Rotational Crop Sequences and N Fertilization Levels Effect on Maize Growth and Productivity

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ABSTRACT

Two field experiments were conducted during the period from 2009/2010 winter season to 2013 summer season to investigate the response of maize (cv. Giza 10) to twelve preceding crop sequences, differing in legumes to non-legumes ratios and terminal crop, under 252, 288 and 324 kg N/ha. Maize traits, i.e. plant height, ear leaf area, leaf area index, ear grain weight, 100-grain weight and grain yield/ha, responded significantly to crop sequences. They were increased with increase of legumes percent in crop sequence and proximity of legume crop to maize. The 100 % legume sequence gave the maximum values for such traits whereas the least values resulted from crop sequence containing legumes of 40 % and terminated with wheat. Differences between N levels, regarding plant height, ear leaf area, leaf area index, ear grain weight, 100-grain weight and grain yield/ha, were significant, indicating the superiority of 324 kg N/ha compared to 252 and 288 kg N/ha. The interaction effect of both crop sequences and N application levels was significant for plant height, ear grain weight, 100-grain weight and grain yield/ha in both seasons, where the highest values of these traits were obtained from 100 % legume sequences and application of 324 kg N/ha. The regression analysis, in both seasons revealed that the linear effect was significant, while the quadratic effect was insignificant regarding number of grains/ear, 100-grain weight and grain yield/ha. That implies the possibility of increasing N level up to 324 kg N/ha to attain maize characters of higher values.

Keywords: Maize, Nitrogen fertilization, Crop sequences and Grain yield.

INTRODUCTION

Crops arrangement in an ordered succession of crop sequences for a certain duration, i.e crop rotation, is accepted as a beneficial practice for agricultural productivity. Benefits of crop rotation, especially those involving cereals and legumes, have been known by Egyptian farmers. Beside providing nitrogenous compounds (Nawar, 2004), legumes have benefited cereals in crop rotation through improving soil physical properties (El-Sodany and Abou-Elela, 2010), suppressing weeds, insects and diseases in addition to maintenance of soil fertility and organic matter (Khalil *et al*., 2004).

Several studies indicated that continuous cropping of maize was associated with yield reduction compared to that when maize was rotated with other crop (Selim and Gouda, 1998). Such yield reduction with maize monoculture cropping was explained due to the adverse effects of corn on corn (Crookston *et al*., 1991). Yield advantage due to rotation has been reported for maize when soybean was the preceding crop in the previous year (Crookston, 1984 and Egli, 2008) and was attributed to the stimulatory effect of soybean on subsequent maize (Anderson, 2011).

The effects of crop allocation in crop sequence within a rotation were reported by several studies. Selim and Gouda (1998) revealed that yield of summer crop tended to be more after legumes than after non-legumes. Moreover, Danso and Papastylianou, (1992), Khalil *et al*. (2000) and Nawar (2004), in divergent studies, found that maize growth, yield and yield attributes increased with maize planting after legumes, whereas, the reverse was obtained when maize was preceded by wheat. In addition, Khalil *et al*., (2004) reported that sunflower growth increased with increase of legumes percent and the proximity of legume to sunflower in crop sequence.

Nitrogen fertilizer affects maize dry matter production through the influence on leaf expansion and duration in addition to photosynthetic efficiency (Khalil, 2003 and Nawar, 2004) and consequently grain yield (Nawar, 2004, Subedi *et al*., 2006,Nawar *et al*., 2009 and Khalil *et al*., 2009 and 2011).Increases in plant height with increasing N levels may be attributed to N – stimulating effect on the internode elongation through meristematic activity during vegetative growth stage. Also, nitrogen supply causes an increase in leaf number and ear leaf area in addition to leaf expansion and consequently LAI (Nawar, 2004, El-Ganbeehy *et al*., 2009 and Khalil *et al*., 2011).Yield and its attributes, i.e. number of grains/ear, ear grain weight and individual grain weight responded proportionally to N application (Uhart and Andrade, 1995, Subedi *et al*., 2006 and Khalil *et al*., 2011).

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The present investigation was conducted to study the influence of rotational crop sequences and N levels on maize growth and yield traits.

MATERIALS AND METHODS

Two field experiments were conducted during 2009 – 2013 period to investigate the effect of twelve crop sequences on growth traits of maize cv. Giza 10 which was treated with 252 (N1), 288 (N2) and 324 (N3) kg N / ha levels as ammonium nitrate (33.5% N). The first experiment was initiated in the winter season of 2009/2010 and terminated in the summer season of 2012, corresponding to the winter season of 2010/2011 and summer season 2013 for initiation and termination of the second experiment. This investigation was conducted at the Agriculture Research Station, Alexandria University. The experimental site soil had the following properties: pH= 8.1, total organic matter= 1.3%, available N= 37.0 ppm, available P= 11.0 ppm and available K= 615.0 ppm. A split-plot in randomized complete block design, with three replicates, was used in both experiments. Each sub-plot comprised 5 ridges of maize, each 4.0 m length and 0.7 m in width (area= 14.00 m^2). Hills were sown at 25 cm spacing and thinned to one plant per hill. Crop sequences and N levels occupied, respectively, the main and sub-plots. Crop sequences in both experiments are presented in Table (1). Sowing dates of the preceding crops were as follows in the two experiments, respectively: September 10 and 15 for clover, October 20 and 25 for faba bean, May 20 and 25 for maize and May 3 and 5 for soybean. Sowing dates for third season winter crops were November 10 and 15 for wheat, September 10 and 10 for clover and October 25 and 30 for faba bean in the two experiments, respectively.

Table1. Crop sequences, terminal crop (Bold) before maize and legume % in the two experiments

Sequence number	Crop sequence					Sowing (%) of Legumes
1	C	M	F	M	W	40
2	C	M	F	M	F	60
3	C	M	F	M	C	60
4	C	So	F	M	W	60
5	C	So	F	M	F	80
6	C	So	F	M	C	80
7	C	M	F	S0	W	60
8	C	M	F	S0	F	80
9	C	M	F	S0	C	80
10	C	So	F	S0	W	80
11	C	So	F	S0	F	100
12	C	So	F	S0	C	100

C = meskawi berseem clover, M = maize cv. Giza 10 (single – cross), F = faba bean cv. Giza 716, So = soybean cv. Giza 111 and W = wheat cv. Giza 168.

Maize cultivar Giza 10 (Single cross) was sown after wheat (cv. Giza 168), faba bean cv. Giza 716) and clover (Meskawi berseem), respectively, on June 1 and 5, May 10 and 15 and May 15 and 20 in both experiments. Sowing ratios for legume crops in the twelve sequences, before maize, are presented in Table (1).

At harvest, the inner 3 ridges of each maize plot were harvested for determination of grain yield (GY) per plot then it was transferred to tons per hectare. Random samples , each of 10 plants were taken from each sub plot to determine plant height (PH, cm) , ear height (EH, cm), leaf area index (LAI), ear leaf area (ELA), number of grains per ear (NGE), ear grain weight (EGW, g) and 100 grain weight (HGW, g). Statistical analysis of data, including analysis of variance and regression analysis of number of grains/ear, 100-grain weight and grain yield/ha on nitrogen levels, were carried out according to Gomez and Gomez (1984).

RESULTS AND DISCUSSIONS

I. Effect of cropping sequences on maize:

Response of maize plant height (PH) to crop sequences, which preceded maize, were significant in both seasons (Tables2 and 3).That response was influenced by legume / cereal ratio for the twelve crop sequences where the higher the legume ratio, the greater the increase in plant height. Khalil *et al*. (2004), in sunflower, reported that increase in legume ratio of crop rotations resulted in taller plants than rotations higher in cereal ratio. Furthermore, when clover was the preceding crop to maize, maize produced taller plants, either significantly or insignificantly compared to when maize followed wheat. These results were in agreement with Nawar (2004) and Khalil *et al*. (2011) who found that when clover preceded maize, plant height of maize was superior to that of maize grown after non legumes. Legumes are known to increase soil N and organic matter in addition to the improvement of soil physical properties (El-Sodany and Abou-Elela, 2010). Continuous cropping of maize in the summer season produced shorter plants than when it was replaced with soybean in any of the two seasons (Rizvi and Rizvi, 1992).

Ear height (EH) and number of grains per ear (NGE) showed insignificant response to crop sequences in both seasons. It was observed that values of those two characters were of minimal variation (Tables 2 and 3) with varying the crop sequence and percent of legumes in the sequence. That may imply the genetic control of those two traits and insignificant response to soil environmental conditions imposed by the different crop sequences.

Ear leaf area (ELA) was significantly influenced by cropping sequences in both seasons (Tables2 and 3). That trait increased with increasing legume percentage in the sequence from 40 to 100 %. In addition, within the same crop legume percentage, terminating the sequence with a legume crop resulted in higher leaf area compared to that when the sequence was terminated with wheat. Moreover, the sequence terminating with berseem clover was more beneficial than fababean regarding that trait. The same trend was found for leaf area index (LAI) in both seasons. Decay of legumes residues furnished a nitrogen supply to the subsequent crop and hence led to an increase in vegetative growth in term of increases in ear leaf area. These results are in accordance with Selim and Gouda (1998), and Khalil *et al*(2011).

Grain yield and yield components except (NGE) were significantly affected by cropping sequences in both seasons (Tables2 and 3). Ear grain weight (EGW) was significantly higher in sequences containing high legume percentages (80 % or more). The highest value for that trait was obtained from sequence 12 which was terminated with clover compared to sequence 10 which was terminated with wheat. The same trend was observed in 100-grain weight (HGW) in both seasons. These results might be explained by the higher values of ELA and LAI obtained from high legume percentage sequences. Higher values of those two traits imply higher photosynthetic efficiencies leading to more assimilates production and translocation to the sinks (i.e. the ear) resulting in higher grain and ear weights. In conclusion, legumes, i.e. faba bean and clover, were superior to wheat regarding all the studied characters of maize. That was in agreement with the results of Khalil (2000) and Nawar (2004) who reported, in different studies, that leguminous crops caused maize to produce higher values of grain yield and yield attributes, such as number of grains/ear, ear-grain weight, in addition to grain yield/ha compared to the preceding non-legume crops. In addition, Khalil *et al*. (2011) concluded that less N uptake by legume plants increased the N uptake by the following non-legumes, enhancing photosynthesis to increase photoassimilates translocation to plant different sinks and, in turn, enhancing yield and yield attributes.

The superiority of yield components in high legume percentage sequences led to a significant increase in grain yield (GY) of those sequences compared to low legume percentage sequences. In addition, the nearer the legume crops (especially clover) to maize in the sequence, the higher yield and yield components of maize indicating a beneficial effect for those crops on maize compared to wheat. That beneficial effect arise from the well-established role of legumes in enriching the soil with essential nutrients and improvement of soil characteristics. These results were in accordance with Khalil *et al*. (2004) who found, in sunflower, that increase in legume percent in sunflower sequence and the proximity of legume to sunflower increased sunflower growth traits.

II. Effect of N levels on maize characters:

Results presented in (Tables2 and 3) revealed that increasing N levels from 252 to 324 kg N/ha increased all studied traits significantly and gradually except ear height, in both seasons. That increase in studied characters is closely related to the role of N in plants which include enhancement of several biological processes and controlling plant organs growth (Blair *et al*, 2006 and Fageria, 2009). Increasing N levels led to significant increases in plant leaf area (as shown in LAI) and photosynthetic capability, hence production of assimilates and dry matter, which led to increases in yield and yield components. It could be concluded that inadequacy of N seriously affected the grain yield because it reduced ear grain weight and its attributes (number of grains and one-hundred grain weight). Loss in number of grains might be a result of failure in spikelets fertilization and/or increase in the abortion of developed grains due to inadequate N supply. A reduction in N supply was paralleled with a decrease in crop growth rate leading to a decline in grain yield and its attributes. This conclusion has been reported by several investigators such as Hassan (1995), Nawar (2004) and Khalil *et al* (2011).

The regression analysis, in both seasons (Figure 1), revealed that the linear effect was significant for number of grains per ear, one hundred grain weight and grain yield, while the quadratic effect was insignificant. That implies the possibility of increasing N level above 324 kg N/ha to achieve higher values of those three characters.

III.Response of maize traits to the interaction of crop sequence and N levels:

The interaction of crop sequences x N levels, in both seasons (Tables4 and 5), for plant height, ear grain weight, 100-grain weight and grain yield showed similar trends. All sequences revealed an increase in those traits with increasing N levels from 252 to 324 kg N/ha. However, that increase was significant when legume percentage in sequence was 80 % or more and legumes were placed as terminal crops before maize. El-Sodany and Abou-Elela (2010) reported that growing of maize following faba bean and application of 90 kg N/fed gave the highest grain yield/fed compared to growing maize following wheat.

Table2. Means of studied characters for maize as affected by different sequences and different N fertilizer rates during 2012 season

Factors	Legume %	PH (cm)	EH (cm)	ELA (cm ^{2})	LAI	NGE	EGW (g)	HGW (g)	GY (tons/ha)
Crop sequence									
1- C M F M W	40	267.0	126.3	651.2	3.5	587.2	123.2	20.6	5.85
2- C M F M F	60	273.7	126.2	676.8	3.6	594.9	124.6	21.0	5.92
3- C M F M C	60	279.0	126.3	679.4	3.7	590.4	127.9	21.0	5.98
4- C So F M W	60	289.0	129.3	660.7	3.7	597.2	128.7	21.3	6.09
5- C So F M F	80	290.3	126.2	687.1	3.7	602.9	129.1	21.7	6.22
6- C So F M C	80	291.7	126.2	697.4	3.8	596.1	132.8	22.5	6.36
7- C M F So W	60	288.7	126.3	665.4	3.8	591.1	137.9	22.2	6.46
8- C M F So F	80	294.3	126.2	710.2	3.9	594.6	139.8	22.9	6.46
9- C M F So C	80	298.0	126.3	746.7	4.1	594.9	139.8	23.4	6.73
10- C So F So W	80	302.3	126.3	681.2	4.3	592.0	146.1	24.5	6.87
11- C So F So F	100	300.0	126.3	808.7	4.5	601.0	148.0	24.7	7.07
12- C So F So C	100	308.3	126.4	844.2	4.7	602.4	154.1	25.9	7.45
L.S.D 0. 05		**10.0**	**N.S**	**17.9**	**0.1**	**N.S**	**6.6**	**1.0**	**0.50**
N. levels									
252 kg / ha (= N1)		282.8	126.2	706.8	3.9	589.3	131.3	21.5	6.13
288 kg / ha (= N2)		291.4	126.2	717.5	3.9	596.0	135.5	22.8	6.46
324 kg / ha (= N3)		296.4	126.4	733.8	4.0	600.8	141.1	23.6	6.77
L.S.D 0. 05		**4.2**	**N.S**	**14.4**	**0.1**	**5.2**	**4.0**	**0.7**	**0.23**

N.S: Not significant

Table 3. Means of studied characters for maize as affected by different sequences and different N fertilizer rates during 2013 season

Factors	Legume %	PH (cm)	EH (cm)	ELA (cm ^{2})	LAI	NGE	EGW (g)	HGW (g)	GY (tons/ha)
Crop sequence									
1- C M F M W	40	261.7	128.1	642.3	3.5	599.7	122.6	20.0	5.78
2- C M F M F	60	266.0	128.0	667.6	3.5	606.0	125.8	20.5	5.88
3- C M F M C	60	272.2	127.9	669.8	3.6	607.6	126.9	20.6	5.92
4- C So F M W	60	277.3	127.8	653.6	3.6	600.3	127.1	20.9	6.02
5- C So F M F	80	283.3	127.7	679.7	3.7	595.3	131.6	21.4	6.15
6- C So F M C	80	286.7	127.8	690.6	3.8	595.3	135.1	22.0	6.29
7- C M F So W	60	282.7	127.6	661.8	3.8	592.6	134.1	21.6	6.29
8- C M F So F	80	289.3	127.6	704.3	3.8	597.9	137.5	22.3	6.49
9- C M F So C	80	292.7	128.0	731.9	4.0	600.2	139.9	22.4	6.53
10- C So F So W	80	294.7	127.6	672.0	4.0	597.8	143.3	23.2	6.80
11- C So F So F	100	299.6	127.6	793.0	4.4	598.7	147.6	23.8	7.00
12- C So F So C	100	303.0	127.4	816.9	4.5	598.7	153.9	24.5	7.24
L.S.D 0. 05		**3.5**	**N.S**	**18.3**	**0.1**	**N.S**	**7.0**	**0.7**	**0.40**
N. levels									
252 kg N/ ha (= N1)		275.6	127.7	696.0	3.8	594.8	130.0	21.2	6.15
288 kg N / ha (= N2)		285.2	127.7	708.0	3.9	600.2	135.0	22.0	6.39
324 kg N / ha (= N3)		291.5	127.8	722.7	3.9	604.0	141.4	22.6	6.56
L.S.D 0. 05		**5.6**	**N.S**	**11.9**	**0.1**	**3.3**	**4.2**	**0.6**	**0.17**

N.S: Not significant

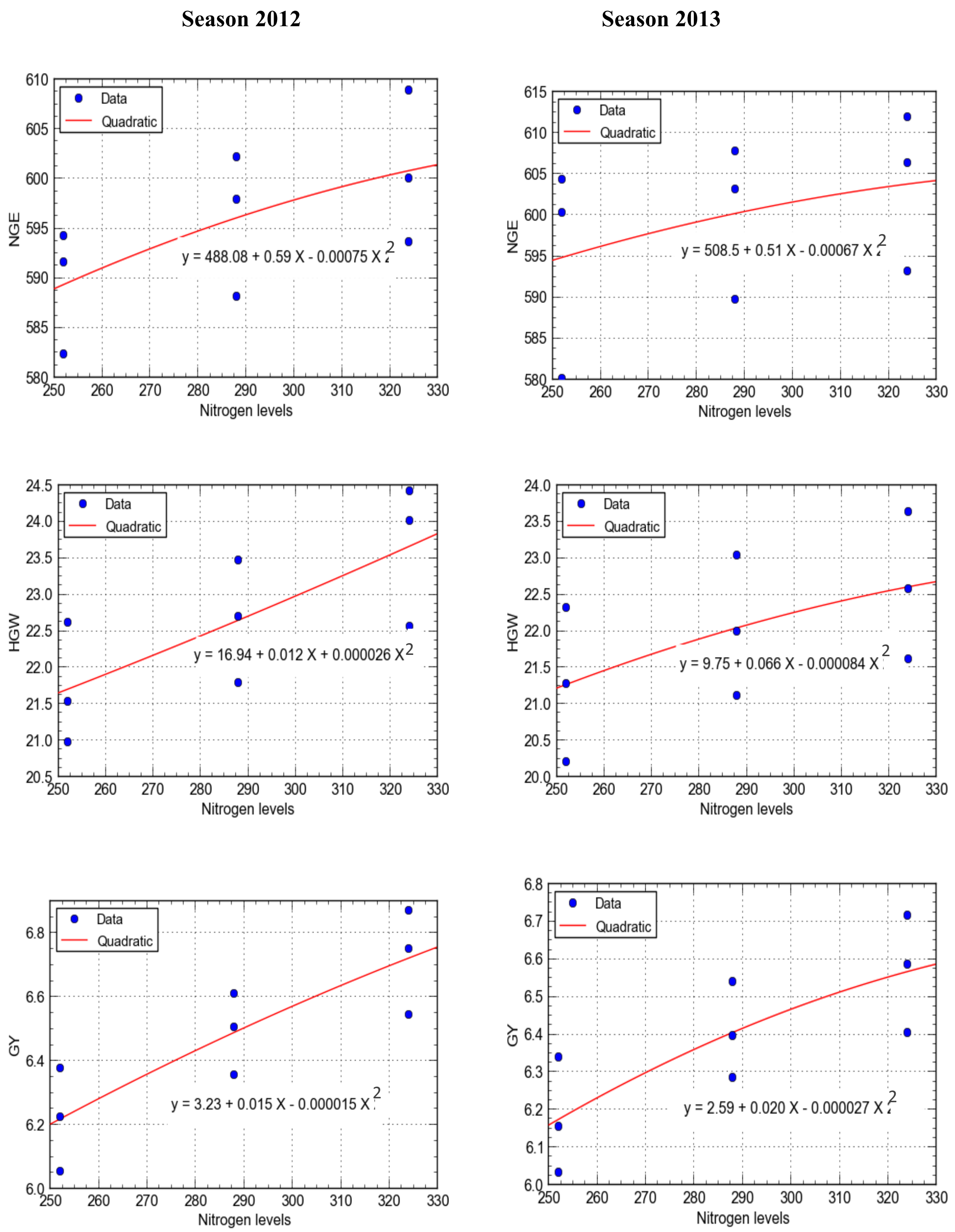

Figure 1.Graphical representation of regression analysis of NGE, HGW and GY on N levels in 2012 and 2013 seasons

They also attributed such increase following faba bean to increase in water and nutrients uptake efficiency.

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ا لمخص العر

تأثير التعاقب المحصولي ومعدلات التسميد النيتروجينى على نمو وإنتاجية الذرة الشامية

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أجريت تجربتان حقليتان فى الفترة ما بين الموسم الشتوى ٢٠٠٩/٢٠١٠والموسم الصيفى ٢٠١٣ لدراسة تأثير اثنا عشر تعاقبا يسبق محصول الذرة الشامية تحت ثلاثة مستويات من التسميد النيتروجينى وهى(٢٥٢، ٢٨٨، ٣٢٤ كجم نيتروجين/ هكتار) على بعض صفات النمو فى الذرة الشامية(جيزة ١٠). وكان التصميم المستخدم القطع المنشقة مرة واحدة حيث تمثل القطع الرئيسية التعاقبات المحصولية بينما وضعت مستويات النيتروجين فى القطع الثانوية.

أوضحت النتائج الاستجابة المعنوية والمتدرجة فى إتجاه ثابت لكل من إرتفاع النبات، مساحة ورقة الكوز، معامل مساحة الورقة، وزن حبوب الكوز، وزن ١٠٠ حبة ومحصول الحبوب/ هكتار للتعاقبات المحصولية من حيث نسبة البقوليات وموقع المحصول البقولىبالنسبة للذرة فى التعاقب، حيث زادت قيمة تلك الصفات بزيادة نسبة محاصيل البقول ودرجة أقتراب المحصول البقولى من التعاقب فكانت أعلى القيم فى التعاقب ١٠٠ % بقول وكان البرسيم هوالمحصول الأقرب فى التعاقب الى الذرة بينما تم الحصول علي أقل القيمحينما كانت نسبة البقول ٤٠ % وأن القمح هو المحصول الأقرب للذرة فى التعاقب.كما أوضحت النتائج انه بزيادة معدل التسميد النيتروجينى أدى الى زيادة معنوية لصفات إرتفاع النبات، مساحة ورقة الكوز، معامل مساحة الورقة، وزن ١٠٠ حبة ومحصول الهكتار حيث أعطى المستوى ٣٢٤ كجم نيتروجين/ هكتار أكثرالقيم تفوقا فى جميع الصفات تحت الدراسة. كما دلت النتائج أيضاً على وجود تفاعل معنوى بين التعاقبات المحصولية والمستوى النيتروجينى لصفات إرتفاع النبات، محصول الكوز، وزن ١٠٠ حبة ومحصول الحبوب/ هكتار حيث تم الحصول على أعلى القيم فى التعاقب الذى يحتوى على ١٠٠ % بقول مع إضافة ٣٢٤ كجم نيتروجين/ هكتار بينما كان العكس صحيح عندما بلغت نسبة البقول فى التعاقب ٤٠ % وكان القمح هو المحصول الأقرب للذرة. كما كانت هناك استجابة خطية بين عدد الحبوب/ الكوز، وزن ١٠٠ حبة ومحصول الفدان/ هكتاروالتسميد النيتروجينى حيث انه يمكن الحصول على اعلى القيم من هذه الصفات بزيادة المستوى النيتروجينى الى ٣٢٤ كجم نيتروجين / هكتار.