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Article

Growth of *Vicia faba* L. seedlings in mixtures of soil with biosolids

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Abstract

In order to investigate the effect of four biosolids from the dairy, malt, soap and paper industries on the growth and production of biomass of *Vicia faba* L. seedlings, biosolid:soil mixtures were made in ratios 20:80, 40:60 and 60:40. Physicochemical and microbiological analyses were performed on each biosolid and mixtures. Biosolids showed differences in the presence (MPN) of fecal coliforms from 3 to 1 100, *Salmonella* sp., from 2 to 3 and from 0 to 16 helminth eggs per g of total solids. The concentration (mg kg^{-1}) of heavy metals in copper was from 0.7 to 1.9, chromium from 0.8 to 2.4, cadmium from 0 to 0.6, zinc from 4.3 to 8.6, nickel from 1.2 to 3.8 and lead from 1.3 to 5.7, without arsenic and mercury. The contaminants were below the permissible limits according to SEMARNAT (2002), in addition, among biosolids the pH varied from 7 to 9.8 and organic material (OM) from 0.3 to 6.2%. Biosolids from the dairy and malt industries incorporated into the soil modified the pH from 8.1 to 7.4, increased OM from 1.2 to 3.5%, the total nitrogen from 7 to 35 mg kg^{-1} and the available phosphorus from 5 to 25 mg kg^{-1}. At 30 days after sowing in the greenhouse, *V. faba* seedlings grown in soil with the biosolid from the dairy industry in the highest ratio increased biomass production by 1 145% and length by 342%.

Keywords: *Vicia faba* L., heavy metals, biosolids, microbiology.

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Introduction

Urban and industrial wastewater treatment plants (WWTPs) generate sludges with a high content of organic matter and nutrients of interest to improve the soil in agricultural production systems (SEMARNAT, 2002). However, the use of industrial sludges is restricted, due to the presence of trace elements, pathogenic organisms, organic xenobiotic substances, endocrine disruptors and hormones (Bücker-Neto *et al*., 2017), which can induce diverse and adverse damage to plants of agricultural interest (Corrêa-Martins *et al*., 2016).

The chemical composition and physical properties of the sludges of WWTPs vary depending on the industry from which they come, and the fertilizers derived from such sludges as well, so before using a residual sludge, they must be stabilized to eliminate pathogens, toxic chemical compounds and unpleasant odors. This stabilization is carried out by physical, chemical and biological processes, using heat (Lang and Smith, 2008), alkalinity, aerobic or anaerobic digestion (Goss *et al*., 2013), among others. After being subjected to the stabilization process, such sludges are called biosolids.

Currently, soil fertility and crop productivity have decreased significantly, and chemical fertilizers are used indiscriminately (Postisek-Talavera *et al*., 2010). Due to the high cost of chemical fertilizer sources and the decrease in raw material, organic waste recycling has been chosen. For this purpose, biosolids are an excellent source to consider. In Mexico, more than 640 million tons of biosolids on a dry basis are produced annually (Mantilla *et al*., 2017), which generates serious problems for their elimination and confinement. Biosolids contain a large amount of essential nutrients for plants, so it would be convenient to use them in an agricultural production system and at the same time reduce the negative impact on the environment with a sustainable production system (Gomiero *et al*., 2011).

Biosolids have great potential for use as organic fertilizer, but the nutrient imbalance needs to be overcome (Antille *et al*., 2013), as they contain a high concentration of micronutrients and some macronutrients are not present in necessary concentrations as required by crops (Dad *et al*., 2018). Nutrient release rates are difficult to predict so the production response is highly variable, which limits their management from the agronomic and environmental perspective (Deeks *et al*., 2013).

Broad bean (*Vicia faba* L.) is a legume and an important source of protein for the population around the world, its consumption is in fresh and dried form by humans and animals (Vela *et al*., 2018), it is an excellent fixer of nitrogen in the soil, due to the characteristics of the rhizosphere (Harris-Valle *et al*., 2019), it is of rapid growth of 150 days and has high capacity to accumulate biomass up to 15 t ha^{-1} of pod (ICAMEX, 2023).

In addition, this species has genes tolerant to osmotic (Ghouili *et al*., 2021) and saline stress (Rajhi *et al*., 2020), is capable of accumulating and transferring heavy metals, such as cadmium (Piršelová *et al*., 2021), arsenic (Gupta *et al*., 2020), boron, lead, zinc, and copper (Alaoui *et al*., 2019), to its inedible organs such as leaves and stems, in addition, with low accumulation in edible organs such as seeds, so it is considered an interesting biological model in soil remediation together with food production, which is a necessary practice in the face of food needs in the population (Tang *et al*., 2019).

V. faba is important in Mexico because it is the second source of vegetable protein nationwide and in the State of Mexico the grain yield is 1.9 t ha^{-1}, lower than the national average of 2.5 t ha^{-1} (SAGARPA, 2022). Therefore, it is necessary to improve its yield with sustainable fertilization alternatives. The objectives of this work were the partial characterization of biosolids from the dairy, malt, soap and paper industries, determination of their effect in different ratios of biosolid:soil in the growth and production of biomass of *Vicia faba* seedlings.

Materials and methods

Biosolids

Samples of each biosolid from the dairy, malt, soap and paper industries were collected in mounds of approximately 6 m^3, deposited the previous day in a plot of agricultural use for incorporation into the soil. The plot is located in the municipality of Santa Ana Nextlalpan, State of Mexico (19° 40’ 50” north latitude, 99° 07’ 56” west longitude), with 2 235 m altitude. The average annual rainfall of the region is 600 mm distributed from April to September with more than 80% and a dry season from October to March, the average annual temperature is 14.1 °C with a minimum of 2.3 and a maximum of 31 °C, the soil is of lacustrine origin with predominantly alkaline pH, because it is located in the vicinity of what was the former lake of Xaltocan (Velasco, 2010).

Before their incorporation into the soil, by means of the quartering method, a sample composed of 15 kg of each biosolid, which was deposited in polyethylene bags, and a sample of 10 g of each one in sterile containers for microbiological analyses, were obtained from each mound. Each biosolid underwent a microbiological analysis that consisted of quantifying the most probable number (MPN) of fecal coliforms, *Salmonella* spp., and determining helminth eggs. Soil samples without biosolid (control) were collected in a plot 300 m away from the plot with biosolids.

The soil and biosolid samples were subjected to digestion with nitric and sulfuric acid, to subsequently quantify the concentration (mg kg^{-1}) on a dry basis of the heavy metals of copper (Cu), chromium (Cr), cadmium (Cd), zinc (Zn), nickel (Ni), lead (Pb), mercury (Hg) and arsenic (As), by means of an atomic absorption spectrophotometer (SavantAA, GBC Scientific Equipment, USA). The standard was a mixture of trace elements at 1000 ppm (SCP Science). All of the above was carried out in accordance with Mexican standards (SEMARNAT, 2002). In addition, the pH and percentage of organic matter (OM) were determined using the method of Walkley and Black (SEMARNAT, 2000).

Biosolid-soil mixture

Biosolid-soil mixtures weighing 15 kg of each of the four biosolids from the dairy, malt, soap and paper industries were carried out, in the ratios of 20:80, maximum ratio used by González-Flores *et al*. (2017) in corn (*Zea mays* L.); that is, 20% biosolids with 80% soil, as well as biosolid:soil mixtures 40:60 and 60:40. Also, a mixture was made with the four biosolids in the ratio 25:25:25:25 and a control sample (soil without biosolids).

Samples of 1.5 kg of each mixture and of the control were considered for laboratory analysis. In three repetitions of each mixture and the control, the pH was determined by means of a potentiometer (Hanna pH112), bulk density (g cm^{-3}), content (mg kg^{-1}) of nitrogen (micro-Kjeldahl) and available phosphorus (Olsen) on a dry basis, in addition, the percentage of organic matter (Walkley and Black) in each of the mixtures according to SEMARNAT (2000) for soil fertility analysis.

Experiment in the greenhouse

Fourteen substrates were used, which resulted from mixing in three different ratios each of the four biosolids with soil, the mixture in equal parts of the biosolids and the control substrate. For the experiment, seeds of *Vicia faba* var. ICAMEX-31 were used, the seeds were disinfected with a 0.6% sodium hypochlorite solution for 2 min and rinsed with distilled water several times, a pre-seed germination analysis was performed on the substrates to ensure the number of repetitions, the percentage of germination decreased in some biosolid-soil mixtures from 100 to 90%; nevertheless, at least one seedling was obtained on each substrate and in each of the four repetitions.

The experimental unit consisted of a pot 15 cm high and 20 cm in diameter containing 2 kg of substrate, three seeds were sown in each pot 10 cm away and 3 cm deep in the substrate, four repetitions per treatment were performed. The pots were placed in the greenhouse and humidity was maintained at field capacity at a temperature between 18 and 28 °C during the test period.

At 30 days after sowing, the whole seedlings were harvested, the roots were separated from the aerial part (leaves and stem) and the length (cm) of each section was measured, then they were added to obtain the total length of the seedlings. Subsequently, the stem and root of each plant were placed separately in an oven (Ríos Rocha®) at 80 °C for 3 days until they reached a constant weight, and the dry weight (g) was determined on an analytical balance. The total biomass of each seedling was obtained by adding the dry weights of the stem with leaves and root.

Statistical analysis

The experiment was established with a completely randomized design with a factorial arrangement; with the factor of biosolid:soil mixtures with four levels (dairy:soil, malt:soil, soap:soil and paper:soil), with the factor of biosolid:soil ratios in three levels (20:80, 40:60 and 60:40); the mixture of the four biosolids and soil. The data were subjected to analysis of variance, when statistically significant differences were found, the means were separated by the Duncan test ($p \leq 0.05$). In all cases, the software of the statistical analysis system (SAS) v.6.12 was used.

Results and discussion

Biosolid analysis

Fecal coliforms and *Salmonella* spp. were found in all biosolids. With regard to helminth eggs, the only biosolid that presented these parasites was that of the dairy industry. All biosolids showed values below the maximum permissible limits. Those from the malt, soap and paper industries were in class A (Table 1), are suitable for application in urban properties. That from the dairy industry had a class C profile, recommended for use only in forest soils without contact with people due to the number of pathogens present (SEMARNAT, 2002).

Table 1. Pathogens, parasites and classification of biosolids from the malt, soap, paper and dairy industries.

Biosolids/industry	Fecal coliforms (MPN g^{-1}) on a dry basis	Class	*Salmonella* spp. (MPN g^{-1}) on a dry basis	Class	Helminth eggs 2 g^{-1} TS	Class
Malt	3	A	2	A	0	A
Soap	93	A	3	A	0	A
Paper	733	A	2	A	0	A
Dairy	1 100	C	2	A	16	C

MPN= most probable number; TS= total solids. A= for urban use in contact with people during its application; C= forest use, only improvement without contact with people (SEMARNAT, 2002).

In order to characterize biosolids for agricultural use, organic matter (OM) and pH were determined according to Mexican standards (SEMARNAT, 2000). The biosolids from the dairy, malt, paper and soap industries, their OM contents were, respectively, 6.2%, 2.5%, 1.5% and soap 0.4%. The pH of biosolids from the dairy and paper industries was 7 and 7.3, respectively, that of the malt industry was 7.6, and the biosolid from the soap industry was 9.8 (Table 2).

Table 2. Organic matter (OM) and potential of hydrogen (pH) of biosolids from dairy, malt, soap and paper industries.

Biosolid	OM (%)	pH
Dairy	6.2♦♦♦♦♦±0.05	7 ±0.05
Malt	2.5♦♦♦ ±0.1	7.6 ±0
Soap	0.3♦ ±0.5	9.8 ±0.05
Paper	1.5♦♦ ±0.5	7.3 ±0.06

pH= strongly alkaline = +; moderately alkaline = ±; organic matter (OM), very low = ♦; low = ♦♦; medium = ♦♦♦; very high = ♦♦♦♦♦ (SEMARNAT, 2002).

These results show that biosolids from the malt and paper industries can be useful to improve soil characteristics, due to low concentrations of pathogens (fecal coliforms and *Salmonella* spp.) and they do not present parasites (helminth eggs). They also show a good percentage of OM and a pH suitable for plant growth. However, the biosolid from the dairy industry, even with good characteristics of OM and pH, needs a more rigorous stabilization process to remove parasites. In relation to the biosolid from the soap-manufacturing industry, its usefulness in agriculture should be reconsidered because Price *et al*. (2021) report that due to its characteristics, it has an effect on the decrease of beneficial soil microfauna.

The four biosolids included essential elements for plants such as nickel, copper and zinc, others such as chromium, cadmium and lead that are not necessary, in no case mercury and arsenic were detected. Copper was only found in biosolids from the dairy and soap industries (Table 3). All concentrations were below the maximum permissible limits indicated by the Mexican standard (SEMARNAT, 2002) and therefore useful to add them to the soil for agricultural purposes.

Table 3. Concentration of heavy metals in biosolids from the dairy, malt, soap and paper industries.

Biosolids/ Industry	mg kg^{-1} on a dry basis					
	Copper	Chromium	Cadmium	Zinc	Nickel	Lead
Dairy	1.9 ±0.07	1.1 ±0.06	0 ±0.01	7.2 ±0.03	1.2 ±0.03	1.3 ±0.01
Malt	BLD	0.8 ±0.07	0.2 ±0.05	4.9 ±0.04	2.3 ±0.08	2.4 ±0.04
Soap	0.7 ±0.06	1 ±0	0.6 ±0.02	4.3 ±0.03	3.8 ±0.03	5.1 ±0.05
Paper	BLD	2.4 ±0.05	0.3 ±0	8.6 ±0.01	3.4 ±0.01	5.7 ±0.02
Permissible limit	1500	1200	39	2800	420	300

Below the limit of detection (BLD). Limit of detection of (SavantAA, GBC Scientific) for Cu (0.05), Cr (0.17), Cd (0.009), Zn (0.4), Ni (0.04), Pb (0.06), Hg (1.6), As (0.04). n = 3; ± standard deviation.

Previous reports in Mexico of analysis of biosolids product of urban WWTPs show a concentration of heavy metals higher than those obtained in this work, although within the maximum permissible limits of the standard. In the state of Puebla, Mexico, González-Flores *et al*. (2017) reported 25.09 mg kg^{-1} copper and 163.99 mg kg^{-1} zinc. In Durango, Mexico, Flores-Félix *et al*. (2014) reported concentrations (mg kg^{-1}) as follows: 266 copper, 14.6 chromium, 899 zinc, 11.7 nickel and 65 lead, in addition to elements such as arsenic and mercury of 12.1 and 1.23 mg kg^{-1}, respectively.

Physicochemical analyses of biosolid mixtures

Soil, when adding the biosolid from the dairy industry to the soil, the pH decreased from 8.1 to 7.2 (Table 4). The same effect, but to a lesser degree, was observed when using malt (8.1 to 7.3) and paper (8.1 to 7.5) biosolids. The biosolid from the soap industry showed an opposite effect, increasing the pH of the soil from 8.1 to 8.8, in this case, to produce soap or detergents, the industries use hydroxides for saponification.

Table 4. Organic matter (OM), potential of hydrogen (pH), total nitrogen (N-total) and available phosphorus (P), in mixtures of biosolid with soil in different ratios and soil without biosolid (control).

Biosolid/Industry	Biosolid:soil mixtures	pH	OM (%)	N-Total (mg kg^{-1})	Available (P) (mg kg^{-1})
Dairy	20-80	7.3 ±0.1	4.8♦♦♦♦ ±0.1	56♦♦♦ ±0.2	30.8♦♦♦ ±0.1
Dairy	40-60	7.2 ±0.1	5.0♦♦♦♦ ±0.1	47♦♦♦ ±0.3	25.5♦♦♦ ±0.4
Dairy	60-40	7.2 ±0.2	6.7♦♦♦♦♦ ±0.2	63♦♦♦♦♦ ±0.1	46.5♦♦♦ ±0.2
Soap	20-80	8.8 ±0.1	1♦♦ ±0.2	11♦♦ ±0.1	17.6♦♦♦ ±0.2

Biosolid/Industry	Biosolid:soil mixtures	pH	OM (%)	N-Total	Available (P)
				(mg kg^{-1})	
Soap	40-60	8.8 ±0.2	1.3♦♦ ±0	13♦♦ ±0	21.5♦♦♦ ±0
Soap	60-40	8.9 ±0	1.3♦♦ ±0	13♦♦ ±0	22.6♦♦♦ ±0.1
Malt	20-80	7.2 ±0.2	3.0♦♦♦ ±0.1	17♦♦ ±0.3	29.6♦♦♦ ±0
Malt	40-60	7.4 ±0.1	3.4♦♦♦ ±0	29♦♦♦ ±0.2	30.2♦♦♦ ±0
Malt	60-40	7.3 ±0.3	3.4♦♦♦ ±0	32♦♦♦ ±0.3	38.1♦♦♦ ±0.3
Paper	20-80	7.4 ±0.1	1.3♦♦ ±0.2	18♦♦ ±0.2	6.8♦♦ ±0.1
Paper	40-60	7.5 ±0	2♦♦♦ ±0.1	19♦♦ ±0.1	7.6♦♦ ±0.1
Paper	60-40	7.6 ±0.1	2.0♦♦♦ ±0.1	21♦♦♦ ±0.1	9♦♦ ±0.1
Mixture	biosolids	6.9 ±0	1.4♦♦ ±0	12♦♦ ±0.1	28.8♦♦♦ ±0.1
Soil	(control)	8.1 ±0.1	1.2♦ ±0.2	7♦ ±0.3	5.1♦ ±0.3

(OM)= very low =♦; low =♦♦; medium =♦♦♦; high =♦♦♦♦; very high =♦♦♦♦♦. Available (P)= low =♦; medium =♦♦; high =♦♦♦; N-total= total nitrogen: very low =♦; low =♦♦; medium =♦♦♦; high =♦♦♦♦; very high =♦♦♦♦♦ (SERMARNAT, 2000). n= 3 ± standard deviation.

The soil samples had on average 1.2% OM, mixing the soil with some of the biosolids increased the OM of the mixtures, but in different amounts. Mixtures with biosolids from the dairy industry with soil had on average 5.5% OM, those from the malt industry with soil had on average 3.2% OM, those from the paper industry with soil had 1.8 OM and mixtures of biosolids from the soap industry with soil had 1.2% OM.

In the same order of mixtures, these provided nitrogen (N-total) and available phosphorus (P). On average, biosolid:soil mixtures of the dairy industry had 55 mg kg^{-1} of N-total and 34 mg kg^{-1} of available (P); those of the malt industry with soil had 26 mg kg^{-1} of N-total and 32 mg kg^{-1} of available (P), those of biosolids from the paper industry with soil had 19 mg kg^{-1} of N-total and 7.8 mg kg^{-1} of available (P), those of soap with soil had 12 mg kg^{-1} of N-total and 20 mg kg^{-1} of available (P). Finally, the mixture of the four biosolids had a pH of 6.9, 1.4% OM, 12 mg kg^{-1} of N-total and 28 mg kg^{-1} of available (P), according to the standard in Mexico (SEMARNAT, 2000).

Analysis of seedling growth and biomass

At 30 days after sowing, the analysis of variance (Table 5), revealed that the biosolid:soil mixtures of the four industries evaluated, as well as in the three different ratios, had highly significant effect differences ($p \leq 0.001$) on the biomass and length of *V. faba* seedlings, it also evidenced that there was no interaction between the mixtures and the ratios; that is, the effect of biosolids on soil was equal to the effect of ratios on both variables.

Table 5. Mean squares and statistical significance of biomass (g) and length (cm) of broad bean (*Vicia faba* L.) seedlings grown in biosolid:soil mixtures.

Source of variation	Degrees of freedom	Mean squares and significance	
		Total biomass	Longitude
Block	3	0.6 ns	265.2**
Biosolid:soil mixtures	5	1.2**	2 470.6**
Ratios	2	1.6**	260.1**
Mixture X Ratios	7	0.2 ns	96.8 ns
Error	38		
Total	55		
CV		22.1	28.3

ns= non-significant difference; **= highly significant difference ($p \leq 0.01$).

Figure 1 shows the average biomass and length of broad bean seedlings. Biosolids from the dairy and malt industries added to the soil achieved the greatest effect on biomass production 1.7 g and 1.6 g, respectively. Biosolids from the soap and paper industries also increased biomass, although to a lesser extent, 1.4 g, compared to soil without biosolid (1.1 g).

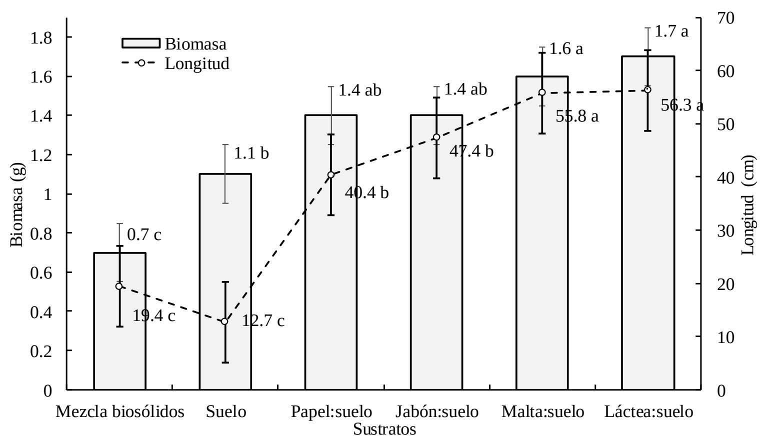

Figure 1. Average biomass and length of broad bean (*Vicia faba* L.) seedlings grown in soil without biosolids (control), biosolid mixtures and biosolid:soil mixtures. Means with the same letter are statistically equal (Duncan, $p \leq 0.05$) in each variable.

This same effect was observed in the length of seedlings with biosolids from the dairy and malt industries, which produced an increase three times more their length 56.3 and 55.8 cm, compared to soil without biosolid 12.7 cm and the length increased with soap and paper up to 40 and 47 cm. With these results it is inferred that the biosolids from the dairy, malt, soap and paper industries individually modified the characteristics of the soil and as a consequence, a highly significant increase in the biomass and length of *V. faba* seedlings was detected. In the case of seedling root biomass, no significant effect was observed on biomass and its length when adding biosolids to the soil, similar to what was reported by Vela *et al*. (2018).

Seedlings that grew in biosolid-soil mixtures of the soap and paper industries showed lower biomass than those that grew in malt and dairy industry mixtures but higher biomass than seedlings that grew in soil without biosolid. From this observation, it follows that the low amount of organic matter and the alkaline pH decreased the adequate conditions of growth and nutrition, which limited the increase in biomass and length of the seedlings, even though *V. faba* has the capacity to grow in unfavorable environments such as pH and salt stress (Belachew and Stoddard, 2017).

In the biosolid:soil mixtures 20:80, the average biomass was 8.8 g, in 40:60 it was 10.4 g and in 60:40 it was 13.4 g; that is, a gradual increase in biomass was observed as a result of the increase in the amount of biosolid that was mixed with soil (Figure 2). Therefore, it follows that the increase in the amount of biosolids in the soil gradually improves soil characteristics and manifests itself in highly significant differences for the biomass and length of *V. faba* seedlings. This is consistent with what was reported by González-Flores *et al*. (2017), who obtained an increase in the height of adult corn plants from 34 to 114 cm and an increase in biomass from 9 to 125 g, by adding biosolids from an urban WWTP to the soil.

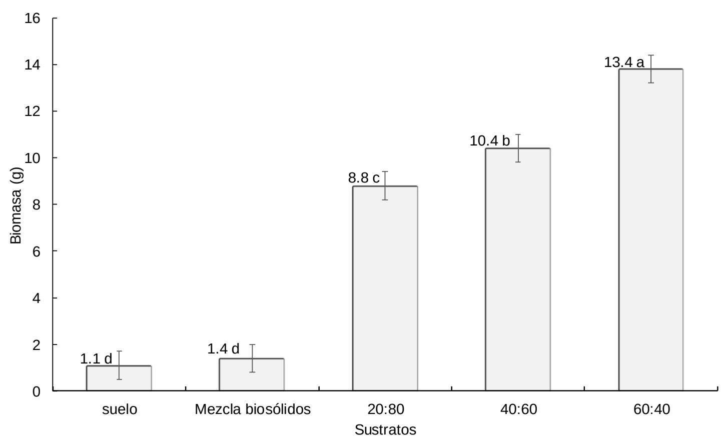

Figure 2. Accumulated biomass of broad bean (*V. faba* L.) seedlings, grown for 30 days from sowing in soil without biosolid, biosolid mixtures, biosolids:soil mixtures in ratios 20:80, 40:60, and 60:40. Means with the same letter are statistically equal (Duncan, $p \leq 0.05$).

However, in Figures 1 and 2, it is observed that the seedlings that were in the substrate that was the mixture of the four biosolids, their length was 19.4 cm which represents only 15.3% of the length in the biosolid from the dairy industry with 56.3 cm, and less accumulation of biomass of 0.7 g which represents 136.3% less than the seedlings in the mixture 80% of dairy biosolids and 20% of soil. This can be explained by the fact that it had a pH of 6.9, minimum concentration of OM and N-total and large amount of available (P), in addition to having a sticky consistency and poor drainage; that is, an inappropriate mixture so that nutrients were available for seedlings, so in the field it should be avoided.

When considering the recommendation of fertilization of *V. faba*, in the study area (INIFAP, 2017), the four biosolids contribute in a very variable way with the amount of nitrogen and phosphorus to cover the needs of the crop. With the exception of nitrogen provided by the biosolid from the dairy industry, the other biosolids provide less than half the nitrogen and phosphorus needed for the crop. This can be corrected if the necessary element or elements are added in a sufficient dose of biosolid to the soil (Sandaña *et al*., 2018).

Interestingly, our results show that the biosolids that come from the WWTPs of the studied industries located in Mexico have a concentration of heavy metals up to ten times lower (Bedoya-Urrego *et al*., 2013; Flores-Félix *et al*., 2014; González-Flores *et al*., 2017), minimal amount of pathogenic microorganisms (Flemming *et al*., 2017; Hernández *et al*., 2017) and do not include metals such as arsenic and mercury, important differences with the biosolids from urban WWTPs, which indicates that some biosolids of industrial origin are favorable for use in agriculture.

Conclusions

Biosolids from the dairy, malt, paper and soap industries showed differences in potential of hydrogen, percentage of organic matter, concentration of heavy metals, total nitrogen and available phosphorus, and microbiological differences. Mixing the soil with biosolids from the dairy, malt and paper industries significantly improved the previous characteristics, decreased the pH from 8.1 to 7.4, increased the percentage of OM from 1.2 to 3.5, as well as total nitrogen from 7 to 35 mg kg^{-1} and available phosphorus from 5 to 25 mg kg^{-1}.

In contrast, the biosolid from the soap industry increased the pH from 8.1 to 8.8, did not modify the OM, only contributed 5 mg kg^{-1} of total nitrogen and contributed an increase in available phosphorus to 20 mg kg^{-1}. In biosolids:soil mixtures, at 30 days the seedlings of *Vicia faba* significantly increased the yield of biomass from 1.1 to 13.7 g, which corresponds to 1 145% more, and the length from 12.7 to 56.3 cm, which corresponds to 343%.

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