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Effect of microbial consortia on maize yield in Chiapas, Mexico

Efecto de consorcios microbianos en el rendimiento de maíz en Chiapas, México

Efeito de consórcios microbianos na produção de milho em Chiapas, México

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Abstract

The use of microbial consortia as biofertilizers allows improving crop productivity and the quality of agricultural soils, by incorporating microorganisms that facilitate the availability of nutrients for plants and change the soil physicochemical conditions. In order to evaluate the effect of microbial consortia on maize yield, inoculums from different environments were used in the maize crop of Villa Corzo and Villaflores municipalities, Chiapas. Six treatments with different consortia were defined: three from agricultural plots and three from mountains “La Frailescana”, “Cerro Nambiyugua” and Biosphere Reserve “La Sepultura”-, and one control, under a randomized block experimental design with four replications. The application of the microbial consortia was made directly to the soil at 20, 40 and 60 days after sowing of the crop. The effect of the consortia on maize yield was determined using a design with nested effects in which the effects of the origin of the microbial consortia were controlled, and the nested treatments in the environments. The association between the physicochemical components of the consortia and the culture yield was evaluated using Pearson’s correlation ($p \leq 0.05$). Only the mountain consortiums from “La Sepultura” were the ones that showed maize yield increase. However, both the mountain and plot consortiums have the potential to be used as biofertilizers in maize cultivation, when combined with another source of organic fertilization, such as poultry manure.

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Resumen

El uso de consorcios microbianos como biofertilizantes permite mejorar la productividad de los cultivos y la calidad de los suelos agrícolas, al incorporar microorganismos que facilitan la disponibilidad de nutrientes para las plantas y cambian las condiciones fisicoquímicas edáficas. Con el objetivo de evaluar el efecto de consorcios microbianos sobre el rendimiento del maíz, se utilizaron inóculos de diferentes ambientes en el cultivo de maíz de los municipios Villa Corzo y Villaflores, Chiapas. Se definieron seis tratamientos con diferentes consorcios; tres de parcelas agrícolas y tres de montaña “La Frailescana”, “Cerro Nambiyugua” y Reserva de la Biosfera “La Sepultura”, y un control, bajo un diseño experimental de bloques al azar con cuatro réplicas. La aplicación de los consorcios microbianos se realizó directamente al suelo a los 20, 40 y 60 días después de siembra del cultivo. Se determinó el efecto de los consorcios en el rendimiento de maíz mediante un diseño con efectos anidados en el que se controlaron los efectos del origen de los consorcios microbianos, y los tratamientos anidados en los ambientes. Se evaluó la asociación entre los componentes fisicoquímicos de los consorcios y el rendimiento del cultivo mediante la correlación de Pearson ($p \leq 0,05$). Sólo los consorcios de montaña provenientes de “La Sepultura”, fueron los que mostraron aumento en el rendimiento de maíz. No obstante, tanto los consorcios de montaña como los de parcela, presentan potencial para ser utilizados como biofertilizantes en el cultivo de maíz cuando son combinados con otra fuente de fertilización orgánica, como la pollinaza.

Palabras clave: consorcios microbianos, componentes fisicoquímicos, *Zea mays* L., rendimiento.

Resumo

A utilização de consórcios microbianos como biofertilizantes permite melhorar a produtividade das culturas e a qualidade dos solos agrícolas, por meio da incorporação de microrganismos que facilitam a disponibilidade de nutrientes para as plantas e alteram as condições fisicoquímicas do solo. Para avaliar o efeito dos consórcios microbianos na produção de milho, foram utilizados inóculos de diferentes ambientes na cultura do milho dos municípios de Villa Corzo e Villaflores, Chiapas. Seis tratamentos com diferentes consórcios foram definidos; três de parcelas agrícolas e três de montanha “La Frailescana”, “Cerro Nambiyugua” e Reserva da Biosfera “La Sepultura”, e uma testemunha, em delineamento experimental em blocos casualizados com quatro repetições. A aplicação dos consórcios microbianos foi feita diretamente no solo aos 20, 40 e 60 dias após a sementeira da lavoura. O efeito dos consórcios sobre a produtividade do milho foi determinado por meio de um delineamento com efeitos aninhados em que foram controlados os efeitos da origem dos consórcios microbianos e os tratamentos aninhados nos ambientes. A associação entre os componentes fisicoquímicos dos consórcios e o rendimento da cultura foi avaliada pela correlação de Pearson ($p \leq 0,05$). Somente os consórcios de montanha de “La Sepultura” foram os que melhoraram o rendimento do milho. No entanto, tanto o consórcio de montanha quanto o de talhão têm potencial para serem utilizados como biofertilizantes na cultura do milho, quando combinados com outra fonte de adubação orgânica, como a cama de frango.

Palavras-chave: consórcios microbianos, componentes fisicoquímicos, *Zea mays* L., rendimento.

Introduction

Maize (*Zea mays* L.) is the most important staple crop for human and animal consumption in Mexico, particularly in the Frailesca region in Chiapas. In 2020, the municipalities of Villa Corzo and Villaflores contributed more than 14,600 tons of the grain, which represented more than 40 % of the region’s production (Servicio de Información Agroalimentaria y Pesquera Estados Unidos Mexicanos [SIAP], 2020), but since 2001 there has been a downward trend in the average annual planting area and yield, due to the indiscriminate use of agrochemicals. The prolonged use of synthetic fertilizers and pesticides affects soil microbial communities, causing an imbalance of nutrients and the functional and structural properties of the soil. This is reflected in weak crops, demanding higher amounts of synthetic products in successive crop cycles (Tripathi *et al*., 2020).

In 2020, in the Frailesca region, 31 % of what was sown in 2001 was sown (Guevara *et al*., 2021) due to a decrease in the productivity of agricultural soils (López *et al*., 2018). As a consequence, soils with generalized acidity and practically no organic matter are found in the region (Martínez-Aguilar *et al*., 2020). Given this situation, the search for alternatives or complements to chemical fertilization is required, which in turn allow the use of more sustainable agricultural practices.

The use of microbial consortia represents an alternative to solve these fertility problems. These comprise a diversity of microorganisms, which intervene in the functioning of any ecosystem, since they facilitate the efficient use of water and soil nutrients by plants and allow some positive effects in different agricultural uses (Rosabal-Ayan *et al*., 2021). Several studies have shown that the use of consortia improves the morphological, physiological and yield characteristics of different crops (Shaheen *et al*., 2017; Ayvar *et al*., 2020), and improve the physicochemical structure of soils (Martínez-Aguilar *et al*., 2020).

The benefits obtained with consortia rather than by the use of individual microorganisms are evidenced by their taxonomic and functional diversity, as multiple relationships between them are obtained (Castro *et al*., 2015). Various factors, such as edaphic and vegetation conditions, influence this diversity. Consortia are formed by microorganisms adapted to the conditions where they developed; this is manifested by variations in their metabolism or even in their genome (Tripathi *et al*., 2020).

In this context, the use of microbial consortia in staple crops such as corn allows improving soil biology and fertility, as well as the availability of essential elements for plants (Castro and González, 2021). In addition, they allow maintaining production, sustaining productivity over time and saving on the purchase of production inputs. The objective of this study was to evaluate the effect of microbial consortia from different environments as biofertilizers on maize yield in Chiapas, Mexico.

Materials and Methods

Characteristics of the study area

The study was conducted in Villa Corzo and Villaflores; two of the six municipalities of the Frailesca region. This region is located between the Sierra del Sur and the Central Depression of Chiapas, where semi-warm humid -A(C)(w2)- and warm sub-humid -AW2-

climates predominate, with rainfall between 1,200 and 2,500 mm in summer. The vegetation found is composed of mountain mesophyll forest, pine and oak forest and agricultural areas (Comité Estatal de Información Estadística y Geografía [CEIEG], 2020), where lithosols, regosols, acrisols and luvisols soils predominate (López *et al*., 2018).

The three experimental plots were located, one in Villa Corzo, km 7.7 of the Villa Corzo-Villaflores road (16°21'43.12" LN and 93°15'51.36" LO, 567 m.a.s.l.) and two in Villaflores, locality Dr. Domingo Chanona (16°20'18.4" LN and 93°26'48.4"LO, 724 m.a.s.l.), whose soil characteristics are presented in table 1.

Soil analyses were interpreted according to the Mexican Official Standard NOM-021-RECNAT-2000 (Secretaría de Medio Ambiente y Recursos Naturales, 2002).

Experimental design and analysis

The experiment was established in the spring-summer (PV) cycle of 2021, with Pioneer® P4082w hybrid corn and consisted of seven treatments (table 2) under a randomized block experimental design (subplots) with four replications.

To evaluate the effect of microbial consortia on corn yield, a nested effects design was used in which the effects of the origin of the microbial consortia (table 2), and the effect of the treatments (table 2) and the treatments nested in the environments, with 21 levels, were controlled.

For comparison of yield means, Tukey's test ($p \leq 0.05$) and Pearson's correlation ($p \leq 0.05$) were used to analyze the association between physicochemical components of microbial consortia and corn yield. Minitab statistical software (Minitab® LLC, 2021) was used for statistical analysis.

Table 1. Physicochemical characteristics of the soil in the three study plots, before establishing the experiments.

		Plot 1		Plot 2		Plot 3	
Deter.	Units	Ind.	Criteria	Ind.	Criteria	Ind.	Criteria
pH	1:2 agua	5.81	MA	5.51	MA	5.92	MA
MO	%	1.20	Low	2.72	Medium	1.16	Low
P-Bray	ppm	71.80	High	52.70	High	25.3	Medium
K^+	ppm	58.50	Very Low	86.70	Low	47.2	Very Low
Ca^{2+}	ppm	432	Medium	527	Medium	1109	High
Mg^{2+}	ppm	64.30	Low	75.10	Low	182.00	High
Na^+	ppm	33.40	Medium	16.90	Low	18.50	Low
Fe^{3+}	ppm	60.20	Adequate	48.70	Adequate	47.00	Adequate
Zn^{2+}	ppm	0.39	Poor	0.23	Poor	0.15	Poor
Mn^{2+}	ppm	25.30	Adequate	21.10	Adequate	18.10	Adequate
Cu^{2+}	ppm	0.29	Adequate	0.29	Adequate	0.32	Adequate
B	ppm	0.10	Very Low	0.10	Very Low	0.11	Very Low
Al^{3+}	ppm	103.00	Medium	36.90	MB	36.7	MB
S	ppm	2.93	Very Low	1.46	Very Low	1.46	Very low
$N\text{-}NO_3$	ppm	9.05	Very low	14.70	Low	6.53	Very low
Da	$g.cm^{-3}$	1.26	No problem	1.44	No problem	1.32	No problem
EC	$dS.m^{-1}$	0.14	Very low	0.18	Very low	0.09	Very low
CEC	$cmol+kg^{-1}$	4.62	Very low	4.09	Very low	7.73	Low
Texture		Loamy sand		Loamy sand		Loamy sand	

Plot 1: plot with chemical fertilization+poultry manure; Plot 2: plot with chemical fertilization; Plot 3: plot with chemical fertilization+foliar fertilization; Deter: determinations; Ind. indicators; OM: organic matter; Da: bulk density; EC: electrical conductivity; CEC: cation exchange capacity; MA: moderately acid; MB: moderately low. Results from the Fertilab® laboratory, Celaya, Guanajuato, Mexico.

Table 2. Treatments of microbial consortia collected from different environments.

Environments	Source	Treatment
None	Control	T0
Plot Microbial Consortia (MP)	Plot with chemical + foliar fertilization	T1
	Plot with chemical fertilization	T2
	Plot with chemical fertilization + poultry manure	T3
Microbial Mountain Consortia (MM)	Cerro Nambiyugua	T4
	La Frailescana	T5
	La Sepultura	T6

Crop management

The experimental areas received the conventional agronomic management carried out by the producer to the rest of the plot (table 3). Four applications of chemical fertilizers were made to the soil, and only one application of organic matter.

Table 3. Agronomic management of the plots where the experimental areas were established.

Plot	Planting area (ha)	Sowing density ($plants.ha^{-1}$)	Fertilizer source ($kg.ha^{-1}$)
1	2	60,000	600 kg urea+240 kg poultry manure
2	7	60,000	900 kg urea
3	1	53,000	80 kg urea+1 L foliar (Bayfolan®)

Preparation of microbial consortia

The leaf litter sample was collected from 0-10 cm depth and soil from 5-20 cm depth, for a total of 25 kg of composite sample, per study area (Suchini, 2012). Sampling was conducted during the months of January to April 2021, in three plots of producers who grow corn conventionally (Plot with chemical fertilization+poultry manure; Plot with chemical fertilization; Plot of Villa Corzo) and three sites of natural protected areas (Protected Area "La Frailescana"; Biosphere Reserve "La Sepultura" and Cerro Nambiyugua).

The consortia were reproduced in solid state and activated in liquid state, both processes under anaerobic conditions for 30 days (Suchini, 2012). Both processes were carried out in an artisanal manner at room temperature, in 19 L containers. For reproduction (solid), 25 kg of leaf litter, 23 kg of corn flour, 2 kg of molasses and 0.5 L of water were used per container. For activation, 800 g of the solid, 200 g of molasses and 18 L of water were used. The physicochemical characteristics presented in the liquid microbial consortia are shown in table 4.

Table 4. Physicochemical characteristics of the liquid microbial consortia.

		Microbial consortia					
Determination	Units	T1	T2	T3	T4	T5	T6
pH		4.40	4.18	4.44	4.30	5.09	4.18
EC	$dS.m^{-1}$	2.80	2.70	3.00	3.00	2.80	3.50
Nitrogen	%	0.08	0.07	0.07	0.09	0.06	0.12
Phosphorus	%	0.0015	0.0015	0.0017	0.0016	0.0011	0.003
Potassium	%	0.05	0.04	0.04	0.04	0.04	0.07
Calcium	%	0.02	0.01	0.02	0.02	0.03	0.03
Magnesium	%	0.01	0.01	0.01	0.01	0.01	0.01
Sodium	%	0.005	0.004	0.005	0.004	0.005	0.004
Sulfur	%	0.02	0.01	0.02	0.02	0.006	0.03
Iron	ppm	87.80	74.90	116.00	110.00	13.60	11.60
Copper	ppm	0.002	0.004	0.001	0.003	0.003	0.002
Manganese	ppm	5.97	6.02	7.15	6.94	11.1	5.42
Zinc	ppm	2.99	2.86	3.20	3.00	2.74	3.17
Boron	ppm	0.32	0.15	0.17	0.20	0.19	0.22
Moisture	%	99.50	99.30	99.40	99.10	99.50	99.40
OM	%	0.31	0.60	0.40	0.75	0.38	0.40
Ash	%	0.17	0.15	0.23	0.15	0.16	0.24
OC	%	0.18	0.35	0.23	0.44	0.22	0.23
C/N ratio		2.23	4.69	3.21	4.69	3.82	1.94

T: treatment; C: carbon; EC: electrical conductivity; OM: organic matter; OC: organic carbon. Results from the Fertilab® laboratory, Celaya, Guanajuato, Mexico.

The consortia were applied directly to the soil at the foot of the plant at 20, 40 and 60 days after planting (DDS), at a rate of 10 mL per plant.

Variables evaluated

For the evaluation of grain yield, 12 ears per experimental unit were randomly selected and the total grain mass per ear was determined at 12 % moisture (Centro Internacional de Mejoramiento de Maíz y Trigo [CIMMYT], 2012).

Results and discussion

The results showed that the effect of microbial consortia on maize yield may be influenced by the environmental characteristics of the inoculum origin, because the response was different in each experimental plot (table 5).

Table 5. Effect of microbial consortia on corn yield in each of the three plots.

	Yield ($t.ha^{-1}$) / Environment (plot)			N	EE	CV	Significance
Treatments	1	2	3				
T0	9.50^{b}	9.23^{bc}	8.36^{cde}				
T1	10.67^{a}	9.42^{b}	7.01^{f}				
T2	10.89^{a}	9.18^{b}	7.02^{f}				
T3	10.59^{a}	8.96^{bcd}	7.54^{f}	48	0.18	14%	p<0.001
T4	10.84^{a}	8.99^{bcd}	7.26^{f}				
T5	10.85^{a}	9.18^{b}	7.07^{f}				
T6	11.05^{a}	8.34^{de}	7.71^{ef}				

Environments-Plot 1: plot with chemical fertilization+poultry manure; Plot 2: plot with chemical fertilization; Plot 3: plot with chemical fertilization+poultry manure. T0: Control without microbial consortia; plot microorganisms (MP) T1: Plot with chemical + foliar fertilization, T2: with chemical fertilization, T3: chemical fertilization + poultry manure; mountain microorganisms: T4: Cerro Nambiyugua, T5: La Frailescana, T6: La Sepultura. N: sample size; SE: standard error; CV: coefficient of variation. Means that do not share a letter are significantly different when applying Tukey's test with 95% confidence.

The nested effects model showed that the highest yield of the three environments was obtained in T6 of plot 1 (La Sepultura consortia in the plot with chemical fertilization+poultry manure). These results could be related to the mountain environmental conditions that characterize the area of La Sepultura and, above all, to a low anthropic influence, which allows the accumulation of organic material (leaf litter), which in turn favors the creation of environmental conditions of a physical, chemical and biological nature that facilitate the stable development of microbial populations.

Castro and González (2021) report that the quality of the inoculum determines the quality of the biofertilizer, being the forests near the agricultural production sites the best source of collection, since they present microorganisms adapted to the area. However, it is noteworthy that the treatments of consortia from the agricultural plots presented a corn yield similar to those obtained with the mountain consortia treatments (table 5); which could suggest the previous adaptation of the microorganisms to these conditions. That is, the consortia obtained from plots are able to establish and increase their populations in the rhizosphere, manifest their potential as biostimulants in the maize crop, and act as promoters of new beneficial microbial populations.

This result could contribute with an important antecedent to the study and use of microbial consortia as biofertilizers, due to the fact that several reports recommend obtaining them from mountains and places with little anthropogenic activity (Castro *et al*., 2015). Other research defends the hypothesis that in soils subjected to some type of stress, there are microorganisms with tolerance characteristics that can be isolated and used due to their high level of adaptation to these conditions (Namasivayam, 2010; Shaheen *et al*., 2017).

However, the agricultural scenarios of the Frailesca region subjected to constant natural and human weathering processes cause abrupt changes in soils, which slows this adaptation process and affects microbial populations (Alarcón-Camacho *et al*., 2019). This element strengthens the idea of using microorganisms from the mountains, because they enhance microbiological processes and improve the health of productive agroecosystems (Castro and González, 2021).

Regarding the analysis by environments (table 4), in plot 1, where poultry manure is used as fertilizer, the highest grain yields were obtained, regardless of the origin of the consortia. All treatments were statistically superior ($P<0.05$) to the control, from 1.09 $t.ha^{-1}$ (T3) to 1.54 $t.ha^{-1}$ (T6); there were no differences ($P<0.05$) between plots 2 and 3 with respect to the control. Córdova-Bautista *et al*. (2009) presented similar results when using poultry manure as a substrate for the development of consortia, since it constitutes a reserve of organic carbon and contains N, P and K^+. In this way, the consortia act efficiently on plant nutrition, soil chemical properties and, in turn, increase the dynamics of beneficial microorganisms (Ramírez-Gerardo *et al*., 2021).

Shaheen *et al*. (2017), evaluated the co-application of different organic manures and chemical fertilizers with and without efficient microorganisms (EM) on spinach growth, and observed an increase of micro and macronutrients such as Zn^{2+}, Fe^{3+} and Cu^{2+}, K^+ and N, when they applied EM+poultry manure (5 $t.ha^{-1}$), compared to treatments without microorganisms and the controls. This treatment even exceeded total N levels with respect to ME+chemical fertilization (NPK; 100:40:56 $kg.ha^{-1}$).

The analysis of the relationship between chemical properties of the consortia and yield showed a positive and significant correlation ($P<0.05$) in plot 1 and highly significant in plot 3 with the variables EC, N, P and K^+ (table 6).

For corn cultivation, it has been determined that the adequate EC range is 1.5 to 2.5 $dS.m^{-1}$ in soils (Fertilab, 2015), and it decreases when the EC of the substrate exceeds 3.7 $dS.m^{-1}$ (Hoffman *et al*., 1983). The results obtained in this research show that soil EC in plots 1, 2 and 3 is low (table 1), which is evidence that there are no salinity problems.

The microbial consortia experienced a slight increase in EC, which varied between 2.7 and 3.5 $dS.m^{-1}$ (table 6), values considered acceptable for these microbial populations (Gamboa *et al*., 2020), which in turn did not contribute to an increase in salts in the soil or damage to the plants, due to the low doses and application frequencies used. These results match with those obtained by Millán *et al*. (2018), who assert that the EC in aqueous organic fertilizers is generally higher than in solids. Likewise, they suggest that substrates with an EC between 4 and 12$dS.m^{-1}$can be incorporated directly into the soil, since they improve its conditions and create suitable niches for microorganisms and their development.

A negative correlation was obtained in plot 2 (table 6). In this plot, a higher amount of fertilization (urea, 900 $kg.ha^{-1}$) was applied (table 2). The producer exceeded (270 %) the urea dose recommended by Fertilab® throughout the crop cycle. However, in plot 1, the producer exceeded the amount of urea to be used by 35 %, while in plot 3 only 52 % of the recommended dose was used. Zhang *et al*. (2021), pointed out that chemical fertilization (125 % N), in the short term, drastically influenced the diversity and stability of the edaphic microbiota, when compared to another plot in which organic fertilization (100 % N) was used.

Zengqiang *et al*. (2019), demonstrated that chemical nitrogen fertilizers can induce a rapid short-term response and change soil microbial and biochemical properties, which "overrides" the effect of microbial consortia. Although urea has a high N content (46 %), it volatilizes rapidly, with a loss of up to 30 $kg.ha^{-1}$ of N when broadcast applied, which is equivalent to 25 % of the fertilizer added (Morales *et al*., 2019). So, the excessive use of urea affects microorganisms and their efficiency in the efficient use of chemical fertilization (Ayvar *et al*., 2020) and increases production costs (López *et al*., 2018), with a loss of 25 % of the fertilizer cost.

The positive correlation between corn yield and the percentage of N in plots 1 and 3 (table 6), shows that there is potential in the

Table 6. Linear relationship between physicochemical components of the consortia and maize yield by Pearson correlation.

Treat.	Yield ($t.ha^{-1}$) / Plot			EC ($dS.m^{-1}$)	Content (%)		
	1	2	3		Nitrogen	Phosforus	Potassium
T1	10.67	9.42	7.01	2.8	0.08	0.0015	0.05
T2	10.89	9.18	7.02	2.7	0.07	0.0015	0.04
T3	10.59	8.96	7.54	3.0	0.07	0.0017	0.04
T4	10.84	8.99	7.26	3.0	0.09	0.0016	0.04
T5	10.85	9.18	7.07	2.8	0.06	0.0011	0.04
T6	11.05	8.34	7.71	3.5	0.12	0.0033	0.07
CC Yield, plot 1				**0.4965***	**0.5964***	**0.5804***	**0.5642***
CC Yield, plot 2				**-0.9479****	**-0.8037****	**-0.9087****	**-0.7207****
CC Yield, plot 3				**0.9101****	**0.6751****	**0.8149****	**0.5961****

Treat. treatments; Plot 1: plot with chemical fertilization+poultry manure; Plot 2: plot with chemical fertilization; Plot 3: plot with chemical fertilization+foliar fertilization; CC: Pearson correlation coefficient; EC: electrical conductivity. *significant differences; **highly significant differences.

consortia as biofertilizers. Córdova-Bautista *et al*. (2009) used various substrates and their combinations in the growth of *Azospirillum* and *Azotobacter* collected in banana (*Musa* AAA Simmonds) soils for the formulation of biofertilizers. In 15 treatments used, high total N contents were obtained, but this element was higher in the organic substrates, mainly in the combination of soil and poultry manure, which also favored the density of *Azospirillum*.

Nitrogen is the main element for vegetative development and the one of greatest care at the time of chemical fertilization, since its loss is very common by leaching (Álvarez-Sánchez *et al*., 2014). In agreement, Zhang *et al*. (2021) report that organic fertilizers decrease nitrate loss by leaching and the presence of microorganisms prevents N loss.

Microbial consortia presented P and K^+ (table 4) and the correlation showed that there is some influence of microbial consortia on maize yield in plots 1 and 3 (table 6), so it is required to deepen these studies, considering that K^+ is a primary element in fruit ripening and P promotes tissue resistance (Cabos-Sánchez *et al*., 2019).

Castro and González (2021) demonstrated that the populations of lactobacilli, yeasts, P solubilizers and N fixers vary due to factors such as aeration, substrates and activation time, so that the levels of nutrients that can be incorporated into the plants and soil also vary. In this sense, the incorporation of microbial consortia regulates the physical and chemical properties of the system, mainly in EC, percentage of N, P and K^+. Namasivayam (2010) also reported that fertility is improved after the application of beneficial microorganisms, due to the rapid mineralization of organic compounds by increasing the levels of N, P and K^+ in the soil, making them available to the plant.

A great taxonomic and functional diversity of microbial communities is found in mountain microorganisms, in which versatile primary and secondary metabolisms are identified. This allows certain microorganisms to expand their range of adaptive elasticity, and therefore, modify their metabolisms to efficiently adapt to other environments in small lapses of time (Pandey and Yarzábal, 2018), which coincides with the results of the present research where the consortia of La Sepultura (T6) were the ones that showed better performance in the maize crop. Contrary to the adapted microorganisms, which have certain metabolic specialization, which does not allow expanding their potential in the interaction with plants, in this case, maize (Wang *et al*., 2018).

Conclusions

The use of microbial consortia from the Biosphere Reserve "La Sepultura" (T6) increased corn yield. The microbial consortia obtained from mountain and agricultural plots have potential for use as biofertilizers in corn cultivation, when they are accompanied by organic fertilization sources such as poultry manure, since it allows strengthening their effects in the short term.

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