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Influence of Vermicompost, Seaweed Extract and Nitrogen Fertilisers on Maize (*Zea mays* L.) Soil Rhizosphere Microbes

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Abstract: This study shows the influence of adding vermicompost fertiliser, seaweed extracts and nitrogen fertiliser on the number of total bacteria in the soil, in the stages of flowering and full maturity. An experiment was carried out in one of the farms located in Nouriya district - Al-Diwaniyah governorate - Iraq, during the autumn season 2019-2020.

The experiment was applied in the order of global experiments, according to the design of full randomised sectors, with three replications. The first factor included adding vermicompost fertiliser with three levels (0, 2 and 4 tons h^{-1}) coded A0, A1 and A2, respectively. The second factor included adding seaweed extract at two levels (0 and 40 kg h^{-1}) symbolised by B0 and B1, respectively. The third factor included adding nitrogen fertiliser in three levels (0, 120 and 240 kg N h^{-1}) symbolised as C0, C1 and C2, respectively.

The levels of vermicompost differed significantly in most of the studied descriptions, as level A2 scored the highest results for the number of bacteria in the two stages of flowering and full maturity, i.e., 88.59×10^7 and 111.54×10^7 CFU gm^{-1} of dry soil. The treatment of adding seaweed extracts B1 significantly affected the number of bacteria in the two stages of flowering and full maturity (80.04×10^7 and 103.29×10^7 CFU gm^{-1} dry soil).

The treatment of adding C1 nitrogen fertiliser was significantly superior to the number of bacteria in the flowering stage (81.40×10^7 CFU gm^{-1} dry soil).

Key words: Maize, rhizosphere, soil microbiology, seaweed extracts, total bacteria.

Introduction

Soil is one of the natural ingredients in agriculture, and the extent of its quality and degree of fertility, plays an important role in the productivity of various plants. Despite this importance, soil found in Iraq, especially in the central and southern regions, is still suffering from a decrease in the readiness of many nutrients necessary for plant growth and development, which is due to many reasons, including those related to the characteristics of the soil itself, such as the degree of soil interaction, texture and composition, as well as its low content of organic matter and others related to agricultural intensification, but the most prominent of which is the failure to follow the scientific method in soil nutrient management programmes, which requires work on the application of appropriate fertiliser programmes for each soil and the resulting from improvement of the physical, chemical and biological properties of the soil, and as a result an increase in its fertility (Colombo,

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2002). The addition of nitrogen fertilisers is one of the factors that increases soil fertility, and it is one of the major elements necessary for plants as a result of the physiological roles it performs within the plant tissue. Its loss from soils by volatilisation and washing (Al-Taweel and Abo-Tabikh, 2019; Bronson, 2004), as well as the unexamined additions to this fertilizer, have led to an imbalance of the readiness of the elements in the soil and the negative impact of that on its fertile state (Havlin, 2005). To reduce these effects and the problems resulting from them, the modern trends of agriculture invite for the observance of indicators of fit environmental management by reducing pollutants and replacing mineral fertilisation or part of it, with organic fertilisers, such as the use of seaweed extracts, which are one of the most important vital growth fertilisers due to their content of organic matter that retains humidity and helps in increasing the readiness of nutrients (Spinelli, 2009), as well as their content of the many natural compounds that act as growth regulators (O′Dell, 2003), and their role in improving the physical properties of the soil as they help in improving the conditions of ventilation, permeability, water holding, reducing the apparent density of the soil and increasing its porosity (Naseem, 2005).

It is also possible to limit or reduce the addition of mineral fertilisers by adding other types of organic fertilisers known as vermicompost, which is an organic fertiliser that earthworms produce by analysing organic compounds and converting them into simple substances, beneficial for the plant. Studies have indicated that vermicompost contains a number of enzymes such as peroxidase, protease and amylase that enhance the effectiveness of soil microorganisms (Al-Taweel and Al-Rashidi, 2018; Bottinelin italic;. 2010) explained that adding organic fertilisers to soil increases the number of fungi while adding mineral fertilizers to soil changes the available types of fungi and their numerical density. The organic fertilisers added to the soil change the physiological composition of the microorganisms, as appropriate conditions are created for the activity of other micro-organisms that did not exist before.

Several studies indicated that adding organic materials to the soil has led to an increase in the number of microorganisms because they contain materials ready for use by the microorganisms in the soil. The results of the study by Al-Rawi (2000) showed the variation of the effect of organic sources in increasing the numbers of soil organisms. Cow manure outperformed giving the highest results for bacterial and fungi numbers (6.2×10^8 and 5.1×10^5 CFU g^{-1} dry soil), while the comparison treatment (without adding organic manure) achieved the lowest values (0.9×10^8 and 0.9×10^5). CFU g^{-1} dry soil) for bacteria and fungi, respectively.

Abo-Tabikh (2019) showed tha t there was a significant increase in the n umbers of Nitrosomonas and Nitrobacter bacteria in the root periphery area of maize when adding urea fert i liser, as their numbers ranged from 33.70×10^5 and 8.31×10^5 CFU g^{-1} dry soil for the two species respectively compared with the comparison treatment (witho ut addition urea), which gave the lowest number of the two types of bacteria, respectively.

Materials and Methods

A field experiment was carried out during the Autumn season of 2019-2020 in one of the farms located in Al-Nouriya sub-district/Al-Diwaniyah governorate- Iraq, where the chemical, physical and biological properties of the soil present in the region have been tabulated in Table I, with the aim of studying the effect of vermicompost, seaweed extracts and urea, and the interaction between them in the total number of bacteria and fungi. In soil, maize was planted during flowering and mature stages.

The field soil was fertilised by triple superphosphate fertiliser (P_2O_5% 48) at a rate of 100 kg P h^{-1} and potassium fertiliser in the form of potassium sulphate (41.5% K) at a rate of 120 kg K h^{-1} and fertilisers were added in one batch before planting, while the Norwegian fertiliser was added in the form of urea (N% 46). According to the transactions in two batches, the first at the planting stage and the second at the flowering stage. The Vermicompost fertilizer, characteristics are mentioned in table 2, which was added in two stages ,the first is about cultivation and the second is at the stage of female flowering and according to the treatments, supplementation the seaweed extract was added as a feed in four batches, distributed in order a long the growing season and according to the treatments.

The land was divided into 54 experimental units with dimensions (2 m × 2 m), which included 4 lines with a distance of 0.50 m and between a plant and another 0.25 m. Maize seeds of a hybrid variety (Furat) were planted on July 27, 2019, by planting 3 seeds in the hole, then diluting to one plant after germination. The plants were harvested on November 27, 2019, when signs of maturity were evident from the drying out of the arid and the appearance of a black scar on the beans.

Table 1: Some physical, chemical and biological characteristics of the study soil before planting

Adjective		*Value*	*Unit*	*Source*
pH1:1		7.69	-	(Black, 1965b)
Ec1:1		2.53	Ds m^{-1}	(Black, 1965b)
CEC		22.13	$Cmol_c$ Kg^{-1} soil	(Papanicolaou, 1976)
$CaCO_3$		255.00	gKg^{-1} soil	(Black, 1965b)
Organic matter		4.65		
Ready nitrogen		26.11	$mgKg^{-1}$ soil	
Ready potassium		137.00		(Page, 1982)
Ready phosphor		13.1		
Soil separators	sand	217.00	gKg^{-1} soil	(Black, 1965a)
	silt	368.00		
Texture	clay	415.00		
Apparent density		1.33	Mg m^{-3}	(Black, 1965a)
Total bacteria		17.3 106×	$CFUg^{-1}$ dry soil	(Black, 1965b)
Total fungi		6.6 104×		

Table 2: Some chemical and physical analyses of vermicompost fertiliser

Adjective	*Value*	*Unit*
pH	6.20	-----
Ec 1:5	1.68	ds m^{-1}
Humidity	26.4	%
Organic matter	43.24	
Organic carbon	25.14	
Nitrogen	1.50	
C:N ratio	16.76	-----
Iron	0.11	Mg Kg^{-1}
Manganese	0.68	
Zinc	0.05	
Cupper	0.33	
Boron	0.29	
Nickel	0.044	
Cobalt	0.04	

The total number of bacteria in the rhizosphere of the maize plant, and for the two stages of flowering and full maturity were estimated, by diluting and counting the plates according to the method given by Black (1965b).

Results and Discussions

The Total number of Bacteria (CFU gm $^{-1}$ Dry Soil) in Flowering and Maturity Stages

The results tabulated in Tables 3 and 4 show that adding vermicompost fertiliser in soil with maize plants led to a significant difference in the number of total bacteria in the two stages of flowering and full maturity, as treatment A2 gave the highest values, 88.59 × 10^7 and 10^7 × 111.54 CFU gm^{-1} dry soil compared to treatment the comparison, which recorded the lowest value in the two stages, was (55.13 × 10^7 and 57.62 × 10^7) CFU gm^{-1} dry soil in the two stages of flowering and full maturity, respectively.The reason for the increase in the total bacterial numbers when adding vermicompost fertiliser is due to the fact that organic additives have an important effect on the numbers of microorganisms because they contain many nutrients that the microorganisms need in structuring their cells, as these elements are a source of carbon and energy needed to sustain the biological activity (Ingale and Phirke, 2017). These results are in agreement with the study by Al-Rawi (2000).

It is noticed from the results that the addition of seaweed extracts to the soil led to significant differences in the number of total soil bacteria in the two stages of flowering and full maturity. The addition of seaweed was recorded in the two stages 80.04 × 10^7 and 103.29 × 10^7 CFU gm^{-1} of dry soil on the relay compared to the comparison treatment gave 74.04 × 10^7 and 82.63 × 10^7 CFU gm^{-1} of dry soil. The reason may be attributed to the role of organic compounds such as amino acids and plant hormones that stimulate enzymes, that are mainly present in the organic extract to encourage cell division and increasing their size, which led to an increase in plant absorption of nutrients, reflected in

Table 3: Total number of soil bacteria (10^7 CFU gm^{-1} dry soil) in the flowering stage

(Vermicompost levels A tone h^{-1})		*A0*	*A1*	*A2*
		55.13	87.39	88.59
$LSD_{0.05}$			1.65	
Seaweed Extract levels B (kg h^{-1})		B0		B1
		74.04		80.04
$LSD_{0.05}$			1.35	
Average nitrogen fertiliser C (Kg N h^{-1})		C0	C1	C2
		70.16	81.40	79.56
$LSD_{0.05}$			1.65	
(Binary interference between (vermicompost) A × B (seaweed extract)				
		B0		B1
A0		49.73		60.54
A1		80.07		94.72
A2		92.31		84.86
$LSD_{0.05}$			2.33	
(Binary interference between (vermicompost) A × C (nitrogen fertiliser)				
		C0	C1	C2
A0		45.92	56.38	63.10
A1		78.09	95.16	88.93
A2		86.45	92.66	86.64
$LSD_{0.05}$			2.86	
Binary interference between (seaweed extract) B × C (nitrogen fertiliser)				
		C0	C1	C2
B0		67.87	78.99	75.36
B1		72.44	83.92	83.75
$LSD_{0.05}$			2.33	
Triple interferenc between treatments A × B × C				
		C0	C1	C2
A0	B0	41.84	49.60	57.73
	B1	52.00	63.16	68.46
A1	B0	71.07	88.14	81.01
	B1	85.12	102.18	95.85
A2	B0	90.70	98.89	87.33
	B1	82.20	86.43	85.95
$LSD_{0.05}$			4.04	

the increase in the photosynthesis process, and then the increase in the effectiveness of the roots and the increase in the number of bacteria.

Nitrogen fertiliser achieved significant superiority in the number of total bacteria in the soil at the flowering stage, as treatment C1 gave the highest value of (81.40×10^7) CFU gm^{-1} dry soil compared to the comparison treatment (C0), which recorded (70.16×10^7) CFU gm^{-1} of dry soil (Table 3), while the differences were not significant between the treatments (C0, C1 and C2) at the stage of full maturity (Table 4).

The reason for the superiority in the flowering stage may be due to the fact that adding nitrogen fertilisers to the soil increases the number of bacteria because these fertilisers contain elements ready to be used by soil biologists (Al-Taweel and Abo-Tabikh, 2020; Phirke,

Table 4: The total number of soil bacteria (10^7 CFU gm^{-1} dry soil) in the fully mature stage

(Vermicompost levels A tone h^{-1})		*A0*	*A1*	*A2*
		57.62	109.71	111.54
LSD $_{0.05}$			2.54	
Seaweed Extract levels B (kg h^{-1})		B0		B1
		82.63		103.29
LSD $_{0.05}$			2.07	
Average nitrogen fertiliser C (Kg N h^{-1})		C0	C1	C2
		91.82	94.45	92.60
LSD $_{0.05}$			N.S	
(Binary interference between (vermicompost) A × B (seaweed extract)				
		B0		B1
A0		34.04		81.21
A1		99.80		119.62
A2		114.04		109.04
LSD $_{0.05}$			3.59	
(Binary interference between (vermicompost) A × C (nitrogen fertiliser)				
		C0	C1	C2
A0		55.28	56.87	60.72
A1		107.94	112.57	108.62
A2		112.25	113.92	108.46
LSD $_{0.05}$			4.39	
Binary interference between (seaweed extract) B × C (nitrogen fertiliser)				
		C0	C1	C2
B0		78.96	86.10	82.82
B1		104.68	102.80	102.38
LSD $_{0.05}$			3.59	
Triple interference between treatments A × B × C				
		C0	C1	C2
A0	B0	32.32	32.97	36.84
	B1	78.23	80.77	84.61
A1	B0	91.25	106.23	101.91
	B1	124.63	118.91	115.33
A2	B0	113.31	119.10	109.71
	B1	111.19	108.73	107.21
LSD $_{0.05}$			6.21	

2014). Cusack (2011) explained that the addition of urea in large quantities negatively affects the density of biomass, especially bacteria, due to the change of soil acidity, or because of the toxicity caused by the ammonium ion in the enzymatic systems of bacteria.

The effect of binary interference between vermicompost fertiliser and seaweed extracts was significant in the number of total bacteria present in the soil for the two stages of flowering and full maturity, combination A1B1 recorded the highest value for the two stages of flowering and maturity, respectively, 94.72 × 10^7 and 119.62 × 10^7, CFU gm^{-1} of dry soil. In contrast, combination A0B0 recorded the lowest value for the two stages in respect of 49.73 × 10^7 and 34.04 × 10^7 CFU gm^{-1} of dry soil (Tables 3 and 4). The reason may be attributed to the role of this extract in providing additional quantities of nutrients, which reflected positively on increasing plant absorption and thus increasing the effectiveness of the roots that lead to an increase in the number of microorganisms, especially in the area of the proliferation of roots.

As for the binary interaction between vermicompost fertiliser and nitrogen fertiliser, it had a significant effect on the number of total bacteria in the soil in the two stages of flowering and full maturity.

At the flowerin g stage, the combination A1C1 recorded the h i ghest number of total soil bacteria, reaching 95.16 × 10^7 CFU gm^{-1} dry soil compared to the combination A0C0 which recorded the lowest value 45.92 × 10^7 CFU gm^{-1} of dry soil (Table 3). In the full maturity stage, the combination A2C1 gave the highest value of 113.92 × 10^7 CFU gm^{-1} of dry soil compared to the combination A0C0 which gave 10^7 × 55.28 CFU gm^{-1} of dry soil (Table 4), and this may be attributed to the complete Fertilization between mineral fertilisation and vermicompost, which leads to the provision of nutrients, because the compost helps to create a balance between the nutrient content of the soil and the amount of production, which leads to an increase in the numbers of microorganisms in the soil, and this corresponds with the findings obtained by Costing (2000).

It is noted from the results of the significant effect of the binary interaction between seaweed extracts and nitrogen fertilisers on the number of total bacteria in the soil for the two stages of flowering and full maturity. The B1C1 combination recorded the highest value for the two stages of flowering and ripening successively, reaching 83.92 × 10^7 and 102.80×10^7 CFU gm^{-1} of dry soil as measured by combination B0C0 recorded 67.87 × 10^7 and 10^7 × 78.96 CFU gm^{-1} of dry soil for the two stages, respectively (Tables 3 and 4). The reason for the increase may be due to the efficiency of seaweed extracts and mineral fertilisation, which led to an increase in root secretions and improved performance in absorbing water and nutrients, thus increasing biomass and increasing the effectiveness of soil enzymes.

The effect of the triple interaction between vermicompost fertiliser, seaweed extracts and nitrogen fertiliser, was significant on the number of total bacteria in the soil i n the two stages of flowering and full maturity.

At the flowering stage, the combination, A1B1C1, gave the highest number of total bacteria in the soil in reaching (102.18 × 10^7) CFU gm^{-1} of dry soil compared with the combination A0B0C0, which recorded the lowest value of 41.84 × 10^7 CFU gm^{-1} in dry soil (Table 3), while in the full maturity Stage, the combination outperformed A1B1C0 and recorded the highest value of 124.63 × 10^7 CFU gm^{-1} of dry soil compared with the combination A0B0C0 that gave the lowest value was (32.32 × 10^7) CFU gm^{-1} dry soil (Table 4). The reason for the superiority of the treatment of the A1B1C1 fertiliser combination consisting of 50% of the fertiliser recommendation for vermicompost + 40 kg h^{-1} seaweed extracts + 50% of the fertiliser recommendation for nitrogen fertiliser may be attributed to the effect of marine extracts on providing additional quantities of nitrogen, in addition to the role of vermicompost in reducing the degree of soil reaction, which led to the replacement of half the recommended amount of nitrogen fertiliser, and then the integration in adding fertilisers increased the readiness of nutrient absorption by the plant and increased the effectiveness of the roots and increased microorganisms, but during the period of full maturity, the numbers of bacteria increased upon treatment. It consists of 2 tons h^{-1} vermicompost + 40 kg h^{-1} seaweed extracts because of the cumulative effect of organic fertilisers, which was positively reflected on the numbers of bacteria after a period of addition, in addition to the fact that organic additions have an important effect in increasing the numbers of microorganisms by supplying the organisms with nutrients and providing the appropriate medium for their growth and reproduction and increasing their enzymatic secretions (Okabe, 2012).

Conclusion

Vermicompost fertiliser has good fertility properties that contribute to improving plant growth, as the addition of vermicompost and seaweed extracts and 50% of the fertiliser recommendation for nitrogen has achieved superiority in giving the highest density numerical of bacteria in the stages of flowering and full maturity.

Recommendations

From our present study, we recommend the integrated use of mineral fertilisers, vermicompost, and seaweed extracts, as they achieve the highest density numerical of bacteria, and thus reduce the amount of mineral fertilisers added, which maintains a healthy environment by improving the agricultural product as well as reducing production costs.

Also, special studies in the production of vermicompost should be expanded from different sources of worms in their species, with the diversity of their source of nutrition, as studies performed on the use of this fertiliser are few, in addition to the positive changes in soil and plant characteristics.

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