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# EFFECT OF ZINC PLUS MANGANESE FOLIAR APPLICATION ON POTATO PERFORMANCE AND QUALITY

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**Abstract:** In order to investigate the effect of Zn plus Mn foliar application on the performance and quality of three commercially cultivated potato cultivars, a field experiment was carried out in 2005/2006 and 2006/2007 cropping seasons, in the Vegetables Crops Experimental Farm, Faculty of Agriculture, Assiut University. The cultivars used were 'Spunta', 'Diamant' and 'Cara'. Combined Zn and Mn foliar application ($ZnSO_4$ and $MnSO_4$) was used (1.5g/L each) at three different frequency levels, twice/week, once/week and once/2 weeks. The tested cultivars significantly differed in most of the studied traits. The cultivar 'Spunta' produced the highest number and size of marketable tubers, and total marketable yield in both seasons. Application of Zn plus Mn foliar combination one time every two weeks significantly increased the number and size of marketable tubers and total marketable tubers. The highest yield of marketable tubers (ton/ha)* was recorded for 'Spunta' cultivar when treated with Zn plus Mn foliar combination every two weeks.

**Key words**: Zn, Mn, marketable tubers, yield component, foliar fertilizers,

## Introduction

Potato is one of the major crops contributing to the world's food requirement. It is one of the richest sources of starch and protein (Eppendorfer and Eggum, 1994, Anonymous, 2008). In Egypt, potato is mainly cultivated in two seasons, autumn and summer. The total cultivated area and productivity of autumn potatoes are 112,000 fedden and 896000 tons, respectively, with mean production of 7.98 tons per fedden. The cultivated area of summer potatoes is particularly restricted (28000 fedden with mean production of 8.5 tons/fedden) due to the high expenses of seed and cultivation (UPEHC DATABASE, 2004).

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***ha = 2.47 fedden**

Potato is considered a heavy nutrient requiring crop because of its bulk yield within a short growing season. There are 16 essential elements required for plant growth and reproduction (Marschner, 1986; Stark and Westermann, 2003). Some are required in relatively large amounts (called macronutrients) while others are required in small quantities (called micronutrients). Although micronutrients are used in smaller quantities, they are just as important as the macronutrients.

Among micronutrients, Zn is playing main metabolic role in plants. This element partially interferes in most of the enzymes structures like, dehydrogenises, aldolase and isomerases. In production of energy and Krebs cycle Zn also is effective (Alloway, 2004). Mn is one of the main components in structure of enzymes involved in photo-synthesis (Heckman, 2000, Alloway, 2004; Sayed et al, 2007). Utilization of Zn and Mn in potato production cause, increase in number of potato tubers, mean tubers weight and resulting in high yield and quality (Iqbal, 1995; Mohamadi, 2000, Sayed et al, 2007). The availability of micronutrients in the soil depends on the soil, antagonistic interaction with other macro- and micro-nutrients and the environment. Generally, as soil pH increases, micronutrient availability dec-reases (Mohamadi 2000; Bari et al, 2001; Sayed et al, 2007). In most of the Egyptian soils, pH is high and they are calcareous. In addition, phos-phorus fertilizer application is excessively used and that affects the availability of microelements and particularly reduce zinc (Zn) uptake and therefore, potato yield and tuber size are depressed (Soltanpour, 1969; Christensen, 1972; Christensen and Jackson, 1981; sayed et al, 2007).

Foliar application of elements e.g. Zn, Mn, Cu and Mn is better than direct application of them in soil due to removing nutrient shortage very fast, easy utilization, decrease poisonousness when gathering and prevention from stabilization of elements in soil (Sayed et al, 2007). Generally, foliar application is very fast method for providing required element in plants because nutrients are absorbing quickly in compare with absorption that through plant roots (Hashemy majd et al, 1998).

The present investigation aimed to study effects of Zn and Mn, through foliar application, on potato tubers yield and quality.

**Material and Methods**

The present study was conducted during two consecutive winter growing season (2005/2006 and 2006/ 2007) in the Experimental Farm, Faculty of Agriculture, Assiut University. The soil was clay and having pH 8 and field capacity 42%. The soil contents of NPK and some

micronutrient elements are presented in Table 1. Before preparing seed bed, soil was supplied with a basal dose of 200 kg/fedden calcium super phosphates (15.5% $P_2O_5$) and 150 kg ammonium nitrate ($NH_4NO_3$ 33.5% N). The remaining amount of nitrogen (250 kg/fed.) and 50 kg/fed potassium sulphate (48% $K_2O_5$) were given after 45 days of planting. The tubers of three different potato cultivars namely 'Spunta', 'Diamant' and 'Cara' were obtained from cold storage (El-Minia province, Egypt) and spread over the floor for sprouting. Well sprouted potato tubers were cultivated on November 1$^{st}$, 2005/2006 and November 5$^{th}$, 2006/2007. The experimental plot contained 5 ridges each 3 m long and 0.7 m wide. The distance between tubers within row was 30 cm. Cultural practices, e.g. weeding, earthing, pests control and irrigation were done as needed.

Zinc and Manganese foliar fertilizers were obtained from El Heelp Company (El-Heelp Company for Fertilizers and Pesticides, Dokki, Cairo, Egypt). These fertilizers were in powder forms containing 13% Zinc sulfate and 15% Manganese sulfate. The dosage recommended from the company of both fertilizers for potato crop was 1.5g/L. At the early stage of tuber bulking (45 days after sowing), a combination of Zn (1.5g/L) and Mn (1.5g/L) foliar fertilizers were supplied to the potato plants in both seasons. Three different treatments were followed to supply the Zn and Mn combination to the plants: a) supplying Zn plus Mn foliar combination two times per week; b) supplying Zn plus Mn foliar fertilizer combination once a week, and c) supplying Zn plus Mn foliar combination once at two weeks interval. No Zn and Mn foliar fertilizer was added to the control plots. The factorial (3 cvs. and 4 fertilizer treatments) field experiments were conducted in randomized complete-blocks (RCB) with 3 replicates in 2005/2006 and 2006/2007. The plants were harvested after 105 days from planting in both seasons. After harvesting, the plant tubers were graded into two classes, marketable and unmarketable tubers according to tuber diameter (cm). The marketable grade was included tubers larger than 45 mm (4.5 cm) in diameter. Tubers that had green color or pest's damage and/or diseases attack were discarded.

The following developmental and yield parameters were assessed on 10 randomly taken plants/plot: plant height (cm) after 90 days from planting (DAP), number of stems/plant, number of marketable tubers/plant, number of unmarketable tubers/plant, weight of marketable tubers (g)/plant, weight of unmarketable tubers (g)/plant, and tuber diameter (cm). Final plant stand, total yield of marketable tubers (ton)/ha and

total yield of unmarketable tubers (ton)/ha were assessed on plot bases.

Separate and combined analysis of variance relevant to RCB experiments, as described by Gomez and Gomez, (1984), were conducted. Homogeneity was tested among error variances in the separate ANOVA for RCB design. Subsequently, combined analysis was performed. Analysis of covariance was conducted to adjust treatment means (Gomez and Gomez, 1984) for total marketable and unmarketable yield using final plant stand as independent variable. The 'Least Significant Differences' test ($LSD_{0.05}$) was used for mean comparisons.

**Table(1):** Soil analysis and element contents of the experimental site[(1)].

| Element | % N | % P | % K | Fe (ppm) | Zn (ppm) | Mn (ppm) | pH |
|---|---|---|---|---|---|---|---|
| Contents | 1.78 | 0.624 | 3.3 | 0.6 | 4 | 11 | 8 |

[(1)]This analysis was conducted by the Soil Testing Lab., Faculty of Agric., Assiut Univ., 71526 Assiut, Egypt.

**Results and Discussion**

Combined analysis of variance (Table 2) showed a significant variance component due to cultivar x year for final plant stand, weight of marketable tubers/plant, tuber diameter and total marketable tuber yield. Variance due to interaction of fertilizer by year, fertilizer by cultivar and the second degree interaction (fertilizer X year X cultivar) were not significant.

**Effect of Zn plus Mn foliar application on growth parameters of the three studied potato cultivars:**

There were no significant effects of Zn and Mn foliar application on potato plant height (cm) at 90 DAP in all the examined cultivars in both growing seasons (Figs 1A and 3A). Limited studies were focused on the effects of microelements on growth and development of potato plants. Islam et al, (1982) noticed no significant effects of S and Zn on potato plant height. Application of Boron did not affect potato plant height (Pregno and Arour, 1992).

The number of main stems/ plant is illustrated in Figs 1B and 3B. The values varied from 4.47 (Cara) to 5.34 (Spunta) in 2005 /2006, and from 4.48 (Diamant) to 5.28 (Spunta) in 2006/2007. There were no significant differences

between treatments in respect to number of main stems per potato plant. Bari et al, (2001), observed contiguous result. They found that spraying a combined treatment of Zn+S+B+Mg increased significantly the number of main stems per potato plant.

As shown in Figs 1C and 3C, 'Spunat' gave the highest average plant stand/plot recording 43 and 41.93 plants/plot in 2005/2006 and 2006/2007, respectively, comparing to 32.08 and 37.42 for 'Diamant' and 35.50 and 36.83 for Cara in 2005/2006 and 2006/2007, respectively. As The difference among the fertilizer treatments were not significant.

**Effect of Zn plus Mn foliar application on number of tubers/plant of the three studied potato cultivars:**

The data presented in Figs 1D and 3D showed the effect of Zn plus Mn foliar application on number of potato marketable tubers (>45mm) per plant of different potato cultivars. The tested cultivars varied significantly in terms of number of potato marketable tubers per plant. The response was consistent among the two years. 'Spunta' cv gave more marketable tubers than 'Diamant' and 'Cara' cvs in 2005/2006 and 2006/2007. With each of the tested cultivars, increasing the time lapsed between spray treatments of Zn plus Mn combination increased significantly the number of marketable tubers per plant (Figs 1D and 3D). The least number of marketable tubers per plant was recorded for 'Cara' cultivar when no fertilizer was applied (control treatment) (3.33 and 3.87 marketable tuber/plant in 2005/2006 and 2006/2007, respectively), while the highest number of marketable tubers per plant was produced by 'Spunta' cv when spraying Zn plus Mn fertilizer combination one time every two weeks. Bari et al (2001) found that spraying Zn either alone or in combinations with Mg, B and S increased the number of marketable (tubers greater than 55 mm in diameter) tubers per potato plant. High concentration of Zn and Mn were reported to decrease the performance of potato plants (Ranjbar and Malakoty, 2000; Bybordy and Malakoty, 2003; Sarkar et al, 2004; Sayed et al, 2007). They observed that high concentration of Zn and Mn either soil-applied or foliar-applied decreased photosynthesis level in plant and consequently, potato plant growth and yield.

Significant differences in number of unmarketable tubers (< 45mm) per plant occurred among the tested potato cultivars with a consistent trend between the two seasons (Figs 2A and 4A). 'Spunta' produced the highest number of unmarketable tubers/plant (7.64 and 7.43 in 2005/2006 and 2006/2007, respectively), while 'Cara' recorded the lowest number of unmarketable tubers/plant with an average of 4.28 and 5.28 in

2005/ 2006 and 2006/2007, respectively. Foliar application Zn plus Mn at one time every two weeks decreased significantly the number of unmarketable tubers per plant as an average of all tested cvs. in both seasons. The control treatment recorded the highest number of unmarketable tubers per plant with an average of 7.42 and 7.84 in 2005/2006 and 2006/2007, respectively. 'Cara' cv. produced the least number of unmarketable tubers per plant when Zn plus Mn combination was weekly sprayed (3.67 and 4.3 for 2005/2006 and 2006/2007, respectively). The highest number of unmarketable tubers per plant was produced by 'Spunta' when sprayed with Zn plus Mn fertilizer combination two times per week in 2005/2006 and with control treatment in 2006/2007(Figs 2A and 4A).

**Effect of Zn + Mn foliar application on tuber diameter of the three studied potato cultivars:**

The effect of Zn and Mn foliar application on average diameter of marketable tubers is presented in Figs 2B and 4B. The results showed significant differences among tested cultivars in terms of diameter of marketable tubers. 'Cara; cv. had larger tubers than Spunta and Diamant with an average of 5.7 and 5.63 cm for 2005/2006 and 2006/2007, respectively. 'Spunta' and 'Diamant' cvs had more marketable tubers than Cara, which may negatively affected tuber diameter (Figs 2A and 4A). These results were comparable with the results observed by Babaji et al, (2008). They found that the potato cultivars Nicola and WC732-1 had more tubers than Greta, in contrary Nicola and WC732-1 cvs produced smaller tubers than Greta. Application of Zn plus Mn foliar fertilizer at one time every two weeks produced the largest tubers in 2005/2006, while applying Zn plus Mn twice per week produced the largest tubers in 2006/2007. 'Cara' and 'Diamant' cvs. produced the largest size of marketable tubers when spraying Zn plus Mn foliar fertilizer one time every two weeks in 2005/2006. In 2006/2007 the largest tuber diameter was recorded for 'Cara' plants when supplied one time every week by Zn plus Mn foliar fertilizer. Bari et al, (2001) reported that Zn+Mg+B foliar application markedly increased the yield of tubers exceeding 55mm in diameter, which is comparable with the presented results. Moreover, foliar application of Zn, B, S and Mg were reported to significantly decrease the percentage of small tubers (< 28 mm in diameter) (Islam et al, 1982; Karmakar et al, 1988; Taya et al, 1994).

**Effect of Zn + Mn foliar application on weight of tubers/plant (g) of the three studied potato cultivars:**

The results of weight of marketable tubers per potato plants are presented in Figs 2C and 4C. The tested cultivars varied significantly in weight of marketable tubers (g) per potato plants. 'Spunta' cv produced the highest yield of marketable tubers per individual plant (592 and 485.29 g for 2005/2006 and 2006/2007, respectively), while the least yield was recorded for Cara (365.67and 386.67 g for 2005/2006 and 2006/2007, respectively). Foliar application of Zn plus Mn at one time every two weeks significantly increased the weight of marketable tubers/plant by 31.02%, 21.96% and 30.30% more than control treatment, twice /week and/or once /week in 2005/2006, respectively. Moreover, the augmentation in weight of marketable tubers was by 28.92%, 15.41% and 25.90% more than control, two times/week and one time/week in 2006/2007. These results are comparable with that reported by Sayed et al, (2007). They found that application of Zn and Mn in combination increased the tuber yield by 17% comparing to control, while spraying Zn and Mn individually increased the tuber yield by 7.2% and 5.2%, respectively, comparing to control.

On the other hand, regarding to weight of unmarketable tubers per plant there were no significant differences between either tested cultivars or foliar applications of Zn plus Mn at all levels in 2005/2006 (Fig 2D). However, the tested cultivars showed significant differences in weight of unmarketable tubers/plant in 2006/2007, Zn plus Mn foliar applications showed no significant differences (Fig 4D). For each of the tested cvs., unmarketable tuber yield per plant was observed to decrease with the application of Zn plus Mn foliar fertilizer at one time every two weeks. These results reflected the effectiveness of utilizing the combination of Zn and Mn at the tested dose in potato production which caused an excess in the number and weight of marketable tubers (>45 mm) per plant. Iqbal, (1995), Mohamadi, (2000), and Sayed et al, (2007) provided same commentary. High yield of unmarketable tubers/potato plant were produced under excessive applications of Zn plus Mn (twice/week and once/ week) was ascribed to the sensitivity of potato to excess Zn and Mn concentration (Lee, 1972; Sarkar et al, 2004). High concentration of Mn and Zn was reported to have a significant effect on P uptake and accumulation in potato microplants (Sarkar et al, 2004). In addition, Lee (1972); Marsh et al (1987) and Sarkar et al (2004) reported that there was a significant reduction of tissue levels of inorganic P at this high level of external Mn and Zn supply.

**Effect of Zn + Mn foliar application on total tubers yield of the three studied potato cultivars:**

The results of total marketable yield (ton)/ha are presented in Figs 5A and 6A. The cultivars tested significantly differed in concern to yield of marketable tuber. 'Spunta' cv recorded the highest marketable yield with average yield of 20.68 and 17.00 ton/ha in 2005/2006 and 2006/2007, respectively, while the least tuber yield was produced by 'Cara' with average of 12.09 and 13.10 ton/ha in 2005/2006 and 2006/2007, respectively. These results may ascribe to: a) genetic variation among tested cultivars, and b) the significant differences between the tested cultivars in terms of plant stand/plot. The adjusted means of total marketable yield of the tested potato cultivars and fertilizer treatments are presented in Figs 5B and 6B. The results elucidated significant difference between the tested cultivars in terms of total marketable yield. Thus, the tested cultivars were genetically differed with concern to the total marketable yield and the difference in final plant stand between experimental units did not affect the performance of tested cultivars (Figs 5B and 6B). The growth, yield and quality of the potato cultivar 'Spunta' under the Egyptian conditions were extensively investigated. In numerous studies 'spunta' was recorded the highest weight of tubers/hill, highest marketable yield and highest total yield/ha (Butt, 1976; Abdall-Aal and Imam, 1984; Fahem and Haverkort, 1988). On the other hand, the tuber yield differed significantly among the Zn plus Mn foliar fertilizer treatments. The highest yield was observed when supplying Zn plus Mn foliar combination one time every two weeks (18.32 and 17.69 ton/ha in 2005/2006 and 2006/2007, respectively), while the control treatment (no Zn plus Mn foliar fertilizer was applied) produced the least yield (15.24 and 13.30 ton/ha in 2005/2006 and 2006/2007, respectively).

'Spunta' cv produced the highest yield of marketable tuber when supplied with Zn plus Mn foliar combination one time every two weeks, while 'Cara' cv recorded the least yield of marketable tubers when no Zn plus Mn foliar combination was supplied. It is suggested that due to the metabolic role of Zn and Mn in synthesis proteins, enzyme activation and metabolism of carbohydrate, utilization of fertilizers containing these elements or foliar application of Zn and Mn combinations increases the quantitative and quality performance of potato tubers (Karmarkar et al, 1988; Iqbal, 1995; Mondy et al, 1993; Alloway, 2004; Sayed et al, 2007).

On the other hand, significant differences in unmarketable yield occurred among the cultivars used, but the trend was not compatible among the seasons of study (Figs 5C and 6C). The results showed that 'Spunta' cv. produced higher

unmarketable tuber than 'Diamant' and 'Cara'. Spraying Zn plus Mn combination at the lowest frequency (one time each two weeks) significantly reduced the unmarketable tuber yield, while the control treatment (no Zn plus Mn combination was supplied) significantly increased the yield of unmarketable tubers. The highest unmarketable tuber yield was produced with 'Spunta' when supplied with no Zn plus Mn treatment (7.34 and 9.90 ton/ha in 2005/2006 and 2006/2007, respectively). On contrary, the least unmarketable tuber yield was produced by 'Cara' when treated with Zn plus Mn foliar combination twice/week (3.60 and 4.76 ton/ha in 2005/2006 and 2006/2007, respectively). The adjusted means of total unmarketable tuber yield (using the final plant stand/plot as independent variable) are presented in Figs 5D and 6D. The results clarified that the difference either between potato cultivars or Zn plus Mn foliar combination with respect to total unmarketable tubers ton/ha is ascribed to the genetic differences between tested cultivars and the applied micronutrients (Figs 5D and 6D). The effect of microelements on potato yield and quality were extensively investigated. Bari et al, (2001) found that foliar application of Zn as a combination either with B and Mg or with S and Mg produced the highest percentage of marketable tuber yield (from 36 mm to 55 mm). Additionally, supplying combinations of Zn+B+Mg and/or Zn+S+Mg produced the least percentage of unmarketable tuber yield. Utilization of Zn and Mn were reported to efficiently increase the quality of potato crop particularly when supplied as foliar fertilizers (Mohamadi et al, 2000; Kelling and Speth, 2001).

## Conclusion

We observed significant effects of application of Zn plus Mn foliar combination on the performance and quality of three potato cultivars, 'Spunta', 'Diamant' and 'Cara'. Foliar supplying of Zn along with Mn from sulfate resources as a combination once each two weeks after 45 days from sowing was increased the tuber yield and quality of tested potato cultivars. The potato cultivar 'Spunta' showed the highest yield of marketable tubers ton/ha. It can conclude that the potato cultivar Spunta performed preeminently by applying Zn plus Mn foliar combination one time each two weeks.

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## تأثير الرش بمخلوط الزنك والمنجنيز علي جودة ومحصول البطاطس

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لدراسة تأثير الرش بمخلوط الزنك و المنجنيز علي جودة ومحصول ثلاثة من الأصناف التجارية للبطاطس ، أجريت تجربه حقليه بمزرعة الخضر البحثية بكلية الزراعة – جامعة أسيوط خلال موسمي 2005/ 2006 و 2006/ 2007 . الأصناف المستخدمة في الدراسة هي اسبونتا ، دايمونت و كارا وتم الحصول عليها من احدي ثلاجات تخزين البطاطس بمحافظة المنيا، مصر. تم رش مخلوط الزنك + المنجنيز بتركيز 1.5 جرام/لتر بعد 45 يوم من الزراعة في ثلاث معاملات هي: أ- الرش مرتين كل أسبوع، ب- الرش مرة كل أسبوع، ج- الرش مرة كل أسبوعين و د- عدم الرش (معاملة مقارنة). صممت التجربة بنظام القطاعات كاملة العشوائية مع استخدام ثلاث مكررات. أظهرت النتائج المتحصل عليها اختلاف الأصناف الثلاثة معنويا في معظم الصفات المدروسة. أعطي الصنف اسبونتا اعلي القيم من حيث عدد وحجم الدرنات القابلة للتسويق وكذلك المحصول الكلي من الدرنات المسوقة. أدت المعاملة بمخلوط الزنك والمنجنيز رشا بمعدل مرة كل أسبوعين إلي زيادة عدد وحجم الدرنات القابلة للتسويق وكذلك المحصول الكلي من الدرنات القابلة للتسويق. الصنف اسبونتا أعطي اعلي محصول من الدرنات القابلة للتسويق عند معاملته بمخلوط الزنك والمنجنيز بمعدل مرة واحدة كل أسبوعين.