Crecimiento de *Pinus greggii* Engelm. bajo diferentes rutinas de fertilización en vivero

Growth of *Pinus greggii* Engelm. under different routines of fertilization at the nursery

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Resumen

Fertilizar la planta en vivero favorece su condición fisiológica y morfológica, lo que contribuye a mejorar su calidad, aspecto fundamental para favorecer la supervivencia y crecimiento inicial después del plantado. En esta investigación se evaluó el efecto de un fertilizante de entrega controlada (*Osmocote*®), combinado con tres fertilizantes solubles (Triple 19, *Poly-feed*® y *Peters professional*®) en dosis fija (200 ppm) y exponencial (100, 200 y 300 ppm) en el crecimiento y los costos de producción de *Pinus greggii* en vivero. Se aplicaron siete tratamientos bajo un diseño experimental de bloques al azar. A los 134 días (4.5 meses) de inició el ensayo de fertilización la planta tenía 7.5 meses de edad; en ese momento se tomaron la altura, el diámetro, la producción de biomasa de la raíz, de la parte aérea y total, el índice de calidad de *Dickson*, el estado nutrimental y la asimilación de N-P-K en el follaje de las plantas, así como los costos de fertilización por tratamiento. Los resultados indican que los tratamientos 1, 3 y 7 respondieron mejor a la aplicación de fertilizantes en las variables morfológicas evaluadas; sin embargo, solo los tratamientos 3 y 7 tuvieron mejor respuesta a las variables fisiológicas, y de ellos, el 3 fue el de menor costo debido a la fertilización aplicada.

Palabras clave: Calidad de planta, costos, fertilizantes solubles, nutrición, *Pinus greggii* Engelm.*,* variables fisiológicas, variables morfológicas.

Abstract

Fertilizing the plant at the nursery favors its physiological and morphological condition, which contributes to improve its quality, a basic aspect to favor the survival and initial growth after planting. This research evaluated the effect of a controlled delivery fertilizer (Osmocote®), combined with three soluble fertilizers (Triple 19, Poly-feed® and Peters professional®) in fixed dose (200 ppm) and exponential (100, 200 y 300 ppm) in the growth and production costs of *Pinus greggii* at the nursery. Seven treatments were applied under an experimental randomized block design. At 134 days (4.5 months) of the fertilization trial started, the plant was 7.5 months old; at that time the height, diameter, biomass production of the root, aerial and total part, the Dickson quality index, the nutritional status and assimilation of N-P-K in the foliage of the plants and the costs of fertilization by treatment. Results indicate that treatments 1, 3 and 7 reacted better to the application of fertilizers in the assessed morphological variables; however, only treatments 3 and 7 had a better response to physiological variables, and of these, number 3 had the lowest cost due to the applied fertilization.

Key words*:* Plant quality, costs, soluble fertilizers, nutrition, *Pinus greggii* Engelm., physiological variables, morphological variables.

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Introduction

For the plantations survival and satisfactory growth, it is necessary to use quality plant, which depends on its genetic origin, as well as on the characteristics of the morphological and physiological attributes developed during its production at the nursery (Landis *et al.,* 2010). The former include the height of the aboveground part, the diameter of the root neck, the size and shape of the root system and the relationships between these variables (Prieto *et al*., 2009); the physiological refer to the content of lignin and carbohydrates, as well as the assimilation of nutrients, defined by their concentration and proportion of macro and micronutriments (Landis *et al.,* 1989).

The application of fertilizers in nurseries is a common cultural practice, which contributes to obtain vigorous plant in less time and, in addition, to minimize costs (Landis *et al.,* 2010). Nutrimental absorption is dynamic and depends on the balance between nutrients and growth patterns, and does not necessarily have a direct relationship with the concentration of the solutions (Román *et al.,* 2001).

When fertilizers are applied in a soluble form, the assimilation of nutriments is fast, which allows a better management of nutrition, since it is more in line with the specific needs of the plant in each phase of cultivation (Peñuelas and Ocaña, 2000); on the other hand, the addition of controlled release fertilizers takes longer time to reflect and once applied they cannot be adjusted (Rose *et al*., 2004). The efficiency of fertilization to avoid losses is accomplished by fractionating the applied nutrients, mainly nitrogen and potassium (Carpenedo *et al.,* 2016).

Fertilization should be based on the development of the plant in the nursery, since the required proportions of the three main macronutrients (NPK) vary depending on the growth phase, which would be: establishment phase, which ranges from germination to the appearance of the first true needles; it is followed by the rapid growth phase, when the seedling grows at an exponential rate and the stem approaches the target height; finally, the hardening phase that begins when the plant finishes growth of its aboveground part and the energy is redirected to growth in diameter and root (Dumroese *et al.,* 2012).

Because each species may have a different response to the application of nutriments, particularly in species that demand high concentrations, it is necessary to know their particular needs (Bustos *et al.,* 2008; Soriano, 2011). In the *Guadiana* Valley, state of *Durango*, Mexico, *Pinus greggii* Engelm. achieves rapid growth, in comparison with other species and is used in commercial forest plantation programs, since it also shows high tolerance to adverse soil and climate conditions (Prieto *et al.,* 2006), so there is a need to study different aspects that favor its good management.

In addition to the technical aspects already described, it is important to evaluate the production costs of the nursery plant, as this concept often represents one of the main factors that affect the financial viability of plantations and reforestations (Hernández *et al*., 2015a). For this reason, and to contribute to the estimation of said viability, Hernández *et al.* (2015b) made a simulator that facilitates a detailed calculation of the unit costs of plant production in forest nurseries.

In this essay the answer in the growth of *Pinus greggii* in the nursery, was assessed in relation to the application of a fertilizer of controlled release, combined with three types of fertilizers soluble in water, in two doses. The aim was to identify a dose that improves production and increases the quality of the plants at the lowest possible cost of fertilization. It was hypothesized that combining a controlled release fertilizer, with at least one dose of water -soluble fertilizer, it is possible to favor the growth of plants and reduce production costs due to this input.

Materials and Methods

Study area

The essay was carried out in the nursery of the *Facultad de Ciencias Forestales de la Universidad Juárez del Estado de Durango* (School of Forest Sciences of the Juarez University of the State of Durango), located at coordinates 24°00'48.38" N and 104°41'03.64" W, at 1 860 m.

Production of the evaluated plant

Sowing was carried out the last week of November 2015, in expanded polystyrene trays of 77 cavities with 170 mL each; a mixture composed of 44 % base mix (54 % peat, 24.5 % vermiculite and 21.5 % perlite) and 56 % of composted pine bark was used as substrate.

In order to know the morphological condition of the plant at the beginning of the experimental stage, an assessment to a sample of 56 three-month old plants extracted at random from the experimental lot was made, previously to the application of the treatments; the average initial characteristics of the seedlings under evaluation were the following: 5.2 cm of height of the aboveground part, 0.82 mm of diameter to the neck and 0.175 g of dry weight.

The plant materials remained in a greenhouse for the first eight weeks, with a 720-gauge polyethylene plastic cover, protected against ultraviolet rays; the next four weeks grew in a 60 % shadow mesh environment, and finally, the last three weeks were out in the open. Table 1 shows the specific conditions of temperature, relative humidity and luminosity, which prevailed in the three conditions where the trial was developed. A Hobo® data logger U12-012 was used to record the reference variables.

Table 1. Environmental conditions prevailing during the development of the fertilization trial of *Pinus greggii* Engelm.

Environmental condition	Duration (weeks)	Temperature (°C)	Relative humidity (%)	Luminous intensity (lum/ft²)
Greenhouse	8	17.1	32.3	272.8
60 % Shade mesh	4	24.2	42.4	286.2
Outdoors	3	24.2	44.4	646.5

Evaluated treatments and experimental design

During the preparation of the substrate, seven treatments were evaluated, all based on the incorporation of 6 kg m^{-3} of the controlled release fertilizer (from 8 to 9 months) Multicote$^®$ 18N - 6P$_2$O$_5$ - 12K$_2$O + 2MgO + micro nutrients (Haifa Chemicals Ltd.). With the exception of treatment 1 (control), which only received irrigation water without fertilization, the other six treatments were supplemented with water-soluble fertilizers: Triple 19 (19 N -19 P$_2$0$_5$ -19 K$_2$O), Poly-feed$^®$ (20 N - 10 P$_2$0$_5$ -20 K$_2$O) and Peters professional$^®$ (20 N -7 P$_2$0$_5$ -19 K$_2$O), applied in fixed doses (200 ppm) and exponential (100, 200 and 300 ppm) (Table 2).

Table 2. Fertilization treatments evaluated during the experiment.

Treatment	Fertilizer	N-P-K doses (ppm) Week 1-4	N-P-K doses (ppm) Week 5-8	N-P-K doses (ppm) Week 9-12	N-P-K doses (ppm) Week 13	N-P-K doses (ppm) Week 14	N-P-K doses (ppm) Week 15
1	FEC+Water	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0	0-0-0
2	FEC+Triple 19	200-88-166	200-88-166	200-88-166	200-88-166	200-88-166	200-88-166
3	FEC+Triple 19	100-44-83	200-88-166	300-132-249	300-132-249	200-88-166	100-44-83
4	FEC+Poly-feed®	200-44-166	200-44-166	200-44-166	200-44-166	200-44-166	200-44-166
5	FEC+Poly-feed®	100-22-83	200-44-166	300-66-249	300-66-249	200-44-166	100-22-83
6	FEC+Peters professional®	200-30-158	200-30-158	200-30-158	200-30-158	200-30-158	200-30-158
7	FEC+Peters professional®	100-15-79	200-30-158	300-45-237	300-45-237	200-30-158	100-15-79

FEC = Controlled-release fertilizer (Multicote® $18N - 6P_2O_5 - 12K_2O + 2MgO +$ micro nutriments, added to the substrate in 6 kg m^{-3} fixed doses for all treatments). Water-soluble fertilizers were applied in fixed and varying doses.

From the variation in the reception of luminosity by the position of the greenhouse, the essay was established under an experimental randomized block design. Each treatment had four blocks and the experimental unit consisted of a tray of 77 cavities of 170 mL; the selected plants were the 45 of the center.

The water-soluble fertilizers were applied for 15 weeks and their amounts were calculated based on the nitrogen concentration of each: 1) Fixed dose (200 ppm), permanently for 15 weeks; 2) Exponential dose, 100 ppm for the first four weeks; the next four, it was increased to 200 ppm. For four more weeks it was increased to 300 ppm; during the last three weeks of the experiment, the doses were reduced in the exponential treatments, adding 300, 200 and 100 ppm per week (Table 2). This allowed the doses to be equal in the fixed and exponential options. Between each

dose change, to drain possible excess salts from previous fertilizations, the plant was just irrigated and not fertilized.

The water-soluble fertilizer was incorporated twice a week with a manual watering can; in each experimental unit (tray) 3.5 liters of water were added with the corresponding fertilizer solution. The pH of water was maintained between 5 and 6, and when it was higher than that interval it was adjusted with diluted hydrochloric acid in the irrigation water; pH was measured weekly with an Ohaus ST10 potentiometer.

Response variables

At 134 days (4.5 months) of starting fertilization, when the plants were 7.5 months old, ten plants of each experimental unit were randomly selected. From each one, the height of the aboveground part (cm) was recorded with a graduated ruler (cm); the diameter at the neck of the root (mm) with a 14388 *SURTEK*® 122204 Trupper® vernier; total dry weight, the weight of the aboveground part and root were quantified with an Ohaus PA214 scale from the samples dried in an oven (FELISA® FE-291D) for 72 hours at 70 °C. With these variables, the Dickson quality index (ICD) was calculated and the concentration and content of N-P-K in the foliage of the plants was estimated with three samples composed of 5 g of needles per treatment.

The chemical analysis of the plant tissue was made in the *Laboratorio de Fertilidad de Suelos y Química Ambiental del Colegio de Postgraduados Campus Montecillo, Texcoco, Estado de México* (Soil Fertility and Environmental Chemistry Laboratory of the *Montecillo* Campus Postgraduate School, *Texcoco*, State of Mexico). The nitrogen content was obtained by the micro-Kjeldahl method (digestion with H_2SO_4), phosphorus by colorimetric determination with yellow vanadomolybdate complex and potassium with flame emission spectrophotometry, with a *SprectrAA Atomic Absorption Spectrometer* 220 Fast Sequential (Chapman y Pratt, 1979).

To establish if there were significant differences ($p \leq 0.05$) in the morphological variables and to make the analysis of variance (ANOVA), the statistical package SAS® (Statistical Analysis System) version 9.0 (SAS, 2002) was used and when such differences were confirmed, the Tukey means test ($\alpha = 0.05$) was performed (SAS, 2002).

The effect of the fertilization treatments on the nutritional status of the plants was evaluated by an ANOVA. Additionally, with the graphic vector method, these results were illustrated. The construction and interpretation of vector nomograms was made based on the methodology described by Haase and Rose (1995).

To evaluate the differences between the costs implied by the use of each fertilizer combination during plant growth, the cost of the Controlled Release Fertilizer incorporated in each treatment was considered, as well as the amount and cost of the water -soluble fertilizer, applied during each watering.

Results and Discussion

Morphological variables

The height of the plants showed a dispersion of data in a range of 29.1 to 31.6 cm with treatment 2 located in the upper statistical group ($p < 0.05$) (Table 3). Rodríguez (2008) indicates that a plant with a stem height greater than 25 cm and a neck diameter smaller than 4 mm is more susceptible to wind damage; however, the NMX-AA-170-SCFI-2016 Mexican Standard (Secretaría de Economía, 2016) establishes that *Pinus greggii*, from six to eight months of age, must have a height of 25 to 30 cm, which coincides with the results obtained in the present investigation.

Table 3. Growth in height, diameter and Dickson's Quality Index in *Pinus greggii* Engelm. at 134 days after starting fertilization.

Treatment	Height (cm)	Diameter (mm)	Dickson´s quality index
1	31.3 ± 0.57 ab	3.3 ± 0.04 b	0.26 ± 0.0 a
2	31.6 ± 0.53 a	3.4 ± 0.05 ab	0.24 ± 0.0 a
3	31.1 ± 0.73 ab	3.5 ± 0.05 a	0.25 ± 0.0 a
4	29.1 ± 0.55 b	3.3 ± 0.03 b	0.23 ± 0.0 a
5	30.4 ± 0.64 ab	3.4 ± 0.05 ab	0.24 ± 0.0 a
6	30.0 ± 0.49 ab	3.2 ± 0.04 b	0.22 ± 0.0 a
7	30.2 ± 0.05 ab	3.3 ± 0.05 b	0.24 ± 0.0 a

1 = FEC (Fast release fertilizer) + water; 2 = FEC+Triple 19, fixed dose; 3 = FEC + Triple 19, exponential dose; 4 = FEC+Poly-feed®, fixed dose; 5 = FEC+Poly-feed®, exponential dose; 6 = FEC+Peters professional®, fixed dose; 7 = FEC + Peters professional®, exponential dose. Values with different letters for the same variable, indicate significant statistical differences ($p < 0.05$), according to Tukey.

For neck diameter, data dispersion was 3.2 to 3.5 mm, -with significant differences ($p < 0.05$) between treatments- with treatment 3, which is located in the upper statistical group and the only one to reach the established standards in the NMX-AA-170-SCFI-2016 for *Pinus greggii* (Secretaría de Economía, 2016), which states that plants in the nursery must reach a minimum diameter of 3.5 mm to ensure satisfactory performance in the field (Table 3). In several species, it has been found that the diameter at the neck of the root is one of the main morphological characteristics that determines the adaptation of plants in the plantation site (Tsakaldimi *et al*., 2013). In the case of the Dickson Quality Index, the values oscillated between 0.22 and 0.26, without significant differences between treatments ($p < 0.05$) (Table 3).

In the production of root biomass, the control plant was the best, despite having only been fed with the Controlled Release Fertilizer, with 26.8 % more biomass with respect to the average value of the other treatments (Table 4); Apparently, plants having insufficient nutriment supply developed more root in their search, which also recorded Soriano (2011), who described that the highest dose of fertilization in *Pinus patula* Schiede ex Schltdl. & Cham and *P. devoniana* Lindl. it disadvantaged the growth of the radical system. According to Berendse *et al*. (2007), as well as Camargo and Rodríguez (2006), under low fertility, the plants allocate greater biomass to the root to favor their growth.

Table 4. Production of biomass of the root, the aboveground part and total in *Pinus greggii* Engelm. at 134 days after starting the fertilization.

Treatment	Root dry weight (g)	Aboveground part dry weight (g)	Total dry weight (g)
1	0.79 ± 0.02 a	2.51 ± 0.07 b	3.30 ± 0.08 ab
2	0.59 ± 0.02 b	2.85 ± 0.10 ab	3.44 ± 0.12 ab
3	0.58 ± 0.01 b	3.04 ± 0.10 a	3.62 ± 0.11 a
4	0.58 ± 0.01 b	2.60 ± 0.08 b	3.18 ± 0.09 b
5	0.58 ± 0.02 b	2.75 ± 0.09 ab	3.33 ± 0.10 ab
6	0.56 ± 0.02 b	2.63 ± 0.07 b	3.19 ± 0.09 b
7	0.58 ± 0.01 b	2.82 ± 0.08 ab	3.40 ± 0.09 ab

1 = FEC (Fast release fertilizer) + water; 2 = FEC+Triple 19, fixed dose; 3 = FEC + Triple 19, exponential dose; 4 = FEC+Poly-feed[®], fixed dose; 5 = FEC+Poly-feed[®], exponential dose; 6 = FEC+Peters professional[®], fixed dose; 7 = FEC + Peters professional[®], exponential dose. Values with different letters for the same variable, indicate significant statistical differences ($p < 0.05$), according to Tukey.

Treatment 3 is also outstanding in the biomass of the stem and the needles; Rendón *et al.* (2001) indicate that the biomass generated in this part of the plant is related to its growth, since the stem works as a support and conduction organ, while the needles help metabolic activity. As the biomass of the aerial part is generally greater than that of the root, the same treatment produced the highest total biomass (Table 4).

Jacobs *et al.* (2009) evaluated in *Quercus ilex* Lour the response to the application of nitrogen in doses of 0 to 200 mg per plant and concluded that a dose of 150 mg may be enough for the growth of plants; however, a higher dose may represent the optimal value to be loaded nutritionally, without toxicity. On the other hand, Prehn *et al*. (2013) observed that in *Guindilla trinveris* Gillies ex Hook. & Arn., when applying nitrogen in increasing doses, the aerial biomass increased up to 2 g plant^{-1} and from then onwards, it decreased until causing its death. In the case of this essay, none of the doses had a toxic effect.

Physiological variables

The seedlings with the highest amount of nutrient reserves were those of treatment 3 while the control showed the lowest value (Table 5).

Table 5. Absolute and relative values of nutritional status of nitrogen, phosphorus and potassium of *Pinus greggii* Engelm. in response to fertilization routines.

Treatment	Dry weight (mg plant^{-1})	Concentration (%)			Content (mg plant^{-1})		
		N	P	K	N	P	K
1	0.59	1.202	0.167	0.846	7.081	0.984	4.980
	(100)	(100)	(100)	(100)	(100)	(100)	(100)
2	0.83	2.369	0.247	1.053	19.770	2.060	8.788
	(141)	(197)	(148)	(124)	(279)	(209)	(176)
3	0.84	2.423	0.254	1.191	20.302	2.130	9.979
	(142)	(202)	(152)	(140)	(287)	(216)	(200)
4	0.72	2.463	0.224	0.976	17.629	1.604	6.987
	(121)	(205)	(134)	(115)	(249)	(163)	(140)
5	0.78	2.459	0.222	1.150	19.092	1.724	8.930
	(132)	(204)	(133)	(136)	(270)	(175)	(179)
6	0.73	2.383	0.226	1.058	17.446	1.652	7.742
	(124)	(198)	(135)	(125)	(247)	(168)	(155)
7	0.76	2.499	0.226	1.226	19.050	1.720	9.346
	(129)	(208)	(135)	(145)	(269)	(175)	(188)

1 = FEC (Fast release fertilizer) + water; 2 = FEC+Triple 19, fixed dose; 3 = FEC + Triple 19, exponential dose; 4 = FEC+Poly-feed®, fixed dose; 5 = FEC+Poly-feed®, exponential dose; 6 = FEC+Peters professional®, fixed dose; 7 = FEC + Peters professional®, exponential dose. Values expressed in parenthesis were calculated as (*VR/VT*) × 100. VR = Reference value of treatment 1; VT = Value of each treatment.

When taking as a reference the nutritional status of treatment 1, vector nomograms show that the six treatments with the addition of water-soluble fertilizer had a high consumption of nitrogen, phosphorus and potassium, which is a condition that should favor the fertilization routines, since this translates into plants with greater

nutritional reserves (Uscola *et al*., 2015). Treatments 3 and 7 show the best ratio content-concentration-total dry biomass (Figure 1).
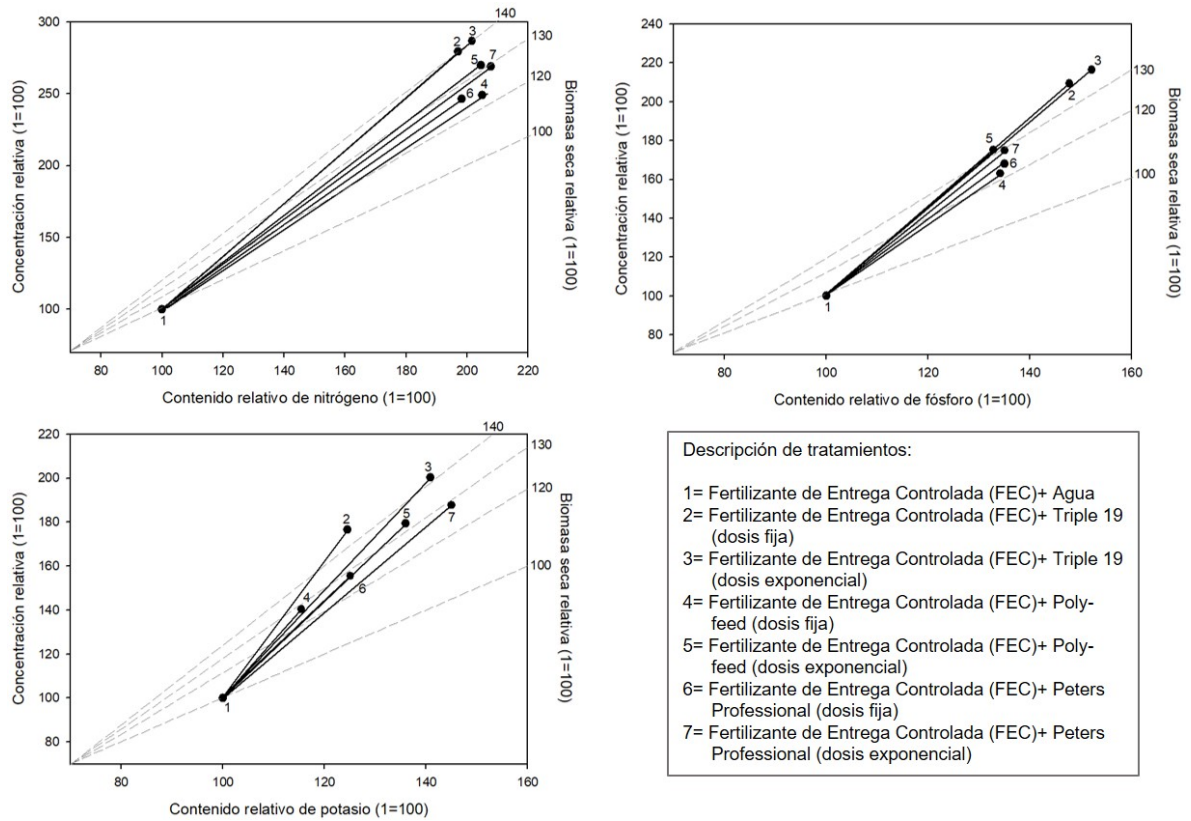
Concentración relativa = Relative concentration; *Biomasa seca relativa* = Relative dry biomass; *Contenido relativo de nitrógeno* = Relative nitrogen content; *Contenido relativo de fósforo* = Relative phosphorus content; *Contenido relativo de potasio* = Relative content of potassium; *Descripción de tratamientos* =Description of treatments: 1 = FEC (Fast release fertilizer) + water; 2 = FEC+Triple 19, fixed dose; 3 = FEC + Triple 19, exponential dose; 4 = FEC+Poly-feed®, fixed dose; 5 = FEC+Poly-feed®, exponential dose; 6 = FEC+Peters professional®, fixed dose; 7 = FEC + Peters professional®, exponential dose.

Figure 1. Nomograms of nutritional status of nitrogen, phosphorus and potassium of *Pinus greggii* Engelm., 134 days after fertilization began.

A high content of nutrient reserves, especially nitrogen, in *Abies religiosa* (Kunth) Schltdl. & Cham. has been related to a competitive advantage of plants in places with low fertility (Navarro *et al.,* 2013). The same manifested Sanchez *et al.* (2017) and Buendía *et al.* (2017) when working with *Pinus greggii* and *Pinus leiophylla* Schl. & Deppe, respectively.

In low -fertility conditions, inducing high contents of nutrient reserves to favor a better performance in the field is the premise of the exponential fertilization regime proposed by Timmer (1996), which is supported based on nursery results; however, in later studies, it is convenient to evaluate if in fact the plants with better nutritional status have a favorable performance in the field, since in spite of the existence of works of this nature that show positive results with the exponential fertilization regime, as for example those of Salifu and Timmer (2003) and Duan *et al.* (2013), there are others such as Everett *et al*. (2007) that indicate the opposite. Such controversy could be based on what was indicated by Burgess (1991), who pointed out that in some species the addition of fertilizer in an exponential way does not always satisfy the needs of the plants, mainly during the initial stages of growth when the demands of nutrients are high and the supply is scarce.

Analysis of fertilization costs

2.587 kg of Controlled Release Fertilizer were used in the 2 156 individuals under evaluation (28 trays with 77 plants each); the average price per kilogram was $ 50.00 Mexican pesos. On the other hand, the total water-soluble fertilizer used during the trial was 1.638 kg of Triple 19 (19 N -19 P_2O_5 -19 K_2O), 1.560 kg of Poly-feed[®] (20 N -10 P_2O_5 -20 K_2O) and 1.560 kg of Peters professional[®] (20 N -7 P_2O_5 - 19 K_2O), each applied in eight trays of 77 plants (equivalent to two treatments per type of fertilizer), with an average cost per kilogram of Mx$21.59, Mx $36.80 and Mx $86.36, respectively. Table 6 shows the average cost per plant due to the alternative fertilization used in each treatment during the 4.5 months that the trial lasted; also, an example of the cost of fertilization for 100 000 plants is presented.

Table 6. Cost of Controlled Release Fertilizer and water-soluble fertilizer applied, by plant and for 100 000 plants, in the evaluated treatments.

Treatment	Cost of FEC used per plant (Mx$)	Cost of FH used per plant (Mx$)	Cost of FEC and FH used per plant (Mx$)	Total cost of FEC+FH for 100 000 plants (Mx$)
1	0.051	0.00	0.051	5 100
2	0.051	0.057	0.108	10 800
3	0.051	0.057	0.108	10 800
4	0.051	0.093	0.144	14 400
5	0.051	0.093	0.144	14 400
6	0.051	0.218	0.269	26 900
7	0.051	0.218	0.269	26 900

1 = FEC (Fast release fertilizer) + water; 2 = FEC+Triple 19, fixed dose; 3 = FEC + Triple 19, exponential dose; 4 = FEC+Poly-feed®, fixed dose; 5 = FEC+Poly-feed®, exponential dose; 6 = FEC+Peters professional®, fixed dose; 7 = FEC + Peters professional®, exponential dose. Values expressed in parenthesis were calculated as $(VR/VT) \times 100$. VR = Reference value of treatment 1; VT = Value of each treatment. Costs are based on average quotes for 2017.

The treatments with the highest cost due to fertilization were number 6 and 7, with $ 0.269 Mexican pesos per plant. On the other hand, treatment 1 was the least expensive, lacking water-soluble fertilizer, with $ 0.051 per plant, followed by treatments 2 and 3 with $ 0.108. If these costs are extrapolated to a production of 100 000 plants, there would clearly be significant statistical differences; treatment 1 would cost 5 100 Mexican pesos, while treatments 2 and 3 would cost 10 800 Mexican pesos and would increase in the other treatments, until reaching the most expensive treatments (6 and 7), with 26 900 Mexican pesos (Table 6), in a fertilization period of 4.5 months.

From the technical point of view, treatments 3 and 7 were within the same statistical group and are the two treatments that responded best to the application of controlled delivery fertilizer supplemented with water soluble fertilizers in terms of the morphological and physiological variables evaluated. However, from the financial point of view, the fertilization in treatment 3 costs less than half of the cost of treatment 7, so, taking into account both aspects, treatment 3 is considered the most recommended.

Conclusions

The nutrition of the plants was favored with the application of controlled delivery fertilizer Multicote®, supplemented with hydrosoluble fertilizers Triple 19 in exponential doses (treatment 3) or with Peters professional® in exponential doses (treatment 7); however, treatment 3 stands out because it implies less than half the cost with respect to treatment 7.

Treatment 1 only based on controlled delivery fertilizer produced high values in the morphological variables; but the results in the physiological values show deficiencies in the assimilation of nutrients.

Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Georgina Irasema Bautista Ojeda: experiment set up, taking and ordering of data, review of literature and writing of the document; José Ángel Prieto Ruíz: experiment design and set up, review and editing of the document; José Ciro Hernández Díaz: advice on the results of cost analysis and review of the document; Erickson Basave Villalobos: interpretation of fertilization results and review of the document; José Rodolfo Goche Télles: review of literature and the document; Eusebio Montiel Antuna: review of the document.

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