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Synergistic Effect of Some Soil Amendments on the Physical Properties and Wheat Productivity of Sandy Soils

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Abstract: A field experiment was carried out in a sandy soil at El-Ismailia experimental farm of Agric. Res. Station. The farm is located at 30º35`41.9 N latitude and 32 º16`45.8̋ E longitudes. Three-facto computer model was implemented to study the combination effect of X1 (polyacrilamid+ bentonite), X2 (biocompost) and X3 (gypsum + sulphur + rock phosphate) on soil properties and plant growth. Wheat plant (Giza 168) was chosen as an indicator crop to study the effect of different combination of soil amendments on some physical characteristics of sandy soil, growth characters and nutrient contents and uptake of wheat crop. Results showed an improvement in soil physical properties and increases in all wheat growth characters as a result of different combinations of the used soil amendments compared to the control treatment.

However, total porosity (TP) show a highly significant correlation coefficient (r = 0.99, 0.91, 0.81 and 0.96) with saturation percentage (SP), soil field capacity (FC), wilting point (WP) and available water (AW), respectively. The maximum values of TP was obtained with the combination ratio of 16.6%, 66.6%, and 16.6% for X1 (polyacrilamid + bentonite), X2 (biocompost) and X3 (gypsum + sulphur + rock phosphate), respectively. Also, wheat growth characters include grains, straw, biological yield, weight of 1000 grain and some morphological yield (plant height & spike length) showed an increase by the application of soil amendments with highly correlation coefficients (r = 0.99, 0.99, 0.98, 0.94 and 0.85) with grains yield, respectively.

On the other hand, nitrogen, phosphorus and potassium status in soil and plant were significantly affected by X1 (polyacrilamid + bentonite), X2 (biocompost) and X3 (gypsum + sulphur + rock phosphate) soil amendments application. Finally, data indicated that it is important to incorporate biocompost with other amendments to increase the available N, P, and K in sandy soil which was reflected on their content and uptake by wheat grains.

Key words: polyacrilamid (PAM), bentonite, biocompost, gypsum, sulphur, rockphosphate sandy soil, nutrients uptake.

Introduction

Sandy soils widely exist in arid and semi-arid regions such as the east and west desert areas of Egypt. Increasing the productive lands is one of the major targets of the agricultural policy. The productivity of sandy soils is mostly limited by several agronomic obstacles. Also, the water availability is often the important limiting factor determining the cultivated area in such sandy soils. Their very low specific surface area caused its inert chemical and biological conditions. The fertility levels of such soils are very poor with respect to their physical, chemical, and biological properties. Soil water – plant relationships and their nutritional status are controlled by their content of clay and organic matter. Soil conditioners, both natural and synthetic, contribute significantly to provide a reservoir of soil water to plants on demand in the upper layers of the soil where the root systems normally develop. The organic materials and hydrogels are improving the soil physical properties.

(1) reported that physical properties like bulk density, porosity, water permeability and hydraulic conductivity were significantly improved when 10 t ha^{-1} of farm yard manures (FYM) was applied in combination with chemical amendments. **(2)** added that increases in water retained in sandy soil treated with some organic materials may be due to decrease in soil bulk density and the increase in soil total porosity. Also, compost is rich source of nutrients and organic matter content and could be beneficial to improve desirable characteristics of sandy soils. Recently, the combination of compost with chemical fertilizer further enhanced the biomass and grain yield of rice and wheat **(3)**.

Moreover, bentonite as natural deposits in Egypt was frequently used for conditioning sandy soil. **(4)** reported that bentonite application resulted in a highly significant increase in soil porosity and available water content. **(5)** found that added bentonite with chicken manure or rice straw compost to soil improved soil physical properties such as total porosity and moisture retention characteristics. **(6)** studied the effect of compost, bentonite and gypsum on some hydrophysical properties of soil. They found that the solely and combined treatments showed positive and significant effects on improving the values of soil total porosity and available water content. The applied combined treatment of 1/2 the added rates of organic compost + bentonite shale, plays a dual positive role in increasing total soil porosity. Such promotive effects of organic (compost) or inorganic (gypsum and bentonite shale) application may be related to the increase of storage pores in the studied sandy soil, which can be regarded as an index of an improved soil structure. Recently, **(7)** noted that the combined use of bentonite and natural zeolite had a significant improvement on total porosity, water holding capacity, and available moisture in sandy soils. The greatest improvement in these soil characteristics is pronounced under the highest rate of conditioner doses. **(8)** illustrated that organic- and clay-based soil amendments improved crop water productivity (CWP) indicating that soil-based interventions could be suitable options for improving agricultural productivity.

In addition, **(9)** found that the application of gypsum at full rate gave 14.3 % higher grain yield than at half rate. Maximum increase of 133 % over control was recorded in FYM combined with full rate of gypsum. These results suggest that gypsum and FYM amendments helped in increasing the yield of wheat, which may be attributed to directly nutritional effect as well as indirectly through improving soil properties. Application of FYM with full rate of gypsum gave 9.14 % increase in straw yield over the full rate of gypsum alone.

On the other hand, synthetic soil conditioner polymers such as polyacrylamide (PAM) can increase the water holding capacity of sandy soil. The effectiveness of synthetic polymers in increasing water-stable aggregations clearly related to the strength with which these compounds are attached to the clay (soil) particle surface. In this context, **(10)** mentioned that coupling agents may be used to advantage in producing water-stable aggregates because of their ability to form chemical bonds with both the polymer and the surface. **(11)** reported that using soil conditioners especially polymers in sandy soil can increase the water holding capacity of the soil. Recently, **(12)** stated that the macromolecule polymers have the ability to improve soil structure. **(13)** used four water saving materials as potassium polyacrylate (PAA), polyacrylamide (PAM), humic acid and bentonite for studying their effect on soil physical characteristics such as, soil porosity, soil water content which were increased with adding these treatments. **(14)** used soil water retention model and their data showed that, hydrogel increased the residual water content and saturated water content. Available water content increased to a maximum of about 2.3 times the control treatment. They concluded that application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils. This is an important issue in arid and semi-arid regions of the world for enhancing the water management of coarse-textured soils.

(15) reported that the application of polyacrylamide (PAM) increased plant growth and dry matter production of plant and that was due to increasing nutrients uptake and both of water and fertilizer use efficiencies. **(16)** concluded that straw-bentonite-PAM composite soil conditioner can improve the ability of nitrogen fixation, consequently decreases the loss of nitrogen from soils by increasing the NH_4^+-N adsorption capacity of soils. The best proportion of PAM in the composite soil conditioner was 0.99%. **(17)** compared grain yield production of plants grown in soil with application of polyacrylamide. The yield was progressively increased by about 6, 9 and 14 times by incorporating 0.05, 0.1 and 0.2% polyacrylamide with the soil, respectively. **(18)** reported that adding PAM to soil can provide adequate environmental and nutritional conditions that favored bacteria with soil aggregative potential to grow and dominate in the micro aggregates. The objectives of this study were: 1) to evaluate the combinational effectiveness of some soil amendments either mineral or organic (natural or synthetic) on the chemical and hydrophysical properties of sandy soil cultivated with wheat plants as an indicator crop, and 2) to predict the best possible combinations ratios of the investigated amendments that could be more efficient in the future, based on the obtained field data processed in a ternary computer model.

Materials and Methods

Study location and soil properties

A field experiment was carried out in a sandy soil at the experimental farm of El -Ismailia Agricultural Research Station. The farm is located at 30º35`41.9 N latitude and 32 º 16`45.8`E longitudes. Wheat plant (Giza 168) was chosen as an indicator crop to study the effect of using some soil amendments and their combinational interaction (polyacrilamid+ bentonite, biocompost, rock phosphate+ sulfur + gypsum) on some physical characteristics of sandy soil and yield components of wheat crop along with nutrient total contents. Some physical and chemical characteristics of the studied soil are shown in Table (1).

Model description and treatments preparation

Table (1): Some physical and chemical properties of the experimental soil.

Soil characteristics	Values	Soil characteristics	Values
Particle size distribution (%)		Physical properties	
Coarse sand	45.2	Saturation percentage	19.0
Fine sand	39.5	Available water AW (%)	4.90
Silt	8.84	Field capacity FC (%)	6.12
Clay	6.46	Wilting point WP (%)	1.22
Texture class	Sandy		
Chemical properties		Soluble cations and anions (meq	
$CaCO_3$ (%)	1.40	L^{-1})	0.85
pH (1:2.5 soil water suspension)	7.78	Ca^{++}	0.79
EC, dS m^{-1} (saturated paste	0.34	Mg^{++}	1.41
extract)	0.36	Na^{+}	0.35
Organic matter (%)		K^{+}	-
Available macronutrients (mg	29.5	CO_3^{--}	1.32
Kg^{-1})	6.30	HCO_3^{-}	0.92
N	50.32	CL^{-}	1.16
P		SO_4^{--}	
K			

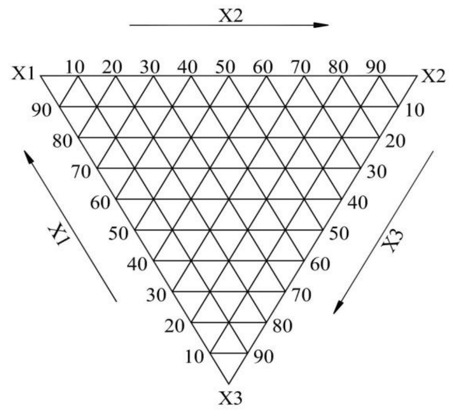
This study was performed using computer modeling diagram introduced by **(19)**. This diagram is a ternary plot (triangle plot) that is a barcentric plot on three variables which sum to a constant of 1.0 or 100%. It graphically depicts the ratios of the three variables as positions in an equilateral triangle. This model is an easy method to evaluate any of the three experimental factors and their interactive effect on any soil or plant attributes for estimating the optimal possible combination of the investigated factors. In order to study the effect of various soil conditioners components on soil and plant in qualitative or quantitative values, the sum of those components (variables) must be equal to 1 or 100%.

The three components in this study were bentonite + polyacrylamide, biocompost, and rock phosphate + gypsum + sulfur which are designated as X_1, X_2 and X_3, respectively. These three factors are placed at the heads of a triangle in a way similar to that used in describing soil texture (soil texture triangle). Each factor amounts equal to 100% of its maximum value in these sites. The level of each factor decreases gradually when moving from the concerned head towards the opposite side at which the level reaches to zero or minimum, when drawing the lines representing the different levels of each factor, different intersections will result. Every intersection represents certain combination. Finally, the diagram will show 66 intersection points, which will cover all the possible combinations between the three factors. The triangle is divided by 9 lines parallel to the three sides. The side represents the zero or minimum level of the factor represented on the opposite head, while the following line represents 10% of the maximum value of the factor and then every following line will increase by 10% of the maximum Fig.(1).

The actual thirteen combined treatments, which are illustrated in Fig. (2) and presented in Table (2), were chosen to carry out this experimental work.

In this design the sum of the three factors will be always 100% of the maximum values, i.e., X1 + X2 + X3 = 100%.

All the data obtained from the different combined treatments were processed by the computer to give the results represented on the triangle at the same site of the considered combined treatments. The results take values equal to or less than 10, and the value of 10 represents the maximum value that could be attained for any attribute and is printed in a place from which it resulted. The other values (0 – 9) are estimated in relation to the maximum calculated value.



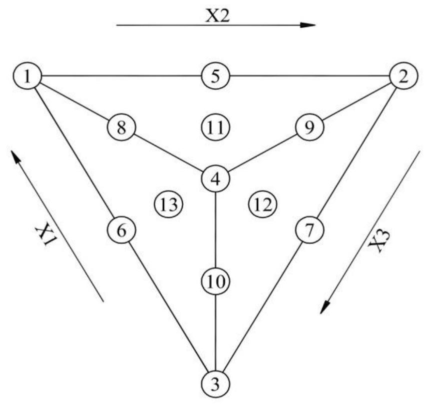


Fig.(1): Guide for the (X_1),(X_2),and (X_3) points Fig. (2): Location of the thirteen chosen combination of each treatments on triangle diagram.

Table (2): Combination ratios and doses of the thirteen treatments used per Faddan.

Treat. No	Treatments percentages, %			Amount of amendments					
				X1		X2	X3		
	X1	X2	X3	PAM Kg Fad^{-1}	Bentonite Ton fad^{-1}	Compost Ton Fad^{-1}	Gypsum Ton Fad^{-1}	Sulpher Kg fad^{-1}	Rock phosph. Ton Fad^{-1}
1	100	0.00	0.00	30.0	9.00	0.00	0.00	0.00	0.00
2	0.00	100	0.00	0.00	0.00	14.0	0.00	0.00	0.00
3	0.00	0.00	100	0.00	0.00	0.00	3.00	500	4.00
4	33.3	33.3	33.3	9.99	2.97	4.662	0.999	166.5	1.332
5	50.0	50.0	0.00	15.0	4.50	7.00	0.00	0.00	0.00
6	50.0	0.00	50.0	15.0	4.50	0.00	1.50	250	2.00
7	0.00	50.0	50.0	0.00	0.00	7.00	1.50	250	2.00
8	66.6	16.6	16.6	19.98	5.99	2.324	0.498	83.0	0.664
9	16.6	66.6	16.6	4.98	1.494	9.324	0.498	83.0	0.664
10	16.6	16.6	66.6	4.98	1.494	2.324	1.998	333	2.664
11	44.4	44.4	11.1	13.3	3.996	6.216	0.333	55.5	0.444
12	44.4	11.1	44.4	13.3	3.996	1.554	1.332	222	1.776
13	11.1	44.4	44.4	3.33	0.999	6.216	1.332	222	1.776

Moreover, the program calculates the average value, determination coefficients, correlation coefficients, fisher criterion, mean square error between replicates, t criterion for control and maximum and minimum values of the attribute. It is worthy to mention that the combination which gives the maximum value or any other combination could be easily defined by covering the output computer sheet with a plastic triangle which its sides written as percentage of bentonite + polyacrylamide, biocompost, and rock phosphate + gypsum + sulfur as X_1, X_2 and X_3, respectively.

On the other hand, biocompost was prepared at the Ismailia Agriculture Research Station by Soil Conditioners Project with aerobic composting of rice straw and activating mixture from nitrogen source as urea, phosphorus source as rock phosphate and potassium source as feldspar. The composite inoculum included two associative N_2 fixing bacterial strains of *Azotobacter chrococcum* and *Bacillus polymyxa* along with one P dissolving bacteria strain of *Bacillus megatherium* and one K dissolving bacteria strain of *Bacillus circulans*. Table (3) represents the main chemical properties of applied biocompost. Table (4) describes some properties of the used mineral amendments of bentonite and rock phosphate.

Table (3): Physicochemical properties of the rice straw biocompost used in this experiment.

Value	Parameters
0.63	Bulk density (Kg / m^3)
130.1	Water holding capacity, WHC (%
6.70	pH (1:10 compost: water suspension)
3.15	EC (dS m^{-1})
37.56	Organic matter (%)
21.1	Organic – C (%)
1.64	Total – N (%)
12.82	C\N ratio
403.9	Available N (mg Kg^{-1})
361.7	Available P (mg Kg^{-1})
698.4	Available K(mg Kg^{-1})

Table (4): Some chemical characteristics of the natural mineral amendments.

Value	Property
	Bentonite
3.80	EC (dS m^{-1} in 1:5 water extract)
7.80	pH (1:2.5) natural minerals: water suspension
21.6	Available N (mg Kg^{-1})
2.10	Available P (mg Kg^{-1})
95.0	Available K (mg Kg^{-1})
	Rock Phosphate
3.07	EC dS m^{-1} (1:5 minerals: water extract)
7.80	pH (1:2.5 minerals: water suspension)
4.37	Available P_2O_5 (mg Kg^{-1})
31.0	Total P_2O_5 (%)

Experiment design and implementation.

Wheat was cultivated in completely randomized block design. Plot dimensions of 3.0 X 3.5m with total plot area of 10.5 m² each. Each treatment was replicated three times.

Soil conditioners were applied before wheat cultivation as described in Table (2), biocompost, bentonite, rock phosphate , sulfur and gypsum were added by thoroughly mixing with the soil surface layer (0-30 cm) whereas polyacrlamide (PAM) was sprayed on the soil surface during soil preparation.

All treatments received mineral fertilizers at the recommended dose from super phosphate (15.5% P_2O_5) at a rate of 200 kg fed^{-1} basically before sowing as well as potassium was added in the form potassium sulfate (48% K_2O) at a rate of 50 kg fed^{-1}. Nitrogen was added in the form ammonium nitrate (33.5% N) at the rates of 358 kg N fed^{-1}. Ammonium nitrate was added in four split equal doses after 2, 4, 6 and 8 weeks from sowing. While potassium was divided into two equal doses, the first was added at sowing and the second after 35 days from sowing. Plants were irrigated by using sprinkler irrigation system, the moisture content of soil being maintained constant (60 - 70% of the holding capacity) during the whole season of plant growth of experiment.

At the end of experiments surface undisturbed soil samples (0-20 cm depth) were gently taken for each treatment using soil core **(20)** , to determine some soil physical properties according to **(21)** and **(22).**

The following soil physical analysis were carried out such as soil moisture content (θ_w, %), total soil porosity (p, %), moisture retention curves of untreated soils were measured at pressures of 0.001, 0.10, 0.33, 0.66 and 6.00 atm according to the methods described by **(23),** while moisture retention curves at 15 atm (wilting point, percentage) was determined biologically by sun flower plants, as described by **(24)** and available water (AW %) capacity was calculated from the difference between field capacity (FC) and wilting point (WP) **(20).** Another part of soil samples were air dried, grinded and sieved through 2mm then stored in plastic bags to determine some soil chemical properties according to **(25)**.

After maturity, wheat plant was harvested and the yield components (straw, grains along with weight of 1000 grains) of each plot were recorded. Biological yield in plant samples was calculated; some morphological properties such as plant height, spike length for all plant samples were also recorded.

The tested wheat samples were collected from each plot weighed oven dried at 70ºC for 24 hr up to a constant dry weight, ground and prepared for digestion as described by **(25).** The digested samples were then subjected to determination of macronutrients (N, P, and K) uptake using procedures described by **(26).**

Results and Discussion

Generally, obtained data of soil physical properties and growth parameters of wheat crop were significantly affected by the tested amendments in sandy soils.

Combination effect of amendments on the soil physical properties

Data presented in Table (5) show some soil physical properties, i.e., total porosity (TP), field capacity (FC), wilting point(WP) and available water (AW), water holding pores (WHP) and the ratio between water holding pores and total porosity (WHP/TP) as affected by tested different combination of soil amendments, X1 (polyacrlmaid + bentonite), X2 (biocompost) and X3 (gypsum + sulphure + rock phosphate). All these soil physical properties showed a remarkable increase by polyacrlmaid + bentonite, biocompost, and rock phosphate + gypsum + sulphure application as compared to control treatment. These results indicated that X1, X2 and

Table (5). Some soil physical properties and moisture relations as affected by different combination of used amendments.

Treat. No	Treatments percentages %			Amount of amendments							soil physical properties and moisture relations					
				X1		X2		X3								
	X1	X2	X3	PAM Kg Fad^{-1}	Bentonite Ton fad^{-1}	B.M Liter Fad^{-1}	Compost Ton Fad^{-1}	Gypsum Ton Fad^{-1}	Sulpher Kg fad^{-1}	Rock phosph. Ton Fad^{-1}	Total porosity (TP %)	Field capacity (FC%)	Wilting point (WP%)	Available water (AW %)	Woter holding pores (WHP)	WHP / TP
1	100	0.00	0.00	30.0	9.00	0.00	0.00	0.00	0.00	0.00	42.3	9.19	1.53	7.65	5.14	0.141
2	0.00	100	0.00	0.00	0.00	12.0	14.0	0.00	0.00	0.00	48.8	13.8	4.03	9.72	7.98	0.187
3	0.00	0.00	100	0.00	0.00	0.00	0.00	3.00	500	4.00	38.7	6.57	1.13	5.43	3.37	0.099
4	33.3	33.3	33.3	9.99	2.97	3.996	4.662	0.999	166.5	1.332	47.8	11.7	2.60	9.06	7.13	0.171
5	50.0	50.0	0.00	15.0	4.50	6.00	7.00	0.00	0.00	0.00	49.8	13.9	3.31	10.6	8.80	0.204
6	50.0	0.00	50.0	15.0	4.50	0.00	0.00	1.50	250	2.00	39.8	7.40	1.30	6.10	3.51	0.101
7	0.00	50.0	50.0	0.00	0.00	6.00	7.00	1.50	250	2.00	44.6	10.1	2.03	8.02	5.76	0.145
8	66.6	16.6	16.6	19.98	5.99	1.992	2.324	0.498	83.0	0.664	46.9	11.3	2.50	8.82	7.01	0.171
9	16.6	66.6	16.6	4.98	1.494	7.992	9.324	0.498	83.0	0.664	51.1	21.3	8.13	13.3	11.87	0.255
10	16.6	16.6	66.6	4.98	1.494	1.992	2.324	1.998	333	2.664	40.9	8.39	1.45	6.92	4.31	0. 122
11	44.4	44.4	11.1	13.3	3.996	5.328	6.216	0.333	55.5	0.444	50.3	17.4	5.72	11.7	10.49	0.231
12	44.4	11.1	44.4	13.3	3.996	1.332	1.554	1.332	222	1.776	44.9	10.39	1.91	8.48	6.60	0.164
13	11.1	44.4	44.4	3.33	0.999	5.328	6.216	1.332	222	1.776	43.3	9.44	1.67	7.87	5.61	0.149
Control											37.0	6.12	1.22	4.90	3.11	0.098
Correlation coefficients with Total porosity (TP %)											--	0.91	0.81	0.96	0.972	0.957

X3 had different effects on the soil physical properties with an obvious role of biocompost application which positively effect on studied physical properties.

Moreover, the role of biocompost and its combination effect with other amendments is more clearly showed in the output data in which all the possible combinations of X1 (polyacrlmaid+ bentonite), X2 (biocompost) and X3 (gypsum + sulphure + rock phosphate) application could be detected. However, physical properties of the studied soil as noticed from the output triangle figures have different trends in response to X1, X2 and X3 of the amendments application.

In respect of total porosity (TP), Table (5) and (Fig. 3) showed that the maximum TP which is indicated by the value of 10 on the output data triangle was obtained with employing the combined application of 20, 60, and 20% for the treatments of X1, X2 and X3, respectively.

However, application of 100% X1 alone resulted in 70 % of the maximum total porosity, whereas application of 100% X2 or X3 resulted in 90 and 70 % of the maximum, respectively. These results suggest that application of biocompost accompanied by a minimum dose of X1 and X3 has the more positively effect on total porosity. In addition, application of 20, 60, and 20% for X1, X2 and X3, respectively, gave a total porosity of 51.2% as compared to control 37.0 % with a net increased value of 14.2%.

AVERAGE VALUES

1 36.71 36.45 36.52 = 36.5600
2 42.81 42.46 42.51 = 42.5933
3 33.82 34.03 34.06 = 33.9700
4 41.82 41.75 41.86 = 41.8100
5 43.17 43.22 42.96 = 43.1167
6 34.56 34.34 34.61 = 34.5033
7 39.53 39.57 39.81 = 39.6367
8 40.95 41.25 40.99 = 41.0633
9 46.48 46.87 46.52 = 46.6233
10 35.31 35.36 35.55 = 35.4067
11 45.19 45.47 45.49 = 45.3833
12 40.08 40.37 40.14 = 40.1967
13 37.42 37.68 37.72 = 37.6067
coeff. deter.= .9989799

correlation function= .9994898

criterion fisher f(12 , 26)= 2121.738

soct= .1530931

control=-4.422226

t= 17.39144

control=-35.84889

t= 140.9841

control=-76.92555

t= 302.5277

36.5600 38.5633 37.9636 38.0242 42.0085 43.1167

43.5784 43.7569 43.6523 43.2644 42.5933

36.0268 39.7128 40.2518 40.9073 44.9426 45.7157

46.2295 46.3484 46.0725 42.2188

35.5545 40.3793 41.5132 42.2196 44.9535 45.9140

46.3681 43.0958 41.7359

35.1432 40.5628 41.7477 41.9612 43.4801 42.4002

40.5477 41.1445

34.7928 40.2634 40.9553 40.1320 39.3979 38.4281

40.4448

34.5033 39.4810 39.1361 37.3611 36.7372 39.6367

34.2748 38.2156 36.2900 35.4749 38.7201

34.1072 36.4673 34.6411 37.6952

34.0005 34.2360 36.5619

33.9548 35.3201

33.9700

Ymax= 46.36814 Ymin= 33.9548

x1 7 8 8 8 9 9 9 9 9 9 9 x2
7 8 8 8 9 9 9 9 9 9
7 8 8 9 9 9 10 9 9
7 8 9 9 9 9 8 8
7 8 8 8 8 8 8
7 8 8 8 7 8
7 8 7 7 8
7 7 7 8
7 7 7
7 7
7
x3

Fig.(3): Total porosity of sandy soils as affected by different combinations of soil amendments after wheat crop.

Regarding soil moisture content (field capacity, FC, wilting point, WP, and available water, AW) followed the same trend, as noted from the output computer data sheet, so, available water have been selected to represent these moisture characters. Data in Table (5) revealed that soil available water ranged between 13.3 and 4.90; the maximum soil available water was obtained by 16.6 % of the maximum PAM + Bentonite dose and 66.6% of the maximum biocompost dose and 16.6 % of rock phosphate + gypsum + sulphure, respectively. Application of single treatment of X1 (PAM + Bentonite), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure) resulting a soil available water equals 50, 70 and 40% of the maximum soil available water, respectively. Moreover, Fig (4) show that the soil available water decreased gradually in the triangle from the X1 (PAM + Bentonite) head toward the X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure), this observation emphasizing the role of X2 to increase soil water retention. The maximum available water in Fig (4) referred by the value of 10 on the triangle data sheet was obtained by 20% of the maximum X1 (PAM + bentonit) admixture, 60 % of the maximum X2 (biocompost) dose, and 20% of X3 (rock phosphate + gypsum + sulphure) admixture.

The role of soil conditioner either natural or synthetic in improving soil water retention doesn't depend only on its highly water adsorption property, but also on the ability to form aggregates. However, adequate pore space is essential to a healthy soil. In this context, knowing the total porosity of soil is not as important as the pore size distribution. Pore space in the soil is generally divided into larger and smaller pores, larger pores are vital to drainage which is not a target in case of sandy soil. Micro pores which act as water holding pores have a vital important in sandy soil, correcting the ratio between the macro and micro pores is considered highly necessary.

Data in Table (5) and Fig (5) show the water holding pores as affected by the different combination of X1 (PAM + bentonit), X2 (biocompost), and X3 (rock phosphate + gypsum + sulphure) mixtures. Obtained data reveal that water holding pores showed increased values by the application of soil amendments as compared to control treatment.

AVERAGE VALUES

1 7.69 7.63 7.64 = 7.6533
2 9.65 9.77 9.74 = 9.7200
3 5.44 5.35 5.51 = 5.4333
4 9.05 9.12 9.02 = 9.0633
5 10.62 10.53 10.55 = 10.5667
6 6.07 6.09 6.13 = 6.0967
7 8.04 7.97 8.06 = 8.0233
8 8.85 8.75 8.86 = 8.8200
9 13.24 13.25 13.31 = 13.2667
10 6.94 6.97 6.86 = 6.9233
11 11.69 11.58 11.69 = 11.6533
12 8.45 8.52 8.47 = 8.4800
13 7.91 7.93 7.79 = 7.8767

coeff. deter.= .9995469
correlation function= .9997734
criterion fisher f(12 , 26)= 4780.182

soct= 5.465262E-02
control=-2.353706
t= 15.49241
control=-6.545186
t= 43.08131
control=-15.97556
t= 105.1533

7.6533 8.1235 7.5788 7.2189 8.2438 10.5667
10.6981 10.6792 10.5099 10.1901 9.7200
7.2705 8.4641 8.4428 8.4063 9.5547 11.9076
12.3608 12.6509 12.7780 9.4521
6.9235 8.6405 8.9425 9.0295 11.3457 12.2837
13.0460 10.9942 9.1485
6.6121 8.6526 9.0781 9.0885 10.5240 10.7046
9.4941 8.8092
6.3365 8.5004 8.8494 8.5833 8.9664 8.2778
8.4341
6.0967 8.1840 8.2565 7.8313 7.3451 8.0233
5.8925 7.7034 7.2993 6.6961 7.5768
5.7241 7.0585 6.3309 7.0945
5.5915 6.2493 6.5765
5.4945 6.0228
5.4333

Ymax= 13.046 Ymin= 5.433334

x1 5 6 5 5 6 8 8 8 8 7 7 x2
5 6 6 6 7 9 9 9 9 7
5 6 6 6 8 9 10 8 7
5 6 6 6 8 8 7 6
4 6 6 6 6 6 6
4 6 6 6 5 6

4 5 5 5 5
4 5 4 5
4 4 5
4 4
4
x3

Fig.(4):- Soil available water (AW) in the studied sandy soil as affected by different combination of used amendment after wheat crop harvested.

AVERAGE VALUES

1	5.15	5.12	5.16	=	5.1433
2	8.02	7.96	7.97	=	7.9833
3	3.36	3.35	3.41	=	3.3733
4	7.17	7.11	7.12	=	7.1333
5	8.85	8.82	8.73	=	8.8000
6	3.48	3.55	3.51	=	3.5133
7	5.74	5.75	5.78	=	5.7567
8	7.02	7.01	7.01	=	7.0133
9	11.86	11.97	11.78	=	11.8700
10	4.29	4.32	4.32	=	4.3100
11	10.43	10.51	10.54	=	10.4933
12	6.58	6.63	6.59	=	6.6000
13	5.61	5.61	5.62	=	5.6133

coeff. deter.= .9998108
correlation function= .9999054
criterion fisher f(12 , 26)= 11450.46

soct= 4.150104E-02
control=-2.714813
t= 20.50609
control=-4.224074
t= 31.90615
control=-11.34667
t= 85.706

5.1433 5.9783 5.3698 5.0139 6.6064 8.8000
8.9945 9.0101 8.8468 8.5045 7.9833
4.6981 6.4753 6.5264 6.5474 8.2342 10.7629
11.2090 11.4047 11.3501 7.5505
4.3125 6.7493 7.1773 7.2926 10.0384 10.9863
11.6125 9.2656 7.1115
3.9865 6.8002 7.3225 7.2493 8.7705 8.8880
7.5120 6.6661
3.7201 6.6281 6.9620 6.4177 6.8316 6.0894
6.2145
3.5133 6.2329 6.0957 5.4436 4.9978 5.7567
3.3661 5.6146 4.7237 4.2372 5.2925
3.2785 4.7733 3.8076 4.8221
3.2505 3.7089 4.3455
3.2821 3.8625
3.3733

Ymax= 11.61254 Ymin= 3.250533

x1 4 5 4 4 5 7 7 7 7 7 6 x2
4 5 5 5 7 9 9 9 9 6

3 5 6 6 8 9 10 7 6
3 5 6 6 7 7 6 5
3 5 5 5 5 5 5
3 5 5 4 4 4
2 4 4 3 4
2 4 3 4
2 3 3
2 3
2
x3

Fig.(5):- Water holding pores8.62µ-0.19µ(WHP %)in the studied sandy soil as affected by different combination of used amendment after wheat crop harvested.

More focus on combination effect role of PAM + bentonit, biocompost and rock phosphate + gypsum + sulphure application could be predicted from the output computer data sheet for all the possible combination of X1, X2 and X3. However, soil water holding pores gave the maximum values using the mixture of 16.6, 66.6, and 16.6% for X1, X2 and X3, respectively, as shown in Table (5). Results presented in Fig. (5) show that the maximum soil water holding pores which is indicated by the value of 10 on the triangle were obtained by the combined treatment of 20, 60, and 20% for X1, X2 and X3, respectively. On the other hand, the single application of biocompost resulted in 60% of the maximum water holding pores, meanwhile application of the single application of X1 (PAM +bentonite) or X3 (Rock phosphate + gypsum + sulphur) resulted in 40 and 20% of the maximum water holding pores, respectively. These results suggest that the application of biocompost in combination with X1 or X3 has more positive effect on soil water holding pores.

Moreover, data presented in Table (5) revealed that the ratio between soil water holding pores and total porosity was increased by the application of soil amendments as compared to control. The maximum ratio was obtained in the combined treatments of (50, 50, 0%), (16.6, 66.6, 16.6%), and (44.4, 44.4, 11.1%) of X1, X2 and X3, respectively. This observation emphasized that the combination effect of PAM + bentonit and biocompost in increasing the ratio between soil water holding pores and total porosity.

Obtained data agree with **(27)** who found that the use of soil conditioners as crop residues, manures, organic substances, and other synthetic organic materials improved plant available water capacity (PAWC), field capacity and wilting point water content in soil and consequently promoted plant growth. This increase in PAWC might be attributed to the increased number of micro pores and decreased number of macro pores as compared with the control treatment. Similar observations were reported by **(28**) and **(29)** who stated that the field capacity and plant available water (PAW) consistently increased with increasing rates of bentonite addition while the wilting point remained relatively unchanged. These results suggest that the effect of bentonite on water holding capacity was beneficial to plant growth in the light textured soils where plants commonly experience moisture stress. Bentonite treatments can bring about significant improvements in the field capacity and PAW content to potentially enhance plant growth and reduce yield losses.

Concerning synthetic soil conditioner, **(17)** found that the water holding capacity of the soil was increased with increasing amounts of polyacrylamide to soil. This increase in water holding capacity can potentially reduce the amount of water otherwise lost by deep percolation. The results from this experiment showed that the polyacrylamide in soil was able to reduce the amount of water lost from the soil through evaporation. According to **(30)**, the cross-linking bridges in the polyacrylamide can act as a structural barrier and provide a physical resistance for the water stored in the vacuoles to escape by evaporation. **(31)** added that the cumulative evaporation of water was significantly reduced by different commercial gel conditioners. Recently, **(13)** who showed that the water content of other treatments were higher than control in the whole growth period, this mainly because of using potassium polyacrylate (PAA), polyacrylamide (PAM) and bentonite can increase soil water conservation ability and decrease the water evaporation. Also, PAA and PAM had effects on increasing soil water content and that materials were ordered as PAA > PAM > bentonite > humic acid. The using PAA and PAM had better effects on conserving soil water content.

Finally, combination of biocompost with either PAM + bentonit or rock phosphate + gypsum + sulphure improved the soil physical properties which were reflected on the growth characters of wheat plant and their total content of NPK.

Combination effect of amendments on some wheat growth characters

Data in Table (6) and Fig. (6) represent the wheat plant growth characters which include grains, straw, biological yield, weight of 1000 grain and some morphological yield (plant height & average values of spike length). Obtained data reveal that all growth characters showed an increase by the application of soil amendments as compared to control treatment. The same trends were produced by the computer modeltriangle with highly correlation coefficients (r = 0.99, 0.99, 0.98, 0.94 and 0.85) with grains yield, respectively. These results suggest that the application of biocompost (X2) has more effect on wheat growth characters as compared to X1 (PAM +bentonite) or X3 (rock phosphate+ gypsum+ sulfur) which contribute to small effect on growth characters.

Moreover, the role of biocompost (X1) and its combination effect with X1 and X3 application could be realized from the output computer data sheet in which all the possible combination of X1, X2 and X3 application were detected. However, the output data presented in triangle figures illustrate that all the wheat growth characters have the similar trend in response to PAM + bentonit, biocompost and rock phosphate + gypsum + sulphure.However, grains yield have a highly significant correlation coefficient with straw yield, biological yield, weight of 1000 grains, plant height and spike length.

Table (6). Some wheat growth characters as affected by different combination of used amendments.

Treat. No	Treatments percentages %			Amount of amendments							Wheat growth characters					
				X1		X2		X3								
	X1	X2	X3	PAM Kg Fad^{-1}	Bentonite Ton fad^{-1}	B.M Liter Fad^{-1}	Compost Ton Fad^{-1}	Gypsum Ton Fad^{-1}	Sulpher Kg fad^{-1}	Rock phosph. Ton Fad^{-1}	Grains yield Ton fad^{-1}	Straw yield Ton fad^{-1}	Biolog yield Ton fad^{-1}	Weight of 1000 grain (g)	Plant height (cm)	Spike length (cm)
1	100	0.00	0.00	30.0	9.00	0.00	0.00	0.00	0.00	0.00	1.99	2.56	4.55	41.8	72	7.23
2	0.00	100	0.00	0.00	0.00	12.0	14.0	0.00	0.00	0.00	2.61	3.39	6.01	50.5	86	11.92
3	0.00	0.00	100	0.00	0.00	0.00	0.00	3.00	500	4.00	2.08	2.67	4.74	42.3	73	12.12
4	33.3	33.3	33.3	9.99	2.97	3.996	4.662	0.999	166.5	1.332	2.53	3.35	5.89	49.7	84	11.52
5	50.0	50.0	0.00	15.0	4.50	6.00	7.00	0.00	0.00	0.00	2.69	3.59	6.25	51.1	87	11.98
6	50.0	0.00	50.0	15.0	4.50	0.00	0.00	1.50	250	2.00	2.14	2.74	4.86	43.9	75	8.03
7	0.00	50.0	50.0	0.00	0.00	6.00	7.00	1.50	250	2.00	2.31	2.95	5.27	47.2	79	10.6
8	66.6	16.6	16.6	19.98	5.99	1.992	2.324	0.498	83.0	0.664	2.18	2.79	4.95	44.4	76	9.35
9	16.6	66.6	16.6	4.98	1.494	7.992	9.324	0.498	83.0	0.664	2.75	3.84	6.58	55.8	97	12.4
10	16.6	16.6	66.6	4.98	1.494	1.992	2.324	1.998	333	2.664	2.34	3.03	5.39	47.8	79	10.96
11	44.4	44.4	11.1	13.3	3.996	5.328	6.216	0.333	55.5	0.444	2.71	3.68	6.39	52.5	93	12.2
12	44.4	11.1	44.4	13.3	3.996	1.332	1.554	1.332	222	1.776	2.27	2.87	5.16	46.2	77	9.53
13	11.1	44.4	44.4	3.33	0.999	5.328	6.216	1.332	222	1.776	2.47	3.15	5.60	48.3	81	11.2
Control											1.44	1.69	3.17	36.5	65	6.51
Correlation coefficients with wheat grains yield (Ton Fad $^{-1}$)											--	0.99	0.99	0.98	0.94	0.85

AVERAGE VALUES

1 1.99 2.00 1.97 = 1.9880
2 2.61 2.62 2.65 = 2.6267
3 2.08 2.07 2.09 = 2.0793
4 2.53 2.54 2.55 = 2.5410
5 2.69 2.66 2.68 = 2.6720
6 2.14 2.12 2.11 = 2.1223
7 2.31 2.32 2.33 = 2.3203
8 2.18 2.16 2.15 = 2.1610
9 2.75 2.74 2.75 = 2.7440
10 2.34 2.36 2.39 = 2.3613
11 2.71 2.70 2.72 = 2.7090
12 2.27 2.29 2.31 = 2.2890
13 2.47 2.44 2.45 = 2.4500
coeff. deter.= .9976351
correlation function= .9988169
criterion fisher f(12 , 26)= 913.9972
soct= 1.467283E-02
control=-.0370369
t= .4704895
control=-2.142408
t= 27.21557
control=-4.495222
t= 57.104
1.9880 1.9655 1.9491 2.0071 2.2075 2.6720
2.7213 2.7414 2.7323 2.6941 2.6267
2.0291 2.0670 2.0997 2.1954 2.4221 2.7567
2.8009 2.7939 2.7355 2.5602
2.0630 2.1500 2.2204 2.3425 2.6215 2.7120
2.7290 2.6379 2.4963
2.0899 2.2146 2.3114 2.4484 2.6072 2.6223
2.5503 2.4350
2.1097 2.2607 2.3725 2.5133 2.5328 2.4726
2.3764
2.1223 2.2884 2.4039 2.4605 2.4048 2.3203
2.1279 2.2977 2.4055 2.3469 2.2669
2.1264 2.2885 2.2989 2.2161
2.1178 2.2608 2.1679
2.1021 2.1223
2.0793
Ymax= 2.80094 Ymin= 1.949149
x1 7 7 6 7 7 9 9 9 9 9 9 x2
7 7 7 7 8 9 10 9 9 9
7 7 7 8 9 9 9 9 8
7 7 8 8 9 9 9 8
7 8 8 8 9 8 8
7 8 8 8 8 8
7 8 8 8 8
7 8 8 7
7 8 7
7 7
7
x3

Fig.(6) : Grain yield of wheat crop (Ton Fed^{-1}) as affected by different combinations of the used amendments in sandy soil.

Therefore, grain yield was selected to represent the growth characters, which gave the maximum values using the combination treatment of 16.6,66.6,and16.6% for X1, X2 and X3, respectively, as shown in Table (6). Data in Fig. (6) show that the maximum grain yield which is indicated by the value of 10 on the triangle was obtained by the combined treatment of 30, 60, and 10% for X1, X2 and X3, respectively, On the other hand, the single application of biocompost (no combination with other treatments) resulted in 90% increase of the maximum grain yield, where the single application of of X1 (PAM + Bentonite) or X3 (phosphate + gypsum + sulphure) resulted in 70% increase of the maximum grain yield.

These results suggest that that application of biocompost in combination with X1 or X3 has more positive effect on wheat grain yield. Moreover, the combined application of 90%) of biocompost and 10% of either X1 (PAM + bentonite) or X3 (phosphate + gypsum + sulphure), gave a grain yield of 2.80 ton Fad^{-1}, compared to the control treatment which gave a value of 1.44 ton Fad^{-1}. These results show that an increase in grain yield by 1.36 ton Fad^{-1} was attained. This observation emphasized the combination effect of biocompost with the other amendments in increasing the yield of wheat grains.

These results agree with those reported by **(32)** who showed that the combination of compost and rock phosphate gave the highest values of morphological parameters. Their improvement in growth resulted from organic fertilization, which stimulates the absorption of nutrients and their reflection on photosynthesis process, which certainly reflected positively on both sunflower growth and yield. In this respect, **(33)** pointed out that the productivity of sandy soils is mostly limited by their low water holding capacity and excessive deep percolation losses. He indicated that the marketable increase of maize yield was due to the incorporation of the composted rice straw and soil conditioners that led to the increase of available water that enhance the availability of nutrients to maize plant. Also, the favorable effect of compost on yield parameters might be attributed to improved biological activity that may lead to provide nitrogen and phosphate as well as produce amino acids, vitamins and growth promoting substances like indole acetic acid and gibberellic acid, which might have promoted growth and improved yield parameters **(34) and (35)**. The noticeable performance of rice straw compost when compared to others in terms of yield improvement was attributed to improved nutritional status, narrow C/N ratio, higher phosphate solubilization and availability of micronutrients as well as improved soil condition **(35)**.

Also, the results reported by **(36)** showed that the increase in wheat yield on the ridges supplemented with gypsum may be due to ameliorative effect of gypsum that lowers the SAR and EC for soils. The same results were achieved by **(37),** where the application of gypsum improve soil physicochemical environment in the root zone and lowering the pH and ESP leading to an increase in the rice yield. The supply of nutrients through gypsum provides conductive physical environments leading to better aeration, root activity and nutrient absorption.

In this respect, the application of compost as organic matter would have increased the yield due to positive effect of compost on the plant physiology by developing elaborate root system, provided growth regulator substances and modifying soil physiological behaviors lead to higher grain yield **(38).**

Combination effect of amendments on macronutrients status in soil and plant.

Nitrogen status.

Available nitrogen in soil , nitrogen content and uptake by wheat grain were significantly affected by the application of tested mixtures of amendments (X1, X2 and X3) as shown in Table (7) which represents soil available N (mg kg^{-1}) , grain N content (%) and N uptake (Kg fad^{-1}), and grain protein content (%). All these parameters showed a remarkable increase by treating soil with X1, X2 and X3 as compared to control treatment. However, all these parameters showed similar trends in response to X1, X2 and X3 amendments on the output triangle figures. Moreover, soil available N, has a highly significant correlation coefficient with grain N content , N uptake and grain protein content, r =0.98, 0.98 and 0.98, respectively. Therefore, soil available N shown in Fig (7) was chosen to represent these parameters which showed that the highest soil available N indicated by the value of 10 on the triangle was obtained by the combined application of 20, 60, and 20% for X1 (PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure), respectively. On the other hand, the single application of 100% biocompost resulted in 80% of the maximum soil available N, whereas the application of 100 % X1 (PAM + bentonit) or X3 (rock phosphate + gypsum + sulphure) resulted in 60 % of the maximum. These results suggest that application of biocompost in combination with minimum amount of X1or X3 has more positive effect on soil available N.

However, the application of 80 % biocompost (X2) combined with 20% of X1 (PAM + bentonit) or X3 (phosphate + gypsum + sulphure) resulted in soil available nitrogen of 73.2 mg Kg^{-1} as compared to control treatment which gave 29.5 mg Kg^{-1}. This increase in available nitrogen reached to 42.9 mg Kg^{-1}. The minimum value of soil available nitrogen (48.4 mg Kg^{-1}) was obtained with the single application of 100% X1 (PAM + bentonit). These results reveal that it is important to apply biocompost soil amendment to increase the soil available nitrogen.

Table (7):-Macronutrients inventories in the study sandy soil and wheat grains as affected by different combination of used amendment.

Treat. No	Treatments percentages %			Amount of amendments							Soil available N (mg Kg^{-1})	Nitrogen inventories in grains		Protein content in grains (%)	Soil available P (mg Kg^{-1})	phosphorus inventories in grains		Soil available K (mg Kg^{-1})	Potassium inventories in grains	
				X1		X2		X3												
	X1	X2	X3	PAM Kg Fad^{-1}	Bentonite Ton fad^{-1}	B.M Liter Fad^{-1}	Compost Ton Fad^{-1}	Gypsum Ton Fad^{-1}	Sulpher Kg fad^{-1}	Rock phosph. Ton Fad^{-1}		Cont. %	Uptake Kg fad^{-1}			Cont. %	Uptake Kg fad^{-1}		Cont. %	Uptake Kg fad^{-1}
1	100	0.00	0.00	30.0	9.00	0.00	0.00	0.00	0.00	0.00	48.4	1.80	35.8	10.4	9.53	0.39	7.82	54.7	0.64	12.7
2	0.00	100	0.00	0.00	0.00	12.0	14.0	0.00	0.00	0.00	61.1	2.30	60.5	13.3	13.4	0.49	12.8	85.4	0.82	21.6
3	0.00	0.00	100	0.00	0.00	0.00	0.00	3.00	500	4.00	50.5	1.86	38.7	10.7	9.79	0.41	8.44	58.6	0.67	13.9
4	33.3	33.3	33.3	9.99	2.97	3.996	4.662	0.999	166.5	1.332	59.0	2.22	56.5	12.8	12.3	0.48	12.1	81.6	0.79	20.0
5	50.0	50.0	0.00	15.0	4.50	6.00	7.00	0.00	0.00	0.00	63.5	2.42	64.5	13.9	14.3	0.50	13.2	93.3	0.83	22.0
6	50.0	0.00	50.0	15.0	4.50	0.00	0.00	1.50	250	2.00	51.5	1.90	40.4	10.9	10.1	0.43	9.02	63.1	0.69	14.6
7	0.00	50.0	50.0	0.00	0.00	6.00	7.00	1.50	250	2.00	55.2	2.05	47.6	11.8	10.9	0.47	10.6	74.2	0.77	17.8
8	66.6	16.6	16.6	19.98	5.99	1.992	2.324	0.498	83.0	0.664	52.8	1.95	42.1	11.2	10.6	0.44	9.52	63.6	0.71	15.3
9	16.6	66.6	16.6	4.98	1.494	7.992	9.324	0.498	83.0	0.664	73.2	2.62	71.9	15.1	18.0	0.59	16.2	120	0.89	24.4
10	16.6	16.6	66.6	4.98	1.494	1.992	2.324	1.998	333	2.664	56.3	2.11	47.9	12.1	11.2	0.46	10.9	75.8	0.71	18.2
11	44.4	44.4	11.1	13.3	3.996	5.328	6.216	0.333	55.5	0.444	65.9	2.51	67.7	14.4	15.6	0.52	14.2	101	0.86	23.3
12	44.4	11.1	44.4	13.3	3.996	1.332	1.554	1.332	222	1.776	54.9	1.99	45.7	11.5	10.5	0.45	10.3	64.3	0.73	16.7
13	11.1	44.4	44.4	3.33	0.999	5.328	6.216	1.332	222	1.776	57.6	2.17	53.1	12.5	11.9	0.47	11.5	76.3	0.79	19.3
Control											29.5	1.45	21.7	8.33	6.30	0.29	4.31	50.3	0.55	8.15
Correlation coefficients with soil available NPK (mg Kg^{-1})											--	0.95	0.94	0.95	--	0.96	0.98	--	0.92	0.93

AVERAGE VALUES

```
1     48.41  48.43  48.42  =  48.4200
 2    61.09  61.02  61.05  =  61.0533
 3    50.46  50.47  50.45  =  50.4600
 4    59.66  59.69  57.65  =  59.0000
 5    63.48  63.45  63.43  =  63.4533
 6    51.49  51.48  51.47  =  51.4800
 7    55.23  55.24  55.25  =  55.2400
 8    52.81  52.82  52.83  =  52.8200
 9    73.29  72.91  73.27  =  73.1567
 10    56.29  56.27  56.26  =  56.2733
 11    65.89  65.86  65.84  =  65.8633
 12    54.89  54.87  54.85  =  54.8700
 13    57.61  57.62  57.65  =  57.6267
coeff. deter.= .9983342
correlation function= .9991668
criterion fisher f( 12 , 26 )= 1298.486
soct= .3309034
control=-4.092972
t= 10.94865
control=-50.09816
t= 134.0119
control=-110.2711
t= 294.9739
  48.4200  49.0196  49.3244  50.3514  53.1176  63.4533
  64.3680  64.5853  64.1053  62.9280  61.0533
  49.3584  50.8464  51.8701  53.4465  56.5926  67.1939
  69.3788  70.8031  71.4665  59.8080
  50.1336  52.3405  53.9136  55.8699  64.8182  69.0343
  72.4262  66.2184  58.6040
  50.7456  53.5019  55.4549  57.6216  63.9321  65.8496
  61.9030  57.4413
  51.1944  54.3306  56.4940  58.7016  61.0973  58.5205
  56.3200
  51.4800  54.8266  57.0309  58.1693  56.0707  55.2400
  51.6024  54.9899  57.0656  54.5538  54.2013
  51.5616  54.8205  53.9697  53.2040
  51.3576  54.3184  52.2480
  50.9904  51.3333
  50.4600
          Ymax= 72.42615            Ymin= 48.42
                                    x1   6   6   6   6   7   8   8   8   8   8   8   x2
                                           6   7   7   7   7   9   9   9   9   8
                                             6   7   7   7   8   9  10   9   8
                                               7   7   7   7   8   9   8   7
                                                 7   7   7   8   8   8   7
                                                   7   7   7   8   7   7
                                                     7   7   7   7   7
                                                       7   7   7   7
                                                         7   7   7
                                                           7   7
                                                             6
                                                             x3
```

Fig.(7): Combination effect of soil amendments on available nitrogen (mg Kg^{-1}) in sandy soil after wheat crop.

Such results were certified by those found by **(39)** who stated that the application of manure and compost resulted in increasing N, P and K concentrations in wheat straw and grains. The nitrogen is very important for plant growth because it represents the main constituent of major cell parts and protein production, while phosphorus is a part of energy compounds and also associated with root development **(40)**. The possible reason for increasing nutrients concentration in wheat straw and grains with the application of farm manure and compost may be attributed to improving soil conditions and the beneficial effects of integrated use of organic and inorganic materials in enhancing the fertilizer use efficiency by the slow release of the applied nutrients and reduced nutrient losses **(41)**.

Recently, it was reported that the application of gypsum may create more favorable environment in soil and maintain elements in more available form due to its ameliorating effect, which consequently increased the soil fertility that in turn is reflected positively on the nutrients uptake by plants. In addition, biofertilizers play a significant role in improving plant nutrients supplies as supplementary factors. They help increasing the biologically fixed atmospheric nitrogen, also increase the availability of native and applied P and other crop nutrients **(38).**

Phosphorus status

Data in Table (7) represent soil available phosphorus (mg Kg^{-1}), phosphorus content (%) and phosphorus uptake (kg fad^{-1}) by wheat grain. The obtained data reveal that using different combinations of soil amendments, i.e., X1 (PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure) have various effect on P status in soil and plant. In general, there was a remarkable increase in available phosphorus, phosphorus content and phosphorus uptake as a result of application for X1, X2 and X3 amendments compared with control treatment. However, all these parameters were shown on the output triangle figures and having similar trends in response to X1, X2 and X3 amendments. Moreover, soil available P, has a highly significant correlation coefficients with grain P content and P uptake, r =0.96 and 0.98, respectively. Therefore, soil available P shown in Fig (8) was chosen to represent these parameters which showed that the highest soil available P, indicated by the value of 10 on the triangle was obtained by the combined application of 20, 60, and 20% for X1 (PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure), respectively. These results are alike to that obtained in nitrogen status. On the other hand, the single application of 100% biocompost resulted in 70% increase of the maximum soil available P, whereas the single application of 100% X1 (PAM + bentonit) or X3 (rock phosphate + gypsum + sulphure) resulted in 50 % increase of the maximum soil available P. However, the combined application of 70% biocompost (X2) and 30% of X1 or X3 resulted in soil available phosphorus equal to 18.0 mg Kg^{-1} as compared to control treatment which gave 6.30 mg Kg^{-1}. This increase in available phosphorus reached to 11.7 mg Kg^{-1}. The minimum soil available phosphorus (9.53 mg Kg^{-1}) was obtained with the single application of 100% X1 (PAM + bentonit) and it was more higher than that of the control treatment. These results are certainly assured that the application of biocompost either as a single dose or as in combined dose with other mineral and synthetic soil amendments is very important to increase the available phosphorus in sandy soil.

The obtained data were in agreement with findings of **(42)** who reported that the plant nutrient uptake was positively affected by the addition of any soil amendment. All the compost treatment combined with mineral fertilizer led to increasing N, P and

<u>AVERAGE VALUES</u>

1	**9.48**	**9.66**	**9.46**	**=**	**9.5333**
2	**13.51**	**13.31**	**13.29**	**=**	**13.3700**
3	**9.81**	**9.78**	**9.81**	**=**	**9.8000**
4	**12.19**	**12.41**	**12.25**	**=**	**12.2833**
5	**14.26**	**14.38**	**14.41**	**=**	**14.3500**
6	**10.07**	**10.31**	**9.98**	**=**	**10.1200**
7	**10.91**	**10.88**	**10.92**	**=**	**10.9033**
8	**10.62**	**10.61**	**10.59**	**=**	**10.6067**
9	**18.21**	**17.98**	**17.89**	**=**	**18.0267**
10	**11.21**	**11.19**	**11.18**	**=**	**11.1933**
11	**15.61**	**15.61**	**15.59**	**=**	**15.6033**
12	**10.51**	**10.48**	**10.39**	**=**	**10.4600**
13	**12.11**	**11.87**	**11.92**	**=**	**11.9667**

coeff. deter.= .9989325
correlation function= .9994661
criterion fisher f(12 , 26)= 2027.461

soct= 9.746074E-02
control=-1.844815
t= 9.093066
control=-10.87519
t= 53.60362
control=-22.91445
t= 112.9449

9.5333 10.0173 10.8206 11.7357 12.5547 14.3500
14.6177 14.6536 14.4576 14.0297 13.3700
9.7232 10.1049 10.8407 11.7228 12.5435 16.0694
16.8151 17.2626 17.4120 12.7676
9.8768 10.1909 10.8937 11.7775 15.0308 16.5526
17.7100 15.3492 12.2197
9.9941 10.2753 10.9797 11.8997 14.2640 15.1232
13.6531 11.7264
10.0752 10.3580 11.0987 12.0896 13.2153 12.3237
11.2876
10.1200 10.4391 11.2507 11.9860 11.3609 10.9033
10.1285 10.5185 11.4356 10.7647 10.5736
10.1008 10.5963 10.5352 10.2984
10.0368 10.6724 10.0777
9.9365 9.9116
9.8000
Ymax= 17.71 Ymin= 9.533334

x1 5 5 6 6 7 8 8 8 8 7 7 x2
5 5 6 6 7 9 9 9 9 7
5 5 6 6 8 9 10 8 6
5 5 6 6 8 8 7 6
5 5 6 6 7 6 6
5 5 6 6 6 6
5 5 6 6 5
5 5 5 5
5 6 5
5 5
5
x3

Fig.(8): Combination effect of soil amendments on available phosphorus (mg Kg^{-1}) in the sandy soil after wheat crop.

K content in soil and plant. The increase in nutrient uptake may be attributed to the increase of available NPK contents in the soil caused by improved soil structure and texture, which create good environment and consequently higher uptake of nutrients which is resulted from the application of organic matter such as rice straw compost **(43).**

Potassium status

The application of different combination of studied soil amendments X1 (PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure) showed various effects on potassium status in soil and plant. Data in Table (7) show soil available potassium (mg Kg^{-1}), plant potassium content (%) and potassium uptake (kg fad^{-1}) by wheat grain. Obtained data indicated that using the different amendments of X1

(PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure) caused an increase in all forms of potassium as compared to the control treatment.

The behavior of K in soil and plant was generally alike that previously mentioned for nitrogen and phosphorus status. The data produced by triangle computer model for all K forms in soil and plant in response to the application of amendments for X1, X2 and X3 treatments are demonstrated on the output triangle figures which have approximately similar trends. Moreover, soil available K has a highly significant correlation coefficient with grain K content and K uptake, r = 0.92 and 0.93, respectively. Therefore, soil available K shown in Fig (9) was chosen as an example to represent these parameters which showed that the highest soil available K indicated by the value of 10 on the triangle obtained by using the combined mixture of 20, 60, and 20% for X1 (PAM + bentonit), X2 (biocompost) and X3 (rock phosphate + gypsum + sulphure), respectively. These results are similar to those obtained by nitrogen and phosphorus status. On the other hand, the single application of 100% biocompost resulted in 70% of the maximum soil available K, whereas the single application of 100% X1 (PAM + bentonit) or X3 (rock phosphate + gypsum + sulphure) resulted in 40 % of the maximum soil available K. However, the combined application of 70% biocompost and 30% of X1 (PAM + bentonit) or X3 (rock phosphate + gypsum + sulphure) resulted in increasing soil available potassium where values were around 120 mg Kg^{-1} as compared to control treatment which gave 50.3 mg Kg^{-1}. This increase in the available potassium was quantified to about 69.7 mg Kg^{-1}. The minimum soil available potassium which was 54.7 mg Kg^{-1} was obtained with the single application of 100% X1 (PAM + bentonit) and this was more than that of the control treatment, with reduction equal to 65.3% of the maximum. These results confirm that the application of biocompost soil amendment either solely or combined with other mineral or synthetic amendments is very important to increase the available potassium in sandy soil.

AVERAGE VALUES

1 54.81 54.69 54.67 = 54.7233
2 85.81 85.44 85.09 = 85.4467
3 58.48 58.81 58.59 = 58.6267
4 81.39 81.91 81.51 = 81.6033
5 93.61 93.09 93.29 = 93.3300
6 63.09 62.98 63.31 = 63.1267
7 74.31 74.19 74.09 = 74.1967
8 63.39 63.58 63.81 = 63.5933
9 118.98 122.01 120.91 = 120.6333
10 75.69 76.01 75.81 = 75.8367
11 101.91 101.48 101.09 = 101.4933
12 64.31 64.09 64.51 = 64.3033
13 76.09 76.61 76.31 = 76.3367

coeff. deter.= .9995198
correlation function= .9997599
criterion fisher f(12 , 26)= 4510.077

soct= .484123
control=-7.667404
t= 16.95676
control=-62.95815
t= 139.2344
control=-149.5978
t= 330.8412

54.7233 57.8898 65.5400 73.7274 78.5052 93.3300
95.4725 95.7555 94.1788 90.7425 85.4467
57.4363 58.9485 65.6024 73.4511 78.5480 105.0996
110.8640 114.3190 115.4647 83.5423
59.6331 60.1489 66.4641 74.6320 98.1326 109.8282
118.7647 100.3568 81.4651
61.3137 61.4910 68.1253 77.2701 95.3467 99.6312

88.1355 79.2151
62.4783 62.9747 70.5860 81.3655 86.4436 78.8006
76.7923
63.1267 64.6000 73.8460 79.2016 72.3522 74.1967
63.2589 66.3670 77.9055 68.7903 71.4283
62.8751 68.2756 68.1148 68.4871
61.9751 70.3259 65.3731
60.5589 62.0863
58.6267
Ymax= 118.7647 Ymin= 54.72334

x1 4 4 5 6 6 7 8 8 7 7 7 x2
4 4 5 6 6 8 9 9 9 7
5 5 5 6 8 9 10 8 6
5 5 5 6 8 8 7 6
5 5 5 6 7 6 6
5 5 6 6 6 6
5 5 6 5 6
5 5 5 5
5 5 5
5 5
4
x3

Fig.(9):-Available potassium (mg Kg^{-1}) in the studied sandy soil as affected by different combination of used amendments after wheat crop harvested.

In conclusion, the synergetic effect of straw biocompost combined with bentonite, PAM, gypsum, sulphur, and rock phosphate could be an excellent mixture for amending sandy soils. Straw biocompost which is rich in organic matter, nitrogen, phosphorus, and potassium, has a great potential on soil fertility and crop production. Bentonite has good adhesion, adsorption, and cation exchange activity. Polyacrylamide (PAM) can effectively improve soil structure, reduce soil bulk density, so that increasing total soil porosity and capillary pores and then soil moisture condition. The utilization of rock phosphate in combination with sulphur and gypsum was more effective in transforming insoluble P to available form. The application of biocompost soil amendment either solely or combined with other mineral or synthetic amendments was definitely the regulatory important factor in this study.

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