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Integration Between Some Soil Improvers and Salt-Resistant Microbes to Improve Some Soil Properties and Their Productivity in Ras Suder, South Sinai, Egypt

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Abstract

A field experiment was conducted on a sandy loam soil in Wadi Sudr South Sinai, Egypt, to study the effect of a mixture of potatoes waste (PW) and farm yard manure (FYM), using a combination for the mixture FYM and PW, with two levels of salt-resistant microbes (SRM) (0 and 7 L ha^{-1}) to reflect some of the properties of calcareous soil below saline irrigation and to improve the sunflower yield. The data obtained showed that soil bulk density (BD), Penetration resistance (PR), Hydraulic conductivity (HC), pH, and CE decreased with increasing application rates of PW using two rates of SRM, while Maximum water holding capacity (MWHC) and Organic Carbon (OC) were increased. The data obtained showed that the yield of sunflower seeds increased with increasing application rates of PW using two rates of SRM. The average increases in sunflower seeds yield were 23.21, 27.68, 44.64, 59.82 and 75.00 % relative to control (0 FYM + 0 PW) Mg ha^{-1} with the application mix of FYM and PW without SRM in the same mixes, respectively. Although they achieved 29.82, 39.47, 55.26, 73.68 and 90.35%, respectively, for blends of FYM and PW with SRM additions on the same blend. High significance was found between the sunflower seed yield altered by FYM and PW mixing and pH, EC, OC, BD, PR, HC or MWHC, respectively. So, we can say that the application mix of FYM+PW is considered effective in improving calcareous soil properties and productivity, which reduces environmental pollution from these wastes.

Keywords: potato waste, farmland manure, sunflower.

Introduction

Environmental protection is one of the most important political issues in many countries. The food industry generates large amounts of waste that can be further processed using biotechnological processes. One of the industries that generates a large amount of polluting waste is the potato sector. Potato (*Solanum tuberosum L.*) is one of the most important crops in the world; According to FAO statistics, annual potato production was over 300 million tons. In addition, the food industry is one of the most important companies in the world, producing a large number of by-products, such as organic waste, which must be handled and managed improperly, not only to prevent environmental pollution, but also to contribute to economic growth through the use of by-products (**Paleologou, et. al., 2016)**. The following wastes are produced during the production of potato starch, chips, and alcohol: potato wastewater, potato peel, pulp, distillery wastewater, and pulp. These wastes may subsequently be used in the production of yeast biomass, protein and lipids, microbial polysaccharides, carotenoids, enzymes, and organic acids as components of microbial medium. This enables, on the one hand, the reduction of the production costs of food components through microbial synthesis and, on the other hand, the environmentally friendly management of industrial waste **Kot, et al. (2020)**. With the ever-increasing food production in the new millennium, the generation agro-industrial waste has skyrocketed. However, these wastes are rich in vital bioactive chemicals. Potato peel waste can enter products including biofuels, dietary fiber, biofertilizers, biogas, biosorbent, antioxidants, and food additives through numerous techniques including fermentation, extraction, and various treatments **Ahsan et al. (2019**). **Priyanga et.al., (2016)** Biofertilizers have been successfully synthesized using potato peel (PP). PP contains a lot of proteins and carbohydrates, which are broken down by soil microbes to form nitrogen-rich fertilizers. The bacterial count in vermicompost made from PP earthworms (*Pheretima elongate*) was higher than in the surrounding soil. The slurry produced by the PP biogas plant (anaerobic digester) is a valuable biofertilizer for land application, replenishing soil nutrients (Muhondwa et al., **2015**). Application of these biofertilizers resulted in an overall increase in vegetative growth and physico-chemical properties of a strawberry fruit **Tiwari et al. (2016).** The mixture of residues (obtained by ethanol production through solid-state fermentation) with the microbes *Azotobacter chroococcum*, *Fischerellamuscicola*, *Anabaena variabilis*, *Nostoc muscorum*, *Cylinder spermummuscicola*, *Azospirillumlipoferumand Azotobacter chroococcum*, *Fischerellamuscicola*, *Fischerellamuscicola*, *Fische* and *Aulosirafertilissima*. Biofertilizers have been successfully synthesized in an equal ratio (Chintagunta et al., 2016). Nitro (N) and potassium (K) levels in potato tubers are high (**Fritsch et al., 2017**). As a result, adding potato trash to soil may increase crop output over time (**Olsen *et al.*, 2001**). PP comprised 40% carbon, 1.4% nitrogen, 3.09 percent potassium, 0.3% phosphorus, 0.156 percent calcium, 0.150 percent magnesium and 0.041 percent sodium. The cull potato also contains 2.14 percent N, 2.40 percent K, 0.29 percent P, 0.074 percent Ca, 0.148 percent Mg and 0.0029 percent Na, according to the researchers. Despite the fact that the wastes were produced under different conditions in different parts of the world, studies suggest that there are differences in the composition of elemental between potato peels and cull potatoes and that both wastes may contain high levels of macronutrients, especially N and K. The chemical composition of potato culls and peels, as well as their impact on biochar properties, has not been completely investigated. This information is crucial for selecting whether to use potato feed stocks directly or to turn them into biochar as a strategy for nutrient recycling and carbon storage in the soil. Converting waste biomass to biochar has proven to be a promising strategy for reducing waste disposal issues and improving nutrient recycling (**Oni *et al.*, 2019).** Compared to pine bark, PW biochar had a low yield and fixed carbon, as well as a high content of ash and volatile matter. Compared to pine bark biochar, potato trash had a higher nutritional content. With increased pyrolysis temperature and high K content, PW biochar showed increases in calcium carbonates equivalent (CCE), pH, and P. At 650 °C, the incorporation of PW biochar (CP) increased soil pH, which could benefit acid soils and increase P availability. **Samukelisiwe (2021)** also recommends learning about the impacts of adding biochar to near neutral and acid soils on pH, CO_2 emissions, mineral N, available P and available K.

The purpose of this experiment was to estimate the effect of potatoes waste (PW) as a soil amendment with farmland manure (FYM) and salt-resistant microbes to improve some soil properties and its productivity of calcareous soil under saline irrigation water.

Materials and Methods

This study was carried out at Agricultural Experimental Station of Desert Research Center, Ras-Sidr province South Sinai, Egypt. It is located on the Gulf of Suez and the Red Sea coast (29^{o} 60' 28" N latitude and 32^{o}68'96" E longitude). It has a desert climate and the average annual temperature and rainfall in Ras-Sidr is 22.2°C and 15mm, respectively.

The soil analysis of the experimental site and the analysis of the two amendment materials used, i.e., PW and farmyard manure (FYM), and the analysis of irrigation water analysis are given in Table (1).

Two highly efficient salt-resistant microbes (SRM) (*Pseudomonas parafulva* and *Bacillus subtilis*) were isolated for their activities under saline conditions. Bacterial strains were tested in vitro for plant growth promoting properties as organic acid production, phosphate solubilization, Amylase production, protease production, Cellulase production, proline production and Indole acetic acid as presented in (Table 2).

PW as a byproduct of food processing industry was obtained from a factory FARM FRITES factory, Industrial in 10th Ramadan city, Egypt.

Before sunflower growing, a mixture of PW and FYM was applied combination to the surface soil layer before sunflower cultivation at twelve mixtures (Table 3).

Before sowing, all treatments received mineral fertilizers in the form of superphosphate (15 percent P_2O5) at a rate of 0.476 Mg ha^{-1}, followed by potassium in the form of potassium sulfate (48 percent K_2O) at 0.12 Mg ha^{-1}, divided into four equal doses at 2, 4, 6, and 8 weeks after sowing. Nitrogen was sprayed at 0.84 Mg ha^{-1} in the form of ammonium sulfate (20 percent N). The first dose was applied at the time of seeding, while the second dose was applied 35 days later.

The experimental design was a split-plots system in a randomized complete block design with four replications. The experiment consisted of twelfth treatments; which represent the combinations among the two factors; the first was the SRM which were arranged as the main plots (0 and 7L/ha.). The second one was placed as sub plots of PW and FYM soil levels (MX_1, through MX_{12}).

A sunflower (*Helianthus annuus L.;Var., Sakha-53*) field trial was conducted during summer season of 2021, at the rate of (11.5 Kg ha^{-1}). Sunflower seeds were planted in hills twenty cm apart at the third week of July 2021.The recommended rates of N, P and K were applied for all plots; also the cultivation practices were followed as the recommendation of Ministry of agriculture and land reclamation.

The sunflower was harvested in the third week of October 2021. A random sample of ten plants were taken from each experimental unit to determine seeds yield per hectare.

Disturbed and undisturbed soil samples from each plot were captured from 0-20 cm depth to determine some physical and chemical soil properties. The pipette method was used to determine particle size distribution, with sodium hexametaphosphate as a dispersing agent (**Kroetsch and Wang 2007).**

Soil BD was measured employing core as described by **Gee et al. (1986)**. PR was determined using a penetrometer. PR measurements were repeated six times in each plot from locations adjacent to BD measurements **(ASAE, 1993)**. HC was determined according to **Klute (1986)**. MWHC was determined according to **(Stolte et al. 1992)**.

The components of the soil water extract were measured in the soil paste extract, and the following determinations were carried out by employing standard methods of analysis according to **Jackson (1973)**. Total soluble salts were determined using EC mater. The soil reaction (pH) was determined in the soil paste, according to **Richards (1954)**. Organic matter was assayed by the modified Walkley and Black method **(Jackson 1973)**.

Results and Discussion

Soil Physical Properties

BD

Table 4 reveals that there were considerable disparities in soil. BD between all treatments. Additionally, the data show that the soil BD values in all treatments (PW +FYM and with or without SRM) are lower than the control treatment and the differences are statistically significant (Table 4). This could be due to the influence of the low BD of both PW and FYM. These findings agree with those obtained by **(Abdeen2020**). Also, respect those obtained by **Abdullah, et.al. (2009)** found that reductions in soil BD with the application of four rates of food factory wastes (10, 20, 40 and 50 t/fed) or chick manure rates at the same rates.

Furthermore, soil BD ranged from 1.59 to 1.37 Mg m^{-3} without SRM for mixture PW + FYM, while with soil amendments, with SRM for mixture PW + FYM, BD were reduced and varied from 1.58 to 1.34 Mg m^{3}. Table 3 showed that soil BD recorded lowest values due to application of PW + FUM compared without treatment. Relative reductions in soil BD, without RSM, reach 5.03, 6.92, 8.81, 11.32 and13.84% on an average basis due to the increase in rate of PW in mixture treatment (0,12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, without application of SRM, while, they reach 5.70, 6.96, 10.13, 12.66, and 15.19% on an average basis due to the in rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, with application of SRM. This clearly demonstrates the negative impact of applying more mixed potato trash than FYM at higher application rates on soil BD.

Moreover, the PW + FYM mixture with RSM significantly decreased soil BD compared with mixture PW+FYM without SRM amendments.

PR

The soil PR is a good indicator for the soil physical properties, the decrease in PR allows the plant roots for easy penetration in the soil. As shown in (Fig. 1), a decrease in soil PR is accompanied by an increase in the rates of either the mixture PW+FYM without SRM or the mixture PW+FYM with SRM. Significant differences in soil PR are obtained between without and with mixture PW+FYM with SRM.

Moreover, the PR ranged from 23.22 to 14.37 KP$_a$ without SRM for mixture PW + FYM, while with soil amendments, with RSM for mixture PW + FYM, PR values were reduced and varied from 23.14 to 13.83 KP$_a$. (Fig. 1) showed that PR recorded lowest values due to the PW + FYM application compared without treatment. The relative reductions in PR, without SRM reach 19.42, 20.20, 26.4, 32.60 and 38.11% on an average base due to the increase in rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, without application SRM, while, they reach 20.35, 20.96, 29.34, 36.43 and 40.23% on an average base due to the rate of PW in mixture treatment (0,12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, with application SRM. This clearly shows that rising application rates has a negative impact of mixture PW than FYM on soil PR.

MWHC

Incorporating of mixture PW + FYM and SRM with surface soil could enhance soil physical properties. Data in (Table 5) illustrate that the effects of mixture PW + FYM and SRM rate on MWHC are significant as they increase with increasing either mixture PW + FYM or without and with SRM. Moreover, a significant difference is detecting between the MWHC under the five rates mixture PW+FYM or without and with SRM additions. The relative increases in the MWHC, without SRM, reach 14.63, 21.34, 34.08, 48.08 and 60.24% on an average base due to the increase in rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, without application SRM, while, they reach 17.85, 27.14, 42.34, 60.75, and 74.89% on an average base due to the in rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, with application SRM. This clearly shows the adverse effect of increasing the rates of application of mixture PW than FYM on soil BD.

HC

Concerning the effect of mixture PW + FYM and SRM rates on soil HC, the data presented in (Table 6) show a decrease in HC with the increase of amendments application rates.

The soil HC ranged from 27.25 to 13.77 cm/min, when soil amendments with, mixture PW + FYM and without SRM, while soil amendments, with SRM for mixture PW + FYM, HC were reduced and varied from 27.14 to 12.72 cm/min. Table 6 showed that soil HC recorded lowest values due to the PW + FYM application compared without treatment. The relative reductions in soil HC, without SRM, reach 14.57, 17.76, 27.89, 39.85, and 49.47% on an average base due to the increase in the rate of PW in the treatment of mixture (0, 12.5, 25.0, 37.5 and 50.0 Mg / ha), respectively, without application SRM, while they reach 16.25, 20.56, 33.42, 42.56, and 53.13% on an average base due to the increase in rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, with application SRM. This clearly shows the adverse effect of increasing the rate of application of mixture PW mixtures in comparison to FYM on soil HC.

Moreover, the mixture PW+FYM with SRM significantly decreased soil HC compared to the mixture PW+FYM without the combination treatments of SRM amendments.

In this respect, **Abdullah et.al., (2009)** found that the relative decreases in HC reach 19.98, 27.95 and 30.51% on an average base due to the increase in food factory wastes manure application rates from 0 to 10, 20, and 30 t/fed., respectively. While, the relative decreases in HC reach 9.29, 14.56, and 21.03% on an average base due to the increase in poultry manure application rates from 0 to 10, 20, and 30 t/fed., respectively.

Soil Chemical Properties

Soil pH

Concerning the effect of Incorporating of mixture PW + FYM and two rates of SRM on soil pH, the obtained values slight decreased from 7.96 to 7.65 when soil amendments with mixture PW + FYM and without SRM, while soil amendments, with SRM for mixture PW + FYM, soil pH values were reduced and varied from 7.93 to 7.56. Fig. 2 shows that the application of mixture PW + FYM and two rates of SRM at the five mixture rates decreased the pH values than that treatment without the mixture PW + FYM and two rates of SRM (control). The application of PW + FYM on the pH of the treated soil may be explained by the production of organic acids, CO_2 and hydrogen ions (H +). These realities are in line with those obtained by **Bulluck,.et.al. (2002)**.

In this respect, **Abdel-Aal (2015)** found that the used amendments (FYM) caused desirable effects on decreases all of BD, ECe, soil pH and soil ESP and increases all of, total porosity, HC and soil organic matter with significant trends.

EC of Saturated Soil Extract (EC_e)

Effect of mixture PW + FYM and two rates of SRM on Ec_e of the saturated soil extract (Table 7), the obtained values decreased from 18.05 to 14.31 dS m^{-1} when soil amendments with mixture PW+ FYM and without SRM, while soil amendments, with SRM for mixture PW + FYM, electrical conductivity of the saturated soil extract (EC_e) values were reduced and varied from 17.98 to 13.80 dS m^{-1}. Soil ECe is affected by the applied mixture of PW + FYM and SRM.

Table (7) shows that the relative reductions in the $EC_e$of soil, without SRM, reach 13.68, 15.12, 17.06, 19.06, and 20.72% on an average base due to the increase in the PW rate in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}) than in the control treatment, respectively, without application of SRM, while, they reach 13.79, 15.41, 17.85, 19.91 and 23.25% on an average base due to the rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}) than that the control treatment, respectively, with application SRM. This clearly shows the adverse effect of increasing rates of the PW the application of mixture compared to FYM on the saturated soil extract.

In this respect, **Abdullah et. al., (2009)** found that the rate of food waste increased the EC_e of soil decreased being, on the average, 7.18, 11.17 and 18.62% lower than that of control treatment.

Soil OC

Fig. (3) shows that there were significant differences in soil OC between all treatments. Furthermore, show that the soil OC values in all treatments (PW +FYM and with or without SRM) gradually increased than the control treatment and the differences are statistically significant. In this respect, **Abdullah et.et. al., (2009)** found that the OC was increased with rising rates of the application of food waste and poultry manure.

Furthermore, soil OC ranged from 1.70 to 4.08 g kg^{-1} without SRM for the mixture of PW + FYM, while with soil amendments, with SRM for the mixture of PW + FYM the soil OC values increased and varied from 1.73 to 5.31 g kg^{-1}. Fig 3 showed that soil OC recorded highest values due to the PW+ FYM application compared without treatment. The relative increase in soil OC, without SRM, reach 46.47, 65.29, 74.71, 110.0 and140.0% on an average base due to the increase in the rate of PW in the treatment of mixture (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, without application of SRM, while, they reach 64.74, 71.68, 95.95, 137.57, and 206.94% on an average base due to the rate of PW in mixture treatment (0, 12.5, 25.0, 37.5 and 50.0 Mg ha^{-1}), respectively, with application SRM. This clearly shows the adverse effect of increasing the rates of application of mixture PW compared to FYM on soil OC. These results were in line of those obtained by **Speir et al. (2004**) who found that the total OC of soil increased markedly by increasing rate of organic amendments. Furthermore, the mixture PW+FYM with SRM significantly increased soil OC compared with mixture PW+FYM without SRM amendments.

Sunflower Seeds Yield

Data in (Table 8) represent the response of sunflower seed to the applied mixture ratio of PW+FYM at the two rates of SRM. The applications of mixture ratio of PW+FYM and two rates of SRM significantly increase the sunflower seed yield. Maximum yield is achieved with the application of mixture 0 and 50 Mg ha^{-1} of FYM+PW, respectively and two rate of SRM.

Referring to data presented in (Table 8) the difference between mixture of FYM and PW used is significant and increases with increasing application rates of PW under the application of two rates of SRM. Furthermore, Fig. 4 shows that the all mixture PW+FYM and application 0 L / fed of SRM treatments increases the yield of sunflower seeds by an average of 23.21, 27.68, 44.64, 59.82 and 75.00% relative to control (0 Mg hat^{-1} FYM + 0 Mg hat^{-1} PW) with the application mixture FYM+PW (MX$_2$, MX3, MX$_4$ MX$_5$ and MX$_6$).While, Fig. 5 shows that the all mixture PW+FYM and application 7 L hat^{-1} of SRM treatments increases sunflower seed yield by an average of 29.82, 39.47, 55.26, 73.68 and 90.35% relative to control with the application mixture FYM+PW (MX$_8$, MX9, MX$_{10}$, MX$_{11}$, and MX$_{12}$). Statistical analysis of the data in (Table 8) shows a highly significant effect of application mixture of FYM and PW on the sunflower seeds yield. Such in effect is more pronounced with PW than with FYM waste at all application ratios.

The relationships between either PW and FYM or SRM rates and sunflower seed production were fitted using best fitting equation [1] without SRM and [2] with SRM, respectively, are as follows:

Seed yield = 1.12 + 0.009 x FYM rate + 0.046 x PW rate + 0.000273 x FYM rate^2– 0.000407 x FYM rate x PW rate–0.00058 PW rate^2 [1]

Seed Yield =1.14–0.000412 x FYM rate + 0.006 x PW rate–0.000140 x FYM rate^2 + 0.000341 x FYM rate x PW rate + 0.000288 PW rate ^{2} [2]

This indicates that the increase in yield is attributable to additional amendment additions. A highly significant relationship was found between the sunflower seed yield amended by the PW and FYM mixture and the pH, EC, OC, BD, PR, HC or MWHC, respectively. Furthermore, multiple regression that relates seed yield to some soil properties and the mixture of PW + FYM or SRM amendment rates yields the following equation [3] without SRM and [4] with SRM, respectively:

Seed yield = 1.89 + -0.158 pH +0.020 EC–0.049 OC+ 0.658 BD–0.027 HC–0.036 PR + 0.043 MWHC [3]

Seed yield = 3.07 + -0.418 pH -0.072 EC + 0 002 OC + 1.019 BD–0.009 HC + 0.018 PR + 0.060 MWHC [4]

The multiple correlation was highly significant (r = 0.99 **); this means that 96.04% of the variations in seed yield could be due to the variation in soil OC, pH, CE, BD, PR, HC, MWHC in either mixture ratio of JPW + FYM or SRM amendment rate.

Table 1: Some chemical and physical properties of the soil additives and the used irrigation water used.

Parameter	pH	ECe dS m^{-1}	OC g kg^{-1}	BD Mg m^{-3}	CaCO$_3$ %	Particle size distribution				
						Fine sand %	Coarse sand %	Silt %	Clay %	Texture class
Soil depth (0-20 cm)	7.96	20.19	1.47	1.48	35.7	45.28	34.72	10.65	9.35	Sandy loam
PW	4.71	1.92	401	0.67	-					
FYM	6.98	2.15	370	0.92	-					

Total content of some elements of amendments used

Parameter	N gkg^{-1}	P g kg^{-1}	K g kg^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}
PW	22.34	4.35	22.73	137	24	12	3
FYM	18.41	2.58	19.38	123	21	15	4

Chemical Properties of the irrigation water used in the study

Parameter	pH	ECe dS m^{-1}	Cation (m mol$_c$ /L^{-1})				Anion (m mol$_c$ /L^{-1})				SAR
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO$_3^{2-}$	HCO$_3^{-}$	SO$_4^{2-}$	Cl^{-}	
Irrigation water	8.03	9.43	23.54	24.48	40.05	0.14	Nil	9.50	29.77	48.94	8.17

Explanations: PW: potato waste, FYM; pH in soil suspension and ECe in soil paste extract

Table 2: Plant growth promoting properties.

Characteristics	Pseudomonas parafulva	Bacillus subtilis
Organic acid production	+++	++
Phosphate solubilization	++	+
Amylase production	+++	++
Protease production	+	+
Cellulose production	++	++
proline production	+	+
Indole acetic acid (IAA) production	+	+

Table 3: Different treatments used in the experiments.

Abbreviation	Without salt-resistant microbes			Abbreviation	With SRM		
	FYM		PW		FYM		PW
MX$_1$	0 Mg ha^{-1}	+	0 Mg ha^{-1}	**MX$_7$**	0 Mg ha^{-1}	+	0 Mg ha^{-1}
MX$_2$	50 Mg ha^{-1}	+	0 Mg ha^{-1}	**MX$_8$**	50 Mg ha^{-1}	+	0 Mg ha^{-1}
MX$_3$	37.5 Mg ha^{-1}	+	12.5 Mg ha^{-1}	**MX9$_3$**	37.5 Mg ha^{-1}	+	12.5 Mg ha^{-1}
MX$_4$	25 Mg ha^{-1}	+	25 Mg ha^{-1}	**MX$_{10}$**	25 Mg ha^{-1}	+	25 Mg ha^{-1}
MX$_5$	12.5 Mg ha^{-1}	+	37.5 Mg ha^{-1}	**MX$_{11}$**	12.5 Mg ha^{-1}	+	37.5 Mg ha^{-1}
MX$_6$	0 Mg ha^{-1}	+	50 Mg fed^{-1}	**MX$_{12}$**	0 Mg ha^{-1}	+	50 Mg fed^{-1}

Table 4: Effect of the mixture PW and FYM or SRM on soil BD.

Treatment		BD (g/cm^3)	Treatment		BD (g/cm^3)	Mean mixture
Without salt-resistant microbes	MX$_1$	1.59	**With salt-resistant microbes**	MX$_7$	1.58	1.53
	MX$_2$	1.51		MX$_8$	1.49	1.44
	MX$_3$	1.48		MX$_9$	1.47	1.41
	MX$_4$	1.45		MX$_{10}$	1.42	1.38
	MX$_5$	1.41		MX$_{11}$	1.38	1.34
	MX$_6$	1.37		MX$_{12}$	1.34	1.29
Mean without salt-resistant microbes		1.47	Mean with salt-resistant microbes		1.45	
LSD	SRM			*0.011*		
	Mixture (PW+ FYM)			*0.020*		
	Interaction (PW+ FYM) x SRM			*0.010*		

Table 5: Effect of the mixture PW and FYM or SRM on soil MWHC.

Treatment		MWHC %	Treatment		MWHC %	Mean mixture
With out salt-resist	MX$_1$	17.43	**With salt-resist**	MX$_7$	17.76	17.60
	MX$_2$	19.98		MX$_8$	20.93	20.46
	MX$_3$	21.15		MX$_9$	22.58	21.87

	MX_{4}	23.37		MX_{10}	25.28	24.33
	MX_{5}	25.81		MX_{11}	28.55	27.18
	MX_{6}	27.93		MX_{12}	31.06	29.50
Mean without salt-resistant microbes		22.61	Mean with salt-resistant microbes		24.36	
LSD	SRM			*0.011*		
	Mixture (PW+ FYM)			*0.020*		
	Interaction (PW+ FYM) x SRM			*0.010*		

Table 6: Effect of the mixture PWand FYM or SRM on HC.

Treatment		**HC cm/min**	**Treatment**		**HC cm/min**	**Mean mixture**
Without salt-resistant microbes	MX_{1}	27.25	**With salt-resistant microbes**	MX_{7}	27.14	27.20
	MX_{2}	23.28		MX_{8}	22.73	23.01
	MX_{3}	22.41		MX_{9}	21.56	21.99
	MX_{4}	19.65		MX_{10}	18.07	18.86
	MX_{5}	16.39		MX_{11}	15.59	15.99
	MX_{6}	13.77		MX_{12}	12.72	13.25
Mean without salt-resistant microbes		20.46	Mean with salt-resistant microbes		19.64	
LSD	SRM			*0.0121*		
	Mixture (PW+ FYM)			*0.021*		
	Interaction (PW+ FYM) x SRM			*0.011*		

Table 7: Effect of the mixture PW and FYM or SRM on soil EC_{e}.

Treatment		**EC_{e} dS m^{-1}**	**Treatment**		**EC_{e} dS m^{-1}**	**Mean mixture**
Without salt-resistant microbes	MX_{1}	18.05	**With salt-resistant microbes**	MX_{7}	17.98	18.02
	MX_{2}	15.58		MX_{8}	15.50	15.54
	MX_{3}	15.32		MX_{9}	15.21	15.27
	MX_{4}	14.97		MX_{10}	14.77	14.87
	MX_{5}	14.61		MX_{11}	14.40	14.51
	MX_{6}	14.31		MX_{12}	13.80	14.06
Mean without salt-resistant microbes		15.47	Mean with salt-resistant microbes		15.28	
LSD	SRM			*0.012*		
	Mixture (PW+ FYM)			*0.021*		
	Interaction (PW+ FYM) x SRM			*0.011*		

Table 8: Effect of the mixture PW and FYM or SRM on the seed sunflower yield.

Treatment		**seeds sunflower yield Mg ha^{-1}**	**Treatment**		**seeds sunflower yield Mg ha^{-1}**	**Mean mixture**
Without salt-resistant microbes	MX_{1}	1.12	With salt-resistant microbes	MX_{7}	1.14	1.13
	MX_{2}	1.38		MX_{8}	1.48	1.43
	MX_{3}	1.43		MX_{9}	1.59	1.51
	MX_{4}	1.62		MX_{10}	1.77	1.70
	MX_{5}	1.79		MX_{11}	1.98	1.89
	MX_{6}	1.96		MX_{12}	2.17	2.07
Mean without		1.55	Mean withsalt-		1.69	

salt-resistant microbes	resistant microbes	
LSD	SRM	*0.011*
	Mixture (PW+ FYM)	*0.020*
	Interaction (PW+ FYM) x SRM	*0.107*

Table 9: Correlation coefficient between sunflower seed yield amended by PW or FYM rates and some soil properties.

Soil properties	**Sunflower seed amendments**	
	PW+FYM without SRM	**PW+FYM with SRM**
Bd	-0.95^{**}	-0.97^{**}
HC	-0.99^{**}	-0.99^{**}
Penetration	0.98^{**}	0.98^{**}
MWHC	-0.98^{**}	-0.99^{**}
pH	-0.87^{**}	-0.96^{**}
EC	-0.96^{**}	$- 0.93^{**}$
OC	0.96^{**}	0.97^{**}

****:** Significant at 1%

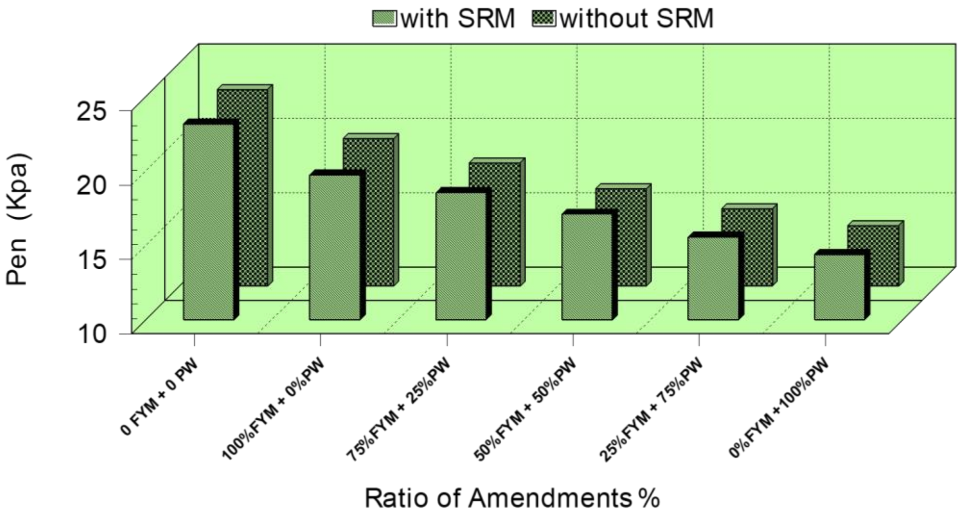

Fig. 1: Effect of the mixture PW and FYM or SRM on soil PR.

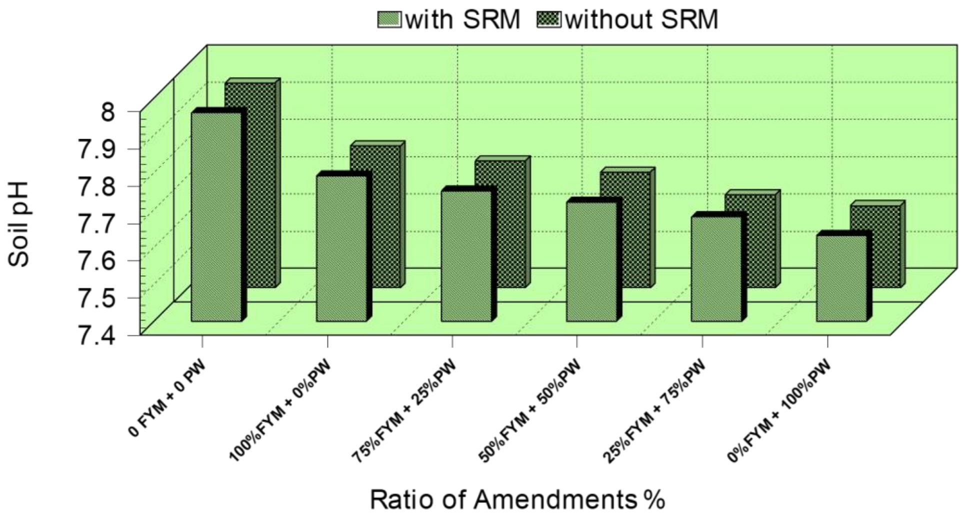

Fig. 2: Effect of the mixture PW and FYM or SRM on soil pH.

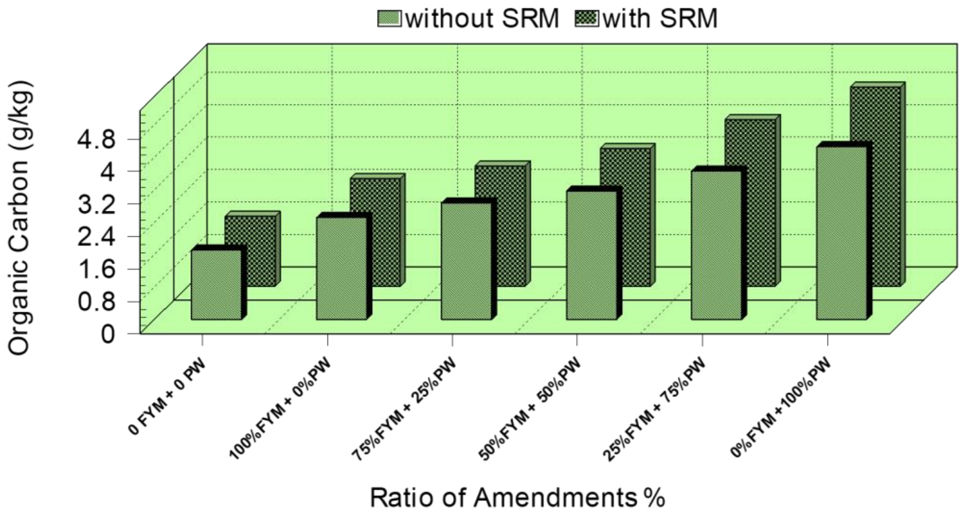

Fig. 3: Effect of the mixture PW and FYM or SRM on soil OC.

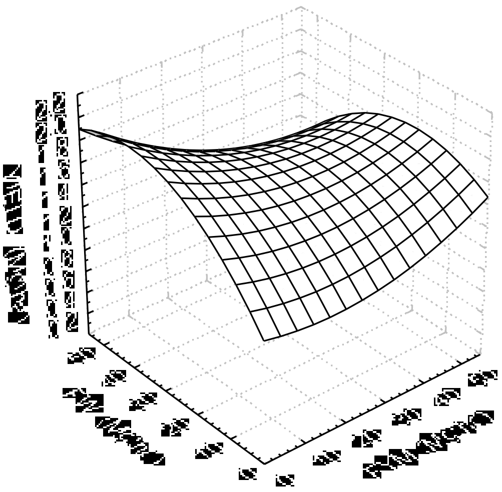

Fig 4: Effect of mixture PW and FYM without added SRM on seed sunflower yield.

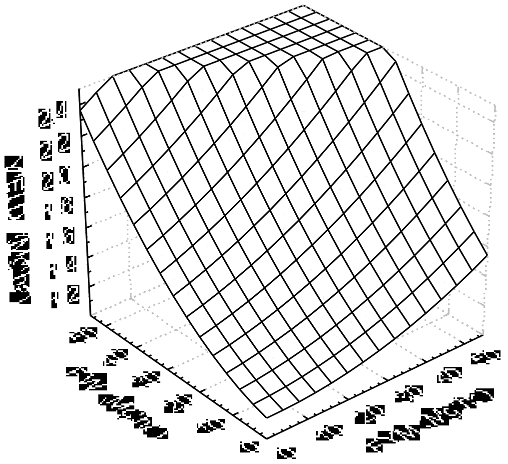

Fig 5: Effect of mixture PW and FYM with added SRM on seed sunflower yield

Conflicts of Interest/ Competing interest

All authors declare that they have no conflicts of interest.

Data availability statement:

All data sets collected and analyzed during the current study are available from the corresponding author on reasonable request.

Abbreviations

BD	Bulk density
FYM	Farmyard manure
HC	Hydraulic conductivity
IAA	Indole acetic acid
MWHC	Maximum water holding capacity
OC	Organic Carbon
PP	Potato peel
PR	Penetration resistance
PW	Potatoes waste
SRM	Salt-resistant microbes

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