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Influence of carbofuran on the concentration of primary soil macronutrients in potato growing areas in the Peruvian highlands

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Abstract. Potatoes have a high production demand in the world, but they are constantly under threat from germination to harvest due to pest infestation; for control, insecticides are used, which are highly polluting chemicals, systemic insecticides of the carbamate group due to their mode of action, with contact activity against different pests. This research sought to evaluate the influence of carbofuran on soil macronutrients in the District of Chongos Bajo, in the highlands of Peru. Through the experimental study method, with a quantitative research approach in a deductive process. We worked with a representative area of 10 m^2 with 6 analyses of soil samples every 15 days in a period of 3 months. The results showed a loss value of 7.85% of total nitrogen, 14.05% of available phosphorus and 10% of available potassium in the period of 90 days, where there was a variation in the pH in water with a tendency of acidity, and a decrease in organic matter with a loss value of 6.93%. It was possible to demonstrate that the toxicity of the insecticide carbofuran had an influence on the decrease in the concentration of the main macronutrients and on the physical and chemical properties of the soil.

1 Introduction

The Solanaceae family's member and leading tuber crop is the potato (tuberosum Solanum.L), which has the biggest global production. [1], potato production in coastal and highlands in Peru is generally of white flesh, for fresh consumption [2]. Pigmented tubers have different flesh colors (violet, red, blue, black, cream and bicolor). Those pigmented varieties have a high content of vitamin C and natural anthocyanins [3].

This crop is under constant threat from insect pest infestation, from germination to the harvest stage [4]; one of the pests with the greatest attention by farmers are the species of the Premnotrypes complex, they are known collectively as "Andes weevil" or "white grubs"[5]. Weevil larvae cause damage of economic importance directly to the tubers[6], these larvae damage the potato when it is in formation by making irregular perforations that are very deep, because of this it does not enter the market; while the damage caused by adult weevils are sporadic and less serious[6] by witnessing cuts or perforations in the leaflets; The damage is

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registered from the presence of the adult weevil in the areas of cultivation, it seeks where to place its eggs, and another pest that is proliferating with the main varieties of potato, are the potato cyst nematodes, which diversified in the Andes of South America[7]; bad practices, results in increased damage by pathogens present in the soil and a reduction in crop profitability[8], in this sense, the symptoms caused by nematodes are damage to the roots, growth reduction, chlorosis and wilting[8]. For the control of these pests, insecticides are used, which are the chemical pollutants that cause the greatest impact on the environment[9], the use of organophosphorus pesticides has become a common and necessary practice for the sustenance of agricultural crops[10], carbamate is mainly used as an insecticide, with nematicide and acaricide effect[11]. Within the carbamate group; we find Carbofuran, the most harmful systemic pesticide for controlling pests [4] its method of action is endocrine disruption with potential intoxicant reproduction, making it a systemic insecticide [4]; This procedure may leave behind residues that are very dangerous to human health. Mild to moderate symptoms like tremors, diarrhea, vomiting, chest pain, and gait disruption can be brought on by a 50-90% inhibition of AChE [12]. In comparison, inhibition greater than 90% can lead to death from cardiac and respiratory failure [12]. Agricultural production systems require knowledge of the importance of nutrients for plants [13], for the development of crops, the three main macronutrients Nitrogen (N), Phosphorus (P), and potassium (K) are essential. They are also categorized as the fundamental elements of life required for wholesome development [14]. In soil, under aerobic and anaerobic conditions, microorganisms and plant and animal waste decompose to produce organic matter. Humic material, which is a component of organic matter, contributes to plant nutrition by expanding the root system, improving the availability of certain minerals in the soil, and boosting their enzymatic activity and cell division [14]. Therefore, the present study evaluated the toxicity of the carbamate insecticide carbofuran, which is widely commercialized in the country for its excellent results against potato cyst nematodes and the Andean weevil. In this sense, it is expected that the higher the concentration of carbofuran dosage, the lower the percentage of macronutrients (NPK) in the soil, due to the negative effect on the growth, morphology and cell viability of the microorganisms.

2 Materials and methods

2.1 Location

To obtain the samples, we opted for cultivated fields in the district with the highest potato production and conservation of native potatoes in the province of Chupaca: Chongos Bajo, which is located 40 minutes from the capital of the Junín region.

The test site is located in the district of Chongos Bajo, 470435.1 E and 8658910.7 N, 3 293 m.a.s.l. (Fig.1) with an average temperature between 10°C and 15°C.

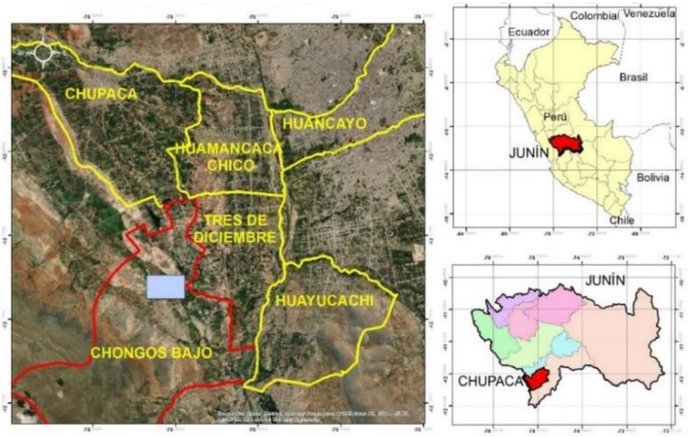

Fig. 1. Map of test site location

2.2 Test Floor

The experiment was conducted in 2 potato cultivated groups for the period 2022, it was arranged in a plot of 3.50 m long x 3.00 m wide (10.5 m^2) which was divided into 2 panels. The first panel will be used as Test Zero (P0), this space has not had any dosage or intervention of the contaminant Carbofuran; the second space considered as Test Soil (P01), has dosage and intervention of the contaminant carbofuran with increasing concentrations, and according to the development of the crop. The potato variety considered for the trial is the "unica" species; the dormancy period of the seed reaches 40 to 50 days. The vegetative period is early (70 to 90 days after sowing) [15]. It is a variety that helps us to obtain optimum results in a short time.

2.3 Toxicological test

Cypermethrin was taken as an example for the increasing concentration of carbofuran, since the information was not available in other scientific studies. The treatments consisted of increasing concentrations of cypermethrin: 0; 7.5; 15; 22.5 and 30 $mg*kg^{-1}$ of soil [16]. These doses were 3 g/m^2 (equivalent to 15 $mg*kg^{-1}$)[16], this increasing concentration mentions the recommendations of the cypermethrin producing company. For carbofuran, the considerations presented by the carbofuran producing company were taken into account, after the control of Servicio Nacional de Sanidad Agraria del Peru (SENASA); the recommendations given for the use of carbofuran, had scope of the carbofuran producing company, who indicates 2 ml of carbofuran per 1 liter of water, for the trial the increasing concentrations of: 0; 2; 4; 6; 8 and 10 ml of carbofuran/l of water, the plant was not induced by stress or starvation by the overdose of carbofuran concentration, starvation was found in several groups of chemicals such as orgatine, some trianthenes and carbamates[17]; using very high concentrations can starve or eliminate the crop, that is why the recommendations of the product and according to the period of crop development are taken into consideration. A 15-day period was taken into account for dosing and obtaining a soil sample (Table 1), which was evaluated in a soil fertility laboratory.

Table 1. Monitoring of crescent concentration for carbofuran

	Days after potato germination						
	Sprouting	Emergence	Tuberization and flowering			Tuber development	
Dosage: ml/l	15 days	30 days	45 days	60 days	75 days	80 days	90 days
	0	0	2	4	6	8	10

The potato plant is dosed with an atomizer by spraying, the plant does not immediately absorb the carbofuran and water solution; with the help of heat the solution will remain on the leaves and stem. What does not adhere to the leaves and stems enters the soil.

Excessive use of carbofuran, which has direct contact with microorganisms, has negative effects; depending on the concentration and mode of action, it has been reported to have detrimental implications for beneficial soil bacterial genera, including rhizobia[18] that promote plant growth by being able to colonize roots and stimulate plant growth[19] ; The use of carbofuran reduces the population of rhizobia and nitrogen-fixing bacteria, making it more difficult to capture atmospheric nitrogen and reduce it to NH3 (ammonia)[20].

3 Results

3.1 Zero test

The results of the Zero Test showed the following information (Table 2):

Table 2. Zero test data obtained in laboratory

Initial data		
Total Nitrogen	mg/kg	1240.00
Available Phosphorus	mg/kg	95.00
Available potassium	mg/kg	4.20
pH in water	U. pH	6.13
Organic Matter	% p/p	4.12
Texture		Franco Sandy
Sand	% p/p	58.00
Clay	% p/p	17.20
Silt	% p/p	24.80

In the Table 2, the data obtained allowed us to interpret the physical and chemical characteristics; in the case of primary macronutrients, the place where the test trials were conducted is used for potato planting campaigns, this space receives concentrations of synthetic fertilizers, foliar fertilizers and pesticides such as: cypermethrin, mancozeb and glyphosate.

3.2 Trial test

The table showed decay in the concentrations of primary macronutrients, organic matter, pH, organic matter and soil texture (Table 3).

Table 3. Laboratory data obtained with increasing carbofuran concentration results.

Days after germination		15	30	45	60	75	80	90
Dosage: ml/l		0	0	2	4	6	8	10
Total nitrogen	mg/kg	-	-	1229.32	1217.20	1195.35	1181.23	1142.66
Available phosphorus	mg/kg	-	-	93.34	92.75	89.56	87.20	81.65
Available potassium	mg/kg	-	-	4.18	4.15	4.02	3.99	3.78
pH in water	U. pH	-	-	6.10	6.01	5.92	5.85	5.28
Organic matter	% p/p	-	-	4.76	4.75	4.71	4.62	4.43
Sand	% p/p	-	-	59.00	61.12	62.54	63.47	65.23
Clay	% p/p	-	-	16.41	14.45	14.15	13.64	13.52
Silt	% p/p	-	-	24.59	24.43	23.31	22.89	21.25

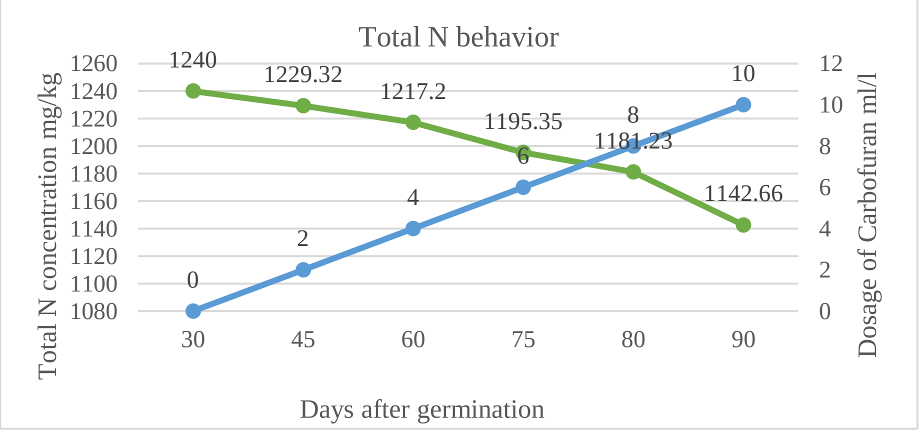

Fig. 2. Nitrogen values according to dosing days

3.2.1 Nitrogen

The maximum value is 1240 mg/kg and the minimum value is 1142.66 mg/kg, the loss value is 7.85% in a period of 3 months (Fig. 2). The enzyme amidase which is very important in the nitrogen cycle, for the reduction to NH3, the enzyme activity is an indicator that there is presence of agrochemicals or any pathogen[21]. It is evident that the population of atmospheric nitrogen-fixing bacteria has been reduced due to the toxicity of carbofuran, which has altered the physiology and symbiosis of the bacteria.

3.2.2 Available Phosphorus and Potassium

The maximum value of available phosphorus is 95.00 mg/kg and the minimum value is 81.65 mg/kg, the loss value is 14.05% and for potassium, the maximum value of available potassium is 4.20 mg/kg and the minimum value is 3.78 mg/kg, the loss value is 10% in a period of 3 months (Fig. 3). The low solubility of organic and mineral compounds containing phosphorus is the main reason for the low availability of phosphates and the high consumption of soil fertilizers for plants.[22]. The values found are part of the disposition of synthetic fertilizers and phosphorous foliar fertilizers; for potassium, synthetic fertilizers with a high concentration of synthetic potassium were also incorporated.

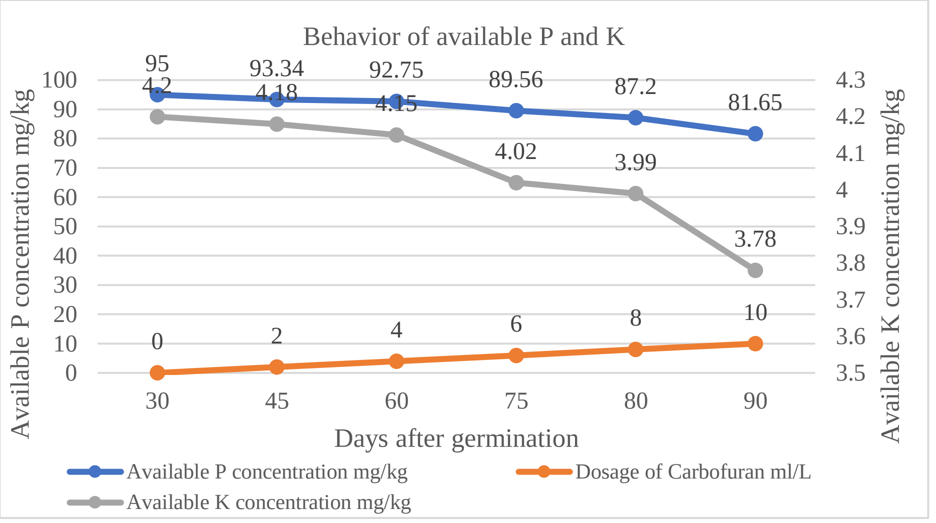

Fig. 3. Available Phosphorus values according to dosing days

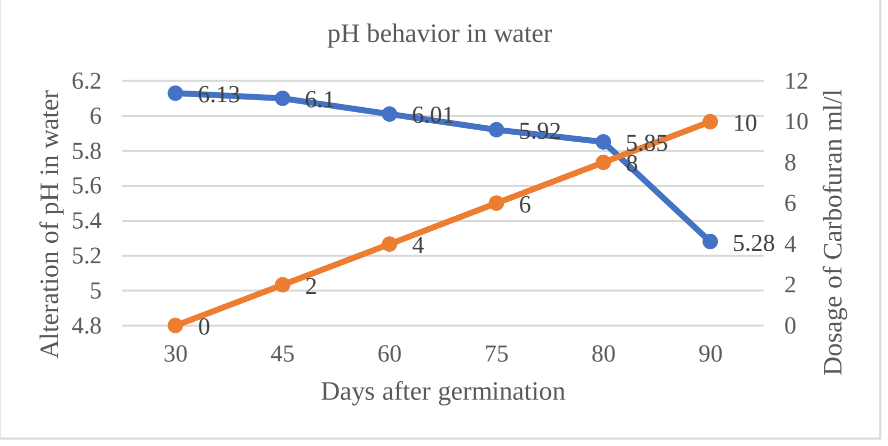

Fig. 4. pH values according to dosing days

3.2.3 pH

The maximum pH value is 6.1 and the minimum value is 5.28, the loss value is 13.44% in a period of 3 months (Fig. 4). The pH plays a very important role, the more acidic the soil is, the slower the process to degrade the carbofuran.[20]; carbofuran has a life time of 20 to 30 days in the soil and this causes the solution concentration to accumulate.

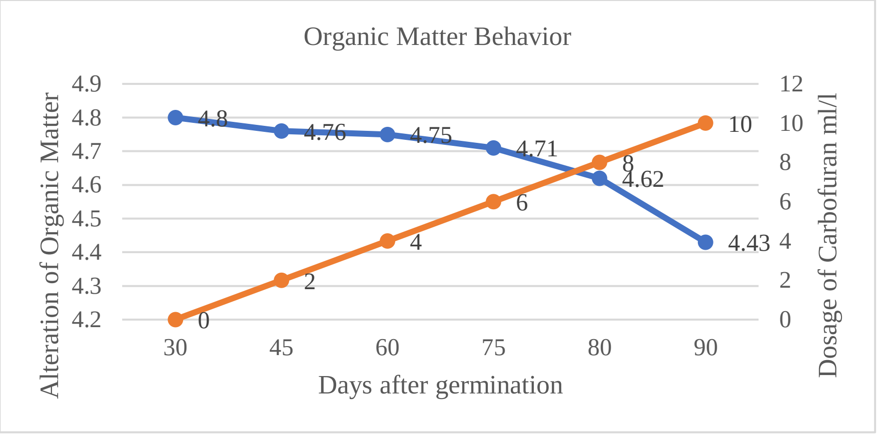

Fig. 5. Organic Matter Values according to dosing days

3.2.4 Organic Matter

The maximum value of OM (organic matter) is 4.76 and the minimum value is 4.43, the loss value is 6.93% in a period of 3 months (Fig. 5). Due to the loss of primary macronutrients, it is observed that there is a loss of OM, showing that the soil is losing nutrients and is becoming poorer, therefore, it will lose fertility.

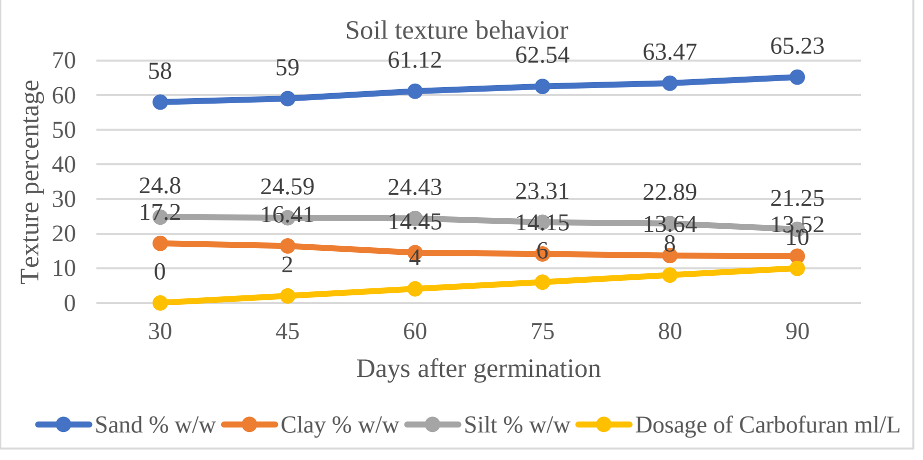

Fig.6. Values of Sand, Silt and Clay according to dosing days

3.2.5 Texture

It was observed that the percentage of sand has increased by 10.56%, in the case of clay and silt, they decreased by 13.58% and 17.61% respectively (Fig. 6). The topography of the site influences the dispersion of carbofuran.[23], by having an increase in the percentage of sand, which shows that dispersion and filtration will be easier for carbofuran.

4 Conclusions

The toxicity of the insecticide carbamate carbofuran had influence on the decrease of the concentration of the main macronutrients in the soil, which was evidenced by the evaluation of the zero test with 1240.00 mg/kg of total N, 95.00 mg/kg of available P and 4.20 mg/kg of available K. And the continuous decrease from 45 days after potato germination with a dosage of 2 ml/l, where the amount of total nitrogen was 1229.32 mg/kg, available phosphorus 93.34 mg/kg, available potassium 4.18 mg/kg; until 90 days after germination with a dosage of 10 ml/l resulting in a loss value of 7.85% of total N, 14.05% of available P and 10% of available K in the period of three months.

The concentration of carbofuran in the time lapse also altered the concentration of pH in water, because in the zero test it presented a pH of 6.13, but in the process of dosing the carbofuran solution, it showed a 13.44% loss, giving the tendency to an acid pH of 5.28, therefore, slowing down the degradation process of the insecticide. And finally, the proportion of organic matter decreased, presenting a 6.93% loss value due to the influence of the concentration of primary macronutrients, impoverishing and losing its fertility. With the values found in the research, it was possible to demonstrate that carbofuran alters the characteristics of the soil, negatively affecting the concentration of macronutrients and pH, impoverishing the soil and losing fertility.

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