two seasons (Table 5). With regardless to the summer crop, application of the highest mineral N fertilizer rate (80 kg N/fad) to wheat plants achieved the highest grain yield/fad compared with the others. These results could be justified with logic that N availability satisfied wheat requirement for growth and development, which enabled the plant to produce more number of grains/spike. On the other hand, application of 40 kg N/fad + ascobien did not integrate with summer crops to have sufficient supply of N for the plant which achieved unacceptable source and sink capacity. These data indicate that there was effect of summer crops x mineral N fertilizer rates on grain yield/fad.

Interaction between cropping sequences and mineral N fertilizer rates

Grain yield/fad was affected significantly by the interaction between cropping sequences and mineral N fertilizer rates in the two seasons (Table 5). Application of 80 kg N/fad or 60 kg N/fad + ascobien to wheat plants that followed Egyptian clover recorded the highest grain yield/fad compared with the others. These results may be due to 60 kg N/fad + ascobien interacted positively with residues effects of Egyptian clover to reach the highest mineral N fertilizer rate effect on grain yield/fad. These data show that mineral N fertilizer rates responded differently to cropping sequences for grain yield/fad.

Interaction among preceded summer crops, cropping sequences and mineral N fertilizer rates

Grain yield/fad was affected significantly by the interaction among preceded summer crops, crop sequences and mineral N fertilizer rates in the two seasons (Table 5). With regard to the summer crop, the optimum grain yield/fad was observed by growing wheat plants after Egyptian clover and fertilized with 80 kg N/fad or 60 kg N/fad + ascorbic acid. These data reveal that there was an effect of summer crops x cropping sequences x mineral N fertilizer rates on grain yield/fad.

CONCLUSION

Our results showed that intensive cropping system (maize or rice/ Egyptian clover/wheat) with application of ascorbic acid could be an alternative way to decrease mineral N inputs of wheat by about 25 % N of the recommended mineral N fertilizer rate of wheat plants.

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الملخص العربي

تأثير التعاقب التقليدي والمكثف على إنتاجية القمح تحت معدلات مختلفة من التسميد النيتروجيني

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تم تنفيذ دراسة لمدة سنتين بمحطة البحوث والتجارب بمركز البحوث الزراعية بسخا بمحافظة كفر الشيخ - مصر خلال موسمي ٢٠١٣/٢٠١٤م و ٢٠١٤/٢٠١٥م لتقليل مدخلات النيتروجين المعدني لمحصول القمح. أشتمل البحث على تجربتين حقليتين تبدأ كل تجربة في الموسم الصيفي (الأرز أو الذرة الشامية) وتشتمل كل تجربه على ٩ معاملات وهي عبارة عن التوافقات بين ثلاثة تعاقبات محصولية (المحصول الصيفي /البرسيم المصري/القمح، المحصول الصيفي /الذرة/القمح والمحصول الصيفي/بور/القمح) وثلاثة معدلات من التسميد النيتروجيني المعدني (٨٠ كجم نيتروجين/فدان، ٦٠ كجم نيتروجين/فدان + أسكوبين و ٤٠ كجم نيتروجين/فدان + أسكوبين). أستخدم بهذه الدراسة تصميم القطع المنشقة مره واحده في ثلاث مكررات مع عمل تحليل (مشترك) للتجربتين كل عام. أشارت النتائج إلى عدم وجود فروق معنوية بين الذرة الشامية والأرز على محصول حبوب القمح، كما أدى التعاقب المحصولي (ذرة شامية أو أرز/برسيم فحل/قمح) إلى زيادة معنوية لجميع صفات القمح مقارنة بالتعاقبات المحصولية الأخرى في كلا الموسمين.

أظهرت النتائج أيضا عدم وجود فروق معنوية بين تطبيق معاملة الـ ٨٠ كجم نيتروجين/فدان و ٦٠ كجم نيتروجين/فدان + أسكوبين على محصول حبوب القمح في كلا الموسمين. تم الحصول على أفضل محصول حبوب قمح للذرة بزراعة البرسيم الفحل في الفترة البيئية بين محصول الذرة الشامية او الأرز السابق في الموسم الصيفي والقمح الذي تم تسميده بـ ٦٠ كجم نيتروجين/فدان + أسكوبين في الموسم الشتوي.

الكلمات الدالة: القمح - الذرة الشامية - الأرز - البرسيم المصري - أنظمة محصولية - التسميد النيتروجيني.