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Effects of NPK And Sulfur on the Yield and Absorption of Nutrients of *Lepidium peruvianum* Ch. in Field and Greenhouse

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Abstract

Increasing the quality and yields of maca are important goals to meet market demands. The objective of the research was to quantify the extraction of nutrients from the soil and evaluate the effect of three levels of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) on agronomic indicators of maca cultivation under field and greenhouse conditions. The experiment was conducted under the randomized complete block design with four repetitions per treatment. The levels were 240-180-210-60, 160-120-140-40 and 0-0-0-0 NPKS, respectively. Tukey's test was used for the comparison of means. Different indicators of plant growth and development were evaluated, such as plant height, hypocotyl diameter, hypocotyl weight, dry matter percentage and yield. The evaluation of nutrient extraction was evaluated according to the methodology used in the AGROLAB laboratory: Nitrogen: micro kjeldahl method. Phosphorus: Bray–Kurtz colorimetric method. Potassium: Peech's turbidimetric method. Sulfur: Massoumi's turbidimetric method. Calcium and Magnesium: volumetric method of complexometry. Among the results, significant differences were found between S levels in all the variables evaluated. No statistical differences were found in nutrient extraction due to NPKS doses. It is concluded that higher doses of NPKS increases in the values of height, hypocotyl size, hypocotyl weight and yield, except for dry matter, in maca plants are obtained.

Keywords: *Lepidium Peruvianum, NPK Fertilization, Sulfur Fertilization, Plant Nutrition, Nutrient Extraction.*

1. Introduction

Maca (Lepidium peruvianumChacón) is a species belonging to the family Brassicaceae native to the Central Andes of Peru, which grows above 4000 m a.s.l. in extreme weather conditions unsuitable for the growth of many other arable species (Gonzales and Alarcón, 2018). In the last 20 years, interest and demand for maca root has increased in the world market, thanks to its high nutritional value and secondary metabolites such as macaridin, macamides and glucosinolates (Tafuri et al., 2019; Beharry and Heinrich, 2018). Content important nutritive in calcium, sodium, magnesium, potassium, iron, copper, zinc, high level of protein, essential amino acids, carbohydrates, fatty acids; especially in the leaves that are a rich source of dietary fibers, essential amino acids, vitamins and minerals and with Bioactive compounds responsible for providing benefits to those seeking a healthy diet (Jagdale et al., 2021; Leitao et al, 2020).

The importance of maca also lies in its effect on the treatment of multiple diseases and medical conditions, regulation of sexual dysfunction, neuroprotective effects, memory enhancement, antidepressant, antioxidant, anticancer, anti-inflammatory and skin protection effects (Alarcón et al., 2021; Todorova et al., 2021; Korkmaz, 2018). attributing to him for these benefits, The property of being a highly nutrient-extracting crop from the soil, to such an extent that in two or three consecutive production cycles it leaves the soil completely exhausted. Various studies have shown that there is variation in the composition of nutrient elements and biological properties between ecotypes, and seem to depend on differences in soil properties and the interaction of environmental factors in the place of cultivation.

For maca nutrition to be adequate, it must have sufficient and balanced fertilization, that is, it must contain the necessary nutrients in optimal amounts and in the appropriate relationships (Abreu et al., 2018) However, in most of the soils dedicated to this crop, these are not found in sufficient quantities which makes it necessary to apply external substances carrying required elements such as sulfur, which is considered one of the 17 essential elements for normal metabolism, growth and development of plants (Prakash et al, 2022; Feinberg et al., 2021), being considered the fourth most important nutrient after nitrogen (N), phosphorus (P) and potassium (K) in plants (Hussain et al, 2022).

The aZufre is a constituent of protein amino acids such as methionine and cysteine, vitamins (biotin and thiamine), phytochelatins, chlorophyll, coenzyme A and S-adenosyl-methionine (Nakai et al., 2020; Yoshimoto et al., 2019), Participates in the formation of disulfide bonds in protein and enzyme regulation, particularly in redox control (Hussain et al, 2022), Offers protection against oxidative damage through glutathione and its derivatives (Aarabi et al., 2020), It is part of several secondary metabolites of plants that is necessary for their physiological functions (Prakash et al., 2022), are required in multiple biological processes, such as photosynthesis, energy generation, photoprotection and metabolic reactions (Jogawat et al., 2021; Yadav et al., 2021).

The demand for sulfur in plants depends on species types and stages of development; Thus, during seed development and vegetative growth, a greater amount of sulfur is required. (Gohain et al., 2019), which is absorbed by plants in the form of SO4-2 and its availability to plants is mainly affected by the degree of concentration, pH, characteristics of colloids and the concentration of other anions in the soil solution. (Zhao et al., 2017), Their requirement for optimal growth varies between 0.1 and 0.5% based on the dry weight of plants and increases in increasing order in grasses, legumes and cruciferous (Sutar et al., 2017).

The NPK fertilizer efficiency, growth, development, disease resistance and plant yield are severely affected under conditions of sulfur deficiency (Kopriva et al., 2019; Johnson et al., 2018). Farmers must have the necessary knowledge and experience to protect their crops, as various situations can lead to dissatisfaction and dissatisfaction; in such a way that, a technological change for the repowering of crops and conservation of agricultural soils constitutes the most suitable way for better productivity (Hinojosa et al., 2021). To date there is very little research on levels of nutrient extraction from the soil and the effect of sulfur fertilization on maca cultivation, which is why the objective of this research is to quantify the variation of nutrient extraction and The effect of sulfur on the production of maca hypocotyls.

2. Materials And Methods

The research was conducted at the Research and Development Center of the National Autonomous University of Huanta, population center of Canrao, district of Sivia, province of Huanta, Ayacucho region, at 12º 40' 46.8" South latitude and 74º 8' 21" West longitude, at an altitude of 4089 meters above sea level, in field and greenhouse conditions. Botanical seed of maca of the variety "Amarilla" from a commercial field in the town of Carhuamayo-Junín was used. The experiment was conducted under the design of completely randomized blocks, with 3 treatments and 4 repetitions. For the comparison of averages, Tukey's test ($\alpha = 0.05$) was used. The variables evaluated were plant height (cm), hypocotyl size (cm), hypocotyl weight (g), dry matter (%) and yield (g). To evaluate the rate of nutrient extraction (N, P, K, Ca, Mg, S, Na, Zn, Cu, Mn, Fe and B) 10 plants were randomly selected from each treatment, with a frequency of 30 days after planting.

Plant sampling was carried out with care not to damage the aerial and underground organs (roots and hypocotyl); Once washed and labeled, they were placed in polythene bags. In the AGROLAB laboratory the following procedures were done: 1.- the different parts of the plants (roots and leaves) were separated, chopped and bagged 2.- the samples were subjected to an oven at 105 ° C for 24 hours. 3.- Subsequently, they were weighed in an analytical balance to obtain the dry matter yield and finally proceeded with the analysis of the mineral composition in the plant tissue, based on which the extraction of nutrients by the plant was determined. For the chemical analysis of plants, the following steps were carried out: a) the different parts of the maca plant (leaf and hypocotyl) were milled using a mortar. b) 100 to 500 mg of sample was weighed for nitrogen and mineral nutrient analyses respectively. The methodology used in the laboratory was as follows: Nitrogen: micro kjeldahl method. Phosphorus: colorimetric method, according to Bray – Kurtz. Potassium: Peech's turbidimetric method. Sulfur: Massoumi's turbidimetric method. Calcium and magnesium: volumetric method of complexometry.

3. Results and Discussion

The morphoagronomic characteristics of growth and development of a plant are directly related to the yield and its components and the objective of every farmer is to produce high quality plants, with compact growth and with good branching. Plants with these characteristics are stronger and able to withstand environmental stress. Under the greenhouse experimental conditions (I), the variables plant height, hypocotyl diameter, hypocotyl weight and yield were significantly influenced by the effect of the treatments; conversely, in field conditions (C) for these same variables no differences were found, only in the yield significance was found in both environmental conditions (Table 1). In this regard, Carhuaz and Cuellar (2018) when comparing levels of chemical and organic fertilization in field conditions, reported statistical significance in plant height, hypocotyl diameter, hypocotyl weight and yield. Osmani et al, (2017) report that the yield of a crop depends to a large extent on the formation of foliage capable of taking advantage of solar radiation intensely and efficiently, at the same time that the metabolites formed favor the accumulation of reserves in the hypocotyl and not in the excessive growth of foliage. Also Díaz (2018) when evaluating 12 levels of NPK in potato, observed highly significant differences for plant height and polar diameter of commercial tubers.

			To	B	C	D	And
F V		GL	Floor height	Hypocotyl diameter	Hypocotyl weight	Dry matter	Yield
			CM	CM	CM	CM	CM
Block	I	3	1.01 NS	0.02 NS	9.54 NS	1.51 NS	0.00054 NS
	C		3.05 NS	0.02 NS	0.34 NS	0.67 NS	0.003 NS
Treatments	I	2	8.52 *	0,34 *	134.72 *	0.20 NS	0,13 *
	C		0.52 NS	0.045 NS	0.76 NS	71.02 *	0.16 *
Error exp.	I	18	0,47	0,01	4,86	3,39	0,00008
	C		1.50	0.017	0.15	0.71	0.0016
CV (%)	I		3,48	2,90	6,46	6,16	5,26
	C		7.44	3.66	2.24	3.0	20.97

* = Statistically different values (α = 0.05).

NS = Values that do not differ statistically.

CM = Mean square.

CV (%) = Coefficient of variation

I = Greenhouse

C = Field

When comparing the means of the parameters evaluated (Table 2), it is visualized that between the doses of 60 and 40 kg / ha of sulfur significant differences have been detected; However, when comparing with the control there are statistical differences. This suggests that the exogenous application of sulfur is sufficient to increase the growth and development indicators of maca plants.

Table 2: Comparison of means of the variables under study by effect of three doses of sulfur (Tukey, α = 005).

		To	B	C	D	And
Order of Merit	Sulphur dose (kg/ha)	Plant height (cm)	Hypocotyl diameter (cm)	Hypocotyl weight (g)	Dry matter (%)	Yield (kg/m2)
1	60	21.10 [1] a	3.66 to	40.27 to	30.15 to	0.75 to

2	40	20.07 to	3.53 to	33.09 to	29.78 to	0.58 b
3	0	18.22 b	3.10 b	28.78 b	29.76 to	0.39 c
	Total average	19.80	3,43	34,04	29,90	0,57

[1] = Values in the same column followed by different letters are significantly different ($\alpha = 0.05$).

Extraction of mineral nutrients

The practice of fertilization by the extraction levels of crops, seeks to replenish the nutrients that are absorbed and deposited in harvestable tissues and organs, and that therefore are not recycled because they do not re-enter the soil system. In the study, it has been found that on average treatments (sulfur levels) has not influenced the levels of nutrient extraction by the cultivation of maca due to the effect of NPKS levels; however, in field and greenhouse conditions significant differences were found (Graphs 1 and 2). That is to say that, in the different evaluation dates, no statistically significant differences have been detected in the extraction content of each nutrient due to the effect of the sulfur doses applied to maca plants. Similar results were reported by Cáceres and Calderón (2018), who assert that it is currently being planted in greenhouses at distances of 15cm between plants in order to increase their yield and at the same time reduce the production costs of said crop.

The total extraction of nutrients was similar in the three treatments, however, the absorption rate was differentiated in the initial stages of the crop.

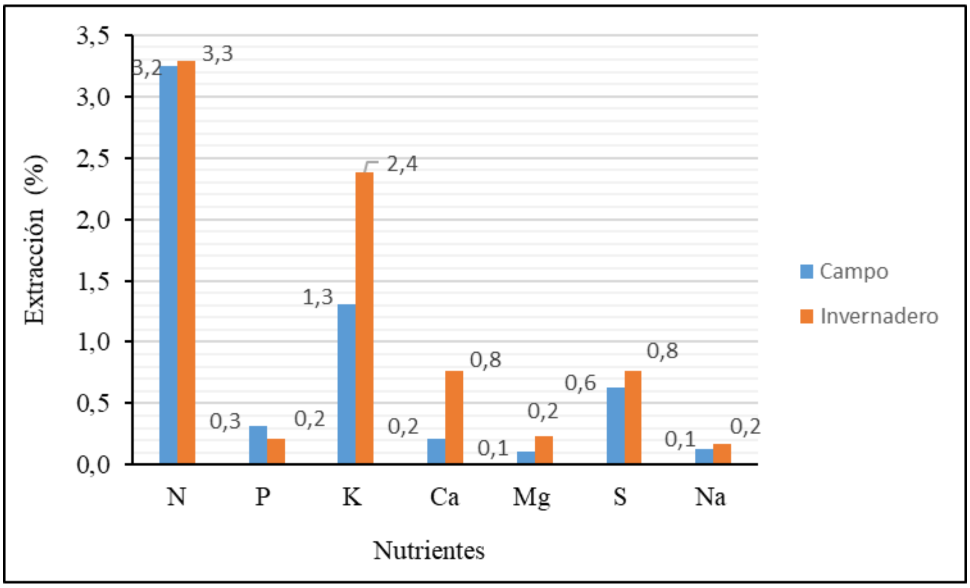

Figure (1). Variation in macronutrient extraction (%) in maca culture

When comparing the two environments, it appears that at the greenhouse level greater extractions of macronutrients, Fe and Cu among the micronutrients were obtained. Conversely, the micronutrients Zn, Mn, and B were extracted from the soil in greater proportion in the field than in the greenhouse.

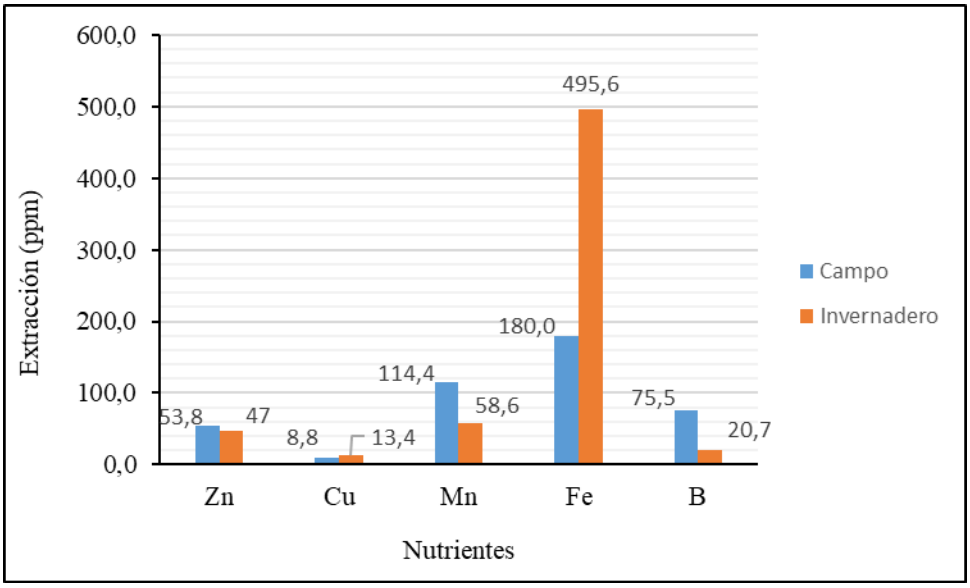

Figure (2) Variation in micronutrient extraction (ppm) in maca cultic

4. Conclusion

The variables plant height, hypocotyl diameter, hypocotyl weight and yield were significantly influenced by the effect of NPK and sulfur fertilization doses in field conditions; conversely in greenhouse conditions no differences were found. Likewise, significant differences between environments in the extraction of nutrients were detected in the different evaluation dates.

Gratitude

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Conflict of interest:

The authors declare no conflict of interest.

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