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Vegetative development and bean yield in magnetized nutrient solution in combination with variable pH

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ABSTRACT

Objective: Due to the importance of bean in human consumption, vegetative development and seed yield of Negro Veracruz beans were evaluated using a nutrient solution with different magnetization times in combination with different pH levels.

Design/Methodology/Approach: The experimental design used was completely randomized with a 4×6 factorial arrangement with three replications. 24 treatments of the combination of four magnetization times and six degrees of acidity of the nutrient solution were evaluated. The variables evaluated were vegetative development and yield components. The results were subjected to an analysis of variance and media separations were performed using Tukey's test ($\alpha \leq 0.05$).

Results: The magnetization and the degree of acidity of the nutrient solution significantly influenced the variables. The most outstanding treatments were 2 and 24 hours of magnetization in combination with pH values of 4 and 5, for most of the variables of vegetative development and evaluated yield components. The magnetization treatments of 2 h together with pH values of 4 and 5 increased height, biomass, days to flowering, number of pods, harvest index and seed yield.

Study Limitations/Implications: Care should be taken that exposure to the magnetic field at high intensities may produce adverse effects on growth and development.

Findings/Conclusions: It is concluded that an appropriate combination of magnetization time and degree of acidity of the nutrient solution improves vegetative development and yield.

Keywords: *Phaseolus vulgaris* L, magnetization, acidity, biomass, production.

INTRODUCTION

Bean (*Phaseolus vulgaris* L.) is the most important legume for human consumption, rich in bioactive components such as enzyme inhibitors, lectins, phytates, oligosaccharides, phenolic, and anti-mutagenic and anti-proliferative properties (Suárez-Martínez

Image by PublicDomainPictures at Pixabay *et al.*, 2016). In Mexico, the per capita consumption of bean is approximately 9.8 kilograms (SAGARPA, 2015), and currently 82% of the needs are covered by domestic production while the rest comes from imports from the United States, Canada and China (SAGARPA, 2017). Likewise, studies by Gilani *et al.* (2017) indicate that there is a relationship between magnetized water and pH values, as well as the electric conductivity of water with pH adjustment. On the other hand, Hassan *et al.* (2019) mention that there are significant increments in the pH when the water is treated ionically with magnets in different intensities, forming alkaline molecules and decreasing the acidity. According to Amor *et al.* (2018), the pH increased slightly through time with the use of four magnets of different intensities, and after the magnets were withdrawn the initial pH was reestablished. The pH of water is varied, depending on the intensity of the magnetic field and the time of exposure; the changes in pH are electrochemical reactions that result from electric currents generated by the Lorentz force (Gatard, Deseure and Chatenet 2020; He *et al.*, 2022).Therefore, the objective of the study was to determine the vegetative development and the bean seed yield using nutritional Steiner solution subjected to different magnetization times in combination with different pH levels, under greenhouse conditions.

MATERIALS AND METHODS

The experiment was conducted in February 2019, in the greenhouse of Universidad Autónoma Agraria Antonio Narro Unidad Laguna, located in the city of Torreón, Coahuila, with geographical coordinates 25° 31' 11" North and 103° 25' 57" West, and 1123 masl. The climate according to Köppen modified by García (2004) is warm desert, type BWh, with maximum temperature of 40 °C and minimum of 6 °C, with mean rainfall of 250 mm.

Treatments and experimental design

Twenty-four (24) treatments were evaluated resulting from the combination of four magnetization times (Factor A: 0, 0.333, 2.0 and 24.0 hours per day) and six degrees of acidity (Factor B: pH of 3, 4, 5, 6, 7 and 8) of the nutritient solution in bean (Table 1). The experimental design was completely randomized with factorial arrangement 4×6 with three replications. These treatments began when the plants presented the simple unfolded leaves. The experimental unit consisted of one plant (López-Pérez *et al.*, 2019).

Development of the experiment

The variety Negro Veracruz from the INIFAP national bean program, liberated in 1980, was used. The seeds were disinfected with sodium hypochlorite at 4% (Espinosa-Palomeque *et al.*, 2019), submerging them for three minutes. Then, they were transplanted to pots with different treatments of the nutrient solutions in greenhouse conditions. Circular plastic containers with capacity of 5 liters were used. Aeriation was provided by a 120 W turbine, Hailea brand, model VB290G.

The chemical and physical properties of water, based on the laboratory analysis were the following: in microelements, Iron (Fe^{3}) 0, Zinc (Zn^{+}) 0.02, Copper (Cu^{+}) 0.03,

Table 1. Magnetization treatments and pH in the nutrient solution in black bean developed in a hydroponic system in greenhouse.

Factor A:	Factor B:	Treatments
Tm1: 0	pH1: 3	1 Tm1 pH1: 0 hours + pH de 3
		2 Tm1 pH2: 0 hours + pH de 4
Tm2: 0.333	pH2: 4	3 Tm1 pH3: 0 hours + pH de 5
		4 Tm1 pH4: 0 hours + pH de 6
Tm3: 2.0	pH3: 5	5 Tm1 pH5: 0 hours + pH de 7
		6 Tm1 pH6: 0 hours + pH de 8
Tm4: 24.0	pH4: 6	7 Tm2 pH1: 0.333 hours + pH de 3
		8 Tm2 pH2: 0.333 hours + pH de 4
	pH5: 7	9 Tm2 pH3: 0.333 hours + pH de 5
		10 Tm2 pH4: 0.333 hours + pH de 6
	pH6: 8	11 Tm2 pH5: 0.333 hours + pH de 7
		12 Tm2 pH6: 0.333 hours + pH de 8
		13 Tm3 pH1: 2.0 hours + pH de 3
		14 Tm3 pH2: 2.0 hours + pH de 4
		15 Tm3 pH3: 2.0 hours + pH de 5
		16 Tm3 pH4: 2.0 hours + pH de 6
		17 Tm3 pH5: 2.0 hours + pH de 7
		18 Tm3 pH6: 2.0 hours + pH de 8
		19 Tm4 pH1: 24.0 hours + pH de 3
		20 Tm4 pH2: 24.0 hours + pH de 4
		21 Tm4 pH3: 24.0 hours + pH de 5
		22 Tm4 pH4: 24.0 hours + pH de 6
		23 Tm4 pH5: 24.0 hours + pH de 7
		24 Tm4 pH6: 24.0 hours + pH de 8

Factor A: magnetization time in hours per day (Tm); Factor B: degree of acidity (pH).

Manganese (Mn^+) 0.01, Boron (B^+) 0.99; in cations (+), Sodium (Na^+) 120, Potassium (K^+) 13.0, Calcium (Ca^+) 288, Magnesium (Mg^+) 29.0; in anions (−), nitrates (NO_3) 23.03, Phosphorus (phosphates) 0.080, Dihydrogen phosphorus (H_2PO_4) 0.250, Sulfate (SO_4) 643.6, Carbonates (CO_3) 0, Bicarbonates (HCO_5) 170.83, Chlorides (Cl) 198.52; physical parameters, pH 7.80, electric conductivity (mS/cm) 2.21, rate of sodium absorption 1.80, and interchangeable sodium percentage 0.38%.

A potentiometer brand Hanna HI98130 was used for the pH readings. Magnets were used that were 2.5 cm long, 2.0 cm diameter, cylindrical, made from an alloy of neodymium, Iron and Boron, with lining of Chromium, Nickel and Copper, to magnetize the water, of the Obi brand, model 255590. The magnets were placed with an upwards direction (extreme North) and downwards (extreme South) (extreme Sur) (Zhang *et al.*, 2017), which presented an intensity of 0.380 Tesla. To measure the magnetic field of the magnets, a portable Gauss meter and biomagnetism polarity detector were used (Zhang *et al.*, 2017).

Variables evaluated

The phenological variables were recorded since sowing, using the methodology proposed by Escalante and Kohashi (2015): total biomass (TB, obtained when harvesting and determining the dry weight of the roots and the aerial biomass of plants); days to flowering (FL, number of days at 50% of flowering since sowing); height (PH, when measuring the total length of the main shoot on the surface); number of leaves (NL, obtained when counting all the leaves that are completely expanded and exposed with photosynthetic activity, including the two primary leaves and the trifoliate one), number of normal pods (NP, considering as a normal pod the one that had at least one normal seed with the size of the characteristic black color of the Veracruz genotype), number of grains per pod (NG, average number of seeds produced in each of the pods and which reached full development), seed yield (SY, determined by weighing all the normal seeds produced by the plant) and harvest index (HI in %, calculated when dividing the seed yield by the final aerial biomass) ($HI=SY/BM \times 100$).

Statistical analyses

The data of the variables evaluated were processed through the statistical package SAS, version 9.0 (SAS, 1999), with an analysis of variance conducted under a completely randomized design with factorial arrangement 4×6 and three replications. When significant statistical differences were detected in the variables, Tukey's honestly significant difference was used for means comparison (HSD, P=0.05).

RESULTS AND DISCUSSION

Vegetative development

The values of plant height were significantly different between magnetization times, pH and their interaction. The plants grew more when the nutrient solution was magnetized during 24 hours and its pH was 4 and 5. Regarding the effect of the interaction magnetization time and pH on plant height, the combinations of 24 hours with pH of 4 and 5, as well as 2 hours and pH of 4 resulted in higher plants, with increments of 48.4, 70.5 y 23.4%, respectively, compared to the control and same values of pH (Table 3). This agrees with Alattar *et al.* (2021) who mention that in *Zea mays* L. plants the length of the plants is significantly influenced by magnetized water.

The variable number of leaves per plant (NL) showed significant differences between magnetization times and pH, but not for their interaction. Magnetization times of 0.333, 2.0 and 24 hours presented higher number of leaves, being statistically similar between one another, but different from the control. The pH values of 3 to 6 showed higher numbers of leaves per plant and pH levels of 7 and 8 were lower, being statistically similar between one another (Table 2). The total biomass per plant (TB) showed significant differences between magnetization times, pH and their interaction. The exposition time to magnetism of 2.0 hours presented plants with higher weight, followed by the control and 24 hours, while a time of 0.333 hours showed the plants with lowest weight (Table 2).

For their part, Vashisth and Joshi (2017) indicated that increases in the number of leaves and plant height were due to times of exposure. In terms of the effect of the interaction between magnetization time and pH on plant biomass, the combinations of 2 hours and pH of 4, 2 hours and pH of 5, 24 hours with pH of 4 and 5 presented the plants with highest weight, corresponding to increments of 8.4, 81.6, 7.2 and 37.2%, respectively (Table 3).

Table 2. Main effects of different magnetization times and pH of the nutrient solution on plant height, number of leaves per plant, biomass, and days to flowering of black bean under greenhouse conditions.

Treatments	AP (cm)	NH	BT (g)	FL (d)
Magnetization time (hours)				
0	18.00 b	17.0 b	7.10 b*	67.28 ab
0.333	20.10 ab	17.9 ab	4.95 c	63.56 b
2.0	17.40 b	18.8 ab	8.72 a	76.83 a
24.0	23.10 a	19.6 a	7.61 b	70.83 ab
P>F	0.0010	0.0070	< 0.0001	0.0075
pH				
3	11.70 d	18.9 ab	3.14 c	58.33 b
4	30.10 a	19.4 a	10.25 a	63.83 b
5	26.00 ab	20.9 a	10.70 a	68.08 ab
6	21.00 bc	18.6 ab	6.40 b	70.00 ab
7	15.80 dc	16.6 bc	6.71 b	78.50 a
8	13.30 d	15.5 c	5.40 b	79.00 a
P>F	<0.0001	<0.0001	<0.0001	0.0002

AP: plant height (centimeters), NH: Number of leaves per plant, BT: Total biomass per plant (grams), FL: Days to flowering. * Means with different letters in a column are statistically different (Tukey 0.05).

The time of exposure to magnetism of 0.333 hours presented a shorter flowering period, while a time of 2.0 hours recorded the longest period to flowering. Concerning the effect of the interaction between magnetization time and pH on number of days to flowering, the combinations of 0 hours and pH of 5, as well as 0.333 hours and pH of 3 showed the shortest flowering periods, while 0 hours and pH of 7 and 8, 0.333 and pH of 7, 2.0 hours and pH of 5 and 8, as well as 24 hours and pH of 5 presented the longest periods to flowering (Table 3).

Yield components

The variable number of pods per plant showed significant differences between magnetization times, pH and their interaction. In relation to the effect of the interaction between magnetization time and pH on number of pods per plant, all the magnetization treatments with pH values of 4 to 7 showed high production of pods, whose increments varied from 47.4 to 168.6%. A similar behavior to the production of pods was observed on the variable number of grains per pod, since magnetization of the nutrient solution during 0.333 to 24 hours significantly increased the number of grains per pod compared to the control without magnetizing (Table 4).

Regarding the interaction between magnetization time and pH, no significant differences were detected between treatments (Table 5). The plants had higher seed yields when the nutrient solution was magnetized during 2 and 24 hours, which represent increments of 21.4 and 16.1% compared to the control. In relation to the

Table 3. Effects of the interactions between different magnetization times and pH levels of nutrient solution on plant height, number of leaves per plant, biomass and days to flowering of black bean under greenhouse conditions.

TEH	pH SN	PH (cm)	NLP	TBP (g)	DF (d)
0	pH3	11.88 gf	15.7 bc	2.50 i	57.67 abc
	pH4	24.53 abcdef	19.8 abc	10.73 cb	56.00 abc
	pH5	20.23 cdegf	18.3 abc	8.53 bcde	49.33 bc
	pH6	20.32 cdegf	17.3 abc	7.73 cdef	71.33 abc
	pH7	18.78 cdegf	14.9 bc	7.97 cdef	84.67 ab
	pH8	12.43 gf	16.0 abc	5.17 efghi	84.67 ab
0.333	pH3	10.60 g	20.2 abc	2.49 i	41.33 c
	pH4	29.10 abc	18.2 abc	7.13 defg	62.67 abc
	pH5	28.80 abcd	21.1 ab	7.10 defg	60.33 abc
	pH6	26.50 abcde	19.5 abc	5.47 efghi	64.33 abc
	pH7	11.10 gf	13.6 c	3.67 hi	82.00 ab
	pH8	14.20 egf	15.0 bc	3.83 ghi	70.67 abc
2.0	pH3	12.30 gf	19.5 abc	3.87 ghi	77.33 ab
	pH4	30.30 abc	19.5 abc	11.63 b	69.00 abc
	pH5	20.70 cdegf	21.6 ab	15.49 a	80.67 ab
	pH6	15.30 defg	17.8 abc	5.81 efghi	74.67 abc
	pH7	14.20 efg	17.8 abc	10.47bcd	70.00 abc
	pH8	11.50 fg	16.5 abc	5.12 fghi	89.33 a
24.0	pH3	11.88 fg	20.2 abc	3.70 hi	57.00 abc
	pH4	36.42 a	20.1 abc	11.50 b	67.67 abc
	pH5	34.50 ab	22.8 a	11.70 b	82.00 ab
	pH6	21.85 bcdefg	20.0 abc	6.60 efgh	69.67 abc
	pH7	19.17 cdefg	20.2 abc	4.70 fghi	77.33 ab
	pH8	14.97 efg	14.6 bc	7.50 cdef	71.33 abc

PH: plant height (cm), NLP: Number of leaves per plant, TBP: Total biomass per plant (g), DF: Days to flowering. *Means with different letters in a column are statistically different (Tukey 0.05).

effect of the interaction between magnetization time and pH on seed yield per plant, the best combinations were 24 hours and pH 4, as well as 24 hours and pH 5, with yields of 3.80 and 3.20 g per plant, equivalent to increments of 46.2 and 45.4%, compared to the non-magnetized solution and same acidity. The combinations of 2.0 hours and pH of 4 also stood out, as well as 2.0 hours and pH of 5, which had yields of 3.43 and 3.13 g per plant, whose increments were 31.9 and 42.3%, compared to the non-magnetized solution and same acidity (Table 5). Regarding the effect of acidity on the soil, Tosquy *et al.* (2020) reported that a pH decreases the yield in the bean crop. The variable harvest index (HI) showed significant differences between pH values and for the interaction between magnetization time and pH, but there were no significant differences for the magnetization time. The plants showed higher harvest indexes (26.8 to 32.5%) in the nutrient solution with pH values of 4 to 7. On the contrary, the harvest indexes were

Table 4. Main effects of different magnetization times and pH levels of the nutrient solution on number of pods, number of grains, seed yield and harvest index of black bean in greenhouse conditions.

Treatments	NNP	NG	SY (g)	HI (%)
Magnetization time (h)				
0	5.56 c	3.83 b	1.68 c	27.43 a
0.333	8.17 b	4.50 a	1.00 d	24.72 a
2.0	8.17 b	4.67 a	2.04 a	26.25 a
24.0	10.67 a	5.06 a	1.95 b	27.88 a
P>F	<0.0001	<0.0001	<0.0001	0.1760
pH				
3	2.75 c	2.00 d	0.47 f	19.33 c
4	11.00 a	5.42 ab	2.86 a	32.45 a
5	12.17 a	5.67 a	2.46 b	28.10 ab
6	11.08 a	5.08 ab	1.52 d	28.35 ab
7	9.25 b	4.75 bc	1.62 c	26.79 b
8	2.58 c	4.17 c	1.10 e	24.40 bc
P>F	<0.0001	<0.0001	<0.0001	<0.0001

NNP: Number of normal pods per plant, NG: Number of grain in normal pods, IC: Harvest index %, SY: Seed yield (g). * Means with different letters in a column are statistically different (Tukey 0.05).

low (19.3 and 24.4%) when the nutrient solution was very acid and alkaline (pH of 3 and 8) (Table 4). In relation to the effect of the interaction between magnetization time and pH on the harvest index, the best treatments were: 24 hours and pH of 4 to 6 (HI of 32.3 to 38.5%), as well as 2.0 hours and pH of 4 (HI of 34.8%); meanwhile, the combinations of 0, 2 and 24 hours with pH of 3.0 showed the lowest harvest indexes (12.3 to 18.5%) (Table 5). In the review by Nyakane *et al.* (2019) about the effects of magnetic fields on plants reported during 20 years and the beneficial effects of magnetized irrigation water, in the appropriate combination of intensity of the magnetic field and time of. Ospina-Salazar *et al.* (2018), when subjecting water to a magnetic field found that biomass and fruit yield of Tabasco chili pepper plants were higher, fresh weight and number of fruits of 27 and 13%, respectively. El-Ssawy (2020) reports that the integration of the NFT (nutrient film technique) hydroponic system with magnetized water at a high intensity (level 3) fostered a significant increase in the nutrient concentrations (N, P and K) and total soluble solids, although the pH decreased in a nutritious solution in lettuce. Zareei *et al.* (2019) determined that magnetized water and nutrient solutions stimulate biosynthesis. When it comes to forest species, Liu *et al.* (2019) indicated that irrigation with magnetized water promoted the growth of seedlings, root development, photosynthesis, and mineral nutrient contents of *Populus* × *euramericana*, and that saline water was improved with magnetized water, allowing its use for irrigation.

Table 5. Effects of interactions of different magnetization times and pH levels of the nutrient solution on number of pods, number of grains, seed yield, and harvest index of black bean in greenhouse conditions.

TEH	pH SN	NNP	NG	SY (g)	HI (%)
0	pH3	4.33 ijk	1.33 e	0.40 k	18.54 cde
	pH4	6.33 hij	4.67 abc	2.60 d	30.58 abcd
	pH5	7.67 fghi	4.67 abc	2.20 e	31.46 abcd
	pH6	7.00 ghi	4.67 abc	1.60 gf	24.26 abcde
	pH7	5.00 ijk	4.33 abcd	2.08 e	31.53 abcd
	pH8	3.00 jk	3.33 bcde	1.20 hi	28.21 abcd
0.333	pH3	1.67 k	1.67 e	0.49 jk	28.17 abcd
	pH4	9.33 efgh	5.33 ab	1.63 gf	25.97 abcde
	pH5	14.00 abc	6.00 a	1.27 h	24.88 abcde
	pH6	13.00 bcd	5.00 ab	1.37 gh	28.71 abcd
	pH7	9.00befgh	4.67 abc	0.60 jk	19.89 cde
	pH8	2.00 k	4.33 abcd	0.67 j	20.70 bcde
2.0	pH3	3.00 jk	2.33 de	0.42 k	12.28 e
	pH4	11.33 cde	5.67 a	3.43 b	34.80 ab
	pH5	12.00 bcde	6.00 a	3.13 c	23.20 bcde
	pH6	10.67 cdef	5.00 ab	1.26 h	28.15 abcd
	pH7	10.00 efgh	4.67 abc	2.75 d	30.27 abcd
	pH8	2.00 k	4.33 abcd	1.26 h	28.78 abcd
24.0	pH3	2.0 k	2.70 cde	0.60 jk	18.3 de
	pH4	17.0 a	6.00 a	3.80 a	38.5 a
	pH5	15.0 ab	6.00 a	3.20 bc	32.9 abc
	pH6	13.7 abc	5.70 a	1.80 f	32.3 abcd
	pH7	13.0 bcd	5.30 ab	1.00 i	25.5 abcde
	pH8	3.3 jk	4.70 abc	1.30 h	19.9 cde

NNP: Number of normal pods per plant, NG: Number of grain in normal pods, HI: Harvest index %, SY: Seed yield (g). * Means with different letters in a column are statistically different (Tukey 0.05).

CONCLUSIONS

The effect with the highest increment in treatments of 2 and 24 hours of magnetization, with pH of 4 and 5, was found on the variables mentioned before, where the most outstanding treatments were 2 and 24 hours of magnetization in combination with pH values of 4 and 5, for most of the variables of vegetative development and of yield components evaluated. The treatments of 24 hours of magnetization together with pH values of 4 and 5 increased height, biomass, days to flowering, number of pods, harvest index and seed yield.

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REFERENCES

Alattar E., Elwasife, K., y Radwan, E. (2021). Effects of magnetic field treated water on some growth parameters of corn (*Zea mays*) plants. *AIMS Biophysics, 8*(3). 267-280. Doi: 10.3934/biophy.2021021

Amor H., Elaoud, A., Hozayn, M. (2018). Does Magnetic Field Change Water pH? *Asian Research Journal of Agriculture. 8*(1). 1-7. Doi: 10.9734/ARJA/2018/39196

El-Ssawy W., Abuarab, M., El-Mogy, M., Kassem, M., Wasef, E., Sultan, W. y Rady, M.M. (2020). The impact of advanced static magnetic units on water properties and the performance of aeroponic and NFT systems for lettuce. *Polish Journal of Environmental Studies. 29*(4): 2641-2652. Doi: 10.15244/pjoes/112364

Escalante-Estrada J.A.S., Kohashi, S.J. (2015). El rendimiento y crecimiento del frijol: manual para la toma de datos. Colegio de Postgraduados. 1ª ed. Texcoco, Estado de México. 84.

Espinosa-Palomeque B., Cano-Ríos, P., Salas-Pérez, L., García-Hernández, J. L., PreciadoRangel, P., Sáenz-Mata, J., y Reyes-Carrillo, J. L. (2019). Bioinoculantes y concentración de la solución nutritiva sobre la producción y calidad de tomate. *Biotecnia. 21*(3). 100-107.

García, E. (2004). Modificaciones al sistema de clasificación climática de Köppen. 5ª. (Ed.). Instituto de Geografia. Universidad Nacional Autónoma de México (UNAM). México, DF. 246.

Gatard V., Deseure, J., Chatenet, M. (2020). Use of magnetic fields in electrochemistry: A selected review. *Current Opinion in Electrochemistry*, 23: 96–105. Doi: 10.1016/j.coelec.2020.04.012

Gilani A., Kermanshahi, H., Gholizadeh, M. y Golian, A. (2017). Agricultural water management through magnetization of irrigation water: A Review. *Journal of Aridland Agriculture*. 3. 23-27. Doi: 10.25081/jaa.2017.v3.3353

Hassan S. M., Sulaiman, M. A., Madlul, N. S., Fadel, A. H., y Abdul Rahman, R. (2019). Influence of continuous magnetic field exposure on water properties and subsequent effects on the growth performance, plasma biochemistry, nutritive value and liver histopathology of Jade Perch Scortum barcoo in a recirculating system. *Aquaculture Research, 50*(7). 1931-1941. Doi: 10.1111/are.14080

He Y., Tang, J., Kalantar-Zadeh, K., Dickey, M. D., Wang, X. (2022). Noncontact rotation, levitation, and acceleration of flowing liquid metal wires. *Proceedings of the National Academy of Sciences. 119*(6). Doi: 10.1073/pnas.2117535119

Liu X., Zhu, H., Meng, S., Bi, S., Zhang, Y., Wang, H., Song, C., Ma, F. (2019). The effects of magnetic treatment of irrigation water on seedling growth, photosynthetic capacity and nutrient contents of *Populus × euramericana* 'Neva' under NaCl stress. *Scientific reports, 9*(1) 1-14. Doi: 10.1038/s41598-019-45719-6

López-Pérez L., Quiñones-Aguilar, E. E., Rincón-Enríquez, G. (2019). Hongos micorrizícos arbusculares y vermicomposta en el crecimiento de papaya (*Carica papaya* L) en invernadero. *Agro Productividad, 12*(3). 47-52. Doi: 10.32854/agrop.v0i0.1343

Nyakane N. E., Markus, E. D., Sedibe, M. M. (2019). The Effects of Magnetic Fields on Plants Growth: A Comprehensive Review. *International Journal of Food Engineering. 5*(1). 79-87. Doi: 10.18178/ijfe.5.1.79-87

Ospina-Salazar D. I., Benavides Bolaños, J. A., Zúñiga-Escobar, O., Muñoz-Perea, C. G. (2018). Fotosíntesis y rendimiento de biomasa en ají, rábano y maíz sometidos a agua tratada magnéticamente. *Ciencia y Tecnología Agropecuaria, 19*(2). 291-305. Doi: 10.21930/rcta.vol19_num2_art:537

S.A.S. 1999. SAS Institute. 2004. The SAS system release 9.0 for Windows. SAS Institute. Cary, NC, USA.

SAGARPA Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. (2017). Planeación Agrícola Nacional 2017-2030. Disponible en: https://www.gob.mx/agricultura/acciones-y-programas/planeacion-agricola-nacional-2017-2030-126813

SAGARPA Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. (2015). Uso de tecnología y servicios en el campo. Disponible en: https://www.gob.mx/siap/documentos/tecnificacion

Suárez-Martínez S. E., Ferriz-Martínez, R. A., Campos-Vega, R., Elton-Puente, J. E., De La Torre Carbot, K., García-Gasca, T. (2016). Bean seeds: Leading nutraceutical source for human health. *CYTA - Journal of Food, 14*(1). 131-137.

Tosquy-Valle O. H., Zetina-Lezama, R., López-Salinas, E., Ibarra-Pérez, F. J., Villar-Sánchez, B., Rodríguez-Rodríguez, J. R. (2020). Comparación de genotipos de frijol negro opaco en suelos ácidos del sur de Veracruz. *Revista Terra Latinoamericana, 38*(1). 91-102. Doi: 10.28940/terra.v38i1.411

Vashisth A., y Joshi, D. K. (2017). Growth characteristics of maize seeds exposed to magnetic field. *Bioelectromagnetics, 38*(2). 151-157. Doi: 10.1002/bem.22023

Zareei E., Zaare-Nahandi, F., Oustan, S., Hajilou, J. (2019). Effects of magnetic solutions on some biochemical properties and production of some phenolic compounds in grapevine (*Vitis vinifera* L.). *Scientia Horticulturae*, 253. 217-226. Doi: 10.1016/j.scienta.2019.04.053