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ALLEVIATION THE NEGATIVE EFFECTS OF PHOSPHORUS- ZINC ANTAGONISM ON GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.) GROWN IN NEWLY RECLAIMED SANDY SOILS

M. Abd Alla Kotb
Department of Agronomy, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt.

ABSTRACT

Two field experiments were conducted in newly reclaimed sandy soils deficient in P and Zn located at an extension field in El–Salhia region, Sharkia Governorate during 2004/2005 and 2005/2006 seasons. This study aimed to evaluate the interactive effects of three levels of P (15, 30 and 45 kg P_2O_5/fad as ordinary superphosphate, 15.5% P_2O_5) and four zinc rates (4, 8, 12 and 16 kg $ZnSO_4.7H_2O$/fad) on growth, yield and the contents of P and Zn in leaf and grain of wheat (Gemmeiza 9 cv). The most important findings could be summarized as follows:

Application of 30 kg P_2O_5/fad or 12 kg $ZnSO_4$/fad significantly increased leaf area index, net assimilation rate, total chlorophyll, 1000-grain weight, grain and straw yields in both seasons. The increase of P level up to 45 kg P_2O_5/fad did not add any significant increase in these traits or grain P content, but decreased leaf P and Zn contents in leaf and grain were significantly reduced to the critical levels in both seasons. Leaf and grain Zn contents did not respond to more than 12 kg Zn SO_4/fad, but leaf area index, net assimilation rate, total chlorophyll, 1000-grain weight, grain and straw yields were significantly reduced and as well the contents of P in leaf and grain in both seasons. These results confirmed that the over P and Zn application induced an antagonistic effects and significantly depressed growth, yield and their concentrations in leaf and grain. The balanced supply of P and Zn helped to alleviate the negative effects of P-Zn antagonism. Application of 12 kg zinc sulphate with 30 kg P_2O_5/fad as ordinary superphosphate could be used and afforded the best beneficial interaction effects on wheat grown in these soils. Further researches are needed to identify the suitable crops and the main areas of phosphorus and zinc deficient soils in order to treat them with the proper nutrient balance. Also, it is important to screen crop varieties so that the more efficient varieties could be grown in these soils.

Key words: Levels of P and Zn, growth, yield of wheat, new reclaimed soils**.**

INTRODUCTION

With the world over growing population, the problem of producing extra food to provide an adequate standard of nutrition for this growing population is very important. Phosphorus and zinc are essential for the normal healthy growth and reproduction of plants, animals and humans and when the supply of plant-available phosphorus and zinc is inadequate, crop yields and quality are reduced. The amounts of available P and Zn which are less than 10 ppm and 1 ppm, respectively, are very low to get an optimum crop production (Marschner, 1995). Moreover, wheat, barley maize, sorghum, flax, cotton and legumes are highly sensitive to P and Zn deficiencies (Bould *et al*., 1983). In Egypt, the soils in many areas where wheat is grown have very low contents from plant-available P and Zn, and hence cause widespread P and zinc deficiency to this crop.

Phosphorus increased leaf area index, leaf chlorophyll content, and hence interception of photosynthetically active radiation which in turn increased grain yield of rice and wheat (Kolar and Grewal, 1989). Also, Hagras (1985) indicated that increasing P level up to 30kg P_2O_5/fad increased 100-grain weight and grain and straw yields of wheat. Tanaka and Aase, (1989) found that application of 20 and 40 kg P_2O_5/ha of P fertilizer increased grain yields of wheat by 75 to 400 kg/ha. Fageria (1990) found that adding phosphorus to wheat produced significant increase in each of shoot P contents 95 days after sowing and grain P content at harvest. Meanwhile, shoot and grain Zn, Fe and Cu contents were decreased with P application. Moreover, Jaggi and Minhas (1990) found that grain yield and P uptake of wheat were significantly increased by increasing P up to 60 kg P_2O_5/ha, whereas, straw yield was significantly increased up to higher addition of 90 kg P_2O_5/ ha. Nataraja *et al*. (2006) noticed that the application of 75 kg P_2O_5/ha to wheat secured the highest number of grains per spike, 1000-grain weight and grain and straw yields.

Zinc deficiency in plants is widespread throughout the world. This deficiency is, usually, associated with calcareous high pH soils due to low Zn availability or with coarse textured (sandy), highly leached, acid soils because of their low total Zn content or with high levels of available soil phosphorus which may decrease Zn availability (Takkar and Walker, 1993).

As most crops, the normal way of correcting zinc deficiency in soils is to broadcast a zinc compound, usually as zinc sulphate, to the seedbed or to incorporate it into the topsoil at rates between 5 and 20 kg Zn/ha (Catmak *et al*, 1999). However, they found that foliar application of zinc is usually only applied to salvage an existing deficient crop but has very little residual value in the soil for the following crops. Yadav (1991) found that application of 50 kg $ZnSO_4$/ha increased grain yields from 3.43 (without $ZnSO_4$) to 3.72 t. Whereas, Dwivedi and Tiwari (1992) noticed that Zn content and uptake in grain and straw were increased with addition of 5 kg Zn/ha particularly in soils with below 0.60 p.p.m. DTPA-Zn. Significantly higher leaf area, leaf area index, leaf area duration, absolute growth rate and crop growth rate of wheat plants were recorded with the addition of 10kg Zn/ha; however, RGR continued to increase with 15kg Zn/ha (Razvi *et al*, 2005). Nataraja *et al*.(2006) also found that the application of $ZnSO_4$ at 10 kg/ha resulted in the highest number of grains per spike, 1000-grain weight and grain and straw yields.

Negative relationships between Zn and several other essential elements (e.g. P, N and Cu) have been reported to lead to Zn deficiencies in plants (Loneragan and Weeb, 1993). The interaction, often called P-induced Zn deficiency is commonly associated with high levels of available soil P or with high soil P application. Applying different sources of Zn to the soil has prevented or corrected the symptoms of Zn deficiency (Loneragan *et al.*, 1979). Verma and Minhas (1987) noticed that the P content in wheat plant was decreased with increasing levels of applied Zn. Singh and Singh (1989) also indicated that during the period of reclamation with high available P in sub-surface soil, applying 10 kg $ZnSO_4$/ha to wheat crop was optimum to obtain the highest yield but wheat did not respond to P application. When wheat was given 30 or 60 kg P_2O_5 and 0, 5 and 10 kg Zn/ha, Choudhary et al (1997) found that dry matter yield and P uptake were increased with rate P fertilizer applications. They added that dry matter yield and Zn uptake were increased with rate of Zn application, but P uptake tended to decrease. Jiao *et al.* (2004) found that increasing the level of P application significantly decreased grain Zn content. Moreover, they found that the content of Zn was increased with increasing Zn level up to 10kg/ha but was decreased with the application of P at 20 kg/ha. Nataraja *et al*. (2006) found that the combined application of 75 kg P/ha and $ZnSO_4$ at 10 kg/ha recorded the highest values of grain yield and yield components.

Therefore, the present investigation aimed to evaluate the interactive effects of P and Zn levels on growth and yield of wheat under new reclaimed soils.

MATERIALS AND METHODS

Two field experiments were conducted at an extension field in El – Salhia region, Sharkia Governorate, during 2004/2005 and 2005/2006 seasons to evaluate the interactive effects of three levels of P (15, 30 and 45 kg P_2O_5/fad as single calcium superphosphate, 15.5% P_2O_5) and four zinc rates (4, 8, 12 and 16 kg $ZnSO_4.7H_2O$/fad, 22.5% Zn) on growth and yield of wheat (Gemmeiza 9 cv.). The soil of the experimental field was sandy with moderately high pH. The soil chemical and physical analyses of the upper 30cm layer are presented in Table 1. The analyses of this soil explained that the amount of available P and Zn are very low (Marschner, 1995).

Table 1: Some of the soil chemical and physical characteristics of the upper 30cm soil depth in the two seasons.

Soil property	2004/2005	2005/2006
	Value	Value
Particle size distribution:		
Coarse sand (%)	51.60	50.45
Fine sand (%)	31.32	32.49
Silt (%)	6.25	6.03
Clay (%)	10.83	11.03
Texture class	Sandy	Sandy
Organic matter (%)	0.18	0.21
Calcium carbonate (%)	1.25	1.36
pH (soil water suspension)	7.9	8.01
EC,dSm^{-1}(saturated paste)	2.13	2.09
Available nutrients ppm:		
P	6.7	6.8
N	3.2	4.7
K	56	45
Zn	0.27	0.31

A split- plot design with 4 replicates was used in both seasons. Phosphorus and zinc fertilizers were applied as broadcasting at sowing. The phosphorus rates were distributed at random in the main plots, whereas, the sub-plots were occupied by Zn rates. The sub plot area was $10.5m^2$ (3 x 3.5) including 15 rows, 20 cm apart. The preceding crop was peanut in both seasons.

Sowing dates were on 25th and 20th of November in the first and second seasons, respectively at a seeding rate of 50kg/fad. The recommend cultural practices for wheat were applied as practiced in this region. Wheat plants from an area of $1m^2$ from each plot were randomly taken at 85 and 95 days from sowing for estimating the vegetative growth characters as follows:

1- Leaf area index (LAI) was determined using the following equation. LAI= (leaf area/m^2) / (land area/m^2).
2- Net assimilation rate (NAR) after 85-95 days from sowing (mg/cm^2/day) was recorded as the following equation:
   NAR = (W_2-W_1) (loge L_2- loge L_1)/ (t_2-t_1) (L_2-L_1). Where W_1 and W_2 refer to total plant dry weight/samples, L_1 and L_2 are the leaf area/ the same samples at time t_1 and t_2, respectively (Radford, 1967).
3- Total chlorophyll (mg/g). Chlorophyll a and b were determined according to Fadeel (1962). The optical density of the extract was measured spectrophotometrically at 662 nm and 644 nm to determine chlorophyll a and b, respectively.
4- Leaf Zn content (ppm).

5- Leaf P content (%).

At harvest, an area of $2m^2$ from each plot was harvested to determine:

1- 1000-grain weight (g). 2- Grain yield (ton/fad).

3- Straw yield (ton/fad). 4- Grain Zn content (ppm).

5- Grain P content (%).

Zinc in leaves and grain was determined by atomic absorption spectrophotometer (Chapman and Pratt, 1961). Phosphorus in leaves and grain was determined colorimetrically (John, 1970).

In both seasons, the analysis of variance and Duncan's were used separately to evaluate the response of each character within treatments according to Steel *et al*., (1997).

RESULTS AND DISCUSSION

1- Plant growth characters:

Data presented in Table 2 show the effects of P and Zn fertilization levels on leaf area index, net assimilation rate, total chlorophyll, leaf Zn and P contents of wheat grown on P-Zn deficient soil (Table 1). Leaf area index, net assimilation rate and total chlorophyll were significantly increased by increasing P level from 15 to 30 kg P_2O_5/fad in both seasons. The further increase in P level up to 45 kg P_2O_5/fad did not add any significant increase in these growth attributes. The leaf P content was significantly increased in both seasons due to the addition of the first P increment whereas the second one decreased both the leaf P and Zn contents. This finding is in harmony with that obtained by Fageria (1990) who found that adding phosphorus to wheat produced significant increase in shoot P contents 95 days after sowing. Meanwhile, shoot Zn content was decreased with P application. The positive effects of P on growth characters may be due to phosphorus enhanced root growth, energy metabolism, metabolic transfer processes, photosynthesis and respiration. It is a component of phospholipids and is required in large amounts for reproductive organs (Prasad and Power, 1997 and Trostle *et al*., 2001). These results are in harmony with those obtained by Kolar and Grewal (1989).

The obtained results from Table 2, also indicate that increasing Zn levels from 4 to 12 kg $ZnSO_4$/fad, was followed by a consistent significant increase in each of leaf area index, net assimilation rate, total chlorophyll and leaf Zn content, while leaf P content was significantly reduced by 7.28 and 5.30% compared with 4 kg $ZnSO_4$/fad in both seasons, respectively. These results are in partial agreement with those of Razvi *et al* (2005). Moreover, the third Zn increment to 16 kg $ZnSO_4$/fad, did not add a significant increase leaf Zn content but, leaf area index, net assimilation rate, total chlorophyll and leaf P content were significantly reduced compared with 12 kg $ZnSO_4$/fad. Also, addition of 16 kg $ZnSO_4$/fad, decreased leaf P content to the critical level (0.198 and 0.174%) where they were reduced by 24.14 and

34.09% compared with the addition of 4 kg Zn/fad in the first and second seasons, respectively. In the same trend, Armstrong (1999) found that applying 10 kg $ZnSO_4$/fad to wheat plants decreased leaf P content to the critical level (0.20%). Verma and Minhas (1987) also, reported that P content in wheat plant was decreased with increasing levels of applied Zn. The beneficial effects of Zn on the growth characters of wheat plants might be attributed to its important roles in cell division, root extension, respiration, N metabolism, chloroplast structure and enzymes activation (Marschner, 1995).

Data in Table 3 clearly demonstrated that except leaf area index and total chlorophyll in the first season, all plant growth characters were significantly responded to the interaction between P and zinc application levels in both seasons. The results indicated that the maximum values for leaf area index, net assimilation rate and total chlorophyll were obtained from application of 30 or 45 kg P_2O_5/fad with 12 kg $ZnSO_4$/fad. The highest leaf Zn contents were obtained from application 15 or 30 kg P_2O_5/fad with 12 or 16 kg $ZnSO_4$/fad. Meanwhile, the interactions 30 kg P_2O_5/fad with 4 or 8 or 12 kg $ZnSO_4$/fad and the interactions 45 kg P_2O_5/fad with 4 or 8 kg $ZnSO_4$/fad gave the highest leaf P contents. These results concluded that the interaction between 30 kg P_2O_5/fad and 12 kg $ZnSO_4$/fad was optimum to obtain the highest values for leaf area index, net assimilation rate, total chlorophyll, leaf Zn and P contents. That means that increasing the level of P alone or with Zn did not cause any significant increase in all growth characters, but however caused reductions in these traits. These results indicate that phosphorus and Zn behave antagonistically toward each other for nutrient uptake and distribution within the plant. These results are in agreement with those obtained by Loneragan *et al.* (1979), Singh and Singh, (1989), Loneragan and Weeb, (1993) and Choudhary *et al* (1997).

2- Yield and its attributes

The obtained results from Table 4 indicate that increasing P application level from 15 to 30 kg P_2O_5/fad produced gradual and significant increase in 1000-grain weight, grain and straw yields and grain P content in both seasons. Moreover, 1.900 and 1.721 ton grain/fad, 2.959 and 2.785 ton straw/fad, and 0.293 and 0.323% grain P content were obtained from addition of 30 kg P_2O_5/fad compared with 1.319 and 1.223 ton grain/fad, 2.412 and 2.341 ton straw/fad, and 0.247 and 0.277% grain P content obtained when the level of P was reduced to 15 kg P2O5/fad in both seasons, respectively. This finding is in harmony with that obtained by Hagras (1985) who found that increasing P level up to 30kg P_2O_5/fad increased 100-grain weight and grain and straw yields of wheat. Also, Tanaka and Aase, (1989) showed that application of 20 and 40 kg/ha of P fertilizer increased grain yields by 75 to 400 kg/ha. Moreover, Kolar and Grewal(1989) reported that phosphorus increased the leaf area index, chlorophyll content of leaves, and interception of photosynthetically active radiation which resulted in increased

grain yield of rice and wheat. Compared with 30 kg P_2O_5/fad, increasing rate of P up to 45 kg P_2O_5/fad did not add any further significant increase in grain and straw yields, and grain P content but 1000 grain weight was significantly reduced in both seasons. On the other hand, grain Zn content was gradually and significantly decreased by increasing P level from 15 to 45 kg P_2O_5/fad which gave 25.035 and 26.385 ppm compared with 20.333 and 21.800 ppm when 15 or 45 kg P_2O_5/fad were applied in both seasons, respectively. Fageria (1990) indicated that adding phosphorus to wheat plants produced significant increase in grain P content at harvest. Meanwhile, grain Zn content was decreased with P application. In contrast, Srahan (2004) showed that increasing P application significantly increased Zn content in wheat grain. These results are in harmony with those obtained by Jaggi and Minhas (1990) and Nataraja *et al*. (2006).

Table 4 showed also that increasing Zn rates from 4 to 12 kg $ZnSO_4$/fad produced gradual and significant increase in 1000-grain weight, grain and straw yields and grain Zn content in both seasons. On the contrary, grain P content was significantly and gradually reduced as the Zn application rate was increased from 8 to 16 kg $ZnSO_4$/fad. Also, applying 16 kg $ZnSO_4$/fad lowered grain P content to the critical level (0.227 and 0.253%) and significantly decreased grain and straw yields by 9.51 and 7.80% compared with applying 12 kg $ZnSO_4$/fad but grain Zn content did not respond to more than 12 kg $ZnSO_4$/fad in both seasons, respectively. This result confirm the antagonistic effect between P and Zn when they are applied in improper amounts under the new reclaimed soils which are deficient in P and Zn (Table 1). Takkar and Walker (1993) and Armostrong (1999) reported that when P and Zn present in the soil in available forms, they may interact with each other leaving more injury interaction effects. These results are in agreement with Yadav (1991), Dwivedi and Tiwari (1992) and Nataraja *et al.* (2006). In contrast, Yaduvanshi (1995) observed that P content in wheat grain was increased with zinc fertilizer application.

The data presented in Table 5 indicate that P and Zn have an antagonistic relationship on grain P and Zn contents. The highest values of grain Zn content were obtained by applying 12 or 16 kg $ZnSO_4$/fad with the low supply rates of P (15 or 30 kg P_2O_5/fad). In the same trend, The highest values of grain P content were obtained by applying 30 or 45 kg P_2O_5/fad with the low supply rates of Zn (4, 8 and 12 kg $ZnSO_4$/fad). In general, excessive P or Zn application induced negative effects on growth, yield and their contents in leaves and grain (Tables 3 and 5). Pervious studies indicate that increasing availability of P in the growth medium can induce Zn deficiency in plants (Prasad and Power, 1997). Also, larger application of P fertilizer to soils that are low in available Zn may depress tissue Zn content or may even induce Zn deficiency (Gianquinto *et al*., 2000). It seems that addition 30 kg P_2O_5 / fad with 12 kg $ZnSO_4$/fad was balanced to obtain the

highest values for growth, yield, and Zn and P contents in leaves and grain of wheat grown in P and Zn limiting soils. These results are in harmony with those obtained by Verma and Minhas (1987), Loneragan and Weeb (1993), Choudhary *et al*. (1997) and Nataraja *et al.* (2006).

From these results, it could be concluded that over phosphorus and Zn application behave antagonistically toward each other and induced negative effects on growth and yield of wheat grown in new reclaimed sandy soils which are suffering P-Zn deficiency. The balanced supply of P and Zn was effective to alleviate the negative effects of P-Zn antagonism. Application of 12 kg zinc sulphate along with 30 kg P_2O_5/fad as ordinary calcium superphosphate could be recommended as it afforded the best beneficial interaction effects between P and Zn on wheat grown in these soils. This necessitates identifying the main areas of phosphorus and zinc deficient soils and as well the suitable crops and hence treating them with proper nutrient balance of phosphorus and zinc. Also, it is important to screen crop varieties so that the more efficient varieties could be grown on soils of lower available phosphorus and zinc status.

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تخفيف التأثيرات السالبة لظاهرة التضاد بين الفسفور والزنك على نمو ومحصول القمح المنزرع بالاراضى حديثة الاستصلاح

ماهر عبد الله قطب على
قسم المحاصيل-كلية الزراعة-جامعة قناة السويس-الإسماعيلية-ج.م.ع

أجريت تجربتان حقليتان بارض رملية حديثة الاستصلاح بمنطقة الصالحية بمحافظة الشرقية فقيرة فى محتواها من الفسفور والزنك خلال موسمي ٢٠٠٤/٢٠٠٥، ٢٠٠٥/٢٠٠٦. أضيف الفسفور والزنك بمعدلات مختلفة بقصد دراسة ظاهرة التضاد بينهما والتي قد تقلل من قدرة النبات على امتصاصهما من التربة او تعطل انتقالهما من الجذور الى بقية اجزاء النبات. وبالتالي قد تؤدى ايضا الى نقص المحصول. ولذلك فان هذه الدراسة تهدف الى تقييم التاثيرات المتداخلة لثلاث معدلات من الفسفور (١٥و ٣٠و ٤٥ كجم فو$_٢$أ$_٥$/فدان على صورة سوبر فوسفات الكالسيوم الاحادى) مع اربعة معدلات من الزنك (٤و ٨و ١٢و ١٦ كجم كبريتات زنك/فدان) على النمو والمحصول وعلى تركيزات الفوسفور والزنك في الأوراق والحبوب في صنف القمح جميزة ٩. ويمكن تلخيص أهم النتائج المتحصل عليها كما يلى :

أدى إضافة ٣٠ كجم فو$_٢$أ$_٥$/فدان او اضافة ١٢ كجم كبريتات زنك/فدان الى تحسين معنوى لدليل مساحة الاوراق وصافى معدل التمثيل والكلوروفيل الكلى ووزن الالف حبة ومحصول الحبوب والقش فى كلا الموسمين. ولم يكن لزيادة معدل التسميد الفوسفاتي الى٤٥ كجم فو$_٢$أ$_٥$/فدان تأثيرا معنويا على هذه الصفات ولكن حدث نقص معنوى وصل إلى الحد الحرج لتركيزات كل من فوسفور الاوراق وزنك الحبوب والاوراق فى كلا الموسمين.

لم يكن لإضافة ١٦ كجم كبريتات زنك/فدان تأثيرا معنويا على محتوى الحبوب والاوراق من الزنك ولكن أدى لنقص معنوي لدليل مساحة الاوراق وصافى معدل التمثيل والكلوروفيل الكلى ووزن الالف حبة ومحصول الحبوب والقش وكذلك محتوى الحبوب والاوراق من الفوسفورالذى وصل الى الحد الحرج فى كلا الموسمين.

تشير نتائج التفاعل بين العنصرين إلى أن الإضافة الزائدة من الفوسفور والزنك تحدث ظاهرة تضاد تؤدى إلى نقصا معنويا في صفات النمو والمحصول وكذلك تركيزات هذان العنصران فى الاوراق والحبوب. ويمكن تلافى هذه التاثيرات السالبة بالاضافة المتوازنة من العنصرين.

وتوصى هذه الدراسة بان اضافة ١٢ كجم كبريتات زنك مع ٣٠ كجم فو$_٢$أ$_٥$/فدان على صورة سوبر فوسفات الكالسيوم الاحادى هو التوافق الامثل لتقليل ظاهرة التضاد بين العنصرين وبالتالي على نمو ومحصول القمح المنزرع في مثل هذه الأراضي والتي تحتاج إلى المزيد من الدراسات لتحديد المحاصيل والمناطق الفقيرة فى محتواها من الزنك والفسفور لتحديد الإضافات المناسبة من هذين العنصرين. وكما يجب الاهتمام أيضا باختيار الأصناف ذات الكفاءة العالية على النمو والإنتاج تحت هذه الظروف.