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Influence of Phosphorus Fertilizer on Maize Vegetable (*Zea may* L.) in Soil Southern Vietnam

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ABSTRACT

Background: This study evaluated the effect of phosphate fertilizer dose, soil type, or both on the growth and yield of maize vegetable in soil with different P content of Southern Vietnam

Methods: This research was studied from 2015-2018. Experiment 1 was set up in pots with three phosphorus fertilizer levels and five soil types in a greenhouse at Can Tho University. Experiment 2 was set up at Tra Vinh sandy soil (*Dystri-Gleyic-Arenosols*).

Result: The results showed that in the phosphorus-rich groups, there was no difference in the effect of phosphate dose on the growth and yield of maize vegetable, but there were differences between soil types. Differences in the development and yield of maize between soil types may be due to soil composition and pH. Maize plants adapted and yielded better on sandy soils (*Dystri-Gleyic-Arenosols*) compared to alluvial (*Eutri-Mollic-Gleysols*), alkaline (*Umbri-Epiorthi-Thionic-Gleysols*) and red soils (*Hapli-Plinthic-Ferralsols*). In addition, the total phosphorus content in fruit-bearing leaves was higher in the phosphorus-rich treatment than in the low phosphorus fertilizer application treatment. Still, no symptoms of excess phosphorus on maize vegetable was detected.

Key words: Maize, Phosphorus fertilizer, Soil types, Yield.

INTRODUCTION

According to Dardarwal *et al*. (2009), Maize (*Zea mays* L.) is one of the most important cereal crops in the world, serving as a staple food more than any other cereal crop. In recent years, intensive cropping, unbalanced fertilization, soil and climatic changes have exacerbated micronutrient deficiencies (Augustine and Imayavaramban, 2022).

Phosphate compounds store energy from photosynthesis and carbohydrate metabolism for later use in growth and reproduction (Masood *et al*., 2011). The growth increases with fertilizer use is attributed to nitrogen and phosphorus assimilation by maize. Nitrogen increases plant photosynthetic capacity, rapidly converts the synthesized carbohydrates to proteins and protoplasm and this extra protein allows the plant to grow faster (Om *et al*., 2014). Bach *et al*. (2021) used the recycled phosphorus from the biogas digester with the same efficiency as applying superphosphate fertilizer to maize plants in the pot experiment.

Hoa *et al*. (2005) discovered that in many surveyed fields in the specialized vegetable growing area of Tien Giang in the Mekong Delta, the easily digestible phosphorus content is very high (129-234 mgP/kg) and also used very high phosphorus fertilizer (100-150 kgP_2O_5/ha/crop) to fertilize crops. According to research findings on alluvial soil rich in phosphorus in Cho Moi, maize and vegetables absorbed 6% of the phosphate fertilizer applied at 60 kg P_2O_5/ha (Duc, 2010). According to Hung *et al*. (2010), the percentage of pomelo yield generated by nitrogen and potassium fertilizers is 69N-21 P_2O_5-42 K_2O.

Theoretically, each crop is adapted and produced optimally under various soil, water and climatic conditions. Besides, agricultural productivity and temperature relationships vary depending on crop species, type, soil conditions and other weather conditions (Reddy *et al*., 2017; Sánchez and Rasmussen, 2014). However, research on the responsiveness of soil to plants is still limited, so the recommendations for plants are still general.

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MATERIALS AND METHODS

Research materials

Characteristics of the studied soil

Pot experiments were conducted on five types of soil based on the soil map classification system of the research units, including the soil map of Dong Nai province and Can Tho city of the Sub-Institute of Planning and Agriculture, 2008; Land map by Vo Tong Anh, Thesis on Adjusting and supplementing the land map of An Giang province at a scale of 1:100,000 and Tra Vinh soil map (University Can Tho, 2020). The basic physicochemical properties are presented in Table 1.

Crop variety

The maize variety studied is the 'Amazing' (White Beard) variety provided by ANTESCO An Giang company, with a cycle ranging from 50-350 days; however, for maize harvested at the young fruit stage, the average cycle range from 55-60 days.

Research methods

Pot experiment

The experiment was arranged in a randomized complete block design (RCBD) with three replications, three treatments and five types of soil , with each pot weighing 7 kg of dry soil and containing 01 maize plant. The amount of fertilizer for each pot is calculated based on 1 ha of 50,000 maize plants. The treatments are as follows: (1) Treatment 1: 180N - 0P_2O_5- 60 K_2O; (2) Treatment 2: 180 N - 90 P_2O_5 - 60 K_2O and (3) Treatment 3: 180N - 300P_2O_5 - 60K_2O.

Field experiment

The experiment was arranged in a randomized complete block design consisting of four treatments with three replications. Each treatment (lot) corresponds to a bed with an area of about 30 m^2 (25 m long × 1.2 m wide). Maize field have sowed density of 50,000 plants/ha. Treatments including: 180 N- 0 P_2O_5 - 60 K_2O; 180 N - 90 P_2O_5 - 60 K_2O; 180 N - 120 P_2O_5 - 60 K_2O and 180 N - 300 P_2O_5 - 60 K_2O.

Fertilizing, monitoring and analyzing criteria

Fertilizer formula

This was proposed based on the recommended amount of fertilizer per maize by Quyen (2000): (100 - 120 N + 40-60 P_2O_5 + 40-60 K_2O) kg/ha, as well as the results of the field survey of maize growing Vietnam.

Fertilization techniques: Fertilizers used for the study included superphosphate, DAP 18-49 -0, Urea 46% N and potassium 60% K_2O.
Before sowing: 1/2 total P (Superphosphate fertilizer).
+ 1st time (10 days after sowing (DAS)): 1/3 of N+ 1/2 of K.
+ 2nd time (20 DAS): 1/3 of N + 1/2 of P.
+ 3rd time (35 DAS): 1/3 of N+ 1/2 of K.

Data collection

Plant height 20, 30 and 40 DAS: distance from the ground in the pot to the developed leaves has a curvature of about 50%.

Yield and biomass

The biomass and yield of maize at the harvest stage were collected from the entire experimental plot. Maize is harvested when the standard of commercial harvest is reached (1-2 days when the maize silk is about 3 cm long).

Analytical criteria

The analytical criteria include.

Soil analysis

Soil samples were taken from each pot before sowing the maize. The total P, Available phosphorus was analyzed using Bray method 1. The pH meter was used to measure the pH after it was extracted with distilled water at a ratio of 1: 5. The mechanical composition was obtained from 3 levels of particles using the Robinson straw method.

Plant analysis

After harvesting, the leaves bearing fruit (60 DAS) were crushed, mixed and analyzed for total N, K and P contents.

Data processing

Data were statistically analyzed for ANOVA (Minitab 13) using the general linear model function and treatment means were differentiated using Tukey's test. The level of significance used for the tests was at least 5%.

Time and place of study

The experiment was conducted from February 2015 to March 2018. The potted experiment was grown in a greenhouse at Can Tho University. The field experiment was carried out on the sandy soil group (*Dystri-Gleyic-Arenosols*) with available phosphorus (25.8 mgP/kg) and (149.1 mgP/kg). Both families belong to Chau Thanh district, Tra Vinh province.

RESULTS AND DISCUSSION

The effect of phosphate fertilizer on the growth and yield of Maize in pot experiment

Investigate the growth of maize development on high P soil

The height of the maize plants (Table 2) was not significantly different at three times, taking the criteria except for the experiment on Alluvial soil (*Eutri-Mollic-Gleysols*) in An Giang at 40 days after planting. The reason could be due to the high content of easily digestible phosphorus in the soil, which meets the needs of plants.

Table 1: Physical and chemical properties of soils in Vietnam.

Soil type	pH_{H_2O}	Total P (% P_2O_5)	Bray 1 available P (mg P/kg soil)	Soil texture
Soil in pots				
Red soil DN (*Hapli-Plinthic-Ferralsols*)	4.82	0.54	36.8	Clay
Acid soil AG (*Umbri-Epiorthi-Thionic-Gleysols*)	4.41	0.10	9.61	Clay
Sandy soil TV (*Dystri-Gleyic-Arenosols*)	6.02	0.28	224.0	Sand
Alluvial soil AG (*Eutri-Mollic-Gleysols*)	4.18	0.20	87.2	Silt
Alluvial soil CT (*Eutri-Mollic-Gleysols*)	4.30	0.17	120.3	Silt
Experimental soil in the field				
Sandy soil TV (*Dystri-Gleyic-Arenosols*)	6.10	0.29	149.1	Sand
Sandy soil TV (*Dystri-Gleyic-Arenosols*)	5.92	0.25	25.8	Sand

Note: TV: Tra Vinh, AG: An Giang, DN: Dong Nai.

This finding is also consistent with the results of Cahill *et al*. (2008), who studied soils with high P content >120 mgP/kg in experimental farms in the Midwest of the United States on two subjects: (*Zea mays* L.) or cotton (*Gossypium spp*.). There was no difference in growth between the two treatments: 36 N + 15 P and 36 N + 0 P. Similar results were found in P-rich soils in the Northeast region by Ketterings *et al*. (2005).

The effect of phosphate fertilizer on the development of maize on soil types

Comparing heights at 20, 30 and 40 DAS stages on five different soil types reveals a statistically significant difference (Table 3). The reasons that the sandy soil of Tra Vinh, there is a high content of easily digestible phosphorus, the structure is mostly sand and the neutral pH of 6.02, which facilitates the release of phosphorus from immobilized or

Table 2: Recording height of maize plants of five soils in Vietnam.

No. experiment	Height (cm)		
	20 days	30 days	40 days
Red soil (*Hapli-Plinthic-Ferralsols*) in Dong Nai			
180 N- 0 P_2O_5-60 K_2O	35.7[a]	62.0[a]	117.0[a]
180 N- 90 P_2O_5-60 K_2O	37.2[a]	62.0[a]	110.3[a]
180 N- 300 P_2O_5-60 K_2O	43.5[a]	67.3[a]	107.7[a]
CV (%)	9.61	1.96	3.90
Alkaline soil (*Umbri-Epiorthi-Thionic-Gleysols*) in An Giang			
180 N- 0 P_2O_5- 60 K_2O	32.0[a]	60.0[a]	103.0[a]
180 N- 90 P_2O_5- 60 K_2O	28.7[a]	58.7[a]	103.0[a]
180 N- 300 P_2O_5- 60 K_2O	33.0[a]	62.3[a]	106.0[a]
CV (%)	4.18	3.97	6.32
Sandy soil (*Dystri-Gleyic-Arenosols*) in Tra Vinh.			
0 P_2O_5	39.8[a]	76.0[a]	144.0[a]
90 P_2O_5	38.2[a]	81.3[a]	156.7[a]
300 P_2O_5	41.3[a]	81.7[a]	155.0[a]
CV (%)	4.32	1.93	2.45
Alluvial soil (*Eutri-Mollic-Gleysols*) in An Giang			
0 P_2O_5	38.3[a]	69.3[a]	120.7[b]
90 P_2O_5	40.5[a]	72.0[a]	147.3[a]
300 P_2O_5	41.5[a]	75.3[a]	146.3[a]
CV (%)	3.91	1.80	2.65
Alluvial soil (*Eutri-Mollic-Gleysols*) in Can Tho			
0 P_2O_5	47.3[a]	81.7[a]	124.3[a]
90 P_2O_5	47.3[a]	81.3[a]	123.3[a]
300 P_2O_5	43.0[a]	84.0[a]	106.0[a]
CV (%)	1.63	0.86	4.06

Note: Numbers (a,b,c) with the same letter within column are not significantly different at P≤0.05.

Table 3: Recording of yield and biomass of maize plants on soil types in Vietnam.

Soil type	Experiment							
	Yield (gram/plant)				Biomass (gram/plant)			
	0 P_2O_5	90 P_2O_5	300 P_2O_5	CV (%)	0 P_2O_5	90 P_2O_5	300 P_2O_5	CV (%)
Red soil DN (*Hapli-Plinthic-Ferralsols*)	4.90[a]	2.77[b]	2.12[b]	2.96	607.0	534.0[a]	540.6[a]	5.76
Acid soil AG (*Umbri-Epiorthi-Thionic-Gleysols*)	2.91[b]	4.67[a]	2.76[b]	2.22	475.5[a]	584.7[a]	413.5[a]	7.32
Sandy soil TV (*Dystri-Gleyic-Arenosols*)	3.07[b]	5.27[a]	6.29[a]	3.83	524.1[b]	756.0[b]	769.7[a]	3.48
Alluvial soil AG (*Eutri-Mollic-Gleysols*)	4.54[a]	5.2[a]	3.55[a]	2.78	535.1[a]	619.6[a]	583.9[a]	3.65
Alluvial soil CT (*Eutri-Mollic-Gleysols*)	3.52[b]	4.14[a]	3.54[b]	1.79	625.6[a]	679.6[a]	696.2[a]	2.18

Note: Numbers (a,b,c) with the same letter within column are not significantly different at P≤0.05.

adsorbed phosphorus compounds by iron and aluminum hydroxides to meet the needs. It shows that it is better adapted to sandy soil than other soil types. Similar results were found in P-rich soils in the Mekong Delta Vietnam by Thuy (2015).

Effects of phosphate fertilizer on the nutrient accumulation in leaves

Table 4 show that on the five soil types surveyed, the total nitrogen content varies from 1.55 to 2.32% N and the total potassium varies from 1.89 to 2.34% K assessed. The leaf formation was adequate in nitrogen and potassium, even in the high phosphorus treatment. According to Minh (1999), maize leaves lack phosphorus when the phosphorus level is 0.11-0.17%, which is low, but when it is 0.2-0.6%, it is average. Maize can be grown on soil with a pH ranging from 5 to 8, with the best pH being 5.5 to 7. In soil with pH <5, the maize plants were stunted, with leaves burned into long streaks between veins, purple and red and the plants died. Mild cases are only evident in seedlings. Luan's (2010) experiments showed that at pH<5.5, the yield decreased by 30%. In this experiment, due to low pH, phosphate fertilizer application at various doses did not increase the height and diameter of the plants. Similar results were found in P-rich soils in the Mekong Delta Vietnam by Thuy *et al*. (2020).

The effect of phosphate fertilizer on the growth and yield of maize in field experiment

The effects of phosphate fertilizer on plant height

Similar to the experiment in pots, the results presented in Table 5 show that grown on soil with high digestible phosphorus (149.1 mgP/kg) increased well. There was no significant difference in the height of plants at stages 20, 30 and 40 DAS. There was a statistical difference between 20 and 40 DAS periods in the soil group with lower easily digestible phosphorus (25.8 mg P/kg). However, treatments with phosphate fertilizer at 90 and 120 kg P_2O_5/ha had higher tree height, statistically different from those without fertilizer and with phosphate fertilizer at 300 kg P_2O_5/ha. It was possible due to temporary phosphate poisoning during the seedling stage when high doses of phosphorus were applied. The height of the plants in both experimental fields was more significant than the seed characteristic of 150 cm, indicating that the plants are well

Table 4: Weight N, P, K total of maize tissue concentration was studied on some levels phosphorus fertilizer.

Soil type	Experiment	Tissue concentration		
		% N total	% P_2O_5 total	% K total
Red soil DN (*Hapli-Plinthic-Ferralsols*)	0 P_2O_5	1.88	0.45	2.26
	90 P_2O_5	1.82	0.51	2.08
	300 P_2O_5	2.32	0.63	2.17
Acid AG (*Umbri-Epiorthi-Thionic- Gleysols*)	0 P_2O_5	1.55	0.49	2.34
	90 P_2O_5	1.78	0.45	2.2
	300 P_2O_5	2.00	0.62	1.89
Sandy soil TV (*Dystri-Gleyic-Arenosols*)	0 P_2O_5	1.76	0.5	2.16
	90 P_2O_5	1.69	0.57	2.12
	300 P_2O_5	1.75	0.69	1.93
Alluvial soil AG (*Eutri-Mollic-Gleysols*)	0 P_2O_5	1.83	0.52	2.1
	90 P_2O_5	1.88	0.62	2.21
	300 P_2O_5	1.77	0.92	2.26
Alluvial soil CT (*Eutri-Mollic-Gleysols*)	0 P_2O_5	1.79	0.5	2.16
	90 P_2O_5	1.88	0.51	1.98
	300 P_2O_5	2.21	1.25	2.00

Table 5: Recording the height of maize plants on the sandy soil of Tra Vinh.

Treatment	Plant height (cm)					
	Studied sites 1 (149.1 mgP/kg)			Studied sites 2 (25.8 mgP/kg)		
	20 days	30 days	40 days	20 days	30 days	40 days
0 P_2O_5	111.2^a	185.4^a	218.1^a	88.9^b	171.3^a	205.3^b
90 P_2O_5	108.2^a	180.4^a	217.3^a	100.1^a	176.2^a	223.1^a
120 P_2O	110.3^a	182.1^a	217.6^a	97.5^{ab}	174.5^a	215.2^{ab}
300 P_2O_5	108.3^a	179.7^a	216.3^a	91.4^b	172.1^a	201.0^b
CV (%)	1.92	1.99	2.43	3.21	3.24	6.86

Note: Numbers (a,b,c) with the same letter within column are not significantly different at P≤0.05.

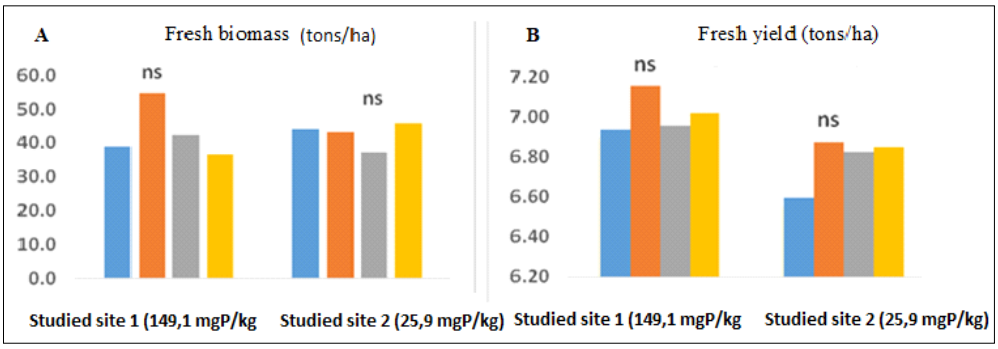

Fig 1: A) Biomass and B) fresh yield of maize on sandy soil (*Dystri-Gleyic-Arenosols*) in Chau Thanh, Tra Vinh province.
Note: ns are not significantly different at P≤0.05.

adapted to the sandy soil and available phosphorus content in the soil to meet plant needs. The application of high phosphorus in many crops can increase the accumulation of phosphorus in the soil, affecting the absorption of nitrogen and potassium and causing nutritional imbalance. The phosphorus content in common plants accounts for about 0.25% to 0. 6%. High phosphorus application can also cause plant phosphorus poisoning (Siber *et al*., 2002).

The effects of phosphate fertilizer on crops biomass and yield

According to Fig 1, the biomass in the two treatments was not statistically significant. Therefore, the results of this study are also consistent with Duc (2010). Based on the experimental results in pots and the field, plants are well adapted to the sandy soil group (*Dystri-Gleyic-Arenosols*) in Tra Vinh. However, the effectiveness of phosphate fertilizers in this soil group is also low due to the loose sandy soil, neutral pH, accessible mineralization of nutrients and high, easily digestible phosphorus to meet the needs. As a result, it is necessary to consider and recommend reducing the number of phosphate fertilizers for plants grown on sandy soils with the high, easily digestible phosphorus content. Reasons can that soil composition and pH can be factors that may influence differences in growth and yield among soil types. According to Hoa *et al.* (2008) on rich phosphorus lands, there was no difference in yield between the plots with fertilizer application. The response of Maize to P and K fertilizers was very low.

CONCLUSION

There was no difference in the effect of phosphate fertilizer dosage on growth and yield maize on land but there were differences between soil types. Plants adapted and yielded better on sandy soils than on alluvial, alkaline and red soils. The total phosphorus content on fruit-bearing leaves was higher in the treatment rich in phosphorus than in the treatment with low phosphorus, but no symptoms of excess phosphorus were detected in plants. More research should be done on the effects of easily digestible phosphorus content, mechanical composition and pH on growth and crop yield.

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Conflicts of interest

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