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Ameliorative Impact of Calcium-Magnesium and Calcium- Zinc Rich Products on Potato Growth, Tuber Yield and Quality in Newly Reclaimed Soil

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ABSTRACT

Potato is considered one of the most important vegetable crops for supplying the world's nutritional needs. For healthy growth, production, and tuber quality, potato needs a lot of nitrogen, phosphorus, and potassium fertiliser as well as a lot of other crucial nutrients like calcium and magnesium. Therefore, this research work was conducted to examine the effects of calcium, magnesium and zinc commercial fertilizers(Manni-Plex®Ca-Mag, and Ca-Zn) at ratios of 350 cm/100L.fad (0.24, 0.13, 0.15 g/L for Ca, Mg and Zn, respectively) and 450 cm/100L.fad (0.32, 0.15, 0.17 g/L for Ca, Mg and Zn, respectively)on potato growth and productivity. This experiment was carried out at a private farm in the El-Kassasin region,Ismailia, Egypt during the two 2021 and 2022 winter seasons. Five treatments were organized as a randomized complete block design with four replicates. Results displayed that the exogenous application of Manni-Plex® Ca-Mag and Manni-Plex® Ca-Zn at ratios of 350 cm/100L.fad and 450 cm/100L.fad significantly improved plant fresh weight, chlorophyll content, and plant dry weight as well as tubers yield, tuber quality (dry matter percentage, starch and protein contents), and shoot and tuber content of N, P, K, Ca, Mg, and Zn. In conclusion, the foliar application of Manni-Plex® Manni-Plex® Ca-Mg, and Ca-Zn at a ratio of 450 cm/L. fad may be a superior option for enhancing potato plant growth and tuber quality in sandy soils. The current results propose that foliar addition of the aforementioned fertilizers can be a promising approach to improving potato growth and productivity in. newly reclaimed soil.

Keywords*: Solanum tuberosum*, quality, nutrient accumulation

INTRODUCTION

The potato (*Solanum tuberosum* L.), one of the most vital vegetable crops belonging to the *Solanaceae* family for meeting the world's nutritional requirements, came in fourth place in terms of output size behind rice, wheat, and corn. (Walker et al., 1999). A cost-effective food that is high in starch, vitamins (such as C and B), minerals, and the right amounts of important amino acids is the potato (Paul Khurana and Naik, 2003). The main variable that restricts potato production is fertilisation. Many research investigations contrasted manufactured and organic methods of fertilizing potatoes and found that the latter generated the best outcomes in terms of both the number and the tuber quality. (Singh and Lallawmkima, 2018). For optimal growth, production, and tuber quality, it needs a lot of nitrogen, phosphorus, and potassium fertilisers. This necessitates a lot of other crucial nutrients (secondary and micronutrients) to keep things in equilibrium. Although they are still essential for healthy plant development, secondary nutrients like calcium and magnesium are only slightly less important than primary nutrients. Calcium (Ca), along with sulphur (S) and magnesium (Mg), is one of the secondary elements that is most crucial for the growth of strong vegetation. In plants, calcium plays a number of important roles, including: aiding in the metabolism of other macro and micro-nutrients' absorption; promoting appropriate cell elongation of plants; strengthening cell wall structure; forming calcium bectate composites, aiding in enzymatic processes; and assisting the plant's defense against environmental stresses(Marschner, 1995). Arvin *et al.* (2005) found that Ca buildup in plants improves the structural integrity of their cell walls and membranes as well as their capacity to endure bacterial phytopathogens. A crucial nutrient for the development and production of plants, such as potatoes, is calcium (Kleinhenz and Palta, 2002). This is due to the finding by Ozgen *et al.* (2003) that soil Ca concentration can influence potato tuber quantity as well as development. One can reduce the quantity of tubers while increasing the size of potato tuber by increasing soil Ca. Hirschi (2004) asserts that the roots on stolons and tubers move Ca to the tuber along with water. In addition, he claimed that applying Ca can raise the level of Ca in the tuber and stop storing decay as well as internal flaws like a hollow heart, and brown center. According to research conducted by Ozgen *et al.* (2006) and Modisane, the use of soluble calcium sources without the inclusion of gypsum improved tuber Ca content and reduced the occurrence of internal brown spots. (2007). According to Gunter and Palta (2008), an increase in tuber Ca content happened even when available Ca was tested at more than 1mg kg^{-1}. Ca applications are only generally advised for potato production if pre-plant soil exchangeable Ca is below 0.3 g kg^{-1}. Additionally, Palta (2010) showed that calcium fertilisation

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improves tuber Ca content and decreases the frequency of physiological diseases like internal brown spots. Calcium is also crucial for the well-being of the sprout and epidermis of potato tubers. According to studies conducted by Hamdi *et al.* (2015), adding calcium nitrate at levels of 0, 20, 40, 60, 80, and 120 kg ha^{-1} had a favorable effect on potato development and other factors like tuber weight and dry matter. Although it also reduced the quantity of tubers per plant^{-1}, it also greatly boosted tuber size and calcium levels in the leaf and tuber. While Helal and AbdElhady (2015) proved that increasing the soil's calcium content greatly enhanced plant development and the chemical makeup of potatoes in both growing seasons in the Nile Delta Region of Egypt. They also concluded that calcium fertilisation could possibly improve potato root production and quality. Magnesium is a necessary nutritive element in the production of chlorophyll. It acts as a bridge between the enzyme molecule and the pyrophosphate constructions of ATP in the majority of enzymes those cofactors that initiate phosphorylation processes (Mengel and Kirkby, 2001). According to Hongwei *et al. (*2000), a Mg shortage decreased the potency of other supplied plant elements. Therefore, the benefits of balanced NPK fertilizer use on output and farmer income cannot be fully exploited. According to Guneş *et al.* (2002), a lack of magnesium could be ascribed to the soil's declining magnesium content, but deficiencies in other cations like H^+, K^+, $NH4^+$, Ca^{++}, and Mn^{++} were also to blame. Additionally, competitive plants apply excessive amounts of potassium and nitrogen fertilizers to soil solutions that contain high concentrations of K^+ and $NH4^+$ ions and Mg^{++} ions, which prevents Mg^{++} from being taken up by those plants (Talukder *et al.,* 2009, Kacar and Katkat, 2007).

On the other hand, zinc is an essential nutrient and is crucial for the stimulation of a number of enzymes in plants. Additionally, it directly contributes to the biosynthesis of metabolic compounds like auxin, which enhance bioactive compound accumulation and raise dry matter (Mahmoud et al. 2019). Zinc oxide applied to the ground increased plant height, total plant biomass, and bioactive substance in red radish plants, according to Hussein et al. [29]. Similarly, to this, Mahmoud et al. (2020) found that spreading nano-Zn to plant foliage improved photosynthesis, the production of metabolic substances, and the development of tubers. Therefore, the purpose of this research study was to investigate the effects of foliar calcium, magnesium, and zinc rich products application on the growth, yield, and quality of potato plants grown in sandy soil under the environmental conditions of Giza Governorate, Egypt, as well as the nutrient accumulation of those plants.

MATERIALS AND METHODS

Two field studies were conducted at a private farm in the El-Kassasin region of the Ismailia Governorate, Egypt, during the winter growing seasons of 2021 and 2022 to examine the effects of exogenous application of calcium, magnesium, and zinc rich products on the growth and yield of potato plants (S. *tuberosum* L. cv. Caruso) grown in sandy soil. Before sowing potatoes, soil sample was collected from the soil surface (0–30 cm) of the experiment land, then air dried and then analyzed (Table 1). As shown in Table (1), the physical and chemical characteristics of soil were measured using the methods of Chapman and Pratt (1961).

Table 1. Physicochemical characteristics of the experimental soil in two seasons

	Physical properties					Chemical properties					
	Sand	Silt	Clay	Texture	pH	EC	CaCO3	OM	N	P	K
		%				dSm^{-1}		%		ppm	
1st season	88.5	7.8	3.7			1.2	1.9	0.4	27	10	47
2nd season	89.4	7.5	3.1			1.1	2.3	0.5	31	14	55

The atomic absorption method was used to separate the readily accessible calcium and magnesium in the $NH_4CH_3CO_2$ solution (1 N at pH 7). (model 2016). Deep plowing was used to split the experiment's soil into six 6-by-6-meter plots, with a 50 cm buffer zone separating each. Three treatments were used in the trial, and they were distributed among four replicates in a randomized complete block design (RCBD). On January 2nd, seed potato tubers (*S. tuberosum* L., cv. caruso) were planted at a distance of 25 centimeters among plants and 70 cm among rows

Application of fertilizers: Farm wastes, such as poultry manure and plant remnants, were combined to produce composted chicken manure. The soil preparation procedure included the full incorporation of this manure. The chemical properties of applied compost are listed in Table 2. The Egyptian Ministry of Agriculture, however, recommended using chemical NPK fertilizers amounts.

Table 2. Chemical properties of applied composted chicken manure

Organic materials	PH	Ec (dS /cm)	O.M %	N %	P %	K %	Fe (ppm)	Mn (ppm)	Zn (ppm)
Chicken manure	7.1	1.4	42	3.03	1.8	2.3	1181.5	23	534.5 5

Application of treatments: Manni-Plex® Ca-Mag, and Ca - Zn as foliar application were used throughout the potato life cycle, calcium and magnesium-rich products (Manni-Plex Ca-Mag, and Manni-Plex® Ca-Zn) weresprayed six times; the first application began after the plant had fully emerged and the second one after 10 days (at various rates of 350 cm/100L (0.24, 0.13, 0.15 g/L for Ca, Mg and Zn, respectively) and 450 cm/100L.fad (0.32, 0.15, 0.17 g/L for Ca, Mg and Zn, respectively.

Data collection:

- **Plant and tuber parameters:** after 80 days from the transplanting date, six plant samples from each plot were selected randomly to determine the following measurements of plant growth: Plant height, number of stems/ plant, Plant fresh and greening index (SPAD).
- **At harvest stage**: After 100 days, physicochemical properties were assessed. Tuber samples were taken from each treatment for determining total tuber yield (t. fed^{-1}), tuber weight (g plant^{-1}), and the number of tubers plant^{-1}, as

well as tubers quality measurements (dry matter %, specific gravity, starch % and protein %) as follows: Specific gravity was assessed according to the technique described by Smith, (1975). Where, the weight of potato tubers in air divided weight of potato tubers in water

- Starch % was computed according to the formula reported by Burton, (1948) as follows:

Starch % = 17.547+ {0.89 x (dry matter -24)}

- Protein content was computed according to the formula stated by Ranganna (1977) where the total nitrogen was multiplied by the conversion factor (6.25).
- **Plant and tuber analysis:** nitrogen content of plant leaves and tuber were assessed using the Kjeldahl digestion method. Phosphorus concentrations in the leaves and tuber of potato plants were assessed colorimetrically as labeled by the Olsen technique. Potassium, calcium and magnesium contents in the leaves and tuber of potato plants were assessed using a flame-photometer.

Statistical analysis: The test of normality distribution was performed according to Shapiro and Wilk method (1965), by using Statistic 7 softwear. A combined analysis of variances a cross both growing seasons was calculated after running the Bartelet test according to Snedecor and Cochran (1994). The attained data from the combined analysis were subjected to the statistical analysis of variance and means were compared according to Duncan's multiple range test ($p<0.05$) using MSTATC.

RESULTS AND DISCUSSION

1- Plant growth performance

Data in Table 3 displays the impact of foliar application of commercial products, containing Ca, on plant height, plant fresh weight, number of stems per plant, and leaf chlorophyll content of potato plants. Maximum values of plant height, number of stems per plant, plant fresh and leaf chlorophyll content (SPAD) were reordered in potato plants treated with MP Ca- Mag at a ratio of 450 cm/100L. fad followed MP Ca- Mag 2L/ ha, MP Ca-Zn at ratio of 450cm/100L. fad, and MP Ca-Zn at a ratio of 350 cm/100Lcompared to plant control (CT). These improvements in agronomical attributes could be linked to Ca, Mg and Zn supplies that respond tostimulating cell elongation; reinforce the structure of cell wall; it forms calcium bectate compounds; contributes to hormonal developments (Marschner, 1995). Furthermore, Helal and AbdElhady (2015) and Mahmoud *et al*. (2020) discovered that the implementation of Ca and Zn fertilisers had a superior impact on the improvement of potato plant development in the Nile Delta region.

Table 3. Impact of exogenous supplementation of calcium and magnesium rich product on the vegetative growth parameters of potato plants.

Treatment	Plant height (cm)	No. stems/ plant	Plant fresh (g)	Chlorophyll content (SPAD)
CT	29.09 c	1.59 c	268.20 e	31.27 c
MP Ca-Zn 350cm/100L.fad	33.53b	1.86 bc	283.83 d	33.43 bc
MP Ca-Zn 450cm/100L.fad.	34.76 b	2.31 ab	303.67 c	35.50 b
MP Ca-Mag 350cm/100L.fad	38.37ab	2.53 ab	338.70 b	37.17 ab
MP Ca-Mag 450 cm/100L.fad	41.77 a	2.72 a	349.87 a	39.67 a

2- Plant dry weight and leaf nutrient accumulation

ANOVA analysis showed that the dry mass of potato plants significantly improved in plants treated with all treatments compared to the control plants (CT), as presented in Table 4. The maximum plant dry weight was noted in plants sprayed with MP Ca-Mag at a ratio of 450 cm/100L. fad followed MP Ca- Mag 350 cm/100L.fad, MP Ca-Zn at ratio 450 cm/100L.fad, and MP Ca-Zn at a ratio of 350 cm/100L. fed , as compared to control treatment (CT). A similar trend was recorded in the concentration of leaf nutrients (N, P, K, Ca and Mg). All the treatments significantly improved the nutrient accumulation (N, P, K, Ca and Mg) in potato leaves in comparison to control plants (CT). The highest accumulation was noted in the potato leaves sprayed with MP Ca-Mag at a ratio of 4L/ ha while the minimum values of leaf nutrients were noted in untreated plants (CT). These increases in dry weight and leaf nutrient accumulation in MP Ca-Zn and MP Ca-Mag-sprayed potato plants may be related to the functions of Ca, Mg, and Zinc in potato plants. Foliar applications of Ca, Mg, and Zn increase photosynthesis rates and chlorophyll concentration, which increases total sugar accumulation, the primary organic component of the dry weight. Similar to the increase in root length, which increased the uptake of N, K, and P nutrients, the improvement in leaf nutrient accumulation may be caused by the involvement of Ca and Mg. (El-Hadidi *et al*., 2017, Hassan *et al*., 2022). Moreover, the addition of Ca, Mg, and Zn to the treatment of potato leaves may have contributed to the rise in Mg, Ca, and Zn levels.

Table 4. Impact of exogenous supplementation of calcium and magnesium rich product on dry weight and leaf nutrient accumulation of potato plants.

Treatment	Plant dry weight (g)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)
CT	14.4 c	2.09c	0.19 d	3.5 c	1.44 e	0.84 e	21.2d
MP Ca-Zn 350cm/100L.fad	19.9 b	2.62 b	0.25c	5.60 b	2.17 d	1.07 d	24.1b
MP Ca-Zn 450 cm/100L.fad.	20.5 ab	2.69 b	0.26c	5.83 b	2.51 c	1.42 c	25.4a
MP Ca-Mag 350cm/100L.fad	21.7 a	2.92b	0.27b	5.84 b	2.89 b	1.89 b	22.9 c
MP Ca-Mag 450 cm/100L.fad	22.60 a	3.18a	0.29a	6.10 a	3.01 a	2.31 a	22.8c

3- Tuber yield and its components

Table. 5 Illustrations of potato production and its components were influenced by foliar application of MP Ca-Zn and MP Cal-Mag. A maximum number of tuber, tuber weight and tuber yield per plant was recorded in plants treated with MP Ca-Mag at a ratio of 450cm/100L.fad followed MP Ca- Mag 350cm/100L.fad ha, MP Ca-Zn at ratio 450cm/100L, and MP Ca-Zn at a ratio of 350cm/100L compared to control treatment (CT). These results were in harmony with El-Hadidi *et al.*, 2017 on potatoes who found that foliar application of Ca and Mg fertilizers improved tuber yield and its components (Tuber number and weight). These results are linked to the improvement in plant growth measurements which could be related to the positive roles of Ca, Mg and Zn in plants. Foliar application of Ca, Mg and Zn stimulates potato growth as chlorophyll content, leaf area, and the number of leaves which is subsequently reflected in plant growth, on its productivity and its tuber components as the number of tubers, tuber weight, and tuber yield. In this regard, El-Hadidi *et al*. (2017) stated that calcium, magnesium and zinc had significant impacts on tuber weight and potato yield. Furthermore, several researchers reported that the application of Ca, Mg and Zn enhanced the plant growth, photosynthesis rates, bioactive compounds, dry matter accumulation, tuber number and tuber weight per plant (Talukder *et al*., 2009, El-Hadidi *et al.* 2017, Hassan *et al*., 2022, Mahmoud *et al.* 2020).

Table 5. Impact of exogenous supplementation of calcium and magnesium rich product on the potato tuber yield and its components.

Treatment	Number of tubers plant^{-1}	Average weight of tuber (g)	Tuber yield (t. fed^{-1})
CT	9.230 c	58.00 d	12.87 d
MP Ca-Zn 350cm/100L.fad	10.27 bc	66.33 c	13.73 c
MP Ca-Zn 450cm/100L.fad.	10.93 b	73.00 b	14.67 bc
MP Ca-Mag 350cm/100L.fad	11.77 ab	75.67 b	15.67 b
MP Ca-Mag 450 cm/100L.fad	12.60 a	83.00 a	18.60 a

Values followed by the same letter (s) within each column did not significantly differ according to the Duncan multiple comparison test at the 5% level.

4- Quality of potato tubers:

Data in Table (6) shows the impact of the exogenous addition of Ca and Mg and Zinc rich products on tubers quality such as the dry matter, specific gravity, starch and protein, and nutrient accumulation of tuber. Regarding the impact of Ca and Mg rich products, data show that foliar application of MP Ca-Zn and MP Ca-Mag significantly improved the ratio of dry matter, starch, protein and nutrient concentration (N, P, K, Ca and Mg) of potato tuber. Furthermore, findings show that when compared to untreated plants, MP Ca-Mag at a ratio of450cm/100L.fedand 350 cm/100L.fad was the superior to untreated control(CT). Consequently, these results reveal a role of calcium and magnesium supplies to improve the absorption of essential elements (N, P, K, Ca and Mg) and enhance tubers quality which might be linked to roles of Ca, Mg and Zn in plants; calcium tougher cell walls, it forms calcium bectate compounds and binds cells together (Mengel and Kirkby, 2001). These findings agree with the results of Helal and AbdElhady, (2015) and Mahmoud *et al.* (2020) who mentioned that calcium, magnesium and zinc are the most important. On contrary, the maximum potato Zn content was noted in plants sprayed with MP Ca-Zn at a ratio of 4L/ ha followed by MP Ca-Zn at a ratio of 2L/ ha, MP Ca-Mag at a ratio of 450 cm/100.fad and MP Ca-Mag at a ratio of 2L/ ha compared the untreated plants (CT).

Table 6. Impact of exogenous supplementation of calcium and magnesium rich product on the potato tuber yield and its components.

Treatment	Dry matter %	Specific gravity	Starch %	Protein %	N %	P %	K %	Ca %	Mg %	Zn ppm
CT	16.0c	1.06 a	9.02 c	7.00 c	1.12 c	0.37 b	2.33c	0.029c	0.022 c	14.3 d
MP Ca-Zn 350cm/100L.fad	18 .0b	1.07a	10.99 b	9.542b	1.53 b	0.37 b	2.83 b	0.042 b	0.029 b	17.2 b
MP Ca-Zn 450cm/100L.fad.	18.5 ab	1.067 a	12.7 ab	10.21 ab	1.63 ab	0.37 b	2.91 b	0.047 ab	0.031 b	18.3 a
MP Ca-Mag 350cm/100L.fad	19.2 a	1.06 a	13.25 a	11.72 a	1.87a	0.43 a	3.44 a	0.05 ab	0.036 ab	16.8 c
MP Ca-Mag 450 cm/100L.fad	20.2 a	1.067a	13.43a	11.75 a	1.88 a	0.45 a	3.54 a	0.06 a	0.044 a	16.7 c

CONCLUSION

The results of this study suggest that foliar applications of Manni-Plex® Ca-Mag and Ca-Zn, at a ratio of450 cm/100L.fad, along with the application of the suggested amounts of N, P, and K, increased the growth rate, tuber output, and tuber quality of potato plants cultivated in sandy soil. Further studies on potatoes and other strategic crops are need to present the correlation between Ca, Mg and Zn rich products dose, and environmental influences.

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التأثير المحسن للمنتجات الغنية بالكالسيوم والمغنيسيوم والزنك على نمو البطاطس ومحصول الدرنات وجودتها في التربة المستصلحة حديثًا

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المخلص

أجريت هذه التجربة لدراسة تأثير أسمدة الكالسيوم والمغنيسيوم والكالسيوم والزنك (Manni-Plex® Cal-Zn و Manni-Plex® Cal-Mag) بمعدل 350 سم / لتر و 450 سم / لتر على نمو النبات وجودة البطاطس Solanum tuberosum L في مزرعة خاصة ، منطقة القصاصين ، محافظة الإسماعيلية ، مصر خلال موسمي النمو 2021 و 2022. تم توزيع المعاملات الحقلية باستخدام تصميم القطاعات الكاملة العشوائية بأربعة مكررات. تم استخدام خمسة معاملات في هذه التجربة و كانت على النحو التالى الكنترول والمعاملات الاخرى من Manni-Plex® Cal-Zn و Manni-Plex® Ca-Mag بنسبة 350 سم / لتر و 450 سم / لتر. أوضحت النتائج أن استخدام التسميد الورقي للمنتجات الغنية بالكالسيوم والمغنيسيوم والزنك ، Manni-Plex® Ca-Zn و Manni-Plex® Ca-Mag بنسبة 350 سم / لتر و 450 سم / لتر أدى إلى تحسن معنوي في وزن النبات الطازج والوزن الجاف للنبات والكلوروفيل و فى إنتاجية الدرنات وجودتها كنسبة مئوية من محتوى المادة الجافة والنشا والبروتين و زيادة مستوى العناصر N و P و K و Ca و Mg و Zn في النباتات والدرنات عند الحصاد.كما زاد إنتاج محصول الدرنات لكل نبات وعدد الدرنات ومتوسط وزن الدرنات مع زيادة إضافة الكالسيوم والمغنيسيوم والزنك على الأوراق. يمكن الاستنتاج أن التسميد الورقي لـ Manni-Plex® Ca-Mag بنسبة 450 سم / لتر يمكن أن يكون حلاً أفضل لتحسين النمو ونوعية الدرنات لنباتات البطاطس في التربة الرملية.