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Response of *Physalis peruviana* to fertilization with different doses of N, P and K in the Altiplano of Pasto, Colombia

Respuesta de *Physalis peruviana* a la fertilización con diferentes dosis de N, P y K en el Altiplano de Pasto, Colombia

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Abstract

In a Typic dystrandept Andisol of Pasto Altiplano (2,800 meters above sea level, 12.6°C, 820 mm/year and 900 hours of sunlight), were evaluated some variables of growth, nutrition and production of *Physalis peruviana* by effect of N, P and K fertilization. The treatments consisted of the application of urea (46% N) as a source of N, superphosphate Triple-SPT (46% P_2O_5) as a source of P, Potassium Chloride-KCl (60% K_2O) as a source of K, in similar doses for each source, 80, 150 and 300 kg/ha/year applied in two periods; at transplant and 30 days later before flowering. The results showed differences in sources and doses ($P \leq 0.01$) in all the analyzed variables. The dose of 300 kg/ha of Urea, 150 kg/ha of SPT and 300 kg/ha of KCl resulted in the highest values of plant height, dry matter and absorption of NPK ($P \leq 0.05$). The absorption of N was greater than K, followed by P in all the assessed interactions ($P \leq 0.05$). All sources evaluated at 300 kg/ha led to higher yields of *Physalis peruviana* ($P \leq 0.05$). Moreover, positive effects were found in the absorption of NPK from yields of *Physalis peruviana* with 300 kg/ha of urea, 150 kg/ha of SPT and 300 kg/ha of KCl ($P \leq 0.05$), therefore these doses of fertilizers are recommended.

Key words: *Physalis peruviana*, Absorption of nutrients, soil analysis, fertilizer doses, dry matter, yields.

Resumen

En un Andisol Typic dystrandept del Altiplano de Pasto (2800 m.s.n.m., 12.6°C, 820 mm/año y 900 h de luz solar), Colombia, se evaluaron algunas variables de crecimiento, contenido de nutrientes y producción de uvilla (*Physalis peruviana*) como respuesta a la fertilización con N, P y K. Los tratamientos consistieron en la aplicación de urea (46% N) como fuente de N, superfosfato triple-SPT (46% de P_2O_5) como fuente de P y cloruro de potasio-KCl (60% K_2O) como fuente de K, en dosis iguales para cada fuente, de 80, 150 y 300 kg/ha/año aplicados en dos épocas al momento del trasplante y 30 días después, antes de la floración. Los resultados mostraron diferencias en fuentes y dosis ($P \leq 0.01$) en todas las variables analizadas. Las dosis de 300 kg/ha de urea, 150 kg/ha de SPT y 300 kg/ha de KCl favorecieron la mayor altura de planta, la materia seca y la absorción de NPK ($P \leq 0.05$). La absorción de N fue mayor que la de K y éste a su vez que la de P en todas las interacciones evaluadas ($P \leq 0.05$). La aplicación de 300 kg/ha de cada uno de los fertilizantes ocasiono incremento del rendimiento de *P. peruviana*. Por otra parte, fueron encontrados efectos positivos en la absorción NPK en relación con los rendimientos de *Physalis peruviana* con 300 kg/ha de urea, 150 kg/ha de SPT y 300 kg/ha de KCl ($P \leq 0.05$), por tanto se recomiendan estas dosis de fertilizantes.

Palabras clave: *Physalis peruviana,* Absorción de nutrientes, análisis de suelos, dosis de fertilizantes, materia seca, rendimientos.

Introduction

Studies of nutrient uptake by plants are a valid tool for fertilization programs in order to improve efficiency and profitability of crops (Bertsch, 2005). Nutrition of *Physalis peruviana* (Cape gooseberry or uvilla) is directly related to its earliness and yield (Martinez *et al.*, 2008). Nitrogen (N) is an essential nutrient with fast effect on plant growth, promotes root development, increase the synthesis of amino acids and proteins and improves the absorption of other nutrients from the soil solution (Malavolta, 2006).

According to Fischer and Almanza (1993) the requirements of *P. peruviana* for N -P- K can be 80 kg/ha/year. Martinez and Sarmiento (2008) and Martinez *et al.* (2008) found in plants of this species a strong reductions in the growth of foliage and performance of the plant when deficiency of N and K take place in the nutrient solution.

Phosphorus (P) is a limiting factor in productivity of crops that grow in Andisols (Espinosa, 1998). This nutrient is mobile within the plant and can be transported from older tissues to the new buds. At the time of fruiting, the need of this nutrient occurs primarily by mobilization of reserves in the plant (Malavolta, 2006).

P concentration in leaves is generally higher in the early stages of development as it focuses on the vegetative parts. When the plant is older, the concentration of P is located to the reproductive parts to promote the development of flowers and fruits (Marschner, 1995). Low supply of P produces poor flowering, low yields, late maturity and low sugar content in the fruits (Thome and Osaki, 2010).

The lack of potassium (K) in plants affects the production and quality of the fruits (Rice, 2007). Good supply of this element helps to the permanence of the crop (Martinez *et al.* 2008) and relieves stress conditions (Malavolta, 2006). According to Guerrero (1998), K plays important role in the osmoregulation, enzyme activation, protein synthesis, stomata functioning, photosynthesis and cell differentiation.

Studies about nutrient absorption requirements, extraction or consumption by crops throughout the whole cycle of production or at the stage of greater production of dry matter, provide insights into the amount of nutrients that are required to produce a given yield in a definite time (Malavolta, 2006). These studies plus the availability of nutrients in the soil, help to improve the efficiency of fertilization programs (Bertsch, 2005).

This research aimed to determine the response of *P. peruviana* to fertilization at different doses of N, P and K in the Highlands of Pasto, Colombia.

Materials and methods

Location and treatments

The research was conducted in the village of Botana, Altiplano de Pasto, 2800 MASL, with an average temperature of 12.6°C, 900 hours of sunshine/ year, rainfall of 820 mm/ year and 79% relative humidity. In the area Andisols Typic Dystrandept (IGAC, 1998) are predominant.

P. peruviana var. Silvania was used at 5 months old, with a seeding density of 1666 plants/ha, spaced 2 m between plants and 3 m between rows. Each plot or experimental unit consisted of seven plants in an area of 14 m^2, arranged in three blocks each with an area of 378 m^2 (42 m long x 9 m wide), including nine parcels and 63 plants. The total area of the experiment was 134 m^2 and the used area of each was plot 10 m^2. Prior to the experimental setup, a soil sample for physico-chemical analysis was made following the methodology of Unigarro and Carreño (2005) (Table 1).

Table 1. Soil analysis in the experimental place.

pH	O.M.[a] (%)	P availa[b] (mg/kg)	K exch[c]	Ca exch (cmol/kg)	Mg exch	BD (g/cc)	Texture[d]
5.98	3.42	43.2	0.81	7.53	3.76	0.82	Ar-A

a. = Low content of N-available (73.55 kg/ ha N-available), b = High contents of P-available (70.84 kg/ha of P-available), c = High contents of exchangeable K (518.07 kg/ ha K - exchangeable), d = sandy clay texture degree.

The experimental design was a randomized complete block in factorial arrangement 3 x 3, with two factors at three levels. The first factor correspond to the sources of fertilization: urea, triple superphosphate (SPT) and potassium chloride (KCl). The second factor consisted of application rates (kg / ha): 80, 150 and 300, for a total of nine treatments with three replicates and 27 experimental units. The quantities of N, P and K contained in each source, depending on the dose of fertilizer applied are indicated in Table 2. The same doses of the fertilizers were applied at transplant and 30 days before flowering.

Table 2. Amount of N, P and K applied for each used source (kg/ha/year).

Sources of fertilizers	Doses	N	P	K	Nomenclature
	kg/ha/year				
Urea	80	36.8	—	—	Urea D80
Urea	150	69.0	—	—	Urea D150
Urea	300	138.0	—	—	Urea D300
SPT	80	—	16.06	—	SPT D80
SPT	150	—	30.11	—	SPT D150
SPT	300	—	60.23	—	SPT D300
KCl	80	—	—	39.84	KCl D80
KCl	150	—	—	74.71	KCl D150
KCl	300	—	—	149.43	KCl D300

Adapted from Guerrero (1998). Urea (46% N) as a source of N, triple superphosphate-SPT(46% P_2O_5) as a source of P and potassium chloride - KCl (60% K_2O) as source of K. Conversion factors to transform P_2O_5 to P (0.4365), K_2O to K (0.8302) Guerrero (1998).

Measurements

Plant height from the base to the apex was measured three times for the stage of full bloom (Obrecht, 1993). Fresh and dry weight was determined for shoot and root in order to identify the total dry matter (kg/ha).

Three plants from each experimental unit were taken for foliar analysis. Samples were collected from the fourth leaf to the apex of the plant, collecting 10 samples per plant (Hartz *et al.*, 1998). N analysis was performed by the Kjeldahl method, P was determined by colorimetric wet oxidation and K by wet oxidation through spectrophotometry technique. Results were expressed in g/100 g of dry matter (Sarruge and Haag, 1974; Malavolta, Vitti, and Oliveira, 1997). These analyses were performed at the Laboratory of Bromatology, University of Nariño.

NPK absorption curve was obtained from the ratio of dry weight and nutrient concentration of the tissues (Bertsch, 2005). The criteria of Malavolta (2006) was used for the interpretation of the results, indicating that leaf analysis is based on the premise that there is a direct relations between fertilization doses, production and leaf nutrient contents, and finally between leaf nutrient content and production.

The production was performed during 12 weeks and the results were used to determine the absorption curve of NPK in terms of kg per ton of produced fruit.

Data analysis was held by analysis of variance, using the statistical package SAS version 5.0. When differences between simple or double effects were present, Tukey's test ($P \leq 0.05$) was applied.

Results and discussion

Plant height

Plant height was affected ($P \leq 0.05$) by sources and doses of fertilizers (Figure 1). The highest values occurred with the application of 300 kg/ha/year of urea (138 kg N/ha/year), 150 kg/ha/year of SPT (30.11 kg P/ha/year) and 300 kg/ha/year of KCl (149.43 kg K/ha/year) with 89.6, 68.7 and 66.96 cm respectively. These results coincide with those of Martinez *et al.* (2008) and Gastelum (2012), but differ from those reported by Fischer and Almanza (1993). The response of uvilla's plant height when applying P to these soils was low, except for the dose of 150 kg/ha when comparing with the obtained results from the N and K applications (Figure 1).

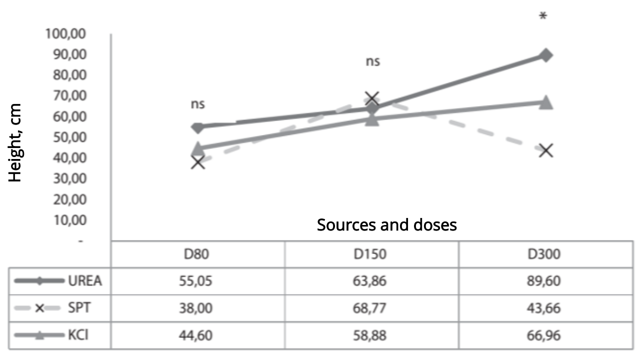


Figure 1. Height of *Physalis peruviana* plants due to the application of N, P and K in different doses. Minimum significant difference according to the Tukey test ($P \leq 0.05$). ns: not significant. * Indicates significant effect with $P \leq 0.05$. Standard error in parentheses: Height cm (14.71).

Dry matter production

The highest yields of dry matter were found with the application of urea at a dose of 300 kg/ha/year (306 kg DM/ha), SPT at a dose of 150 kg/ha/year (286 kg DM/ha) and KCl dose of 300 kg/ha/year (145 kg DM/ha) ($P \leq 0.05$) (Figure 2).

Dry matter production due to the application of urea increased from 56 to 184 g/plant with the dose of 80 kg/ha/year (36.8 kg N/ha/year) and 300 kg/ha/year (138 kg

N/ha/year) respectively. Thus, the importance of this nutrient in the production of MS accumulated during the growth phase of the plant is confirmed. All the assessed sources in doses of 80 kg/ha/year showed low values of dry matter production ($P \leq 0.05$) (Figure 2).

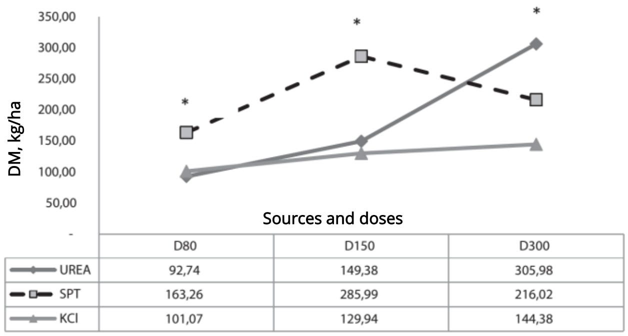


Figure 2. Dry matter of *Physalis peruviana* due to the application of N, P and K at different doses. Minimum significant difference according to the Tukey test ($P \leq 0.05$) ns: not significant. *Indicates significant effect with $P \leq 0.05$. Standard error in parentheses: Dry matter kg (150.28).

Nutrient uptake

The highest absorption of N, P and K (129, 20 and 73 kg/ha) occurred when urea was applied at doses of 300 kg/ha/year ($P \leq 0.05$), followed by SPT (166, 21 and 107 kg/ha) in doses of 150 kg/ha/year, and KCl (61, 7 and 39 kg/ha) at a dose of 300 kg/ha/year ($P \leq 0.05$) (Figure 3). In all cases the sequence was: N absorbed> K absorbed> P absorbed.

The highest N uptake was in the dose of 150 kg/ha/year of SPT ($P \leq 0.05$), while absorption of urea at 150 kg/ha/year was the same as SPT at 80 kg/ha/year. N uptake was the lowest when applying KCl in anyone of the doses (Figure 3). Nitrogen is an essential nutrient for the development and growth of the plant (Berscht, 2005), promotes root development, enhances the absorption of other nutrients in the soil solution, especially P, and is an essential component of proteins (Marschner, 1995).

According to Thomas and Osaki (2010), between 4 to 5% of this element is uptake by the plant in the first month, and about 30% in the second month. Full developed fruits can contain almost half of the nitrogen of the plant (Martinez *et al.*, 2008).

Phosphorus uptake was low and no differences were found as a result of the applied dose or sources (Figure 3). According to Silva *et al.* (2003), phosphate fertilizers have an absorption rate of about 10% while the other percentage reminds in the soil. Taiz and Zeiger (1998) affirm that the increase of N content in the leaf, after the application of nitrogen fertilizer, favours the content of P in leaves between 80 to 95%. Although the plant does not draw large amounts of phosphorus, this nutrient is essential in the growth phase and the beginning of fruit ripening (Boitt et al, 2012), where 94% of the phosphorus is concentrated in the fruits and only 6% in the leaves and stems. This affirmation explains the lower response in P uptake by the plant.

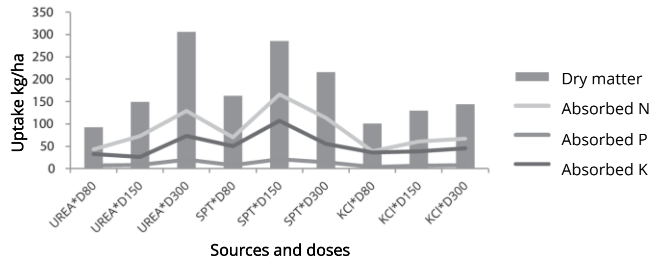
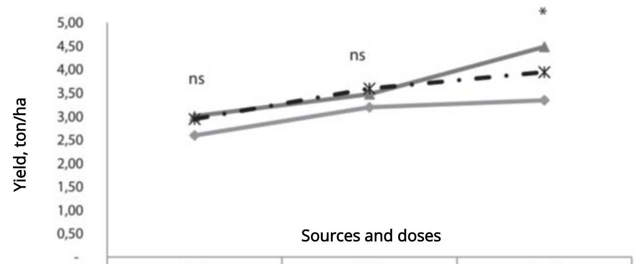


Figure 3. Uptake of N, P and K in the flowering stage of *Physalis peruviana* relate to the production of DM ($P \leq 0.05$). Standard errors (in parentheses): N (91), K (2.24), P (37).

K uptake was higher when 150 kg of SPT/ha/year were applied ($P \leq 0.05$) (Figure 3). All doses of KCl had lower absorption of NPK, although no differences for N and K uptake were found, except for P uptake ($P \leq 0.05$). Plants of *P. peruviana* require low amounts of K at the beginning of the growing season, and then increased as the plant develops. Potassium is needed in the formation of sugars, amino acids and the transportation of food reserves (Martinez *et al.*, 2008).

Fruit production and nutrient uptake

Yields of harvest fruit increased as the fertilization rates were higher ($P \leq 0.05$) (Figure 4). Rufato *et al.* (2008) recommended different doses between 80-120 N, 50-100 P_2O_5 (21.82-43.65 P), and 300-450 K_2O (250-376.29 of K) for *P. peruviana*. Those values are similar to the highest dose of N and P applied in this study. The productive potential of *P. peruviana* increased with practices like mulching with legumes, organic fertilizers, minimum tillage (Contreira *et al.*, 2009) or the use of crop residues like cereals (Reche, 2012). Boitt *et al.* (2012) worked with soils rich in K, but they did not find response in the production of fruits of *P. peruviana* when this nutrient was applied.



	D80	D150	D300
UREA	3,01	3,48	4,49
SPT	2,95	3,60	3,95
KCl	2,60	3,20	3,35

Figure 4. Dose effect of NPK (kg/ha) on the yield of *Physalis peruviana* (values corresponding to 12 weeks). Minimum significant difference according to the Tukey test ($P \leq 0.05$) ns: not significant. * Indicates significant effect with $P \leq 0.05$. Standard error in parentheses: Yield kg (0.1072).

Similar to the results of Martinez *et al.* (2009), Figure 5 shows that N and K were the nutrients with the higher extraction in terms of harvested fruit per tonne ($P \leq 0.05$). Low doses of N may cause delay in the maturation and significantly decrease the yield (Guerreiro, 2007). On the other hand K influences the development of the fruit, participates in the metabolism of carbohydrates and the maintenance of water balance. When this element is lacking, the fruits are small, hard and ripen in different times (Rice, 2007).

Urea, SPT and KCl at doses of 300, 150 and 300 kg/ha/year performed the highest uptake of NPK per ton of harvested fruit ($P \leq 0.05$) (Figure 5). Thus, these sources may be used in fertilization programs of *P. peruviana* in terms of 138 Kg N, 30.11 Kg P and 149.43 Kg K per ha per year. According to Berstch (2005), estimation of specific doses of simple sources with N, P and K may contribute with more efficient and low cost fertilization plans. Moreover, the Inter-governmental Panel on Climate Change-IPCC (2006) indicates lower emissions of N_2O and CO_2 into the atmosphere by the low use of nitrogen, potassium and phosphorus fertilizers.

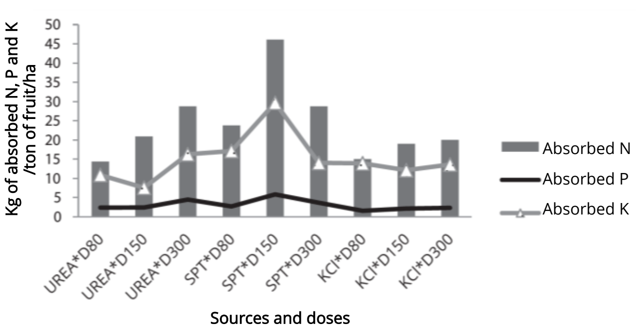


Figure 5. NPK uptake and yield of *Physalis peruviana* Standard errors in parentheses: N absorbed, kg / ton fruit (5.61); P absorbed, kg/ton of fruit (0.108); K absorbed, kg / ton fruit (2.26).

Conclusions

Doses of 300 kg urea/ha, 150 kg SPT/ha and 300 kg KCl/ha showed the best effects on plant growth and production of dry matter of *P. peruviana*.

NPK uptake curves indicated that N is the most absorbed element, followed by K and P. The greater absorptions occurred when doses of 300 kg urea/ha, 150 kg SPT/ha and 300 kg KCl/ha were applied.

P. peruviana performed the highest yield when 300 kg/ha of all the sources were applied.

The ratio of NPK nutrient uptake and yield indicates that *P. peruviana* recommended doses are 300 kg Urea/ha, 150 kg SPT/ha and 300 kg KCl/ha for the conditions of Altiplano Pasto.

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