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Assessment of capsicum nutrient levels affected by lime and phosphorus application in Fijian soil

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Abstract

The application of lime and phosphorus is a common practice for improving crop production in acidic soils of tropical countries and temperate regions. An experiment in factorial combination was laid out at the College of Agriculture, Fisheries and Forestry to investigate the effects of lime and phosphorus on the quality and nutrient content of *Capsicum annum*. Treatment includes 4 levels of lime (0, 250, 500 and 750 kg ha^{-1} represented as L_0, L_{250}, L_{500}, L_{750}) and 4 phosphorus levels (0, 20, 40 & 60 kg ha^{-1} and represented as P_0, P_{20}, P_{40} and P_{60} respectively). Total ash content, moisture content, protein and other nutrients were analysed. Total ash, moisture, protein and other plant nutrients increased significantly with an increase in lime dose up to 500 kg ha^{-1}, while total ash, moisture content, protein and other nutrients increased significantly up to P40 (40 kg ha^{-1}). Copper and magnesium showed no significant difference with the application of lime and phosphorus.

Keywords

capsicum, lime, moisture, nutrients, phosphorus, protein, total ash

Introduction

Vegetables and fruits play an important role in meeting the various vitamin and mineral needs of the human body (1, 2). Therefore, the demand for fruits and vegetables continues to increase. Capsicum contains a good amount of important minerals and vitamins (3). The fruits may be green, yellow, or red when ripe (4). It is relatively non-pungent to low pungent and not very hot, making it the second most important vegetable in the world after tomatoes (5). Capsicum can be used as either cooked or as raw salad. In some areas leaves are also eaten as salads and soup (6) and contain various nutrients that our body needs: vitamin A, vitamin C, vitamin B1 and some important mineral salts like phosphorus, calcium and iron (7).

Agriculture land in Fiji is located at elevations of 20, 10 and 60 meters above mean sea level, respectively. Fiji enjoys a year-round mild tropical climate with maximum temperatures that rarely stray from the range of 31 °C (88°F) to 26 °C (79 °F) and temperatures that range between (23 °C-27 °C) with an average annual rainfall of about 2500 to 3000 mm (8). Fiji is known for its more than 300 islands' diverse vegetation and soil types. In Fiji, oxisol, which has a high concentration of iron, aluminium oxides and hydroxides, typically makes up the low-lying terrain. Due to the volcanic soil called andisol that makes up the archipelago, the majority of Fiji's locations are exceptionally fertile.

Soil acidity is considered one of the important soil characteristics affecting plant growth and the quality of crops (9). The best soil pH for *Capsicum* spp. ranges between 5.6 and 6.0 and are best in mineral soils, which have low levels of organic matter (10). Soil acidity is a common problem in Fiji (11, 12), where heavy rainfall removes large amounts of exchangeable bases from the soil surface (13) through leaching. In heavily weathered acidic soils around the world, calcium, magnesium, phosphorus deficiency (14), aluminium and manganese toxicity are major nutritional disorders that restrict crop yields and crop quality (15, 16). Acid soils, especially such as oxisols and ultisols, generally have problems like low plant nutrient content, nutritional imbalance and multiple nutrient deficiencies (17). The application of liming material is an ancient agricultural practice for improving acidic soils and continues to be recognized as an essential step for effective agricultural production in some areas of the moist tropics. The overall effects of lime on the soil include increased soil pH, Ca and Mg saturation, neutralization of toxic aluminium concentrations, increased pH-dependent cation exchange capacity, increased availability of phosphorus and improvement in plant nutrient uptake by the plant (18, 19).

The availability of phosphorus is influenced by lime application. In heavily weathered soil the availability can be varied from beneficial to harmful (20). Crop yield responses to such soils are usually interdependent (21). The increased response to applied phosphorus with increasing lime addition is due to improved phosphorus supply from soil or improved plant P absorption capacity when Al toxicity is eliminated (22). Heavy doses of lime can reduce crop yield due to lime-induced phosphorus and micro-nutrient deficiencies (23). The application of fertilizer and appropriate management practices reduces fertilizer waste and increases nutrient efficiency which favours the environment (24). In these circumstances, the application of an appropriate combination of lime and phosphorus doses is an effective way for improving the nutritional value and growth parameters of the crop. This study was conducted to understand the effects of lime and phosphorus on the protein, ash and other important plant nutrient content of capsicum.

Materials and Methods

Experimental site

The study was conducted at the Instructional Agricultural Farm Complex, Fiji National University. The geographical references of the research site were S18°2´32" to E178° 32´46". The soil properties of the research farms are given in Table 1. The experimental site was 16 m above mean sea level and was poorly drained. The area has a tropical climate with heavy rainfall from November to April and scanty rainfall during the rest of the year. The average precipitation was 3000 mm (8). The mean maximum temperature was 26 °C and the mean minimum temperature was 21 °C. The mean temperature was 23 °C. The trial was conducted during the winter season. The humidity varied from 71.5 to 81.3%. The day length was 10.5 - 11.0 hrs only and there was occasional rainfall from the beginning of the experiment to harvesting.

Table 1. Physico-chemical properties of the experimental soils.

Soil property	Mean value
Physical-chemical properties	
pH(1:5)	5.79
EC (dSm^{-1})	0.04
Total Carbon (%)	1.92
C.E.C. ($cmol\ kg^{-1}$)	13.23
Texture [a]	Scl-cl
Plant nutrients	
Available nitrogen (%)	0.15
Available phosphorus ($mg\ kg^{-1}$)	16.29
Available potassium ($mg\ kg^{-1}$)	132.47
Calcium ($mg\ kg^{-1}$)	1365.80
Magnesium ($mg\ kg^{-1}$)	608.98
Iron ($mg\ kg^{-1}$)	26.25
Manganese ($mg\ kg^{-1}$)	21.59
Copper ($mg\ kg^{-1}$)	1.65
Zinc ($mg\ kg^{-1}$)	1.03

[a]: Textural class as per Soil Taxonomy (1975); scl: sandy clay loam; cl: sandy clay loam

Experimental treatment and design

The experiment laid was having 4 Lime levels viz. 0, 250, 500 and 750 kg Lime ha^{-1} (designated as L_0, L_{250}, L_{500}, and L_{750} respectively) and 4 Phosphorus levels viz. 0, 20, 40 and 60 kg P ha^{-1} (designated as P_0, P_{20}, P_{40} and P_{60} respectively). The experiment was conducted in a Randomized Block Design (RBD) with 3 replications results in 48 total treatment combinations.

Crop husbandry

Capsicums originate from South and Central America, but how they arrived in Fiji is not yet quoted anywhere. The annual report made by the Department of Agriculture for the year 1967 was verified (25) and they mentioned that research studies were conducted on capsicum in the Fiji Islands in 1996 and the following years. "Capsicum is a high-value crop and can be easily grown all year round; it is especially productive in warm and dry climates." Capsicum is a crop that is currently thriving in the farming lands of Fiji. Currently, Fiji has hybrid varieties such as Yolo Wonder B, Yolo Wonder Y, Hybrid Ace, Summer Bell and the most common hybrid, Blue Star. The capsicums in Fiji are shrubby and grow to a height range from 50-60 cm. The stems are densely or moderately branched based on locations. The flowers are white in shade and the predominant colours of the fruit are green and rarely yellow or red. It is best to plant during the cool, dry season from April to September.

The *Yolo Wonder B*, a high-yielding variety of capsicum (*Capsicum annum* L.) was used in this study. The land was well prepared and converted into loose friable and dried mass to obtain fine tilth. The beds were prepared of the size of 3 x 3m for each plot. A study suggested that the application of lime in the range between 6 - 7.5 tonnes/ha changed the soil pH by one unit (26). Lime treatments were applied 30 days before transplanting. The full doses of phosphorus treatments were applied before transplanting. The seedling was raised in the nursery and transplanted after 21 days to prepared beds. The N and K fertilizers were applied according to Fertilizer Recommendation Guide through urea and muriate of potash (MP) respectively. One-half (1/2) of Urea and a full dose of MP were applied at the end of each treatment plot preparation. The rest of the Urea was top dressed in two equal instalments- at 21 days after transplanting (DAT) and 48 DAT respectively. Uniform and healthy seedlings 20 days old were selected for transplanting in the experimental field maintaining a spacing of 1 m and 0.5 m between plants and rows separately. Thinning, weeding, irrigation and other agronomic practices were done as per the requirements.

Data collection and statistical analysis

Healthy fruits from the plants were harvested at 8-10 days intervals between maturity to ripening. 10 - 12 plants were selected randomly from each plot for the collection of data. The fruits were analysed for total ash and moisture content, protein, phosphorus, potassium, calcium, magnesium and micronutrients. Analysed data were compared statistically by using the ANOVA and the means were compared by using Duncan`s Multiple Range Test using SPSS.

Results & Discussion

Total ash and moisture

Recorded observations showed that total ash content increased significantly with increasing lime content (Table 2). The highest total ash content (0.74%) of pepper was found at the application of 750 kg L ha^{-1} and was statistically similar to 500 kg L ha^{-1} (0.73%) and the lowest level (0.45%) was observed in the control. The moisture content of capsicum increased significantly with increasing lime doses. The maximum moisture content of capsicum (95.13%) was found with 750 kg L ha^{-1}. This was not statistically different from other doses of lime application. The minimum moisture content (94.93%) was recorded in the control treatment. Observed data showed that the application of phosphorus increased the total ash content significantly. The highest value of total ash was found (0.73%) with P_{40} (40 kg P ha^{-1}) fertilizer which was statistically at par (0.73%) with P_{60}. The minimum total ash content was found in the control (P_0) treatment. The application of phosphorus increased the moisture content in capsicum fruits. The maximum moisture content was recorded (95.23%) with P_{60} (60 kg ha^{-1} of phosphorus) fertilizer which was significantly at par with other phosphorus application levels. The lowest moisture content was recorded in the control (P_0) treatment (25, 27).

Protein and phosphorus

Laboratory data revealed that the protein content of capsicum fruits increased significantly with an increase in the level of lime application (Table 3). Maximum protein content (1.10%) was recorded with the application of 750 kg lime ha^{-1} and which was statistically similar to other lime application treatments and the minimum protein content (0.99%) was observed with L_0 kg ha^{-1}(control). Phosphorus content in capsicum fruits increased with an increase in levels of lime application. The maximum phosphorus content (0.53%) was recorded with L_{500} kg $ha^{-1}$and minimum (0.38%) with control treatment. Phosphorus application significantly increased the protein content in capsicum. Maximum protein content (1.18%) was observed with P_{60} (60 kg P ha^{-1}) which was statistically at par with 40 kg P ha^{-1} (P_{40}). The minimum protein content (0.88%) was found in the control (P_0) treatment. The application of phosphorus increased the phosphorus content in capsicum fruits. The highest value (0.54%) of phosphorus was found with P_{60} (60 kg P fertilizer ha^{-1}) followed by P_{40} (40 kg P ha^{-1}). The

Table 2. Effect of lime and phosphorus application on moisture and total ash content of capsicum.

Treatments	Total Ash (%)	Moisture (%)
L_0	0.45a	94.93
L_{250}	0.53ab	94.75
L_{500}	0.73b	94.95
L_{750}	0.74b	95.13
SEm ±	0.09	-
CD $_{(0.05\%)}$	0.22	NS
P_0	0.45a	94.75
P_{20}	0.55ab	94.90
P_{40}	0.73b	94.88
P_{60}	0.70b	95.23
SEm ±	0.09	-
CD $_{(0.05\%)}$	0.22	NS

- Values with similar alphabets are non-significant at P≤0.05

Table 3. Effect of lime and phosphorus application on protein and phosphorus content of capsicum.

Treatments	Protein (%)	Phosphorus (%)
L_0	0.99	0.38a
L_{250}	1.05	0.45ab
L_{500}	1.09	0.53b
L_{750}	1.10	0.50b
SEm ±	-	0.04
CD $_{(0.05\%)}$	NS	0.10
P_0	0.88a	0.34a
P_{20}	1.06b	0.45b
P_{40}	1.13bc	0.53b
P_{60}	1.18c	0.54b
SEm ±	0.05	0.04
CD $_{(0.05\%)}$	0.11	0.10

- Values with similar alphabets are non-significant at P≤0.05

lowest value was identified in the control (P_0) treatment. The above results indicated that the higher dose of lime and phosphorus was influential for protein and phosphorus content up to a certain limit. It was reported that increasing the amount of lime and phosphorus increases the available phosphorus concentration (23). The application of phosphorus influenced the phosphorus uptake significantly. The increase in phosphorus content due to the application of lime is due to the fact that it breakdowns the Al & Fe phosphates in the soil, making P available to plants and the application of lime increases the mineralization of organic phosphorus (28).

Calcium and magnesium

Experimental results showed that the calcium content of capsicum increased with increasing lime application and the magnesium content decreased with increasing lime application (Table 3). The maximum calcium (801.50 mg kg $^{-1}$) was observed with the application of 750 kg lime ha^{-1} which was followed by L_{500} kg lime ha^{-1} and was statistically similar to 500 kg lime ha^{-1}. The lowest calcium content was observed with L_0 kg ha^{-1} (control). Magnesium showed a negative trend with increased levels of lime application. The maximum value of magnesium (98.00 mg kg^{-1}) was recorded with L_0 (control) and minimum with L_{750} kg lime application per hectare. Calcium content in capsicum increased with an increase in levels of P application. The maximum calcium (852.50 mg kg^{-1}) was recorded with P_{60} (60 kg P ha^{-1}) and was statistically at par with the 40 kg ha^{-1} application of phosphorus. The minimum calcium was found in the P_0 treatment. Magnesium content showed a decreasing trend with an increase in levels of P application. The highest (97.25 mg kg^{-1}) magnesium content was recorded with P_0 and the minimum (81.50 mg kg^{-1}) with P_{60}. Although increasing phosphorus level did not show any significant difference after P_{20}. Observed results are similar to the findings of that liming reduces the Al toxicity and results in an increase in the availability of Ca and Mg (30). Liming application significantly favours the optimum pH and increase in exchangeable Ca, although the Mg/Ca ratio was decreased in the highest lime treatment. An increase in lime rates significantly reduces magnesium concentrations (23).

Potassium and sodium

Data in Table 4 showed a decrease in potassium and sodium content with an increase in levels of lime application. Maximum potassium (101.25 mg kg^{-1}) and sodium (743.75 mg kg^{-1}) content was found with the control treatment. Data revealed that potassium content did not show any significant difference with an increase in lime levels. The minimum potassium and sodium content were found with L_{750} kg ha^{-1} treatment. Potassium and sodium content in capsicum fruits increased with an increase in levels of P application. The highest value of potassium (105 mg kg^{-1}) and sodium (670 mg kg^{-1}) was recorded with P_{60} (60 kg ha^{-1} of phosphorus) and were statistically at par with the 40 kg ha^{-1} application of phosphorus. Minimum potassium and sodium were found in the P_0 treatment. Observed results are in accordance with the earlier findings (27), in which it was reported that increasing lime rates reduce the concentration of potassium and sodium.

Table 4. Effect of lime and phosphorus application on nutrient content in capsicum.

Treatments	Calcium	Magnesium	Potassium	Sodium
	mg kg^{-1}			
L_0	379.25a	98.00a	101.25	743.75a
L_{250}	654.75b	90.25b	97.50	695.00b
L_{500}	729.00b	84.25bc	93.75	543.75c
L_{750}	801.50b	80.00c	87.50	437.50d
SEm ±	85.12	2.93	-	24.87
CD (0.05%)	192.55	6.63	NS	56.25
P_0	351.25a	97.25a	80.00a	543.75a
P_{20}	606.75b	88.78b	92.50ab	575.00a
P_{40}	754.00bc	85.00bc	102.50ab	631.25b
P_{60}	852.50c	81.50c	105.00b	670.00c
SEm ±	85.12	2.93	6.59	24.87
CD (0.05%)	192.55	6.63	14.92	56.25

- Values with similar alphabets are non-significant at P≤0.05

Iron, Manganese, Copper, and Zinc

Analysed results further showed that an increase in levels of lime application increased the level of iron and copper, whereas decreased the manganese and zinc content (Table 5). Maximum iron (19.25 mg kg^{-1}) and copper (7.83 mg kg^{-1}) content were recorded with the application of 750 kg lime ha^{-1}, followed by L_{500} (500 kg lime ha^{-1}). Although the treatment L_{750} was statistically at par with L_{500}. The minimum content of iron (10.25 mg kg^{-1}) and copper (4.95 mg kg^{-1}) was obtained with the control (L_0 kg ha^{-1}) treatment. Maximum manganese (3.79 mg kg^{-1}) and zinc (14.00 mg kg^{-1}) were found with control i.e. L_0 kg ha^{-1}) and minimum content of manganese (1.90 mg kg^{-1}) and zinc (9.48 mg kg^{-1}) were obtained with control (L_{750} kg ha^{-1}) treatment. The application of phosphorus increased the iron, manganese, copper and zinc content in capsicum. The highest value of iron (26.25 mg kg^{-1}), manganese (3.46 mg kg^{-1}), copper (7.03 mg kg^{-1}), and zinc (12.75 mg kg^{-1}) were observed with the application of 60 kg P ha^{-1} which was followed by 40 kg P ha^{-1} and minimum values were found with P_0 treatment. However, the treatment P_{60} was statistically at par with P_{40} in case of iron, manganese and zinc. Copper content did not show any significant difference with an increase in phosphorus levels of phosphorus. An increase in lime level application increased the iron and copper content whereas decreased the manganese and zinc concentration in capsicum fruit. Increase in levels of phosphorus increased iron, manganese, copper and zinc. Increasing rates of lime and phosphorus influenced the micronutrient level (24) in capsicum fruits. The manganese and zinc content in the plants diminished with an increase in lime level, whereas iron content increased significantly.

Table 5. Effect of lime and phosphorus application on iron, manganese, copper and zinc content in capsicum.

Treatments	Iron	Manganese	Copper	Zinc
	mg kg^{-1}			
L_0	10.25a	3.79a	4.95a	14.00a
L_{250}	12.75ab	3.35ab	6.18ab	12.69ab
L_{500}	17.50b	2.75b	6.75b	11.00b
L_{750}	19.25b	1.90c	7.83b	9.48c
SEm ±	3.17	0.24	0.67	0.65
CD (0.05%)	7.17	0.54	1.51	1.49
P_0	5.25a	2.40a	6.33	10.98a
P_{20}	9.75ab	2.70ab	5.95	11.31ab
P_{40}	18.50b	3.23b	6.40	12.13ab
P_{60}	26.25c	3.46c	7.03	12.75b
SEm ±	3.17	0.24	-	0.65
CD (0.05%)	7.17	0.54	NS	1.49

- Values with similar alphabets are non-significant at P≤0.05

An increase in P level also increased the level of these nutrients from zero (30). Liming decreased the solubility of Mn and other micronutrients (31). Integrated application of amendments with fertilizers significantly improved the growth (10) and nutrient concentrations in the plant (32). It was mentioned earlier that the higher dose of lime and phosphorus affects the weight and yield of fruits, the current study also reveals that a higher dose of lime and phosphorus played an important role in nutrient levels in capsicum and influenced the moisture, protein, phosphorus and other nutrients (18, 27, 34).

Conclusion

Findings showed that the application of 750 kg lime ha^{-1} resulted in higher values of total ash, protein, calcium and other nutrients although these values were statistically at par with the application of 500 kg ha^{-1} lime. Similarly, the highest dose of P application increased the nutrient content of capsicum which was statistically similar to 40 kg P application ha^{-1}. The presence of lime improves the acidity of the soil and improves the physicochemical properties of the acidic soils. Adequate application of lime and phosphorus fertilizer improved the quality and nutritional value of capsicum fruits. This process favoured the neutralization of soil acidity by creating favourable conditions for better utilization of plant nutrients which subsequently favoured the availability of important plant nutrients. Authors advocate the application of appropriate doses of important plant nutrients from both organic and inorganic sources and the addition of organic matter with other soil amendments. Further studies could be carried out on sustainable and integrated nutrient management approaches.

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Authors contributions

IRS carried out the research trial and write up of the article. PN assisted in grammar and attending to addressing reviewers' comments. DC assisted in statistical analysis of the research data. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest : Authors do not have any conflict of interests to declare.

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