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Effect of Nitrogen Sources Coating Polymers Irradiated by Gamma Rays on N Uptake and Yield Production of Wheat Plants

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ABSTRACT

An experiment was conducted at the green house ofThe National Center for Radiation Research and Technology, Atomic Energy Authority, Cairo, Egypt to evaluate the impact of N-fertilizer sources either treated with coating materials or not, N-rates on wheat yield and nitrogen uptake by straw and grains. Fertilizer-Nwas applied at rates of 60, 75 and 90 kg NFed^{-1}. Irradiated gelatin (cap) and cellulose (cel) acetate were used for coating urea and ammonium nitrate fertilizers. Generally, capsulation and coating of both fertilizers resulted in retardation of solubilization and release in leachate. Capsulated urea or ammonium nitrate was superior over cel ones when applied at rate of 60 and 75 kg N fed^{-1}, while reversible trend was noticed at rate of 90 kg N fed^{-1}. This holds true with either straw or grain yield at the 1st and 2nd seasons. Despite of N-rate and coating treatments, urea seems to be more effective, with some exceptions, than ammonium nitrate when straw and grain yields were considered. The values of straw and grain yields tended to increase with increasing N-fertilizer rates up to 75 kg Nfed^{-1}. Interaction between the all experimental treatments showed an effective impact on crop yield improvement. Similar trend were observed with N-uptake by straw and grains. Released data concluded that capsulated urea added at rate of 90 kg N fed^{-1} resulted in the best values of grain and straw yield.

KEYWORDS

Gamma Rays; Polymers; Coated NitrogenFertilizers; Wheat.

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INTRODUCTION

It is well known that the problem of slowing the nitrogen release from various compounds has been approached by altering the solubility of materials or developing compounds that have low water solubility. Methods of altering the release of nitrogen from soluble materials include coating the water-soluble compounds with materials that are less water soluble, thus retarding the entry of water into the particle and the outward of nitrogen. Coating applied to soluble nitrogen materials generally have been of three types:-

1. Impermeable coating with small pores that allow slow entrance of water and slow passage of solubilized nitrogen compounds out of the encapsulated area.
2. Impermeable coating that requires breakage by physical or chemical or biological action before the nutrient is dissolved.
3. Semipermeable coating through which water diffuses and creates internal pressures sufficient to disrupt the coating.

Thecurrent efficiency of N fertilizer use is very low, and losses are large. It is estimated The current that average N use efficiency by cereal crops is only 35 %, and losses of N fertilizer can be as high as 52 %. In terms of total N loss, the reactive N accounts for 19 % of the N applied with11 % lost via NH_3 volatilization, 5 % via runoff, 2 % via leaching, and 1 % via NO emission **(Zhu and Chen, 2002)**. These considerable amounts of reactive N enter the environmentand pollute both the atmosphere and water systems **(Galloway *et al.*, 2008)**. Polymer-coated urea is a controlled-release enhanced efficiency fertilizer product thatencases urea in a polymer coat. After urea dissolves within the prill, it diffuses out at varying rates **(Blaylock, 2003 & Fujinuma *et al.*, 2009)**.

Khurram *et al.* (2013) used four Nitrogen levels (0, 60, 120 and 180 kg/ha) and five wheat varieties, in winter season of 2011. They concluded that, the nitrogen applied at the rate of 120 kg/ha performed better and enhanced the wheat productivity as compared to other treatments. **Mosalem *et al.* (2002 and Giovanni *et al.* (2004)** studied the effect of nitrogen fertilizer at rates of 75 and 150 kg N/ha on wheat plants. They mentioned that nitrogen application at rate of 150 kg N/ha had a significant effect on grain yield, total nitrogen uptake and grain nitrogen content. **El-Hady and Camilia (2006)** reported that the possibility of using bitumen as basic materials for producing effective coatings for water soluble fertilizers. Coating thickness influences the release rate and longevity of the product.

Polymers – coated urea or ammonium nitrate have been developed as a product with the characteristics of slow nitrogen release. The irradiation of polymeric materials with ionizing radiation (gamma rays, X rays, accelerated electrons, ion beams) leads to the formation of very reactive intermediates. These intermediates can follow several reaction paths, which result in rearrangements and/or formation of new bonds. **(IAEA, 2004**; **Shaviv, 2005 & Xu-shengl *et al.*, 2007).** The release rate of a nutrient from the fertilizer must be slower than that from a fertilizer in which the nutrient is readily available for plant uptake **(Trenkel, 2010).** Wheat is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization **(Iqbal *et al.*, 2012 & Khurram *et al.*, 2013).**

The aim of this investigation was to evaluate the slow release of nitrogen coating polymers as a good source of nitrogen fertilization.Reducing of the high nitrogen losses through different ways.

MATERIALS AND METHODS

Field trials were conducted and initiated in 20 November 2011 and 2012 at The National Center for Radiation Research and Technology, Atomic Energy Authority, Cairo, Egypt;plots were arranged in a completely randomized blockdesign (factorial- 3 factors), and replicatedthree times. Two nitrogen sources – urea and ammonium nitrate were used and three N fertilizer rates (60, 75 and 90 kg N fed^{-1}) were evaluated. The coated and encapsulated nitrogen fertilizer sources were tested. P and K were added as the basal fertilizers at the rate of (150 and 100 kg/fed) before planting in the forms of single super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O), respectively as complementary fertilizers depend on soil native supply. Wheat ***(Triticum aestivum L., var. Gemmieza 9)*** was direct seed into plot ($3m^2$). At seedling, N fertilizer was added. At maturity, wheat was harvested at 5$^{th.}$ May 2012 and 2013. The straw and grain yield per plot, were recorded. Some physical and chemical properties of soil samples are presented in Table (1). The soilanalyses were determined according to themethods described by **(Ryan *et al.*, 1996).** After harvesting, Plants (straw and grains) were collected, driedand weighted. Dried samples were wet digested in H_2SO_4 and H_2O_2 according to the procedure of **(Ryan *et al.*, 1996)** and then the digested plant solutions were analyzed for N, P and K elements.

Table (1) *Some physical and chemical properties of Experimental soil samples.*

Soil Analysis	2011/2012	2012/2013
Clay %	36.2	36.1
Silt %	21	21
Sand %	42.8	42.9
Soil texture	Clay loam	Clay loam
Organic matter %	1.8	2.1
pH (1: 2.5, soil : water)	7.6	7.8
Ec (ds/m)	3.5	3.4
Soluble cation and anion in soil saturated paste (meq/l)		
Ca^{+2}	8.22	7.35
Mg^{+2}	2.44	4.21
Na^{+}	23.72	22.32
K^{+}	1.12	1.22
CO_3^{2-}	0.0	0.0
HCO_3^{-}	1.89	1.10
Cl^{-}	8.11	11.22
SO_4^{-2}	25.50	22.78
Available nutrient (mg/kg)		
N	25.40	28.75
P	8.07	8.50
K	65.98	67.80

Polymer preparation

Two kinds of polymer coating materials namely, Gelatin capsules (cap) and cellulose acetate mixed with acrylic acid (cel), were used. The (cap) were submerged in styrene and irradiated with gamma source at dose 25 kGy using Indian cell at dose rate 3.604 $kGy.hr^{-1}$ on 10/2010 to enhance the structure of capsules by cross-linked, then driedand filled with either urea or ammonium nitrate, with a capacity of 1g/capsule. The (cel) were prepared by mixing 50% cellulose acetate with 50% acrylic acid (used for coating urea) or 40% cellulose acetate, 60% acrylic acid (used for coating ammonium nitrate). The (cel) was irradiated with 20 kGy gamma rays and diluted by acetone as sprayer material and sprayed on normal either urea or ammonium nitrate using glass sprayer at rate of 5% and left to dry.

RESULTS AND DISCUSSION

Effect of fertilization treatments on dry matter yield of straw and grains

Results in Table (2) show that nitrogen coating polymers had a significant effect on the straw yield. This was true for both sources of nitrogen. Despite of N – rates, the highest overall mean values were 4754 and 4811 $kg.fed^{-1}$resulted from application of (cap) treatments in the first and second season, respectively. On the other hand, the lowest straw yields were 4444 and 4498 $kg.fed^{-1}$induced by application of (cont) treatment in the first and second season, respectively.The coating treatments resulted in reduction in the release of N from fertilizers. Consequently, itleads to a slow release of N for a long time which reflectedan improvementof plant growth and yield. Results arein agreement with those obtained by **(El-Aila and AbuoSeeda, 1996 & Kelly *et al.,* 2014),** they found that an increase in wheat yield when fertilized with slow release N fertilizer.In this concern, the straw yield was also significantly affected by the rate of fertilizers application. The comparison held between the N-fertilizers rates indicated that the highest values of straw yield were 4898 and 4982 $kg.fed^{-1}$ recorded at rate of 90 kg $N.fed^{-1}$ added in the first and second season, respectively. While, the lowest straw yields were 4122 and 4173 $kg.fed^{-1}$ with application of 60 kg $N.fed^{-1}$ for the same sequence. This increase may beattributed to the increase in the amount of nitrogen used by the plant toproduce the amino acid for building the tissue so that, the growth and yield was increased**.** Similar trend was noticed by **El-Sherbeny (2008)**, who found that increasing N rate led to increase wheat yield. However, fertilizer source treatment had no significant effect on the straw yield.

The interaction between nitrogen coating polymers and N rates had a significant effect on the straw yield. On the basis of interaction means, the highest values of straw yield 4932 and 5058 $kg.fed^{-1}$were detected with (cap) at rate of 75 kg $N.fed^{-1}$and (Cel) at rate of 90 kg $N.fed^{-1}$in the first and second season, respectively,while, the smallest straw yield 3856 and 3904 $kg.fed^{-1}$were obtained with (cont) at rate of 60 kg N/fed in the first and second season, respectively. In this respect, capsulation treatment was superior over (Cel) treatmentwhen plants fertilized with 60 and 75 kg $N.fed^{-1}$, while reversible trend was noticed at 90 kg $N.fed^{-1}$. This holds true with urea and ammonium nitrate applied at the 1st and 2nd seasons.

The interaction between nitrogen coating polymers and nitrogen source reflected thatthe capsulated urea gave the highest straw yield 4770 and 4819 $kg.fed^{-1}$in first and second season, respectively. However, the lowest straw yield 4421 and 4487 $kg.fed^{-1}$were obtained from un-coated ammonium nitrate applied in the first and second seasons, respectively.

Also, the interaction between the rate of nitrogen fertilizer application and nitrogen source had a significant effect on the straw yield. Urea added at rate of 90 kg $N.fed^{-1}$resulted in highest straw yield 4906 and 4986 $kg.fed^{-1}$in the first and second season, respectively. The lowest straw yield 4102 and 4163 $kg.fed^{-1}$was obtained with ammonium nitrate at rate of 60 kg $N.fed^{-1}$in the first and second season, respectively.

The interaction between the three experimental factors reflected positive significant effect on straw yield. In this regard, capsulated urea applied at rate 75 kg $N.fed^{-1}$ produced the highest straw yield 4957 $kg.fed^{-1}$ in the first season, also (Cel) coated ammonium nitrate applied at rate of 90 kg $N.fed^{-1}$in the second season produced 5058 kg/fed straw yield. On the other hand, the smallest straw yield (3837 and 3894 $kg.fed^{-1}$) was detected with un-coated ammonium nitrate applied at rate of 60 kg $N.fed^{-1}$in the first and second season, respectively.

Dealing with the effect of experimental factors on grain yield, data in Table (3) showed that nitrogen coating polymers treatment had a significant effect. The highest means values (2653 and 2698 kg/fed) wereobtained with application of (cap) treatments in the first and second season, respectively. Whereas, the lowest values (2089 and 2060 kg/fed) were observed with (cont) treatments in the first and second season, respectively.

Table (2) *Effect of nitrogen sources, rates and coating polymers on the strawyield $kg.fed^{-1}$of wheat crop.*

N rates kg $N.fed^{-1}$	coating polymers	Season1		mean	Season2		Mean
		Urea	Amm. Nitr.		Urea	Amm. Nitr.	
60	cont.	3876	3837	3856	3914	3894	3904
	cel	4092	4051	4071	4132	4111	4122
	cap	4462	4417	4439	4505	4483	4494
Mean		**4143**	**4102**	**4122**	**4184**	**4163**	**4173**
75	cont.	4614	4568	4591	4659	4636	4647
	cel	4758	4710	4734	4805	4781	4793
	cap	4957	4908	4932	5006	4981	4993
Mean		**4776**	**4729**	**4752**	**4823**	**4799**	**4811**
90	cont.	4908	4859	4884	4956	4932	4944
	cel	4919	4920	4920	5057	5058	5058
	cap	4891	4891	4891	4945	4946	4945
Mean		**4906**	**4890**	**4898**	**4986**	**4978**	**4982**
Over all for polymers	cont.	4466	4421	4444	4510	4487	4498
	cel	4590	4560	4575	4665	4650	4657
	cap	4770	4739	4754	4819	4803	4811
Mean		**4608**	**4573**		**4664**	**4647**	

L.S.D at 0.05

	season1	season2	interaction	season1	season2
Fertilizer (F)	*n.s*	*n.s*	*F * L*	*151.85*	*161.82*
Level (L)	*107.37*	*114.42*	*F * P*	*151.85*	*161.82*
Polymer (P)	*107.37*	*114.42*	*L * P*	*185.97*	*198.18*
			*F * L * P*	*263.01*	*280.27*

cont. = control treatment without polymer.
cel = cellulose acetate polymer.
cap = gelatin capsules

The rate of nitrogen fertilizer applicationhas significantlyaffectedthe grain yield. The highest values (2580 and 2668 kg/fed) were recorded with application rate of 90 kg N/fed in the first and second season, respectively.While, the lowest grain yields values(2102 and 2018 kg/fed) were obtained with an application rate of 60 kg N/fed in the first and second season, respectively. On the other hand, the fertilizer source hadno significant effect on the grain yield. These increases in wheat grain yield may be due to increasing of yield component (weight of 1000 grains, number of grains/spike etc.). These results are in agreement with **El-Aila and Abuo Seeda, 1996 & El-Sherbeny**, **2008.**

The effect of interaction between nitrogen coating polymers and rate of nitrogen fertilizer applicationon the grain yield was significant. The highest values (3039 and 3086 kg/fed) wereobtained from (cap) with 75 kg/fed in the first season and second season, respectively. While, the smallest grain yields (1932 and 1882 kg/fed) wererecorded (cont) treatment at rate of 60 kg N/fed in the first and second season, respectively.

Table (3) *Effect of nitrogen sources, rates and coating polymerson the grain yield (kg.fed^{-1}).*

N rates Kg N.fed^{-1}	Coating polymers	Season1		Mean	Season2		Mean
		Urea	Amm. Nitr.		Urea	Amm. Nitr.	
60	cont.	1942	1921	1932	1908	1856	1882
	cel	2219	2148	2184	2135	1989	2062
	cap	2200	2184	2192	2183	2039	2111
Mean		**2120**	**2084**	**2102**	**2075**	**1961**	**2018**
75	cont.	2058	2156	2107	2003	1856	1930
	cel	2542	2619	2581	2552	2577	2564
	cap	3072	3006	3039	3093	3080	3086
Mean		**2558**	**2594**	**2576**	**2549**	**2504**	**2527**
90	cont.	2398	2061	2230	2315	2421	2368
	cel	2825	2740	2783	2822	2660	2741
	cap	2770	2686	2728	2806	2985	2895
Mean		**2664**	**2496**	**2580**	**2648**	**2689**	**2668**
Over all for polymers	cont.	2133	2046	2089	2076	2044	2060
	cel	2529	2502	2516	2503	2409	2456
	cap	2681	2626	2653	2694	2701	2698
Mean		**2447**	**2391**		**2424**	**2385**	

L.S.D at 0.05 for:

	season1	season2	interaction	season1	season2
Fertilizer (F)	n.s	n.s	F * L	112.27	150.08
Level (L)	79.39	106.12	F * P	112.27	150.08
Polymer (P)	79.39	106.12	L * P	137.50	183.8
			F * L * P	194.46	n.s

cont. = control treatment without polymer.
cel = cellulose acetate polymer.
cap = gelatin capsules

The interaction effect on grain yield between nitrogen coating polymers and nitrogen source was significant. The highest grain yield was produced by urea with (cap) 2681 kg/fed in the first season, while ammonium nitrate capsulated in (cap) gave 2701 kg/fed in second season.

Whereas, the lowest grain yield (2046 and 2044 kg/fed) were produced from control treatment under ammonium nitrate in the first and second season, respectively.

In this concern, the interaction effect between the rate of nitrogen application and nitrogen source on the grain yield was significant. The highest mean values produced from urea at rate of 90 kg N/fed which gave 2664 kg/fed in the first season and ammonium nitrate at rate of 90 kg N/fed which gave 2689 kg/fed in second season. The lowest grain yield (2084 and 1961 kg/fed) wereobtainedwith ammonium nitrate at rate of 60 kg N/fed in the first and second season, respectively.

Table (4) *Effect of nitrogen fertilizer sources and ratesas well asnitrogen coating polymer on N-uptake by grain and straw of wheat crop.*

Treatments		N uptake by grain (kg N.fed^{-1})						N uptake by straw (kg N.fed^{-1})					
N rates Kg N.fed^{-1}	pol.	Season1		Mean	Season2		Mean	Season1		Mean	Season2		Mean
		U	A		U	A		U	A		U	A	
60	cont.	27.99	25.28	26.64	33.69	25.69	29.69	35.27	28.39	31.83	38.74	25.31	32.03
	cel	35.79	35.64	35.72	35.36	36.99	36.18	40.51	40.51	40.51	40.49	44.40	42.45
	cap	39.01	37.17	38.09	39.86	38.89	39.37	46.40	44.61	45.51	50.91	48.86	49.89
Mean		**34.26**	**32.70**	**33.48**	**33.48**	**33.86**	**35.08**	**35.08**	**37.84**	**39.28**	**39.28**	**39.52**	**41.45**
75	cont.	33.51	32.44	32.98	34.11	28.71	31.41	43.37	40.65	42.01	45.19	39.87	42.53
	cel	38.22	38.27	38.24	38.23	39.39	38.81	49.96	49.46	49.71	49.97	54.50	52.23
	cap	42.84	41.75	42.29	44.50	43.70	44.10	57.01	55.46	56.23	62.57	60.77	61.67
Mean		**38.19**	**37.49**	**37.84**	**37.84**	**37.26**	**38.10**	**38.10**	**48.52**	**49.32**	**49.32**	**51.71**	**52.14**
90	cont.	39.51	35.45	37.48	40.90	39.80	40.35	53.50	53.94	53.72	58.48	59.18	58.83
	cel	40.25	39.71	39.98	41.15	40.73	40.94	54.60	54.12	54.36	60.69	60.19	60.44
	cap	43.65	42.15	42.90	45.40	43.90	44.65	59.18	57.23	58.20	64.78	62.81	63.79
Mean		**41.13**	**39.10**	**40.12**	**42.48**	**41.48**	**41.98**	**41.98**	**55.09**	**55.43**	**55.43**	**60.72**	**61.02**
Over all for polymers	cont.	33.55	31.09	32.36	36.29	31.33	33.82	43.76	40.23	42.52	47.35	40.38	44.46
	cel	38.08	37.94	37.98	38.20	38.96	38.64	48.19	47.88	48.19	49.91	53.01	51.71
	cap	41.87	40.37	41.09	43.34	42.18	42.71	53.90	52.12	53.31	59.27	57.16	58.45
Mean		**37.86**	**36.43**		**39.24**	**37.53**		**48.87**	**47.15**		**52.43**	**50.65**	

L.S.D at 0.05 for: (N uptake by grain)

	S1	S2	int.	S1	S2
Fertilizer (F)	*0.70*	*0.84*	*F * L*	*1.22*	*1.44*
Level (L)	*0.86*	*1.02*	*F * P*	*1.22*	*1.44*
Polymer (P)	*0.86*	*1.02*	*L * P*	*1.50*	*1.76*
			*F * L * P*	*2.12*	*2.50*

L.S.D at 0.05 for: (N uptake by straw)

	S1	S2	int.	S1	S2
F	*0.84*	*0.88*	*F * L*	*1.44*	*1.52*
L	*1.04*	*1.08*	*F * P*	*1.44*	*1.52*
P	*1.04*	*1.08*	*L * P*	*1.80*	*1.88*
			*F * L * P*	*2.52*	*2.64*

pol. = polymer *A = ammonium nitrate* *U = urea*

int. = interaction *S1= season1* *S2=season2*

The interaction effect on the grain yield between three factors (nitrogen coating polymer, nitrogen rate and nitrogen fertilizer source) was significant in first season only. Capsulated urea (cap) at a rate of 75 kg N/fed produced the highest grain yield (3072 kg.fed^{-1}). On the other hand the smallest grain yield was 1921 kg.fed^{-1}with (cont) under ammonium nitrate at a rate of 60 kg N.fed^{-1}.

Nitrogen uptake

Nitrogencoating polymers had a significant effect on N-uptake by grain. The overall means of coating treatments, in spite of N-rate or N-sources, indicated that the highest values 41.09 and 42.71 kg N.fed^{-1}were in case of (cap) treatment in the first and second season, respectivelyTable (4). While, the lowest values ofN-uptake by grain were 32.36 and 33.82 kg N.fed^{-1}in case of un-coated in the first and second season, respectively. Also, the rate of nitrogen application had a significant effect on N-uptake by grain. In this respect, the highest values were 40.12 and 41.98 kg N.fed^{-1} with application rate of 90 kg N.fed^{-1} in the first and second season, respectively. While, the lowest N-uptake by grain were 33.48 and 35.08 kg N.fed^{-1}at the application rate of 60 kg N.fed^{-1} in the first and second season, respectively. Moreover, N sources had a significant effect on N-uptake by grain. The overall means, in spite of N-rates indicated the superiority of urea over ammonium nitrate where the highest values of N-uptake by grain were detected at the 1st and 2nd seasons recording 37.86 and 39.24 kg N.fed^{-1}, respectively. These results are in harmony with those obtained by **El-Aila and AbuoSeeda (1996).**

Double and triple interactions between all tested factors concluded superiority of urea over ammonium nitrate and the best values of N-uptake by grains were recorded with capsulated than (cel) one added at rate of 90 kg N.fed^{-1}.It seems that increasing the N-rate led to enhance N-uptake by grain. Similar trends, but to somewhat higher extent, were noticed with N-uptake by straw (Table 4).

CONCLUSIONS

These results showed that the coating of N fertilizers with some polymers lead to reduction in the release of N from the sources.Consequently,this will lead to the slow release of Ndepending onthe moisture content of the soil. Hence this leads totheavailability of nitrogen tothe plant fora long time. The fertilizer coating polymer and its ratehad a significant effect on yield and N-uptake by either grain or straw. Capsulated urea or ammonium nitrate was superior over cel ones when applied at rate of 60 and 75 kg N fed^{-1}, while reversible trend was noticed at rate of 90 kg N fed^{-1}.

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مجلة
التقنيات النووية
فى العلوم التطبيقية
مجلد 5 ، عدد 3 ، ص 153 : 162 ، (2017)

تأثير الاسمدة النيتروجينية المغطاة بالبوليمرات المشععة باشعة جاما على امتصاص النيتروجين وانتاجية نبات القمح

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تهدف هذه الدراسة الى التحكم فى انطلاق عنصر النيتروجين من كل من اليوريا ونترات الامونيوم عن طريق تغليفها ببعض البوليمرات التى يتم تحضيرها معمليا باستخدام الاشعة المؤينة ودراسة تأثيرها على نمو محصول القمح (*Triticum aestivum L.*) صنف جميزة ٩ وكذلك امتصاص عنصر النيتروجينوقد اجريت تجربة بالمركز القومى لبحوثوتكنولوجيا الاشعاع وكان تصميم التجربة فى قطاعات كاملة العشوائية فى ثلاث مكررات حيث اظهرت النتائج تفوق الاسمدة المغلفة بالكبسولات الجلاتينية على صفات المحصول والنيتروجين الممتص بواسطة الحبوب وكذلك القش. وكانت افضل معاملة لمستوى التسميد ٧٥ كجم نيتروجين/فدان ولم يظهر سلوك معين بخصوص نوع السماد. كما اظهر التأثير المتبادل الثنائى والثلاثى تأثيرا معنويا يستثنى من ذلك التأثير المتبادل للعوامل الثلاثة على محصول الحبوب فى الموسم الثانى.

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