Article

# Response of the Mexican clone of potato 99-39 to potassium in hydroponics and greenhouse

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## Abstract

In order to determine the effect and optimum dose of potassium in the production of minitubers of the Mexican clone of potato 99-39, experiments were established in July and September 2015, where concentrations of 0 (absolute control), 150, were tested. 250 (commercial control), 350, 450 and 550 mg $L^{-1}$ in nutrient solution in hydroponic system. The results indicated that the highest plant height and leaf area index were found in the treatments with the highest concentration of K. The dose of 350 mg $L^{-1}$ of K produced 19% more tubers with a diameter equal to or greater than 15 mm per plant. Than the commercial witness and 194% more than the absolute witness. The second order equation ($R^2$= 0.94) allowed us to estimate that the optimal dose for potato clone 99-39 was 400 mg $L^{-1}$ potassium, which can produce up to 20.67 minitubers per plant. There was statistical significance in the interaction date x dose for tuber production per plant and for the harvest index, with higher production in july planting than in autumn winter season; conversely, it was found that the harvest index was higher in the autumn-winter season. High concentrations of potassium during the whole crop cycle promoted the production of a greater number of tubers.

**Keywords:** *Solanum tuberosum*, nutritive solution, prebasic seed.

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# Introduction

The production of minitubers in potato vegetative material production systems is an intermediate phase between rapid multiplication in vitro and the production of seed tuber in the field (Struik and Weirsema, 1999; Struik, 2007), this practice is carried out in Mexico under different production systems such as the mixture of substrates (Flores-López *et al*., 2014; Patrón-Ibarra, 2014) and hydroponics (Lommen, 2007; Urrestarazu, 2013; Flores-López *et al*., 2016) where management of nutrition is determinant for the development of the plants, the production and quality of tubers (Corrêa *et al*., 2009).

Potassium (K) is an essential element in the productivity of plants, has influence on photosynthesis, chlorophyll content, chloroplast structure, leaf anatomy (Zhao *et al*., 2001) and participates in the mobilization of assimilated organs backup; this is the nutriment that the potato requires in greater quantity (Perrenoud, 1993), having an essential function in the translocation and storage of assimilates since the mobilization of sugars to the tubers allows to obtain a high production and quality, according to Wibowo *et al*. (2014); Marschner (1995); Westermann *et al*. (1994). The formation of tubers is characterized by a change in apoplastic to symmetrical transport of assimilates in the subapical region of the developing stolon (Viola *et al*., 2001) and the factors that influence tuberization are the nutrimental balance, the genotype, the temperature and photoperiod (Struik and Wiersema, 1999; Fernie and Willmitzer, 2001).

On the other hand, potassium participates in tolerance to diseases, as well as in the response to different types of stress, including drought, salinity, cold and some pests (Velasco, 1999; Cooke and Little, 2001; Wang *et al*., 2013); likewise, there are reports of increases in protein content in potatoes fertilized with potassium (Manolov *et al*., 2016), although potato varieties respond differentially to the application of this nutrient (Muro *et al*., 1997; Rolot and Seutin , 1999; Corrêa *et al*., 2009; Chang *et al*., 2011) so the amount of K used in nutritive solutions for hydroponics in potato cultivation has been variable, some studies point out that in the use of concentrations of between 239 to 295 mg $L^{-1}$ K, the responses were different between the Monalisa and Agatha varieties (Corrêa *et al*., 2009). On the other hand, a varietal effect was found at doses of 3.75 mEq $L^{-1}$ of K (146 mg $L^{-1}$) (Chang *et al*., 2011), up to 7.5 mEq $L^{-1}$ of K (292.5 mg $L^{-1}$) (Chang *et al*., 2012), for the cultivars Superior, Atlantic, Jasim, Harycong and Jayong.

In general, the effect of K on the production of tubers has been different for the varieties tested in the studies indicated, so it is important to generate specific information on nutrition and greenhouse management for cultivars generated and used in Mexico, there are few research results on hydroponic management, nutrition and the varietal response of potatoes in the greenhouse. Flores-López *et al*. (2009), used concentrations of 250 mg $L^{-1}$ that were convenient for the production of minitubers in the Gigant variety; although in other works (Flores-López *et al*., 2016) with mexican potato clone 020342.1, they found that the best yields of tubers were obtained with doses of 350 to 400 mg $L^{-1}$. The information obtained so far indicates that each variety or clone requires very specific nutritional conditions with potassium in the production of minitubers, so the objective of this work was to determine the effect of potassium and the optimum dose in the yield of minitubers of the advanced potato clone 99-39, obtained by INIFAP, in hydroponics under greenhouse conditions.

## Materials and methods

Experiments were established on two dates July 23 (date 1) and September 10 (date 2) of 2015, at the facilities of the Experimental Metepec Site of INIFAP, located in the Municipality of Zinacantepec, State of Mexico, Mexico, with a geographic reference of 19º 17’ 28’’ of north latitude and to 99º 42’ 51’’ of west longitude; At an altitude of 2 726 m (SMNl, 2016) and subhumid temperate climate with marked summer and winter rains, the annual rainfall is between 800 and 1 000 mm and average annual temperature of 13 °C according to the INEGI (2009).

The experiments were planted similarly, in a greenhouse; The temperature was recorded with a HANNA Data Logger HIII HCI4ICH CE IP67® thermometer, in the July-October period (date 1) the average temperature was 19 °C, with a maximum of 47 °C and a minimum of 9 °C, while between September and December (date 2) the average temperature was 16 °C, the maximum temperature was 38 °C and the minimum temperature was 6 °C. Minitubers of 15 to 18 mm in diameter, free of pathogens of the advanced clone of potato 99-39 were used as vegetative material. This genotype is intermediate to late cycle, with white cuticle and pulp, superficial eyes, oblong shape, susceptible to late blight of potato (*Phytophthora infestans* Mont. de Bary) and with a yield potential higher than 80 t ha 1. 1.8 L pots were used, for a density of 36 plants $m^{-2}$, in hydroponic conditions, with horticultural grade perlite as an inert substrate, a minituber in each pot was sown, at 10 cm depth.

The solutions used had the following nutrient concentrations in mg $L^{-1}$: N= 200, P= 80, Ca= 100, Mg= 75, plus microelements, in addition to the potassium concentrations to be evaluated. The pH of the solution was maintained between 5.5 and 6 with 98% sulfuric acid. During the development of the crop, fungicides and insecticides were applied for the preventive control of pests and diseases, considering what was indicated by Flores-López *et al*. (2009).

The experiments were established under a randomized complete block design with four replications, the potassium treatments evaluated were: 0 (absolute control), 150, 250, 350, 450 and 550 mg $L^{-1}$, where 250 mg K $L^{-1}$ was considered as a commercial witness (Flores-López *et al*., 2009). The experimental plot consisted of 16 pots, of which 10 were randomly sampled, which constituted the useful plot. The two dates of culture were analyzed as series of experiments, according to the procedure indicated by Martínez-Garza (1996), when the F test of the analysis of variance showed statistical differences, the Tukey test was applied.

At harvest, the number of tubers smaller than 15 mm and greater than or equal to 15 mm in diameter was evaluated (Flores-López *et al*., 2014), number and total fresh weight of tubers per plant. The total dry weight was the sum of the dry weight of leaves, stems, stolon’s, roots and tubers and the harvest index (IC) was the ratio between dry weight of tubers on the total dry weight (Flores-López *et al*., 2009). In addition, the verdure index (SPAD) was evaluated, with a SPAD-502 Konika Minolta®, the leaf area index (IAF) was determined with a Linear Ceptometer model LP-80AccuPAR®, the plant height (AP), measured from the base of the stem to the highest growth point. These three variables were evaluated at 40, 55, 70, 85 and 100 days after the emergency (DDE). The analysis of variance, comparison of averages by Tukey ($p< 0.05$) and Pearson correlation coefficients were performed with the Statistical Software InfoStat, Di Rienzo *et al*. (2015).

# Results and discussion

## Plant height

The comparison of averages of the two dates of cultivation, for the variable height of plant is presented in Table 1, the analysis of variance showed statistical differences ($p\leq 0.01$) in the five dates evaluated during the cycle of cultivation of the advanced clone of potato 99-39. In general, the absolute control (0 mg $L^{-1}$) had the lowest height; even at 100 days after emergence the plants had shorter lengths than at 70 and 85 DDE, because the two cycles were averaged and in September to December the plants were of lower height. It is remarkable that between 250 and 550 mg $L^{-1}$ K, the length of the stem was superior to the absolute control; at 40 days after emergence, the potassium-free plants measured 10 cm less than the treatment with the highest concentration, at 55 DDE the absolute control measured 18 cm less than the 550 mg $L^{-1}$ K treatment, at 70 DDE the difference was of 24 cm, at 85 DDE that measure was 26 cm and at the end of the cycle the absolute control had plants with 22 cm of height against 54 cm of the treatment 550 mg $L^{-1}$, the commercial control (250 mg $L^{-1}$ K ) did not show significant differences with the treatments of greater concentration. For clone 99-39 potassium was a determining factor in the height of the plants, the treatment without potassium showed the plants of lower height and is coincident with what was pointed out by Beukema and Van der Zaag (1990) in the sense that the lack of potassium causes dwarfism in potato plants.

**Table 1. Effect of potassium in hydroponics and greenhouse on plant height, leaf area index and SPAD values of plants of potato clone 99-39 in evaluations made at 40, 55, 70, 85 and 100 days after of the emergency (DDE).**

| Variable | Treatment (mg $L^{-1}$ K) | DDE 40 | 55 | 70 | 85 | 100 |
|---|---|---|---|---|---|---|
| Height of plant (cm) | 0 | 12.4 e * | 18.6 d | 27.9 d | 29.3 e | 22.3 d |
| | 150 | 17.3 d | 29 c | 37.8 c | 43.6 d | 44.4 c |
| | 250 | 18.9 cd | 32.1 b | 41.3 bc | 48.1 cd | 49.5 ab |
| | 350 | 19.8 bc | 35.5 a | 44.3 b | 50.8 bc | 48.3 bc |
| | 450 | 21.4 ab | 35.4 a | 49.4 a | 55.9 a | 51.3 ab |
| | 550 | 22.4 a | 36.8 a | 51.9 a | 55.1 ab | 54.4 a |
| Leaf area index | 0 | 0.77 b | 1.83 c | 2.71 c | 3.57 b | 2.9 c |
| | 150 | 1.45 a | 2.64 ab | 3.48 b | 3.81 b | 4.25 b |
| | 250 | 1.48 a | 2.56 b | 3.93 a | 4.66 a | 4.78 ab |
| | 350 | 1.54 a | 2.9 ab | 3.94 a | 4.96 a | 5.27 a |
| | 450 | 1.61 a | 2.83 ab | 3.83 ab | 4.78 a | 4.55 b |
| | 550 | 1.61 a | 2.98 a | 3.82 ab | 4.8 a | 4.72 ab |
| Values SPAD | 0 | 54.2 a | 61 a | 61.1 a | 63.4 a | 63.3 a |
| | 150 | 44.1 b | 48.6 b | 46.3 b | 47.5 b | 48.1 bc |
| | 250 | 46.7 b | 48.8 b | 48.1 b | 47.2 b | 48.1 bc |
| | 350 | 45.6 b | 47.2 b | 47.6 b | 47.4 b | 48.8 bc |
| | 450 | 45.7 b | 50.4 b | 47.1 b | 46.6b | 49.7 b |
| | 550 | 44.3 b | 50.4 b | 48.5 b | 46.2 b | 46.5 c |

*= values with the same letter in vertical order do not differ statistically, according to the Tukey test ($p\leq 0.05$).

## Leaf area index

The Tukey test ($p \leq 0.05$), result of the combined analysis of variance for the two dates evaluated, July to October and September to December 2015, showed significant differences for K doses in the variable IAF at 40, 55, 70, 85 and 100 DDE, the absolute witness being the significantly lower average of IAF with values of 0.77, 1.83. 2.12, 3.6 and 2.9, respectively; while in the 550 mg $L^{-1}$ dose of K there were values of 1.61, 2.98, 3.82, 4.8 and 4.72, respectively, on the dates indicated (Table 1). The IAF of the plants with 250 mg $L^{-1}$ or more, behaved similarly and plant canopy growth was significantly reduced in the absence of potassium in all measurements made throughout the crop cycle; partly because of the effect on the growth of plants without this element and possibly also because of the late blight of the potato (*Phytophthora infestans*) in plants without potassium, which occurred in the wet season of the year (July to October) , the above coincides with what was mentioned by Velasco (1999); Wang *et al*. (2013); Wibowo *et al*. (2014), who found an increase in the sensitivity of plants to diseases when there is potassium deficiency.

## SPAD values

In the Table 1 shows the SPAD values, which statistically showed the highest average for the absolute control (Tukey, $p \leq 0.05$), this was due to the fact that the plants without potassium showed a dun/brown color and the measurement equipment indicated high readings, same that have no relation with the greenery of the plant nor with the production of chlorophyll. The coloration shown by the plants of the absolute control is the result of the lack of potassium, as indicated by Mulder and Turkensteen (2005), who mention the presence of necrosis in the leaf blade and browning as characteristic symptoms of the lack of potassium in the leaves. Leaflets of potato plants.

## Production of tubers by plant

Tubers smaller than 15 mm in diameter. The combined analysis of variance of the two cultivation cycles (Table 2) for number of tubers smaller than 15 mm in diameter indicated highly significant differences for doses. The concentrations 350, 450 and 550 mg $L^{-1}$ of potassium produced 10.2, 10 and 9.8 minitubers and these treatments were superior (Tukey, $p \leq 0.05$) to the absolute control and to the treatment of 150 mg $L^{-1}$ K, which produced 4.7 and 5.1 minitubers, respectively; the commercial control did not differ statistically from the rest of the treatments with potassium for this variable; this, possibly due to the greater availability of assimilates during the tuberization stage in the treatment of high concentrations of potassium in the formation and filling of tubers, which involves the participation of various physiological processes and transport of assimilates from the aerial part of the plant towards the stolons and that, to greater availability of assimilated there will be more tubers (Minhas *et al*., 2004); likewise, it is also explained by the presence of more than one cycle of tubers, with the consequent production of minitubers of smaller diameter in the treatments with higher doses of potassium; this may be due to the fact that the formation of larger tubers originates in primary stolons, while the smaller ones are the result of secondary stolons from the same main stem (Akira *et al*., 2015).

Tubers equal or greater than 15 mm in diameter. Regarding the number of tubers ≥ 15 mm in diameter, treatments 250, 450 and 550 mg $L^{-1}$ of K produced 18.6, 21.7 and 17.9 per plant, respectively and were statistically equal; whereas treatment with 350 mg $L^{-1}$ of K yielded significantly more tubers (22.1) than the commercial control with 18.6 tubers per plant. Treatments of 0 and 150 mg $L^{-1}$ of K produced 7.5 and 13.1 tubers, respectively (Table 2).

**Table 2. Productivity response of potato clone 99-39 to nutrition with potassium in the hydroponic system and greenhouse.**

| Variable | Dose (mg $L^{-1}$ K) | | | | | | CV (%) |
|---|---|---|---|---|---|---|---|
| | 0 | 150 | 250 | 350 | 450 | 550 | |
| No. of tubers <15 mm | 4.7 ±1.2$^{*b}$ | 5.1 ±0.7$^{b}$ | 7.5 ±0.9$^{ab}$ | 10.2 ±1$^{a}$ | 10 ±1$^{a}$ | 9.8 ±1.1$^{a}$ | 33.1 |
| No. of tubers ≥ 15 mm | 7.5 ±0.4$^{d}$ | 13.1 ±1.3$^{c}$ | 18.6 ±2.7$^{b}$ | 22.1 ±2.5$^{a}$ | 21.7 ±1.3$^{ab}$ | 17.9 ±1.4$^{ab}$ | 16.4 |
| No. of tubers totals | 12.2 ±1.3$^{d}$ | 18.2 ±1$^{c}$ | 26.1 ±2.7$^{b}$ | 32.3 ±2.3$^{a}$ | 31.7 ±2$^{a}$ | 27.7 ±1.5$^{ab}$ | 14.2 |
| Fresh weight (g) tubers | 102 ±6.4$^{c}$ | 210 ±21.9$^{b}$ | 306 ±31.4$^{a}$ | 341 ±21.2$^{a}$ | 320 ±19.7$^{a}$ | 301 ±22.7$^{a}$ | 15.7 |
| Dry weight (g) tubers | 17.4 ±1.1$^{c}$ | 29.7 ±2.8$^{b}$ | 41.4 ±4$^{a}$ | 5.9 ±2.8$^{a}$ | 43.2 ±1.8$^{a}$ | 39.6 ±1.7$^{a}$ | 15.8 |
| Total dry weight (g) of plant | 23.1±1.6$^{c}$ | 41 ±3.8$^{b}$ | 54.1 ±4.7$^{a}$ | 58.7 ±4.2$^{a}$ | 55.3 ±2.6$^{a}$ | 50.7 ±2.3$^{ab}$ | 14.7 |
| Harvest index | 0.76 ±0.01$^{ab}$ | 0.75 ±0.01$^{b}$ | 0.79 ±0.01$^{a}$ | 0.79 ±0.01$^{a}$ | 0.78 ±0.01$^{ab}$ | 0.78 ±0.01$^{ab}$ | 2.8 |

Average values of two culture cycles ± standard error. $^{*}$= values with different letter are statistically different $p < 0.05$, according to the Tukey test; CV (%)= coefficient of variation.

The 350 mg $L^{-1}$ dose of K produced 194% more tubers than the absolute control and 19% more than the commercial control. The results found indicate the importance of potassium in the process of filling the reserve organs in the potato plant, which may be due to the fact that potassium is relevant in yield, as indicated by Westermann *et al*. (1994), who also mention the role of this element in the transport of assimilated to the tubers. On the other hand, in this work the value of the Pearson correlation coefficient between the leaf area index and tuber production ≥ 15 mm in diameter was positive and highly significant r= 0.7, which could be explained by the rapid growth of the foliar coverage in plants with high doses of potassium, especially in the first stages of cultivation, an aspect that agrees with that pointed out by Aguilar *et al*. (2006); Mora-Aguilar *et al*. (2006) who found that in the early stages of potato development the foliar area grew exponentially, while the accumulation of biomass in the tubers increased from the beginning of tuberization.

Number of total tubers. This variable is the result of the sum of the tubers of all sizes, for this case, the concentrations of 350, 450, and 550, with 32.3, 31.7 and 27.7 tubers per plant, respectively, were statistically different from the concentrations of 0 and 150 mg $L^{-1}$ of K, with 12.2 and 18.2 tubers per plant, respectively (Table 2), while the commercial control produced on average 26.1 tubers per plant, exceeded by the concentrations of 350 and 450 mg $L^{-1}$ of K, and as the dose 550 mg $L^{-1}$, however, significantly exceeded the doses of 0 and 150 mg $L^{-1}$. This low number of tubers per plant in treatments with lower potassium may be due to what was mentioned by Viola *et al*. (2001), who claim that competition for assimilated at the beginning of differentiation can cause abortion of tubers.

The 350 mg $L^{-1}$ dose of K produced 163% more tubers than the absolute control and 20% more than the commercial control. The greater number of minitubers in the treatments with high concentrations of potassium is probably due to the greater disposition of sugars at the time of tuberization, as indicated by Xu *et al*. (1998). On the other hand, some authors (Struik and Wiersema, 1999) indicate that useful tubers should weigh between 0.1 and 10 g with a diameter of 5 to 25 mm.

In Mexico minitubers ≥ 15 mm are used for sowing the first generation in the field and children under that diameter can be used in the greenhouse; Needing between 60 and 80 thousand units per hectare (Flores-López *et al*., 2014). Considering an area of one square meter planted with clone 99-39, doses between 350 and 450 mg $L^{-1}$ of K would induce an estimated production of 880 tubers ≥ 15 mm in diameter plus 225 under 15 mm, for a total of 1 105 tubers on said usable surface; amount greater than that reported by Flores-López *et al*. (2009), who obtained 470 tubers with the Gigant variety and also more than 802 minitubers $m^{-2}$ in the Zorba variety, obtained by Farran and Mingo-Castell (2006) in soilless culture, this demonstrates the high productivity of clone 99-39 in hydroponics and greenhouse.

Determination of the optimal dose of potassium. For tubers ≥ 15 mm in diameter, the optimal potassium dose was estimated using a regression, where the trend curve was adjusted to a second-order equation with $R^2$= 0.94 (Figure 1), which applied an optimum concentration of 400 mg $L^{-1}$ of K for the production of 20.67 minitubers ≥ 15 mm in diameter per plant; what amounts to 827 tubers per $m^2$ and 827 thousand tubers in 1 000 $m^2$ of greenhouse useful area, enough to plant more than 10 hectares in the first generation of field. Patron-Ibarra (2014) reported maximum yields of 9.5 and 5.8 tubers per plant for Alpha and Atlantic varieties, respectively, in pre-basic II seed production systems in Mexico; which also indicates the different varietal response in the production of minitubers.

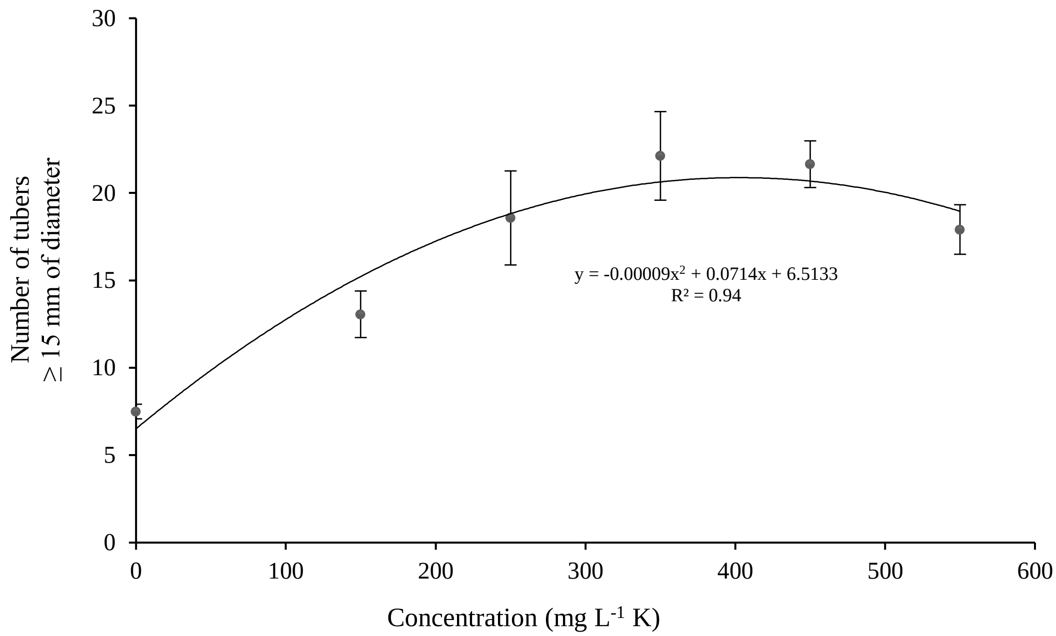


**Figure 1. Linear regression curve of the second degree for the estimation of the optimum concentration of potassium for the production of minitubers by plant of potato clone 99-39, with diameter ≥ 15 mm.** Average values ± standard error.

## Fresh weight of tubers

Doses of 250 to 550 mg $L^{-1}$ induced significantly higher fresh weight of tubers than the treatments of 150 mg $L^{-1}$ and the absolute control (Table 2), yield of potato of clone 99-39 was 306, 431, 320 and 301 grams per plant, in the doses of 250, 350, 450 and 550 mg $L^{-1}$, respectively, while with 150 mg $L^{-1}$ and with the absolute control, the production was 210 and 102 grams average per plant; this indicates that possibly potassium had a marked influence on the filling of tubers and the mobilization of assimilates; that is, in performance, as indicated by Westermann *et al*. (1994); Beukema and Van der Zaag (1990), this element is indispensable in the production of higher yields in the potato plant.

In Figure 2 the response in the genotype 99-39 yield is shown the application of potassium in the nutrient solution in hydroponics and greenhouse, the curve was adjusted to a second-order regression equation with $R^2$= 0.99, which indicates that high doses of potassium increase the fresh weight in the tubers per plant. On the other hand, the value of the Pearson correlation coefficient between fresh weight and leaf area was r= 0.8 and between fresh weight and plant height was r= 0.81, which surely had an effect on the yield of the plants of the plant. Clone 99-39.

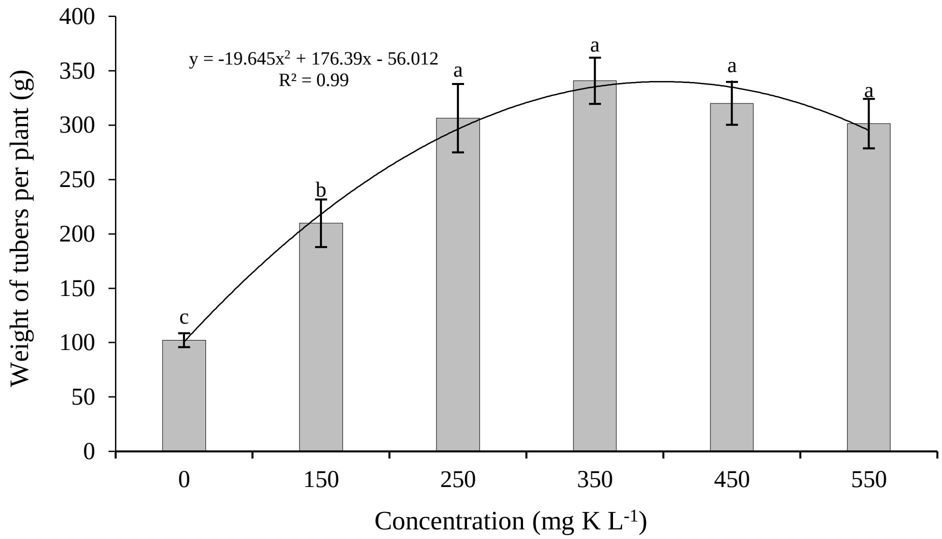


**Figure 2. Effect of potassium and regression curve on the yield of tuber tuberous weight per plant of potato clone 99-39.** Average ± standard error. Tukey (0.05).

## Dry weight and harvest index

The dry weight of tubers of the plant and the value of the harvest index are measurements that allow the estimation of the efficiency of the plants in the accumulation of dry matter in the different organs of the same, especially in the parts of anthropocentric interest; in this study, the combined analysis for dry weight of tubers showed only statistical differences between doses ($p\leq 0.01$), being equal the concentrations of 250, 350, 450 and 550 mg $L^{-1}$, with 41.4, 45.9, 43.2 and 39.6 g, respectively and higher than the doses of 150 and 0 mg $L^{-1}$, with 29.7 and 17.4 g, respectively (Table 2).

In the total dry weight of the plant there were differences between doses and the highest accumulation of dry matter per plant was between 250 and 550 mg $L^{-1}$, while the harvest index (dry weight of tubers/dry weight of the plant) it was statistically superior in the doses of 250 and 350 mg $L^{-1}$, with respect to the dose of 150 mg $L^{-1}$; however, the concentrations of 450, 550, 150 and 0 mg $L^{-1}$ of K were not statistically different among them for the harvest index. In this regard, the Pearson correlation coefficient between the dry weight of tubers and the leaf area index was r= 0.77 and between total dry weight and leaf area index was r= 0.73, while between dry tuber weight and total dry weight was r 0.98; which indicates that the amount of foliage is important in the weight of the tubers and that possibly a large amount of assimilated ones moved towards the tubers, a result that coincides with that indicated by Westermann *et al*. (1994); Aguilar *et al*. (2006); Mora-Aguilar *et al*. (2006).

## Interactions

The combined analysis of variance showed statistical differences for the interactions date x dose in the following variables: SPAD at 40, 70, 85 and 100 DDE, IAF at 70, 85 and 100 DDE, plant height at 55, 85 and 100 DDE, number of tubers of ≥ mm, number of total tubers per plant and harvest index. The SPAD value of the absolute control was statistically higher than that shown in the other treatments, regardless of the sowing time after 40 days after emergence, with values close to 60 units, while the rest of the treatments showed determinations between 45 and 50 SPAD units in both cultivation cycles.

Both the leaf area index and the plant height showed higher values in the treatments of higher doses of potassium, especially from July to October in the treatment of 450 mg $L^{-1}$, with 62 cm on the date 1 against 49 cm on date 2. Treatment with 0 mg $L^{-1}$ showed the lowest plant height on both dates, which coincides with what was pointed out by Beukema and Van der Zaag (1990), who report dwarfism in potato plants when there is a deficiency of potassium.

For the leaf area index the values were higher in the July to October period than in the September to December period, and in both cycles, the absolute witness showed the lowest IAF values, an aspect that coincides with that mentioned by Mulder and Turkensteen. (2005) regarding the reduction of leaf surface due to potassium deficiency.

The interaction date x dose for the variable production of tubers ≥15 mm in diameter, showed statistically higher values for the doses of 450, 350 and 250 mg $L^{-1}$ with 23.3, 28.6 and 24 tubers per plant, respectively, in the July period to October (date 1) when the temperatures and photoperiod were higher than those exhibited between September and December; while the smallest amounts corresponded to treatments 0 and 150 mg $L^{-1}$ on both dates (Figure 3), this could possibly be associated with the production of a greater quantity of assimilates at the time when there was more leaf area, which coincides with that indicated by Minhas *et al*. (2004); Westermann *et al*. (1994); Beukema and Van der Zaag (1990), regarding the importance of the availability of potassium for tuberization.

In this work, it is possible to point out that doses between 250 and 350 mg $L^{-1}$ K in the period from July to October seem appropriate, while for the period September to December more of this element is required.

In the interaction date x dose in the variable total tubers per plant, it is possible to emphasize that the concentrations of 250, 350 and 450 mg $L^{-1}$ of K on the date 1 (July to October) produced 32.6, 37.6 and 33.5 tubers per plant , respectively, in addition to the 550 mg $L^{-1}$ dose on date 2 (September to December), with 29 tubers per plant, were significantly higher; the previous thing, maintains the tendency indicated previously, on the necessity of greater amount of potassium in the time of lower temperature.

## Conclusions

Concentrations greater than 350 mg $L^{-1}$ of potassium during the entire crop cycle promoted higher production of minitubers per plant, in hydroponics under greenhouse conditions for the Mexican potato clone 99-39.

The calculated optimal dose of potassium for the production of minitubers of diameter ≥ 15 mm of the Mexican clone of potato 99-39 was 400 mg $L^{-1}$.

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