Colegio de Postgraduados

Effect of halophilic bacteria as a sustainable strategy to reduce soil salinity in raspberry (*Rubus idaeus*) cultivation

Ramirez-Ramirez-Faustino[1]; Ramirez-Ramirez, María[1]; Peralta Nava, Jorge[1]; Amador-Camacho, Osvaldo[1]; Gama-Moreno, Luis[1]; Murguia-Vadillo, Christian[1]; Diaz-Garcia, Silvia[1]; Tapia-Campos, Ernesto[2]

[1] Tecnológico Nacional de México Tlajomulco Campus, Jal., Departamento de Ciencias Agropecuarias. Laboratorio de Planta Piloto. Km. 10 carretera Tlajomulco-San Miguel Cuyutlán. Tlajomulco de Zúñiga, Jalisco. C.P. 45640.

[2] Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco, A.C. (CIATEJ). Av. Normalistas 800 Colinas de La Normal 44270 Guadalajara, Jal. México

* Correspondence: maria.rr@tlajomulco.tecnm.mx

ABSTRACT

The raspberry (*Rubus idaeus*) is the main crop of Jocotepec municipality, being dedicated to protected agriculture, chemical fertilization causes soil salinization, which results in the crop's not developing its maximum potential. To evaluate the effect of halophilic bacteria as a sustainable strategy to reduce soil salinity in raspberry cultivation, the present research assessed a production unit located at the Jocotepec Municipality, Jalisco state, Mexico. The evaluated halophilic bacteria treatments were doses of 7 L/ha, 5 L/ha, and 3 L/ha plus an absolute control, on three intervals - of 15 days application in saturated furrow irrigation. The assessed soil variables were pH and EC; in the plants: plant height, number of loaders, stem diameter, and number of boxes produced. The evaluation of the effect of halophilic bacteria on the quantitative variables was carried out with an ANOVA in the SAS® Studio 2023 software, in a completely randomized block design, after complying with normality of residuals and homogeneity of variances assumptions associated with the Tukey means comparison statistical test ($p<0.05$). The results show a direct effect of the halophilic bacteria dosage on the soil EC decrease, from 2.35 ds/m (Control) to 1.81 ds/m (Dose 5 L/ha), values equivalent to light salinity (<2 ds/m). Regarding the agronomic variables, improvements were evident in the evaluated characteristics.

Keywords: Halophilic bacteria, salinity, electrical conductivity

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INTRODUCTION

In Mexico, from a socioeconomic point of view, raspberry cultivation is important because of the employment and foreign exchange it generates, because of its exports as a fresh, frozen, and processed product for consumption. The main producing states are Jalisco, Michoacan, Baja California, Guanajuato, Puebla, Mexico, Colima, Tlaxcala, and

Mexico City with a production of 165,677 t (SIAP, 2022). When this crop grows in salinity conditions, at levels exceeding its tolerance, its plants decrease its growth rate, number of leaves, leaf area, and fruit production (Garriga *et al.*, 2015). In Jocotepec municipality, one dedicated to protected agriculture, the main crop is raspberry, from which chemical fertilization causes soil salinization, consequently affecting this cop developed and maximum potential in the area. When the crop grows in salinity conditions, at levels that exceed its tolerance, the plant decreases its growth rate, the number of leaves, leaf area, and fruit production (Garriga *et al.*, 2015). Aniket and Sengupta (2014) state that agriculture improvement depends on various environmental parameters such as soil temperature, soil moisture, relative humidity, soil pH, light intensity, EC, soil fertilization characteristics, etc. This causes yield degradation. Salt-tolerant microbes introduction is an alternative strategy to crop breeding to increase salt tolerance that improves crop growth (Dodd and Pérez-Alfocea, 2012). Identification and utilization of salinity-tolerant microorganisms could not only improve crop salt tolerance but also reduce pressure on arable land. Among these plant-associated microorganisms, plant growth-promoting rhizobacteria (PGPR) have effectively improved plant stress tolerance (Etesami and Beattie, 2017; Etesami, 2018). Therefore, the objective of this research was to evaluate the effect of halophilic bacteria as a sustainable strategy to reduce the electrical conductivity in saline soil for raspberry (*Rubus idaeus*) cultivation.

MATERIALS AND METHODS

The present investigation was established in a production unit located in the Municipality of Jocotepec, Jal., in which a randomized block design with four treatments and three repetitions was used. The treatments evaluated were based on aerobic halophilic bacterial strains from a consortium formulated in a liquid medium developed under a strict fermentation process of specific microbial strains, with a concentration of heterotrophic bacteria of 2×10^9/ml and Actinomycetes of 2×10^9/ml, with the doses of 7 L/ha, 5 L/ha, 3 L/ha plus an absolute control, three applications were made with intervals of 15 days, at 15, 36 and 57, applying during irrigation, saturating the furrow. The variables evaluated were soil EC and pH; in the plant, plant height, number of loaders, stem diameter, and volume of boxes produced. For treatment, phytotoxicity parameters were taken in the crop, and their agronomic interpretation in the corresponding phenological stage, by the scoring scale proposed by the European Weed Research Society (EWRS). The evaluation of the effect of the treatments on the response of the quantitative variables was carried out through an ANOVA in SAS® Studio 2023 after meeting the assumptions of normality of residuals and homogeneity of variances, associated with the comparison of Tukey means ($p<0.05$) to determine the effect on soil condition, as well as the biostimulant effect on vegetative development.

RESULTS AND DISCUSSION

Forty-two days after application, an analysis of variance and Tukey's comparison test (Table 1) established that all treatments with halophilic bacterial strains had a direct effect on decreasing the soil electrical conductivity ($P<0.05$), which indicates the influence of the treatments on the soil. Five L/ha doses of the evaluated halophilic bacterial strains showed their ability to capture sodium and mobilize it. Their growth is sodium (Na+) dependent, and used for various bioenergetic reactions, therefore, constantly mobilized to maintain a (sodium) ions gradient across their cytoplasmic membranes through primary and secondary transport systems (Oren, 2008; Müller & Saum, 2005; Faraj *et al.*, 2016).

The sodium mobilization was evidenced by the electrical conductivity decrease in the evaluated soil, from 2.35 ds/m - corresponding to moderate salinity - to 1.81.0 ds/m - which corresponds to light salinity. Regarding the variables associated with vegetative development in raspberry plants, significant differences are present in all the determined agronomic variables (Table 1), showing the control having lower height, chargers, and stem diameter as well as symptoms of chlorosis and wilting of some plants. Salt-tolerant PGPRs have the potential to stimulate plant growth and productivity by increasing plant nutrient availability, phytohormones, and nitrogen production (Podell *et al.*, 2013). In the variable directly associated with production, there were significant differences in the Tukey tests between the different treatments, reaching the highest number of harvested boxes at a 5 L/ha dose of inoculant halophilic bacteria, with 2953 boxes. While the control reached only 2046.67 boxes. The halophilic bacteria classified within the BPCV directly or indirectly influence through biological nitrogen fixation (BNF), phytohormones synthesis (phytostimulation), increased nutrients availability, P, K, and Zn solubilization, production of siderophores, which reflected as increase crop yields (Mushtaq *et al.*, 2021).

CONCLUSIONS

Based on these results, halophilic bacteria induce a positive response in the variables associated with the soil, such as pH and EC. The evaluated 5 L/ha dose statistically shows to be the best treatment, since it induced better plant height, number of loaders, stem diameter, and volume of boxes produced responses. The halophilic bacteria at the doses evaluated had no phytotoxic effects in raspberry plants, classified as 1 (No effect on the crop) on the EWRS scale. Inoculation of halophilic strains promotes plant growth and

Table 1. ANOVA and Duncan Grouping on each variable 42 days after application.

TRAT	VARIABLES											
	pH*		EC*		Ph*		NUM CAR*		DIASTEM*		NB*	
	CV=0.3932		CV=0.4204		CV=1.009		CV=0.1388		CV=2.08		CV=0.1067	
	Average	cluster	Average	cluster	Average	cluster	Average	cluster	Average	cluster	Average	cluster
0 L/ha	7.030	A	2.3500	A	1.5333	D	11.1100	D	0.6267	D	2046.67	D
3 L/ha	6.550	B	2.1500	B	1.5900	C	11.8200	C	0.7000	C	2451.00	C
5 L/ha	5.667	D	1.8100	D	1.7700	A	15.2000	A	0.9600	A	2953.00	A
7 L/ha	5.840	C	1.9300	C	1.7300	B	15.1267	B	0.9767	B	2913.14	B

Source: SAS® Studio 2023. CV: coefficient of variation. pH.- soil pH value. EC.- soil Electrical conductivity. Ph-. Plant height. NUM CAR.- Number of chargers. DIASTEM.- stem diameter. NB.- Number of harvested boxes.

reduces salt stress in raspberry cultivation. This may be because they can reduce soil EC and, therefore, the salinity concentration. These results show the possibility of recovering soils with salinity and/or sodicity problems through biological processes based on halophilic microorganisms.

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