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EFFECT OF USING SOME OF MICROBES AND SOIL CONDITIONERS TO MITIGATE SOIL DEGRADATION IN BALOZA NORTH SINAI REGION, EGYPT.

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ABSTRACT

Little is known about how future climate change may impact soil erosion is critical for developing appropriate management strategies, food security and significant hazards to human food and health. This study expected to have regionally variable effects in the studied area of Sinai on important how can controls of wind erosion phenomenon by using biofertilizers. Wind erosion assessed by BSNE traps. Panicum crop was cultivated on sandy soil in Baloza area, North Sinai. This study was carried out during the period from Nov.2020 to Oct. 2021. Five treatments were conducted, two added rate (15 -30 m^3/ha) for compost added individually and combination with biofertilizers. From the results, the best treatments were 30 m^3/ha of compost with biofertilizers which decreased annual quantity of soil loss by wind erosion about 60% as compared to control and about 42% with compared to compost individually. Also, the effect of biofertilizers substances such as Exopolysaccharide (EPS) and Fungi haiphi increased dry stable aggregate >0.84 and decrease of erodibility factor about 39% when compared with control. On the other hand, the addition of 30m^3/ha compost with biofertilizer increased soil moisture about 97%, and reduced Enrichment Ratio (ER) of soil organic matter and total nitrogen, Phosphorus and potassium nutrients in eroded material as follow 83%,48%,62% and 57% respectively. Therefore, it significantly increased the total yield of Panicum about 70% when comparing with control. These potential biological fertilizers would play a key role in productivity and sustainability of soil and also in protecting the environment as eco-friendly and cost-effective inputs for the farmers.

Key Words: wind erosion, climate change, biofertilizers, growth promoting rhizobacteria, exopolysaccharide

INTRODUCTION

Sinai is located in the arid belt in North Africa and Southwest Asia and it will be one of the economically promising areas in Egypt **(Sharkawy *et al.*, 2010 and Roushdi *et al.*, 2016).** From the economic and social point of view, the Egyptian Government is interested by Sinai development attention to protecting the environment in order to preserve the integrity of the land and its inhabitants**.** It can be referred to (1) long-term changes in average weather variables (2) all changes in climate induced their impacts (3) human- induced climate change and changes in climatic variability continue to be major global change issues for present and future generation **(Roushdi *et al.*, 2016).** It is one of the most promising areas in Egypt have agriculture extension and development depending on El-Salam canal water and underground water **(Sharkawy *et al.*, 2010, Dadamouny & Schnittler 2015 and Roushdi *et al.*, 2016).** On this context, climate change is a complex phenomenon not easy to limited (**Dadamouny and Schnittler 2015).** According to **Edwards *et al.*, 2019** wind erosion has serious effects for food security and therefore significant hazards to human nutrition and health & communities. In this context, the climate conditions in Sinai encourage to soil erosion by wind **(Wassif 2007)**. In addition, the potential impacts of climate change on control of wind erosion especially vegetation cover, community composition, frequency magnitude, and erosive weather events particularly in North Sinai (**Edwards *et al*, 2019 and Sharkawy *et al.*, 2010**). In view in these facts, global climate change directly or indirect affect of some climatic and agronomic factors such as temperature and water quantity and quality which leads to disturbs of these factors especially those related to abiotic aspects such as temperature **(Morcillo and Manzanera 2021)**. **Singh *et al.*, (2020),** reported that abiotic factors have intensive effect of depletion agricultural yield such as high temperature (20%), drought (9%) and other stress (47%) lead to average of 50% crop yield loss. So, association between drought effect on soil erosion is quite complex (**Parsons 2017 and Masroor *et al.*, 2022**). Furthermore, the effect of drought on soil reduces soil moisture and increasing soil erodibility which causes of soil degradation and/or soil desertification leading to decrease in vegetative growth **(Wassif 2007 and Masroor *et al.*, 2022).** The behavior of temperature and low rainfall during drought conditions leads to wind erosion **(Masroor *et al.*, 2022)**. This last can reduce important properties of soils such as organic matter and making agriculture on eroded soils more susceptible to climate-related risks **(USDA NIFA 2013)**. Little data are available concerning the relationship between using biofertilizer or Plant Growth Promoting Microbes PGPM and mycorrhizal fungus (AMF) “microbial inoculants” to mitigate climate change risks or wind erosion in direct way. Otherwise, to overcome climate change risks and control wind erosion by using a substance (may be a solid or liquid) which contains living microorganisms (bacteria individual or in combination with algae or fungi) was called biofertilizers (**Asoegwu *et al.*, 2020**, **Yadav *et al.*, 2020**

and Ibeh *et al*., 2019). Harahap *et al*., (2018), Abd El-Hamid *et al*., (2013), Itelima *et al*., (2018), Awasthi *et al*., (2017), Ibeh *et al*., (2019) and Yadav *et al*., (2020) studied biofertilizers to improvement soil properties, plant availability & uptake of mineral nutrients, improvement agriculture yield, in the same time have time consuming, not expensive, eco-friendly, easy to use, soil and plant improvement & sustainable **(FIXSOIL 2016, Al Shankiti and Gill 2016 and Singh *et al*., 2020)**. Otherwise, it needs special storage care for a longer period, must be used before the expiration date, accuracy in selecting the strain, cannot used alone and it must be combination with organic fertilizer to ensure the revival of the microbe **(Ibeh *et al*., 2019 and Abd El-Hamid *et al*., 2013)**. The aim of this research was to investigate the relationship between biofertilizers and control wind erosion. As well as the effect of such relationship for enhancing Banicum crop yield by in North Sinai.

MATERIAL AND METHODS

A field experiment was deducted at Baloza Research Station of the Desert Research Center, Egypt, lie within the latitudes at 31^{0} 3' 0 "North and within the longitude, 32^{0} 36' 0 "East. It is located at North Sinai Peninsula as showed in **Fig (1)**. It was conducted in 2020-2021. It is occupied about 1 ha.

Experimental design:

It was established as split-split plot experimental design. The main plots involved two fertilizer types i.e., organic fertilizers and biofertilizer. The sub-plots were two added rates i.e., organic fertilizers with and without biofertilizers (15 m^3/ha and 30m^3/ha). So that all study treatments were five treatments as the following: **(C0)** was carried out as the local farmers practice in this area (control), **(C1)** compost at rate of 15m^3/ha, **(C2)** compost at rate of 30 m^3/ha, **(C3)**, biofertilizers with added 15m^3/ha rate of compost, **(C4)**, biofertilizers with added 30 m^3/ha rate of compost. Each treatment with its three replicates was carried out in a rectangular plot (5×110 m) for oriented in NW to SE direction. The distance between treatments were kept at 1 m, which created a buffer zone area between treatments. At harvesting, three randomized samples were taken from each plot using a square wooden frame (1 m^2) to determine the yield. In addition, the Banicum crop was cultivated under drip irrigation system from El-Salam canal which it salinity about 2.27 dS/m. Moreover, it is green forage crop was cultivated in first November 2020 in all plots using tillage machine. The yield was harvested by five cutting during the experimental period which harvested in October 2021. **Table (1)** shows some properties of the soil depth (0-30 cm) of the experimental site. It is clear that soil texture is sandy. Soil bulk density (BD) reached 1.60 $Mg.m^{-3}$ and it is considered poor of soil fertility. **Table (2)** shows the chemical analysis of the used organic fertilizer (compost). Plants were treated with combined mixture of bacterial culture and VAM twice; the first dose was at age of 3 weeks and the socend after 45 days. Total microbial counts were estimated according to **Allen, (1959**). Soil dehydrogenase activity was estimated according to **Casida *et al.*, (1964).**

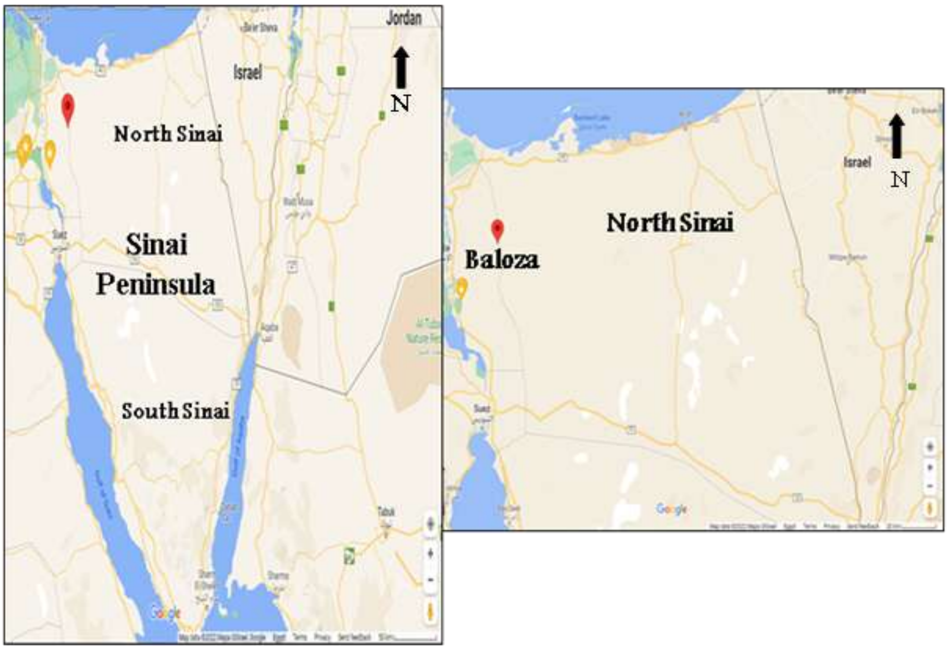


Fig (1): Location map of the experimental site at Sinai, Egypt

Table (1): Some soil properties of surface layer (0-30 cm) for the experimental site.

Soil depth (cm)	pH	EC (dS/m)	$CaCo_3$ (%)	Particle Size Distribution (%)				Texture class	BD* (Mgm^{-3})
				C.S*	F.S*	S*	C*		
0-30	7.89	1.37	10.5	80.48	8.64	6.34	4.54	Sandy	1.60

C.S*: Coarse sand, F.S*: Fine sand, S*: Silt, C*: Clay, BD*: Bulk density

Table (2): Chemical composition of compost sample

Sample type	moisture (%)	pH	Ec (dS/m)	N (%)	*OM (%)	C/N ratio	P (%)	K (%)
Plant/Animal compost	20	6.56	4.39	0.56	24.23	25:1	0.57	0.75

Study parameters:

Soil erodibility factor I, was calculated for the surface soil (0-5 cm) based on the regression equation between soil erodibility and percentage of dry soil fraction >0.84 mm was determined as follows: $I=525\times2.718^{-04F}$, where: F is the percentage of non-erodible fractions > 0.84 mm according to **Schwab *et al*. (1993).** Big Spring Number Eight samplers (BSNE) were used to measure the soil loss rate in each treatment as shown in **Fig (2)** described by **Fryrear *et al.,* (1986)**. Samples of eroded materials were collected at three heights from soil surface 0.1, 0.5 and 1m. Two sampls were installed at the beginning of the field and 100 m leeward from field edge. It collected at one year during Nov. 2020 to Oct. 2021. The mass/ height data at each cluster were analyzed as attained by **Fryrear and Saleh (1993) and Fryrear, (1995)**. The exponential and power equation were integrated to calculate the amount of eroded and deposited materials transported by saltation (Qsa, $Kg.m^{-1}$ width) and suspension ($Q_{su,}$ $Kg.m^{-1}$ width), respectively. The total soil loss transported by wind (Q_t, $Kg.m^{-1}$ width) was calculated by summing the amount of saltated and suspended materials. Meteorological records as described by **FAO AQUASTAT (2019)**. Climatic erosivity factor (C) was calculated by **$C= 386\ U^3/(PE)^2$,** where: U is the average annual wind velocity from soil surface (ms^{-1}) and PE is the precipitation effectiveness index of Thornthwaite. The PE index calculated by the following equation: **$PE= 3.16\ \Sigma\ (Pi/(1.8\ Ti +22))^{10/9}$** , where: Pi is monthly precipitation (mm), and T_i is average monthly air temperature (°C) (**Woodruff and Siddoway 1965).** Non erodible fractions percentage > 0.84 mm was determined according to **USDA, SCS (1988)**. Soil samples were collected at triplicate of surface soil layer (0-30 cm) The particle size distribution using the pipette method particle size distribution, Bulk Density (BD), Organic Matter content (OM), Total Nitrogen (TN), available P and available K were determined using the relevant standard methods described by **Klute (1986) and Jackson (1973).** The Enrichment Ratio (ER) was calculated as the following equation: ER= Ce/Co Where, Ce is the concentration of nutrient in the sediment, and Co is the concentration of soil nutrients in the bare soil according to **Are *et al.,* (2011)**.

Fig (2): The Big Spring Number Eight (BSNE) trap **(Fryrear, 1986)**

Isolation of bacteria that produce organic acids:

Serial dilution method was used to isolate bacteria from soil obtained from Baloza (North Sinai) using nutrient medium. Bacterial isolates were examined for their ability to produce organic acid according to **Suntornsuk and Hang (1994)**. For organic acid determination with HPLC, organic acids were determined following the methods of **Yadav *et al*., (2013).** In addition, isolation of exopolysaccharide (EPS) producing bacteria, the soil EPS producing bacteria were isolated from agricultural soil of North Sinai. The isolation of bacterial culture was done by means of serial dilution followed by spread plate method using sucrose medium **(Amellal *et al*., 1998).**

Vesicular Arbuscular Mycorrhizal (VAM) spores:

It was collection the spores of VAM from twenty-seven soil samples of many locations from different Egyptian Governorates by the wet sieving and decanting technique, described by **Gerdemann and Nicolson (1963)**. The number of spores present in soil was determined according to their morphological features using keys of **Gerdemann and Trappe (1974)**. In order to facilitate rapid spore counts, the spore suspensions were filtered through 60 mm diameter squared membrane filter No. 100, grad 0.45, U.K according to **Trappe (1982)**. The number of spores / ml was calculated by counting the spores contained in a portion of the membrane filter and then estimating the number of spores in the volume of the utilized soil. Spores were kept moist by storing at 4°C according to **Schenck and Perez (1987).** Propagation of VAM inoculums, the collected VAM spores were used to inoculate sterile soil which cultivated with berry plant, as greenhouse experiment. After 3 months, the spores were propagated in soil and the roots of berry plants were infected with VAM. These collected spores can be used as inoculums to treated soil as described by **Ravolanirina *et al*., (1987)**. Thus, the spores of VAM were extracted from their cultivations and propagation pots, planted by berry, using wet sieving and decanting method **(Daniels and Skipper, 1982)**. The spore suspension was diluted with water, so that each ml has 135 spores. Identification of the potent isolate by the methods described by **Gordon *et al*., (1973)**. Phylogenetic Analysis: Sequences of 16S rRNA for the selected isolates were constructed in Bio Edit software (**Hall 1999**). Nucleotide sequence through BLAST program. Multiplication of nucleotide sequences alliance was performed using Bio Edit and Clustal W. Neighbor joining phylogenetic tree was constructed by using Phylip 3.65 (**Felsenstein 1993**). Neighbor Joining (NJ) method was used to assemble the phylogenetic tree (**Saitou and Nei 1987**).

Plant growth promoting properties of selected bacteria isolates were tested *in vitro* for plant growth promoting properties. Nitrogen fixation was determined according to **Dobereiner and Day (1976).** For studying phosphate solubilization, the method of **Liu *et al*., (2014)** was followed. Hydrogen cyanide (HCN) production, was determined according to the method described by **Bakker and Schipper (1987).** The method of **Apine, and Jadhav, (2011)** was followed for the estimation of indole acetic acid (IAA). Determination of mycorrhizal colonization in roots was take samples of 1cm root segments from plant to assess colonization percentage through clearing and staining of the root samples. The staining method of **Phillips and Hayman (1970)** was used for preparing root samples for microscopic observation. Root pieces were then stained with 0.05% (w/v) trypan blue-lactic acid staining solution which was prepared by mixing 0.05 g trypan blue with, 40 ml lactic acid, 40 ml glycerol, and 20 ml tap water. The gridlines intersect described by **Giovannetti and Mosse (1980)** was used to estimate the mycorrhizal colonization percentage. Vertical and horizontal gridlines were scanned under light microscope and the absence or presence of colonization was recorded at each point where a root segment intersects a line. The formula used for calculation of mycorrhizal colonization percentage is: AM% = No. of positive intersect points/ Total number of observed intersect points× 100.

Statistical analysis

Using Statistic version 9 computer software, the outcomes of this study were statistically assessed, and the differences between the treatment approaches were declared significant when they were more than the Least Significant Differences (LSD) at the 5% stage. **(Analytical software, 2008).** The significant differences of yield as affected by the treatments were evaluated by Duncan's Multiple Range-Test **Duncan (1955).**

RESULTS AND DISCUSSION

Isolation of organic acid producing bacteria:

Detection of organic acid:

Detection of organic acids in the culture broth of the selected isolate was determined through HPLC after 96 h of incubation. Three different organic acids, including lactic acid, malic acid and acetic acid were detected from the culture medium of the selected isolate. These acids were confirmed by comparing HPLC results of six pure organic acids as standard **(Fig 4)**. Deionized water was taken as a control. Out of the three different organic acids, Hexanoic acid was produced in the largest quantity (494.8 mg/l), followed by Isovaleric acid (181.8 mg/l) and Lactic acid (173.1 mg/l). HPLC analysis indicates the presence of Hexanoic acid, lactic acid, and Isovaleric acid in the broth culture of selected organic acid bacteria.

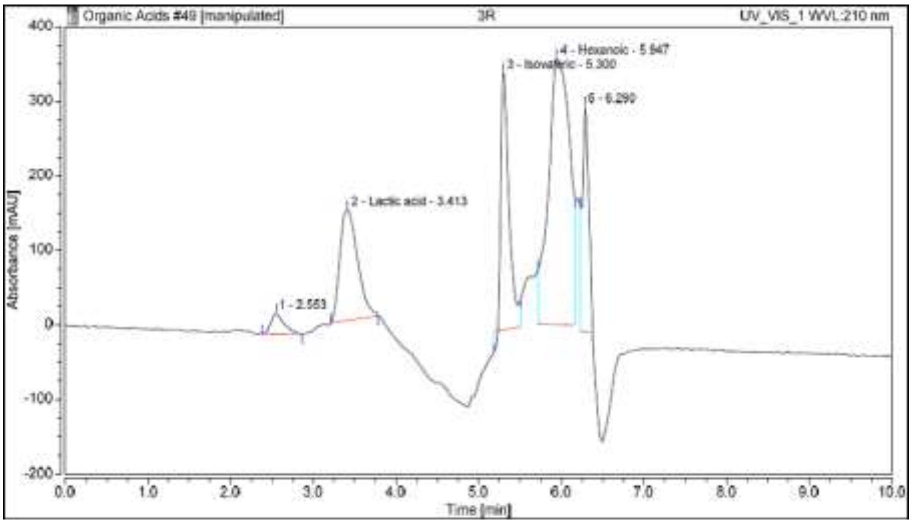


Fig (4): HPLC analysis of organic acids in the culture supernatant of isolate at 144 h of incubation in NBRIP broth. The corresponding peaks detected in culture medium were lactic acid, Isovaleric acid and Hexanoic acids including two unknown peaks (2.36 and 12.66)

Isolation of exopolysaccharide (EPS) producing bacteria:

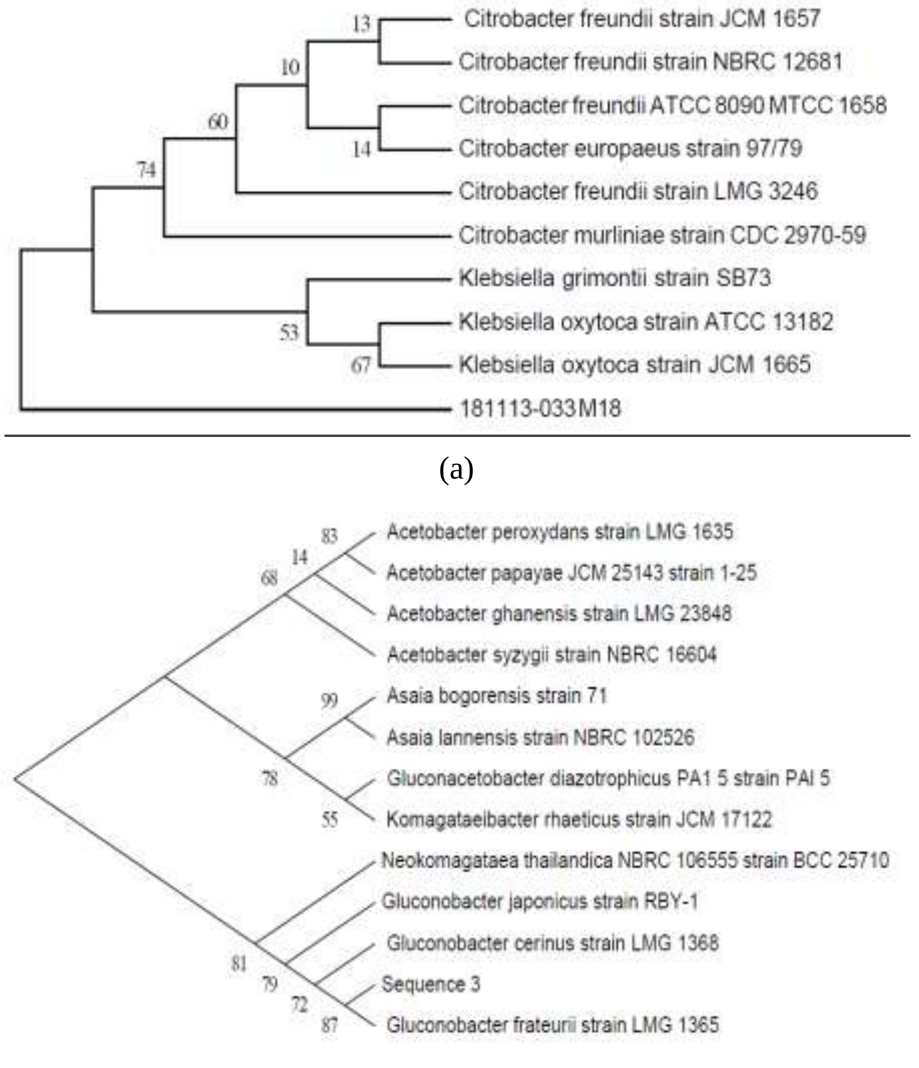
The ability of bacterial isolates to produce exopolysaccharides was determined and the highest EPS from six isolates was selected and identified. The EPS production ranged from 0.43 to 1.62g/100ml.

Identification of selected isolates:

Morphological and biochemical characteristics of the selected isolates are summarized in **Table 3**. Molecular characterization of bacterial isolate that produced the highest amount of organic acids was performed by partial sequencing of 16S rRNA and it was belonging to *Gluconobacter frateurii* with blast identity of 99 %. The isolate that showed good production of EPS was closely related to *Klebsiella oxytoca* with 100% blast identity. Phylogenetic tree of the two bacterial strains and closely correlated strains is illustrated in **(Fig 5)**.

Table (3): Morphological and biochemical tests of selected strains:

Characteristic	***Gluconobacter frateurii***	***Klebsiella oxytoca***
Gram staining	**Gram-negative**	**Gram-negative**
shape	**Rod**	**Rod**
Motility test	**motile**	**motile**
Spore forming	**-ve**	**-ve**
Methyl red test	**+ve**	**-ve**
Oxidase test	**-ve**	**+ve**



(a)

(b)

Fig (5): Phylogenetic tree of partial 16S rRNA sequence for isolate (a) *Gluconobacter frateurii* and (b) *Klebsiella oxytoca*.

Plant growth promoting properties of bacterial isolates

The selected isolates exhibited plant growth promoting properties as shown in **Table 4**. The two tested isolates had the capacity to dissolve phosphate and produce indole acidic acid (IAA) and hydrogen cyanide (HCN). These results suggest that the *Gluconobacter frateurii* and

Klebsiella oxytoca can be beneficial in improving growth of panicum and other plants by providing nitrogen and phosphorous nutrition. They also produced considerable amount of IAA which is a valuable trait of PGPR, as this growth regulator helps the plant to establish greatly organized root system, thus increasing the nutrients uptake and improving plant growth **(Rizvi & Lee (2022)**. In addition, the studied isolates gave promising results for HCN production by altering the filter paper colour to dark brown. Rhizobacteria-based HCN development suggests their ability to inhibit phyto-pathogens growth and thus promote plant growth **(Dhole & Shelat 2022 and Kumawat & Sharma 2022)**.

Table (4): Plant growth promoting properties:

Characteristic	*Gluconobacter frateurii*	*Klebsiella oxytoca*
Nitrogen fixation	-ve	+ve
Phosphate solubilization (ppm)	220.5	79.8
IAA production (ug/ml)	3.20	1.23
HCN production	-ve	-ve

Climatic erosivity factor:

According to the data of monthly means of meteorological data during Nov. 2020 to Dec. 2021 of the studied area **Table (5)**, the mean monthly average air temperature was 22.69 °C. High air temperature prevails from May to October. The summer is the hottest season and is virtually dry. Annual rainfall reached 96.23 mm. Most of it occurred from November to March. The average of monthly wind speed was 4.96 $m.s^{-1}$. Generally, the highest wind speed occurred in March and included the khamassien wind period. **Fryrear *et al.*, (2008**) and **Afifi & Gad (2011)** stated that the average of wind speed ranged between >5 $m.s^{-1}$ to occur wind erosion phenomenon. Therefore, average values reached its maximum, 5.35 $m.s^{-1}$ during March, while it reached its minimum, 2 $m.s^{-1}$ during October. It is about 75% of the windy day's recorded warm dusts storms. Days with dust storms mostly occurred during October and January. Generally, Baloza area is characterized by its arid weather conditions to extreme arid **(UNEP 1992).** Therefore, such area is subjected to wind erosion phenomenon. **Shata 1992 and Sharkawy *et al.*, 2010** explained the desertification in Sinai is intimately related to the climatic fluctuations. The climatic erosivity factor (climate factor) was 6.39 which agree with **Sharkawy *et al.*, 2010**. **Chepil *et al.*, (1963), Sharkawy (2006) and Sharkawy *et al.*, 2010** showed that the climatic erosivity factor greater than 1.5 is an indicator for the very high degree of wind erosion hazards. Consequently, the studied area is highly erosive and suffers from wind erosion hazards, where its conditions are characterized by low rainfall and high air temperature throughout the year.

Table (5): Monthly means of some meteorological records from Nov. 2020 to Oct. 2021 and calculated wind erosivity factors for Baloza areas.

Month	Temperature (°C)	Wind speed max. (m/s)	Rainfall (mm)
November	20.00	5.00	20.90
December	18.00	5.05	6.58
January	15.85	4.71	12.11
February	15.82	4.60	31.36
March	16.90	5.35	17.25
April	20.03	5.08	1.26
May	25.54	4.93	0.13
June	26.53	4.92	0.00
July	29.88	5.18	0.00
August	30.69	4.76	1.07
September	28.17	5.28	2.57
October	24.85	4.68	3.00
Total			96.23
Mean	22.69	4.96	
Erosivity factor of wind or climatic factor (C,dimensionless)	6.39		

The phenomenon of wind erosion and hazards:

Soil loss by wind erosion (**Table 6)** was determined at different heights using BSNE sampler. Obviously, it was affected by the treatments and decreased with increasing height above the soil surface. The quantities of airborne materials Kg/m width /y collected at three heights (0.1, 0.5 and 1m) are shown in **Fig (5)**. Eroded materials quantities are dependent on sampler’s height, measurement period and the chosen site **(Sharkawy *et al*., 2010 and Wassif *et al*., 2020)**. In addition, it was fitted the power and exponential decay mass-height profile, which was reported as most appropriate for arid and semi-arid regions (**Ali *et al*., 2011 and Wassif *et al*., 2020)**. The suspended or saltated eroded particles exhibit considerable variations between treatments and measurement period. The annual values of eroded materials moved by saltation (up to 0.2m height above the soil surface) ranged between 38.13 and 89.02 Kg/m width. In addition, suspension height (up to 1 m above the soil surface) ranged between 18.13 and 35.22 Kg/m width.

Table (6): Soil loss values as affected by compost and biofertilizers measured by BSNE samplers during the study period (Nov.2020 to Oct. 2021)

Treatment	Time of soil loss sampling	Eroded materials (g/cm^2) at different heights above the soil surface (m)			Qsa*	Qsu*	Qt*
		0.1	0.5	1	Kg/m width /y		
C0	Nov.	1.221	1.106	0.942	8.31	3.00	11.31
	Dec.	1.419	1.21	0.962	9.09	3.47	12.57
	Jan.	1.263	0.926	0.79	7.52	2.93	10.45
	Feb.	1.248	0.903	0.69	6.88	2.89	9.77
	March	2.852	1.541	1.006	10.25	4.54	14.79
	April	1.852	1.541	1.006	9.25	4.54	13.79
	May	1.323	1.007	0.802	7.58	3.09	10.67
	June	1.3789	1.001	0.784	7.86	3.22	11.08
	July	1.556	1.232	1.05	9.64	3.71	13.35
	Aug	1.289	0.946	0.751	7.39	3.00	10.39
	Sep.	1.543	1.352	1.02	9.39	3.78	13.17
	Oct.	1.221	0.906	0.642	7.86	2.89	10.75
	Annual				101.02	41.06	142.08
C1	Nov.	1.221	1.006	0.742	6.25	2.94	9.19
	Dec.	1.319	1.11	0.862	7.09	3.19	10.28
	Jan.	1.163	0.826	0.69	5.67	2.66	8.33
	Feb.	1.148	0.803	0.59	5.45	2.67	8.13
	March	1.656	1.207	1.095	8.96	3.85	12.81
	April	1.152	1.041	0.806	6.66	2.86	9.51
	May	1.223	0.907	0.702	6.11	2.87	8.99
	June	1.2789	0.901	0.684	6.02	2.95	8.98
	July	1.318	1.032	0.95	7.16	3.07	10.23
	Aug	1.189	0.846	0.651	5.58	2.74	8.32
	Sep.	1.243	0.952	0.92	7.07	2.90	9.97
	Oct.	1.121	0.706	0.542	4.88	2.51	7.40
	Annual				76.91	35.22	112.12
C2	Nov.	1.121	0.906	0.642	5.79	2.72	8.51
	Dec.	1.018	0.932	0.75	6.20	2.54	8.74
	Jan.	1.063	0.726	0.69	5.29	2.38	7.67
	Feb.	0.948	0.603	0.59	4.65	2.09	6.74
	March	1.456	1.007	0.995	7.66	3.29	10.94
	April	0.852	0.841	0.706	5.49	2.16	7.65
	May	1.023	0.807	0.602	5.20	2.44	7.64
	June	1.1789	0.801	0.684	5.69	2.67	8.36
	July	0.943	0.852	0.72	5.66	2.32	7.98
	Aug	1.089	0.746	0.651	5.22	2.46	7.68
	Sep.	0.506	1.01	0.762	6.59	2.97	9.56
	Oct.	0.821	1.219	0.442	3.67	1.80	5.47
	Annual				67.10	29.84	96.94

Qsa*= Quantity of saltated material, Qsu*= Quantity of suspended materials, Qt*=Quantity of total field soil loss

Table (6): Cont.

Treatment	Time of soil loss sampling	Eroded materials (g/cm^2) at different heights above the soil surface (m)			Qsa*	Qsu*	Qt*
		0.1	0.5	1	Kg/m width /y		
C3	Nov.	1.021	0.906	0.642	5.66	2.55	8.20
	Dec.	0.918	0.732	0.55	4.66	2.19	6.85
	Jan.	0.463	0.326	0.29	2.35	1.06	3.41
	Feb.	0.448	0.303	0.19	1.85	1.03	2.88
	March	1.056	0.907	0.895	6.42	2.52	8.94
	April	0.852	0.541	0.506	3.98	1.87	5.85
	May	0.523	0.407	0.202	2.20	1.28	3.48
	June	0.5789	0.401	0.284	2.60	1.34	3.94
	July	0.843	0.652	0.52	4.46	2.01	6.47
	Aug	0.489	0.346	0.251	2.33	1.14	3.48
	Sep.	1.119	0.91	0.762	6.26	2.69	8.95
	Oct.	0.321	0.206	0.142	1.36	0.73	2.09
	Annual				44.13	20.41	64.54
C4	Nov.	0.921	0.706	0.542	4.63	2.18	6.81
	Dec.	0.818	0.632	0.45	3.96	1.94	5.90
	Jan.	0.263	0.226	0.19	1.66	0.97	2.62
	Feb.	0.405	0.285	0.15	4.65	2.09	6.74
	March	0.956	0.707	0.695	5.39	2.21	7.60
	April	0.752	0.441	0.506	3.73	1.60	5.33
	May	0.423	0.307	0.102	1.48	1.06	2.54
	June	0.3789	0.301	0.184	1.80	0.93	2.73
	July	0.743	0.552	0.42	3.73	1.75	5.49
	Aug	0.289	0.246	0.151	1.47	0.72	2.19
	Sep.	0.819	0.61	0.562	4.42	1.90	6.32
	Oct.	0.361	0.196	0.142	1.40	0.78	2.18
	Annual				38.32	18.13	56.45

Qsa*= Quantity of saltated material, Qsu*= Quantity of suspended materials, Qt*=Quantity of total field soil loss

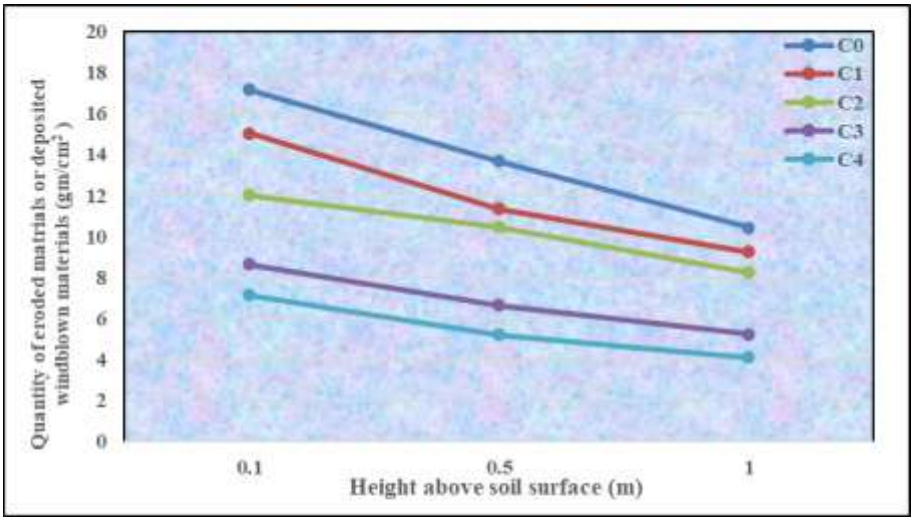


Fig (5): Vertical distribution of the eroded materials collected by BSNE samplers during the study period (Nov.2020 to Oct. 2021) at studied area

The ratio between saltated particles to the total quantity of mass transported was 71% for flat and bare soil is in agreement with **Sharkawy *et al.*,(2010).** During the experimental period from Nov. 2020 to Oct. 2021, the mass of transported materials in spring season was higher than the other months due to the response to high intensity of wind. This is may be due prevalence of the strong El-KHAMASN wind which prevails in such period. These results agree with **El-Flah (2009), Ali *et al.*, (2011), Wassif *et al.*, (2013), Sharkawy *et al*., 2010 and Wassif *et al*., 2020**. The transported soil mass via wind in Oct. was much lower as compared with the other months. This is might be due to a decreasing both air temperature, wind speed and soil texture of sandy soils. From above mentioned, the potential annual soil loss affected by treatments, which the order of it was as followed the order C0> C1> C2> C3 > C4 which the values were 142.08, 112.12, 96.94, 64.54 and 56.45 Kg/m width consequently. The best treatment was C4 which have the lowest annual soil loss 56.45 Kg/m width. Therefore, it can explain that the effect of biofertilizers with organic fertilizers reduced soil loss quantity in treatments C4 and C3 than the treatment C2 and C1 with organic fertilizers (compost) only. This is may be due to reduce soil surface disturbance by biofertilizers as will be explained in this study. These data are similar to those obtained by **Abdel Hamid *et al*., 2013, FAO (2019) and Wassif *et al*., 2020** who reported that the principal factor for minimizing soil erosion is to maintain and protects soil surface from erosion.

Soil erodibility factor:

The erodibility factor is nonresistance of soil to erosion by detachment and transport. Which meaning a high erodibility factor that the soil exposed to erosion processes leads to a larger removal of soil material. Which, it is depended on non-erodible aggregates or dry stable aggregates >0.84mm particle diameter to investigated susceptibility the soils to erode by wind. The results of non-erodible aggregate as shown in Table (7) that varied from 2.95 to 15.39%. Where, it is the lowest value due to the sandy soil in Sinai as stated by **Sharkawy *et al*., (2010).** On the other hand, there was a positive relationship between annual quantity of soil loss and erodibility factor affecting in wind soil erosion in studied area as shown in **(Fig 6)**. The results of erodibility factor (Table 7) varied from 283.68 to 466.57 Mg/ha /y. The highest value was related to the coarse soil texture which clarifies the negative relationship between coarse sand and dry stable aggregates. Due to their particles have less cohesiveness and consequently increase the soil erodibility index. In this respect, the **Sharkawy *et al.*, 2010 and Wassif *et al.*, 2020** stated that when fine particles are high, the cohesive forces between their particles cause them to coalesce into larger, less erodible particles and there will be progressive reduction in soil flux due to wind action. On the other hand, the high value of soil erodibility factor (466.57 Mg/ha/y) classified the soil to high erodibility class according to **Wassif *et***

***al*., (2013)**. In addition, the effect of treatments on soil erodibility index, the organic fertilizers treatments (C1 and C2) (425.57 and 412.16 Mg/ha/y) respectively reduced it than the bare soil C0 466.57Mg/ha/y. On the other hand, the treatments of bio and organic fertilizers were the lowest erodibility factor, and it considered the best treatments (C3 and C4) which 349.55 and 283.68. This results agree with those reported by **Sharkawy *et al*., 2010, Wassif *et al*., 2014, FIXSOIL 2016 and Wassif *et al*., 2020.**

Table (7): Soil erodibility of surface layer (0-5 cm) as affected by the studied treatment at Sinai, Egypt.

Treatment	Measurement period	Dry stable aggregate >0.84mm (%)	Soil erodibility (Mg/ha/y)
C0	Nov.-April	3.40	466.57
	May -Oct	2.50	
	Average	2.95	
C1	Nov.-April	5.80	425.57
	May -Oct	4.70	
	Average	5.25	
C2	Nov.-April	6.80	412.16
	May -Oct	5.30	
	Average	6.05	
C3	Nov.-April	9.80	349.55
	May -Oct	10.54	
	Average	10.17	
C4	Nov.-April	18.28	283.68
	May -Oct	12.50	
	Average	15.39	

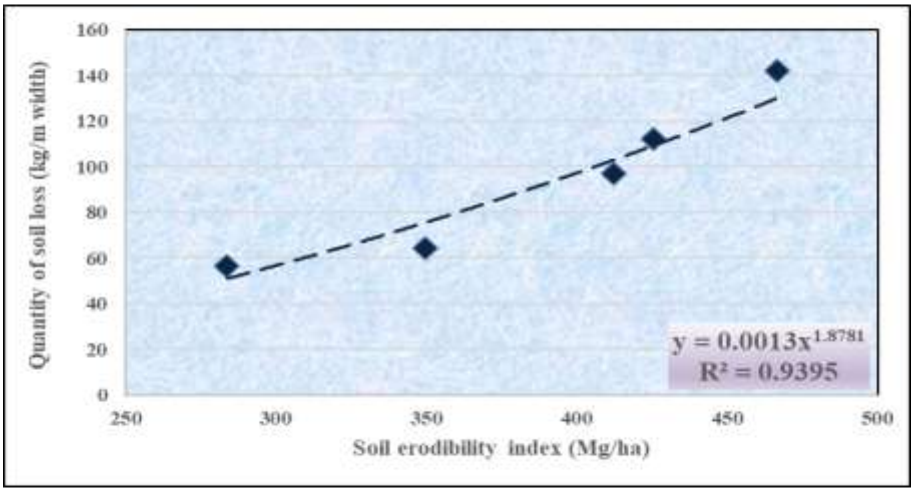


Fig (6): The relationship between annual soil loss rate and soil erodibility index affecting in wind soil erosion.

Soil erodibility and microbial activity:

From the above mentioned, the effect of treatments of bio with organic fertilizers (C3 and C4) was reduced the erodibility factor and reduce erosion susceptibility. Because of, the addition of organic matter was the only way to initiate microbial activity and structuring sandy soil **(Alshankiti and Gill 2016)**. Because of plant growth promoting Rhizobacteria (PGPR) or biofertilizers can secrete extracellular polymeric substances which called exopolysaccharides (EPS) (**Morcillo and Manzanera 2021, Abdel Hamid *et al.*, 2013, Awasthi *et al.*, 2017, FIXSOIL 2016 and Harahap *et al.*, 2018). Morcillo and Manzanera (2021)** defined EPS as a natural blend of polymers of high molecular weight release by bacteria to protect it from external climatic variability. The treatments of bio- with organic- fertilizers (C3 andC4) were the lowest erodibility factor and high dry stable aggregate >0.84 mm due to EPS mechanism and Mycorrhiza fungi haiphi. Therefore, it binds the soil particles as cement substances when it adsorbed on soil due to formation of cations bridges, hydrogen bonding, van der waals forces, and anion adsorption mechanisms between soil particles **(Morcillo and Manzanera 2021 and FIXSOIL 2016).** This leads to increased dry stable aggregate >0.84 and decrease of erodibility factor which improve soil structure and reduce erosion potential. These results are similar to those obtained by **Abdel Hamid *et al.*, (2013), Awasthi *et al.*,(2017), FIXSOIL (2016) and Harahap *et al.*, (2018).**

Soil moisture content as affected by the treatments:

The results of soil moisture content as affected by the treatments under consideration are given in **Fig (7)**. The effect of the treatments on soil loss can be arrange in the descending order as follows: C4 > C3 > C2 > C1 > C0 which their values were 19.98 > 18.33 > 16.69 > 12.29 > 10.14, respectively. Such results indicated that, the treatments of compost with biofertilizers (C3 and C4) were the highest which increased about 97% and 81% with comparing to control C0. On the other hand, the treatments of organic fertilizers individual application of (C1and C2) were about 65% and 21.2% comparing to control. So, using biofertilizers increased retained moisture in the soil as compared to application of organic fertilizers individually. These results are in agreement with those obtained by **Morcillo and Manzanera (2021) Awasthi *et al.*, (2017) Abdel Hamid *et al.*, (2013).** Obviously, these results can be explained the fact that organic acids produced by bacteria which attain a pronounced high content of active organic compounds that enhancing the water molecules to be chelated (**Abdel Hamid *et al.*, 2013).** On the other hand, EPS that was produced by PGPR have possess unique role in the rhizosphere. Which, it acts as reservoir and a conductor of water to plant's root when bulk soil water is scarce specially under drought stress. Therefore, it is increased plant resistance to drought stress by maintaining higher water potential around the roots **(Awasthi *et al.*, 2017 and Morcillo and Manzanera 2021).**

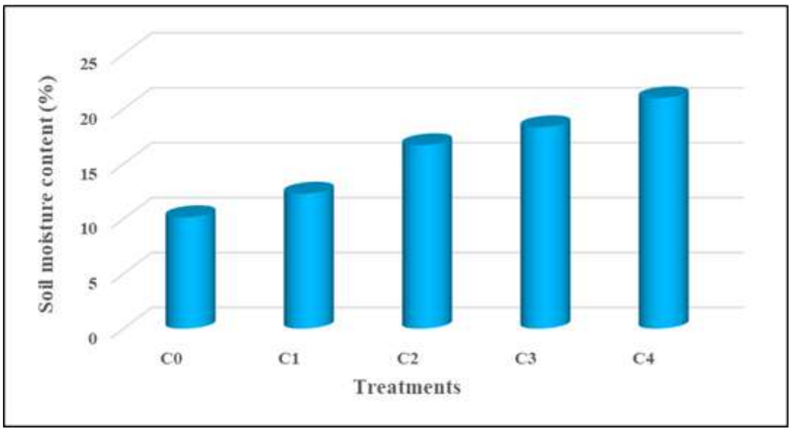


Fig (7): The effect of treatments (C0, C1, C2, C3 and C4) on soil moisture content (%).

Hence, it can be indicated to positive relationship between drought stress and increased wind erosion which can mitigated that by increased the soil moisture content **(Masroor *et al.*, 2022).** So, the increment increased of soil moisture content was decreased soil loss quantity induced by wind erosion as shown in **Fig** (8). The later shown a negative relationship between soil moisture content and quantity of soil loss.

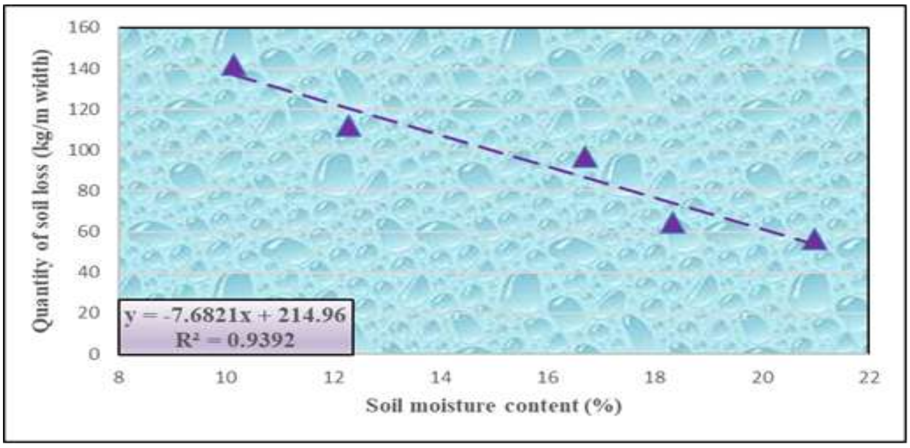


Fig (8): The relationship between annual soil loss quantity (kg/m width) and soil moisture content (%)

Effect of treatments on microbial population:

Table (8) and Fig (9), show higher total microbial counts in all treatments compared to control in panicum rhizosphere. The results of experiment revealed that increasing compost levels from 15 to 30 m^3/ha and co-inoculation with PGPR+VAM significantly increased the total microbial counts in the soil rhizosphere. The increase in microbial population might be due to increasing levels of N, P and K which increases the biomass, root exudates & ultimately provides carbon and energy to the soil microbes resulting into multiplication of microbial population **(Xiong and Zhu 2021; Niraula *et al.,* 2021)**. The increment increased microbial population might be due to application of compost (30m^3/ha) in turn provides adequate biomass as a feed for the microbes and helps in increasing microbial population in soil **(Khmelevtsova *et al.,* 2022)**. The bioinoculants trigger the microbial population might be possibly due to the improvement in the porosity and more availability of nutrients (especially P) to the plant by the bioinoculants **(Dukare *et al.,* 2022)**.

The activity of dehydrogenase enzyme differed significantly amongst all the treatments **(Table 8)**. The minimum activities of these enzymes were recorded in control and maximum was found at each highest levels of the treatment. The increased activity by increasing the rate of compost application might be attributed to the fact that inorganic source of nutrient stimulated the activity of microorganisms to utilize the native pool of organic carbon as a source of carbon, which acts as substrate for these enzymes **(Bhunia and Mukherjee 2021). Liao *et al.,* (2022)** reported that dehydrogenase activity was dependent on addition of number and amount of nutrient. Moreover, addition to compost (30 m^3/ha) significantly increased the enzyme activity in the soil. This increased might be due to manure promote biological & microbial activities and accelerated the breakdown of organic substances in the added compost, which is known to stimulate the dehydrogenase activity **(Dincă *et al.,* 2022)**. The significant increase of enzyme activity was also found by the use of bioinoculants (PGPR+VAM) as compared to no inoculation control **(Table 8)**. Increased enzyme activity of soil significantly over no inoculation, may possibly be due to the improvement in the porosity and more availability of nutrients (especially P) to the plant **(Vahedi *et al.,* 2022).** The AM root colonization was increase significantly by compost addition (15kg) and (30kg). The levels of compost addition significantly increased AM root colonization compared with control. The results indicated that compost addition enhanced AM root colonization. These results are consistent with previous studies that compost addition most often had positive effect on AM growth and sporulation **(Boutasknit *et al.,* 2021 and Ait-El-Mokhtar *et al.,* 2022)**.

Table (8): Effects of biofertilizers and compost on total microbial count, dehydrogenase activity in Rhizosphere of the Panicum Plant and mycorrhizal colonization in roots.

Treatment	Total microbial counts×10^5cfu /g dry soil	Dehydrogenase(µg) triphenyl formazan /g dry soi	AM%
C0	43^e	0.264^e	20^e
C1	75^d	0.424^d	47.5^d
C2	95^c	0.556^c	52.5^c
C3	165^b	0.625^b	65^b
C4	207^a	0.925^a	76^a

bio=(G. frateurii+ K. oxytoca+VAM)

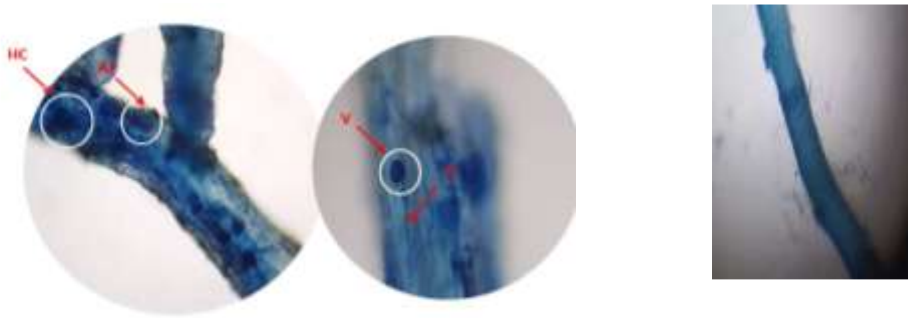

(+ve) (-ve)

Fig (10): The staining of root segments from panicum to assess colonization percentage through clearing and staining of the root samples. Hc=Hyphal coils, V=Vesicles, Ar=Arbuscules, H=Hyphae (+ve)= treatments, (-ve)= control

Enrichment ratio for eroded materials:

Fertility constituents were determined for eroded martials transported by wind within 0.1 – 1 m height above soil surface. The results are given in **Table (9) and Fig (10)**. The effects of the treatments Enrichment Ratio (ER) as a measure of the erosive process, the ER is the concentration of each component in the eroded materials divided by its percentage in the original soil 0-5cm surface layer, both on oven dry basis (**Sharkawy *et al.*,2010)**. The ER values for the organic matter (SOM), total nitrogen (TN), available phosphorus (Av. P) and available potassium (Av. K) varied from 0.14-0.97, 0.46-0.90, 0.41-1.08 and 0.41-0.97, respectively.

Obviously, the ER of OM, TN, Av. P and Av.K increased in the eroded materials as compared to the original soil surface in control (C0) due to sorting action of wind erosion in removing fine particles and there isn’t any protection to decrease eroded material **(Sharkawy *et al*., 2010**). In this respect, **Drinkwater& Snapp, (2007)** and **Wassif *et al*., (2020)** stated that low soil organic diminishes the ability of the soil to release nutrients. Also, the data was obtained under prevailing condition in Sinai, wind soil erosion process leads to degraded cultivated soils, reduced of soil productivity, & increased soil ability to erosion susceptibility, drought stress and climatic change. Otherwise, the results of ER of OM, TN, Av. P and Av. K show differences between treatments with addition of individual compost (C1 and C2) and in combination with biofertilizer (C3 and C4). It is arrange as follow ER C4<ER C3 <ER C2 <ER C1. This is meaning the best treatment with the lowest of ER was ER C3 and ER C4 which combination of biofertilizer with compost at the rate of 15 and 30m^3/ha. This is meaning, that bio- with organic fertilizer decreased the loss of eroded material (fine particle) which was carried NPK nutrient and OM with compared with the same original treated soil. This because of the stimulation effect between compost and biofertilizer inoculation on improving the physical properties of the soil i.e., soil erodibility, soil structure and moisture content. On the other hand, the relative positive effect of biofertilizer treatment of production PGPR substances such as organic acid. This is aligned with **Abdel Hamid *et al*., 2013, Asoegwu *et al*., 2020, Itelima *et al*., 2018 and Singh *et al*., 2020.**

Obviously, the results of **Table (9)** clarify the NPK nutrient and OM content of treatment soil increased in C3 and C4 when compared with content treatment soil of C1 and C2. Therefore, the order for content OM and NPK nutrients was as follow C4> C3 > C2 >C1. Because of, functions of biofertilizers are manifold and in most cases beneficial to enhancement of soil fertility status by improve nutrient availability to plants as reported by **Alshankiti and Gill (2016)**. In this respect, **Ibeh *et al*., (2019)** reported that the biofertilizers can a function as direct and indirect source of nitrogen, phosphorus potassium to soil microbes and indirectly after mineralization to plant root. Which have ability to convert nutritionally important elements from unavailable to available form through biological process **(Asoegwu *et al*., 2020).** Also, the biofertilizers component i.e., sugar, carbohydrates, proteins, amino acids, vitamins and fats are most important contributes to soil conservation and sustainable soil fertility.

Table (9): Enrichment ratio of Organic Matter (OM), Total Nitrogen, (TN) Available Phosphorus (Av. p) and Available Potassium (Av. k) for eroded materials.

Treatment	Sample type	OM (%)		TN %		Av. P (ppm)		Av. K (ppm)	
		(%)	ER	(%)	ER	ppm	ER	ppm	ER
C0	Bare soil	0.19	0.97	0.01	0.90	5.27	1.08	62.40	0.97
	Eroded Material	0.18		0.01		5.68		60.68	
C1	Treatment soil	0.41	0.53	0.006	0.67	6.20	0.97	62.80	0.94
	Eroded Material	0.22		0.004		6.04		58.88	
C2	Treatment soil	0.83	0.25	0.005	0.60	7.18	0.84	75.20	0.76
	Eroded Material	0.21		0.003		6.01		57.07	
C3	Treatment soil	0.88	0.21	0.004	0.50	7.74	0.76	91.80	0.53
	Eroded Material	0.18		0.002		5.88		48.40	
C4	Treatment soil	0.98	0.14	0.004215	0.46	10.28	0.41	99.80	0.41
	Eroded Material	0.14		0.001958		4.26		40.47	

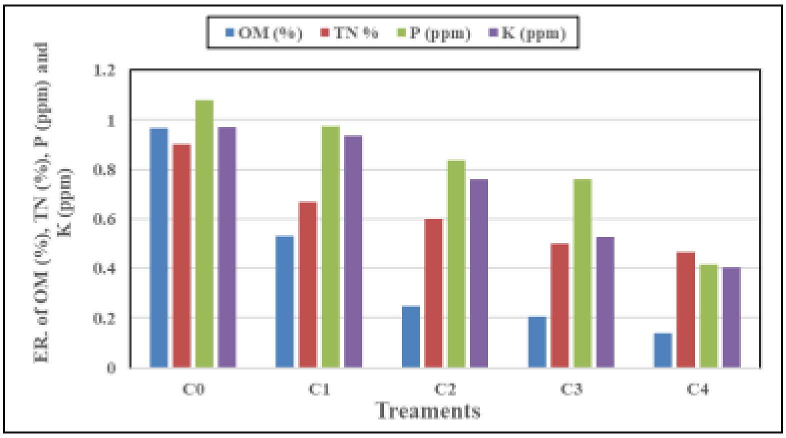


Fig (10): Effect of treatments (C0, C1, C2, C3, C4) on Enrichment Ratio (ER) of OM, Av. p and Av. K for eroded material.

Wind erosion and total yield of Panicum:

The results given in **Table (10) and Fig (11),** show positive response panicum yield to treatments. Therefore, the total yield in ascending order was C4, C3, C2, C1 & C0, 48.91, 44.32, 38.20, 34.16

and 28.75 (Mg ha^{-1}), respectively. Obviously, the % of yield increased by affected to treatment which it increments increased 70% and 54% of C4 and C3 by effect of combination of bio and compost fertilizers, respectively. This enhance the yield as compared to C0. On other hand, the increased of C2 and C1 were about 32.86% and 18.8 % comparing to C0 by compost only. It is clear from that, the effect of biofertilizer combination with compost fertilizer was increased total yield and such results are in agreement with **Itelima *et al*., (2018), Asoegwu *et al*., (2020), Abdel Hamid *et al*., (2013) and Morcillo and Manzanera (2021).** This result may be due to biofertilizer effect which keep the soil environment rich in all types of nutrients via N fixation, P and K solubilization or mineralization, release plant growth regulating substances, production antibiotic, modulates the activity of plant antioxidant enzymes and biodegradation of organic matter in the soil which supports healthy plant growth (**Sinha *et al*., 2014 and Itelima *et al*., 2018**). In addition, PGPR production of some hormones such as Indol Acetic Acid (IAA), Gibberellins, and cytokinin which improved plant root exudates, increase root growth, helping plants to enhance water & nutrient uptake, plant drought protection & consequently enhance and increase plant growth (**Abdel Hamid *et al*., 2013 , Itelima *et al*., 2018 and Morcillo & Manzanera 2021).** From the above mentioned results, it could be noted as shown in **Fig** (12) that there is a negative relationship between quantity annual soil loss and total yield. This result aligns with **Wassif *et al*., (2020)**. It is clarifying the advantages of biofertilizers, the important role to using a tool to control of wind erosion phenomenon and mitigate climate change risks.

Table (10): Effect of treatments on Banicum yield during the period from Nov.2020 to Oct. 2021.

Treatment	Mg/ha					
	First cut	Second cut	Third cut	Fourth cut	Fifth cut	Total
C0	7.97	6.09	5.73	5.21	3.75	28.75
C1	9.46	7.27	6.76	6.17	4.50	34.16
C2	10.76	8.19	7.32	6.86	5.07	38.20
C3	12.32	9.39	8.46	7.94	6.21	44.32
C4	13.57	10.32	9.31	8.66	7.05	48.91

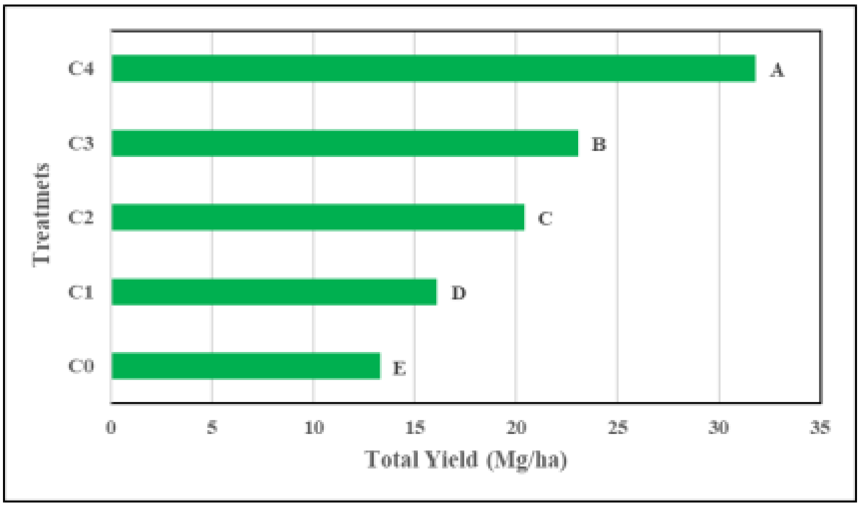


Fig (11): Effect of treatments on yield (Mg/ha). Loss means of different letters superscripts are significantly different ($p<0.05$).

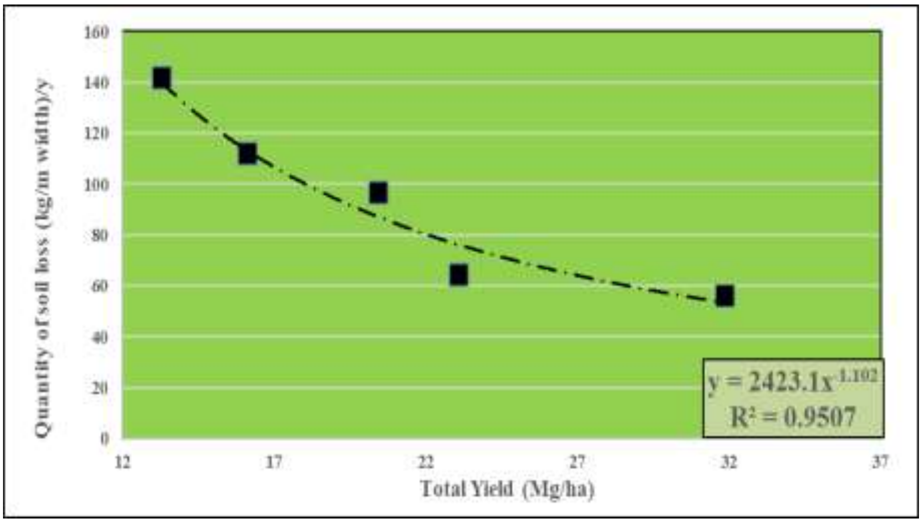


Fig (12): The relationship between quantity annual soil loss (kg/m width/y) and total yield (Mg/ha)

CONCLUSIONS

Wind erosion is a main factor of land degradation of land surface process and poses significant hazards to human health and communities. Accordingly, understanding how future climate change may impact soil erosion is critical for developing appropriate management strategies that mitigate climate change through control its potential impacts on control wind erosion. This study is one of the few studies that have been expected to have regionally variable effects in the studied area of Sinai on important how can controls of wind erosion hazards by using biofertilizers with compost. So, this study concluded how can improve resilience and efficacy of climate change adaptation by using biofertilizers combination to compost. Biofertilizers can help solve the problem of food and crop productivity. Also, it is playing a key role in productivity and sustainability of soil and protect environment as eco-friendly and cost-effective inputs for the farmers. It can be considered as low input system can help to achieve sustainability of farming. On the other hand, this technology will also help provide relief from environment stresses i.e., drought stress which leading to wind erosion at the studied area in Sinai. This study recommended using biofertilizers as a tool for wind erosion control to mitigate climate change risks and improving soil health and consequently increased crop yield. Also, it is recommended to use rate of addition 30 m^3/ha of compost with combination biofertilizers to mitigate climate change risks.

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تأثير استخدام بعض الميكروبات ومحسنات التربه على تقليل تدهور التربة تحت ظروف بالوظه شمال سيناء، مصر.

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1 وحدة ميكروبيولوجيا الاراضي- قسم خصوبة وميكروبيولجيا الارضى- مركز بحوث الصحراء - المطرية- القاهرة- مصر.

2 وحدة انجراف التربة - قسم صيانة الاراضي- مركز بحوث الصحراء - المطرية- القاهرة- مصر.

لا يُعرف سوي القليل عن تأثير التغير المناخي في المستقبل على انجراف التربة وهو أمر بالغ الأهمية لتطوير استراتيجيات الادارة المناسبة ، والأمن الغذائي ، وبالتالي المخاطر الكبيرة على غذاء الإنسان وصحته. توضح هذه الدراسة بعض التأثيرات الإقليمية المتغيرة في منطقة بالوظة شمال سيناء تحت الدراسة على أهمية كيفية التحكم في ظاهرة الانجراف بالرياح باستخدام الأسمدة الحيوية. تم تقييم انجراف التربة بالرياح بواسطة مصائد BSNE. تمت زراعة محصول البانيكوم على تربة رملية بمنطقةبالوظة بشمال سيناء. أجريت هذه الدراسة خلال الفترة من نوفمبر 2020 إلى أكتوبر. 2021. تم إجراء خمسة معاملات ، بمعدل 15و30 م^3 / هكتار للكومبوست المضاف بشكل فردي والمدمج مع الأسمدة الحيوية. من النتائج ، كانت أفضل المعاملات هي 30 م^3 / هكتار من السماد العضوي المدمج مع الأسمدة الحيوية مما قلل من الكمية السنوية المفقودة للتربة بسبب انجراف التربة بالرياح بحوالي 60٪ مقارنة بالكنترول وحوالي 42٪ مقارنة بالسماد المنفرد. كما أن تأثير المخصبات الحيوية مثل عديد السكاريد الخارجي (EPS) و هيفات الفطريات زاد من تجمعات التربة الثابتة> 0.84 ونقص عامل قابلية الانجراف بنحو 39٪ عند مقارنته بالكنترول. من ناحية أخرى ، أدت إضافة 30 م^3 / هكتار من السماد العضوي إلى زيادة رطوبة التربة بحوالي 97٪ ، وخفض نسبة الاغناء (ER) للمواد العضوية بالتربة ومغذيات النيتروجين الكلي والفوسفور والبوتاسيوم في المادة المنجرفة كما يلي: 83٪ ، 48٪ و 62٪ و 57٪ على التوالي. لذلك ، فقد أدى إلى زيادة كبيرة في العائد الاجمالي للبانيكوم بنحو 70 ٪ مقارنةً بالكنترول. في الواقع ، ستلعب هذه الأسمدة البيولوجية المحتملة دورًا رئيسيًا في إنتاجية واستدامة التربة وأيضًا في حماية البيئة كمدخلات صديقة للبيئة وفعالة من حيث التكلفة للمزارعين.