Response of Wheat plant grown on Calcareous, Sandy, and Clay Soils to Farmyard manure and *Spirulina* extract application as sustainable agriculture

Abstract.

The main objective of this investigation was to boost wheat productivity by reinforce calcareous, sandy and clay soils properties, i.e., some physical and chemical properties of the study soils using organic farmyard manure and *Spirulina platensis* extract (SPE) for achieving the sustainable agriculture aspect. The field experiments conducted in kafr Elskhiekh and El-Behera Governorate, Egypt. Yield of wheat crop, concentrations of macronutrient in straw and grains as well as total microbial count were determined. Application of organic farmyard manure (FYM) significantly improved the hydro-physical properties of tested soils, i.e., Bulk density (Mg m^{-3}), Total porosity (%), EC, pH, organic matter, SAR, Cations (Na^+, K^+, Ca^{++}, and Mg^{++} $meqL^{-1}$), Anions ($CO^{3=}$, HCO^{3-}, Cl^- and $SO^{4=}$ $meqL^{-1}$) and chemical available macronutrient (NPK) compared to control (minerals fertilizer) in the cultivated soils during 2021 and 2022 seasons. Application of Farmyard Manure (FYM), with rate of 10-ton ha^{-1} and foliar with SPE consisted of 2.4 L during the vegetative growth stages of wheat alone or together improved the yield content of straw and grains of wheat as well as concentrations of N, P, K and protein content during two separated seasons 2021 and 2022. Clay soil had the best effect with the treatments compared with minerals applied at N rate of 360 kg ha^{-1}. Clay soil with the great number of total count, calcareous and sandy soil was the last arrangement. Also, results showed that clay soil was the best effected with FYM application compared with other soils. Thus, these treatments can replace partially N, P and K mineral fertilizers, which reduce production costs and conserve the environment from chemical pollution hazards on human and animal health.

Keywords: FYM, SPE, soil properties, grain yield, microbial community.

1. INTRODUCTION

There can be no longer any question about the significance of sustainable agriculture; it is at the core of a new social contract between society as a whole and its farmers. However, putting sustainability into practice is still a challenge. In many agricultural contexts, the idea of sustainability has not yet been putted into practice **(Gafsi et al., 2006).** The practice of agriculture that aims to maximize knowledge and technology in order to ensure the long-term stability of the agricultural enterprise is known as sustainable agriculture. It accomplished through methods for enhancing the soil and sources of soil fertility **(Gold, 1999).** A significant portion of the North Coastal region of Africa covered in calcareous soils. Calcareous soils, which contain significant levels of calcium carbonate, have an impact on both physical and chemical soil characteristics that are important for plant growth, such as soil-water relationships and soil crusting. In Egypt, **calcareous soils** are common. According to **Noufal et al. (2005),** the main issues with these soils were related to one or more of the following: high pH, inadequate texture and structure, very little organic matter, the distracting effect of some micronutrient availability, low moisture content, and low hydraulic conductivity. Egypt is dealing with a noticeable decline in the old Nile's productive agricultural soils.

One of northwestern coastal region is Egypt and around 0.65 million feddans are calcareous **(Rasha, 2005).** Due to its significant potential and position. A lot of work has put into assessing Egypt's agricultural potential in order to supply the country's rapidly growing population with food. Plants have reduced fertility in calcareous soils where CaCO3 predominates and pH is high. In addition, **sandy soils** in Egypt cover more than 70% of the entire land area. When compared to other desert soils, most of these soils showed reclaimed at a low cost. Furthermore, these soils are better suited to many economically important crops such as wheat, barley, and maize. Furthermore, such soils were find within or near the Nile River Valley **(FAO, 2021).** For the majority of people on earth**, wheat (*Triticumae stivum* L.),** is regarded as the most crucial and strategically essential cereal crop. In Egypt, wheat is the most significant and strategically significant crops, only approximately thirty percent of the country's needs was met by its production. One method of enhancing wheat yield, especially in newly reclaimed regions, is the careful application of organic wastes.

Wheat accounts for around 10% of total agricultural production in Egypt and over 20% of total agricultural imports **(GASC, 2020).** Wheat has increased its proportion of winter-farmed area from 41 to 47%, however cultivation is limited to a narrow stretch along the Nile Valley **(FAO, 2015)**. Egypt's wheat production was expected to reach 9 million metric tonnes in 2021, up 1.12% from previous years **(FAO, 2022),** As a result, more than six million tonnes of imports are required each year. As part of a trial to enhance wheat-growing area and reduce reliance on wheat imports. As a result, initiatives had made to raise the cultivated area in Egypt by one or more of the following approaches should take. The first is to increase wheat cultivation in both old and newly reclaimed soils. The second method is to cultivate resistant cultivars (plant certified must-free seed), which is regarded the most cost-effective and successful method of disease control. The third method is to improve agricultural practices, such as the quantity of time, irrigation, and chemical fertilization **(Elbaalawy, 2010).** According to **FAO 2022**, wheat is Egypt's most significant grain and its single greatest crop in terms of area. It offers roughly 55% of the carbs and 20% of the food calories consumed globally, making it the most significant staple meal for about two billion people **(Briggle and Reitz, 1963; Simmonds, 1976).** Wheat is cultivated in a variety of climatic circumstances and outperforms all other grain crops in terms of productivity and acreage **(Tomi et al., 2016).** Wheat is cultivated in a variety of climatic circumstances and outperforms all other grain crops in terms of productivity and acreage **(Tomi et al., 2016).** The majority of the recently reclaimed land in Egypt's deserts has sandy soil, which presents significant farming challenges. Both in terms of organic matter concentration and fertility, sandy soils are highly deficient. On the other hand, organic materials are abundant and reach enormous proportions every day. Examples include crop residues, farmyard manure, industrial wastes (filter mud), etc.

Farmyard manure is an important component of the nutrients cycle in agricultural ecosystems. FYM played a crucial role in the continual supply of well-balanced nutrient meals to crops. According to **Ali *et al*. (2005),** FYM application at rates of 2 or 3% to sandy soil after maize harvesting reduced pH and EC values marginally. Several studies have confirmed organic amendments' roles as an improving agent. The reasonable use of organic materials as amendments has an enormous effect on the improvement of soil physical and chemical properties, as well as nutrient status. **Seddik (2006)** discovered that organic manure and natural minerals boosted the N, P, and K contents of examined plant sections as well as yield components in both tomato and pea plants. When treated frequently over multiple seasons, farmyard manure improves the soil pH of moderately acidic soils. It contains a lot of K and N. As a result, the use of FYM alone or in combination with fertilizers expected to steadily improve and sustain soil productivity over time **(Mwangi, 2010).**

Microalgae biostimulants are utilized in small amounts along with inorganic fertilizers to enhance crop growth and production **(Tamoi et al., 2006, Ronga et al., 2019),** most probably by enhancing chlorophyll content, antioxidants, metabolism, and the shelf life of harvested products **(Garcia-Gonzalez and Sommerfeld, 2016; Rouphael and Colla, 2018).** The photosynthetic **blue-green microalgae, *Spirulina platensis*,** is a biostimulant with high nutritional value and thus has been commercially used as a biofertilizer **(Sanchez et al., 2003).** *S. platensis* extract (SPE) has been identified as a potential biofertilizer that can be used as a foliar application during the vegetative growth stages of various crops such as maize, barley, cotton, tomato, oats, lettuce, chili pepper, and sugarcane **(Ordog, 1999; Garcia-Gonzalez and Sommerfeld, 2016).** SPE is abundant in osmoprotectants and antioxidants, such as salicylic acid, GSH, proline, AsA, α-TOC, soluble sugars, selenium, and vitamins (e.g., A, B, and E). Furthermore, it is rich in phytoormones (e.g., cytokinins, gibberellins, and auxins) and nutrients that support plant growth and production **(Yanni et al., 2020).** It also contains amino acids, which play significant roles in stress relief, HMs and toxin detoxification, chlorophyll and vitamin biosynthesis, nutrient uptake, translocation, and metabolism **(Bashir et al., 2018; Hussain et al., 2018).** Amino acids also maintain the protein structure required for cell division and growth stimulation **(Kakkar et al., 2000; Souri and Hatamian, 2018).** Previous studies on the SPE used under salinity stress have been reported (**Rady et al., 2018; Selem, 2019; Seifikalhor et al., 2020; Hamouda et al., 2022).** Concurrently, foliar application of *Spirulina* **(*Spirulina platensis*),** a type of blue-green algae, has garnered interest for its potential to enhance plant growth and productivity through its rich nutrient content and growth-promoting properties **(Abd El-Shedeed *et al.* 2022).** *Spirulina*, renowned for its high protein content, vitamins, and antioxidants, offers a natural solution to enhance plant growth and resilience to environmental stressors **(Seğmen and Özdamar-Ünlü, 2023).**

The main objective of this investigation was to boost wheat productivity by reinforce calcareous, sandy and clay soils properties, i.e., some physical and chemical properties of the study soils using organic farmyard manure and *Spirulina platensis* extract for achieving the sustainable agriculture aspect during the two successive seasons 2020-2021 and 2021-2022.

2. MATERIALS AND METHODS

A field experiment was conducted under split plot experimental design (with three replicates) to assess the performance and productivity of wheat plants grown in various soil types (as main factor), including clay, sandy and calcareous. Concurrently, the study aimed to evaluate the effects of four treatments (as sub main factor), including **T_1:** Control (no treatment), **T_2:** Addition of farmyard manure (FYM) to the soil, **T_3:** Foliar application of spirulina (SP), and **T_4:** Combined treatment (FYM+SP), on selected soil properties and wheat performance**.**

2.1. Experimental site

Field experiments were carried out across two successive seasons (2020-2021 and 2021-2022) at private farms situated in Baltim and Elhamoul within the Kafr El-Sheikh governorate, Egypt, as well as in the Badr region of the Elbehara governorate, Egypt.

2.2. Soil sampling

Soil samples were collected from various locations in Kafr El-Sheikh Governorate, including Baltim sandy soils and Elhamoul clay soil, as well as from Elbehara Governorate, where the Badr region represented the calcareous soil. Samples were collected at three depths: 0-15 cm, 15-30 cm, and 30-45 cm for further study. The collected soil samples were air-dried, crushed, and sieved through a 2 mm sieve before undergoing chemical analysis. The soil characteristics are detailed in Tables 1 and 2.

2.3. Preparation of the experimental materials

2.3.1. Farmyard manure (FYM):

The farmyard manure utilized in the experiment during both studied seasons was sourced from a private animal farm. Table 4 presents some of the chemical properties of the farmyard manure used in the experiment.

2.3.2. Spirulina (*Spirulina platensis*):

It was kindly supplied from microbiology department, Soils, Water and Environment Research Institute, Agricultural Research Center, Sakha Agriculture Research Station, Kafr El-Sheikh, Egypt. Spirulina platensis extract was obtained as follow; Two grams of dry powder from the S. platensis extract was added into one liter of deionized water, regularly mixed for fifteen minutes, and autoclaved at 121 °C for 60 min (**Geries and Elsadany, 2021**). The warm extract was purified using Whatman No. 40 filter paper from Sigma-Aldrich (Merck KGaA, Darmstadt, Germany) and stored at -4 °C until additional analysis. Spirulina extract contains eighteen amino acids (%): alanine 2.62; arginine 1.96; aspartic 3.4; cysteine 1.71; glutamic acid 3.82; glycine 1.82; histidine 0.45; isoleucine 1.59; leucine 2.55; lysine 1.35; methionine 1.05; phenylalanine 1.77; proline 1.17; serine 1.22; tryptophan 1.70; threonine 2.66; tyrosine 1.14; and valine 2.09. Their chemical compositions are as follows: oligosaccharide (3%); alginic acid (5%); phytin (0.003%); menthol (5%); natural growth regulators such as cytokines (0.001%), indole acetic acid (0.0002%), and pepsin (0.02%); and minerals (potassium oxide (18%), phosphorus oxide (5%), N (5%), Ca (1.5%), Zn (0.3%), Fe (2%), and Mn (0.1%)). Spirulina platensis was sprayed after 45 and 60 day of sowing.

Table 1: Some chemical characterization of clay, sand and calcareous soils in the experiment

Depth (cm)	**Texture**	**F.C. (%)**	**P.W.P (%)**	**B.D (Mg m^{-3})**	**SAR**	**ESP %**	**Total porosity (%)**	**$CaCO_3$ (%)**	**O.M (%)**	**N (mg kg^{-1})**	**P (mg kg^{-1})**	**K (mg kg^{-1})**
Clay soil												

0-15	Clayey	44.12	25.18	1.32	9.44	11.24	50.19	2.76	1.23	52.23	9.32	343
15-30	Clayey	41.24	23.42	1.34	10.03	11.92	49.43	2.71	1.21	63.32	9.85	346
30-45	Clayey	40.13	22.75	1.38	11.09	13.12	47.92	3.15	0.96	41.48	9.44	331

Depth (cm)	**pH**	**EC dSm^{-1}**	**Na$^+$**	**K$^+$**	**Ca^{++}**	**Mg^{++}**	**HCO$_3^-$**	**Cl$^-$**	**SO$_4^=$**
			meq L^{-1}						
0-15	8.68	5.26	30.77	0.263	10.99	10.25	2.63	25.53	24.11
15-30	8.75	5.94	34.75	0.297	12.41	11.58	3.32	28.84	26.88
30-45	8.81	6.86	42.47	0.363	15.17	14.16	3.18	35.25	33.74

Sand soil

Depth (cm)	**Texture**	**F.C. (%)**	**P.W.P (%)**	**B. D (Mg m^{-3})**	**SAR**	**ESP %**	**Total porosity (%)**	**CaCO$_3$ (%)**	**O.M (%)**	**N (mg kg^{-1})**	**P (mg kg^{-1})**	**K (mg kg^{-1})**
0-15	Sandy	15.36	8.36	1.25	7.65	9.11	52.83	1.95	0.62	62.15	5.12	77.32
15-30	Sandy	15.41	8.31	1.26	7.59	9.04	52.45	2.35	0.75	63.62	5.15	77.48
30-45	Sandy	15.44	8.35	1.26	6.98	8.28	52.45	3.65	0.74	61.82	5.44	7746

Depth (cm)	**pH**	**EC dSm^{-1}**	**Na$^+$**	**K$^+$**	**Ca^{++}**	**Mg^{++}**	**HCO$_3^-$**	**Cl$^-$**	**SO$_4^=$**
			meq L^{-1}						
0-15	8.44	3.41	20.15	0.273	7.13	6.75	11.12	14.47	8.71
15-30	8.41	3.36	19.86	0.269	7.02	6.65	10.24	14.26	9.3
30-45	8.36	2.84	16.78	0.227	5.94	5.62	9.72	12.05	6.79

Calcareous soil

Depth (cm)	**Texture**	**F.C. (%)**	**P.W.P (%)**	**B. D (Mg m^{-3})**	**SAR**	**ESP %**	**Total porosity (%)**	**CaCO$_3$ (%)**	**O.M (%)**	**N (mg kg^{-1})**	**P (mg kg^{-1})**	**K (mg kg^{-1})**
0-15	Sandy loam	15.17	9.11	1.26	7.31	8.69	52.45	16.95	0.95	22.75	5.22	247
15-30	Sandy loam	15.22	9.13	1.27	6.71	7.95	52.08	17.35	0.93	23.62	5.35	248
30-45	Sandy loam	15.31	9.56	1.29	6.99	8.3	51.32	17.65	0.86	21.72	5.24	246

Depth (cm)	**pH**	**EC dSm^{-1}**	**Na$^+$**	**K$^+$**	**Ca^{++}**	**Mg^{++}**	**HCO$_3^-$**	**Cl$^-$**	**SO$_4^=$**
			meq L^{-1}						
0-15	8.81	3.11	18.38	0.202	6.5	6.16	8.16	11.36	11.72
15-30	8.77	2.62	15.48	0.17	5.48	5.19	6.13	9.57	10.62
30-45	8.84	2.85	16.84	0.185	5.96	5.64	6.21	10.41	12.01

Table 2: Some of the chemical properties of the farmyard manure used

pH 1:10 sus	**OM %**	**N %**	**C %**	**C:N**	**P %**	**K %**	**Mn**	**Fe**	**Zn**
								ppm	
6.17	47.52	1.48	28.16	19.03	0.95	1.25	135	246	65
6.15	47.54	1.49	27.86	18.7	0.97	1.29	142	252	67

2.4. Seeds

Wheat (*Triticum aestivum* L.) grains (Misr 3) were kindly supplied from Field Crop Research Institute, Agricultural Research Center, Department of Cereals, Sakha Agriculture Research Station. Kafr El-Sheikh, Egypt.

2.5. Experimental set up

Seeds were sown on November 15th in both study seasons. In all plots and under all soil conditions, urea was applied as the nitrogen (N) fertilizer, consisting of two equal doses applied within 45 days of sowing, at a rate of 360 kg ha^{-1}. Farmyard Manure (FYM) was incorporated into the soil under all soil conditions based on the studied treatments, at a rate of 10 tons ha^{-1} before tillage. The foliar application of spirulina solution, comprising 2.4 liters of *Spirulina* extract and 250 liters of water ha^{-1}, was conducted at 30 and 50 days after sowing, according to the specific treatments being studied. Additionally, calcium superphosphate was applied as the phosphorus (P) fertilizer (15.5% P_2O_5), and potassium sulfate was used as the potassium (K) fertilizer (48% K_2O). Both fertilizers were applied to all treatments during the two experimental seasons at the time of plowing, with rates of 230.3 kg ha^{-1} for calcium superphosphate and 120 kg ha^{-1} for potassium sulfate.

2.6. Harvesting

The harvest took place in the last week of April in both the studied cropping seasons

2.7. Measurements

Three collected sites of studied soils area were growing with wheat and subjected to the following parameters determination in the two seasons (2020-2021 and 2021-2022); EC (dSm^{-1}), PH, SAR, soil organic matter (%), available soil nitrogen ,phosphorus and potassium (mg kg^{-1}) , grain and straw yield (kg fed^{-1}) after harvesting . Additionally the content of N, P, K (%) and protein (%) in both grain and straw were determined according to the stander methods (Table 3). On the other hand, total count of bacteria was determined by soil extract agar medium according to Allen (1959).

Table 3. Methods and references

Parameters	Methods	References
	Soil properties	
EC,dSm^{-1}	EC meter	**Jensen HL (1951), Richards, (1954), Jackson, M. L. (1958, 1967, 1973), Rynk (1992); Atlas, R. M. (2004)**
pH	PH meter	
Organic matter content (O.M ,%)	Walkley and Black method	
Soil-available nitrogen (NH_4+ NO_3^-), mg kg^{-1}	Kjeldahl method	
Soil-available phosphorus, mg kg^{-1}	Olsen method using spectrophotometer	

Soil-available potassium, mg kg^{-1}	Flame photometer method	
Grain and straw analyses		
Samples digestion	H_2SO_4+$HClO_4$	**Peterburgski (1968).**
Total nitrogen,%	Kjeldahl method	**Walinga *et al*. (2013)**
total phosphorus,%	Olsen method using spectrophotometer	
Total potassium,%	Flame photometer method	
Total protein,%		**AOAC (2000)**

2.8. Statistical analysis

The obtained collected data were subjected to the statistical analysis, using the analysis of variance (ANOVA). The LSD range tests were used to compare between the means **(Steel and Torrie, 1980).**

3. RESULTS AND DISCUSSION

3.1. Soil properties at harvest stage (EC, pH and SAR)

Data presented in Table 4 illustrate the response of soil properties (EC, pH and SAR) to the various application treatments at the harvest stage during the 2020-2021 and 2021-2022 seasons. Statistical analysis of the data reveals that the clay soil exhibited the highest EC and SAR values under all studied sub-main treatments, followed by the sandy soil and then the calcareous soil. Conversely, concerning pH values, it is evident that the calcareous soil displayed the highest values, followed by the clay soil and then the sandy soil under all studied sub-main treatments. Furthermore, it is observed that EC of Calcareous and sandy soils where decrease with increasing the depth. pH showed different value depend on the depth of the sample and the soil type. Data of the field experiment (seasons 2021-2022) presented in Tables 4 showed EC variation of three soils where, clay soil was the highest value 4.86 dSm^{-1} and Calcareous was the lowest 3.02 dSm^{-1} at control treatment. Also, application of farmyard manure, spirulina extract and both of them decreased EC of clay, sandy and Calcareous soils in the first and second season compared with control treatment while, the clay soil was significant effected with 4.12 dSm^{-1} value. Application of all treatments in the separated seasons decreased EC compared with the value before planted. Table 4 showed variation pH of the studied soils. Calcareous soil was the high pH value in the control treatment followed by sandy and clay in the first and second season. Sandy soil was the most effected by the four application of treatments compared with pH before planted. Tables 4 showed SAR variation of three soils. The mean value of both seasons of SAR of clay soil was the highest value 9.06 at all treatments. In addition, application of farmyard manure, spirulina extract and both of them decreased SAR of clay, sandy and Calcareous soils in the first and second season compared with control treatment. The clay soil was significant effected with 6.345 value compared with other treatments. Application of all treatments in the separated seasons decreased SAR compared with the value before planted.

Table 4: Effect of different application treatments on soil properties at harvest stage (EC, pH and SAR) during the two growing seasons under different soil types conditions

Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
			EC, 1st season		
S_1 (Clay soil)	4.86 a	4.18 b	4.21 b	4.12 b	4.34 a
S_2 (Sandy soil)	3.34 c	2.74 de	2.86 de	2.87 de	2.95 b
S_3 (Calcareous soil)	3.02 cd	2.63 e	2.75 de	2.53 e	2.73 c
Mean	3.74 a	3.18 b	3.27 b	3.17 b	
			EC, 2nd season		
S_1 (Clay soil)	4.85 a	4.14 b	4.26 b	4.05 b	4.32 a
S_2 (Sandy soil)	3.17 c	2.18 e	2.21 e	2.07 e	2.41 b
S_3 (Calcareous soil)	2.84 cd	2.19 e	2.49 de	2.17 e	2.42 b
Mean	3.62 a	2.84 b	2.98 b	2.76 b	
			pH, 1st season		
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S_1 (Clay soil)	8.53 a	8.21 bc	8.16 bc	8.07 cd	8.24 b
S_2 (Sandy soil)	8.29 b	8.07 cd	7.93 de	7.90 e	8.04 c
S_3 (Calcareous soil)	8.64 a	8.29 b	8.32 b	8.27 b	8.38 a
Mean	8.47 a	8.14 bc	8.18 b	8.08 c	
			pH, 2nd season		
S_1 (Clay soil)	8.44 ab	7.99 e	8.26 bc	8.04 de	8.18 b
S_2 (Sandy soil)	8.26 bc	7.90 e	8.03 de	7.90 e	8.02 c
S_3 (Calcareous soil)	8.52 a	8.20 cd	8.29 bc	8.26 bc	8.31 a
Mean	8.41 a	8.03 c	8.19 b	8.07 c	
			SAR, 1st season		
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S_1 (Clay soil)	9.074 a	8.415 b	8.445 b	8.505b	8.61 a
S_2 (Sandy soil)	7.57 c	6.86 ef	7.01 de	7.02 de	7.12 b
S_3 (Calcareous soil)	7.2d	6.72ef	6.87 def	6.59 f	6.84 c
Mean	7.95 a	7.33 b	7.44 b	7.37 b	

SAR, 2nd season					
S$_1$ (Clay soil)	9.06 a	8.37 a	8.49 a	8.46 a	8.59 a
S$_2$ (Sandy soil)	7.38 b	6.12 d	6.16 d	5.96 d	6.41 b
S$_3$ (Calcareous soil)	6.98 bc	6.13 d	6.54 cd	6.10 d	6.43 b
Mean	7.81 a	6.87 b	7.07 b	6.84b	

T$_1$: Control (no treatment), **T$_2$:** Addition of farmyard manure (FYM) to the soil, **T$_3$:** Foliar application of spirulina (SP), and **T$_4$:** Combined treatment (FYM+SP).

3.2. Organic matter (OM), available nitrogen (A-N), phosphorus (A-P) and potassium (A-K)

Table 5 depict the impact of farmyard manure (FYM), *Spirulina* and their combination on soil fertility indicators, including soil organic matter (OM, %), available nitrogen (A-N), phosphorus (AP), and potassium (A-K) levels, across three soil types (clay, sandy, and calcareous) during the 2020-2021 and 2021-2022 seasons. The findings revealed a soil fertility hierarchy, with clay soil exhibiting the highest fertility (highest values of OM, A-N, AP, A-K), followed by calcareous soil, and then sandy soil. Notably, the combined treatment (FYM+SP) emerged as the most effective in enhancing soil quality (highest values of OM, A-N, AP, A-K). Following this, the FYM treatment ranked second in efficacy, succeeded by the spirulina treatment, with the control group exhibiting the least improvement. Variation of OM means values in control treatment, FYM, SEP and both were detected (0.91, 1.217, 1.087 and 1.24), respectively. The mean value of OM in both seasons showed that duel treatment FYM and SE was the best treatment. On the other hand, response of clay soil to FYM and SE was the great effect followed by calcareous and sandy soils (1.42, 1.017 and 0.89), respectively.

Available NPK (mg kg^{-1}) of the studied soils reported in Table 5. Date appeared that clay soil with high N,P and K content, in the second position calcareous soil and sandy soil was the lowest and last one (30, 26.18 and 17.28 N-content), (11.31, 10.91 and 5.36 K-content) and (429.02, 279.08 and 164.79 K-content), respectively. Nitrogen soil content (mg kg^{-1}) soil average of both season 2021-2022 appear that duel treatment FYM+ SE was the high N value followed by FYM, control (mineral fertilizer) and SE was the lowest value (26.74, 25.88, 25.85 and 19.47), which mean that application of FYM separated or with SE increased soil N-content. P soil content (mg kg^{-1}) average of both season 2021- 2022 appeared that mineral treatment increased P-content compared with other treatments and FYM became in the second ranking with value 10.55 and 9.57 mg kg^{-1} respectively, these showed that FMY application is necessary to increase P-content of all types soils compared with soils before planted. The means value of K-content of studied soils showed a verity value; clay was high value, calcareous in the second arrangement and sandy soil was the lowest and last value (429.02, 279.08 and 164.79 mg kg^{-1}) respectively. Application of mineral fertilizer (control) compared with FYM alone or with SPE gave the best K-content, while the effect is not significant.

Table 5: Effect of different application treatments on Organic matter (OM), available nitrogen (A-N), phosphorus (A-P) and potassium (A-K) during the two growing seasons under different soil types conditions

OM, 1st season					
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S_1 (Clay soil)	1.05b	1.52a	1.35 a	1.47a	1.35 a
S_2 (Sandy soil)	0.73 c	0.91bc	0.85 bc	1.01 b	0.875 b
S_3 (Calcareous soil)	0.85 bc	1 bc	0.99 bc	1.07 b	0.98 b
Mean	0.88b	1.14 a	1.06 a	1.18 a	
OM, 2nd season					
S_1 (Clay soil)	1.20 cd	1.65 ab	1.43 bc	1.72 a	1.5 a
S_2 (Sandy soil)	0.74 f	1.02 def	0.83 ef	1.06 de	0.91 b
S_3 (Calcareous soil)	0.89 ef	1.18 cd	1.07 de	1.08 de	1.06 b
Mean	0.94 c	1.28 a	1.11 b	1.27 a	
A-N, 1st season					
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S1 (Clay soil)	31.65 ab	28.39 abc	22.39 def	32.79 a	28.81 a
S2 (Sandy soil)	17.87 fg	18.75 f	12.45 g	17.23 fg	16.58 c
S3 (Calcareous soil)	26.06 bcde	25.97 cde	20.84 ef	27.05 bcd	24.98 b
Mean	25.19 a	24.37 a	18.56 b	25.69 a	
A-N, 2nd season					
S1 (Clay soil)	32.18 abc	33.43 ab	24.55 ef	34.6 a	31.19 a
S2 (Sandy soil)	19.45 g	19.86 g	13.76 h	18.87 g	17.99 c
S3 (Calcareous soil)	27.89 de	28.91 cd	22.84 fg	29.87 bcd	27.38 b
Mean	26.51 a	27.4 a	20.38 b	27.78 a	
A-P, 1st season					
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S1 (Clay soil)	9.6 abc	9.6 abc	9.5 abc	9.6 abc	9.58 a
S2 (Sandy soil)	7.7 bcd	5.8 cde	2.2 e	4.8 de	5.13 b
S3 (Calcareous soil)	12.09 a	10.24 ab	8.78 abcd	11 ab	10.53 a
Mean	9.8 a	8.55 ab	6.83 b	8.47 ab	
A-P, 2nd season					
S1 (Clay soil)	14.2 a	13.8 a	10.5 bcd	13.7 ab	13.05 a
S2 (Sandy soil)	8.3 def	6 ef	2.4 g	5.7 f	5.6 c
S3 (Calcareous soil)	11.4 abcd	12.01 abc	9.1 cde	12.6 ab	11.28 b

Mean	11.3 a	10.6 a	7.33 b	10.67a	
A-K, 1st season					
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S1 (Clay soil)	450.67 a	407.88 ab	402.53 ab	413.23 ab	418.58 a
S2 (Sandy soil)	189.33 e	170.33 ef	102.67 f	152.83 ef	153.79 c
S3 (Calcareous soil)	342.3 bc	279.6 cd	215 de	295 c	282.98 b
Mean	327.43 a	285.93 b	240.07 c	287.02 b	
A-K, 2nd season					
S1 (Clay soil)	451.37 a	439.7 a	416.44 a	450.3225 a	439.46 a
S2 (Sandy soil)	214.67 de	195.33 de	121.67 f	171.5 ef	175.79 c
S3 (Calcareous soil)	293.5 bc	260 bcd	231.57 cde	315.67 b	275.19 b
Mean	319.85 a	298.34 a	256.56 b	312.49 a	

T_1: Control (no treatment), **T_2:** Addition of farmyard manure (FYM) to the soil, **T_3:** Foliar application of spirulina (SP), and **T_4:** Combined treatment (FYM+SP).

3.3. Soil microbiological activity

At harvest, the microbial community, which includes the total number of bacteria, was found to be significantly ($P < 0.05$) different in the rhizosphere of wheat plants grown under soil additive with FYM and foliar spray with SPE in both the 2021 and 2022 growing seasons (Table 6). Overall, the findings show that the microbial community varied depending on the tested treatments. In comparison to the other treatments, the T4 treatment (combination) demonstrated the highest population of total counts of bacteria (5.91, 3.58 and 4.48 CFU $1 \times 10^6 m^{-1}$); followed by T2 treatment (FYM), recorded (5.51, 3.49 and 4.21 CFU $1 \times 10^6 m^{-1}$), followed by T3 treatment (SEP), recorded (4.65, 3.20 and 4.05 CFU $1 \times 10^6 m^{-1}$), followed by T1 treatment (control) recorded (4.3. 2.7 and 3.89 CFU $1 \times 10^6 m^{-1}$) for clay, sandy, and calcareous soils during the first (2021) second, respectively. The same pattern was observed in 2022 season (Table 6).

Table 6: Effect of different application treatments on Organic matter (OM), available nitrogen (A-N), phosphorus (A-P) and potassium (A-K) during the two growing seasons under different soil types conditions

TCB 1st season					
Main treatments	**Sub main treatments**				**Mean**
	T_1	**T_2**	**T_3**	**T_4**	
S_1 (Clay soil)	4.3 cd	5.51 ab	4.65 bc	3.91 a	5.09 a
S_2 (Sandy soil)	2.7 f	3.59 def	3.20 ef	3.58 def	3.2 c
S_3 (Calcareous soil)	3.89 cde	4.21 cde	4.05 cde	4.48 cd	4.16 b
Mean	3.63 c	4.44 ab	3.97 bc	4.65 a	
TCB, 2nd season					
S_1 (Clay soil)	4.91 b	7.02 a	5.13 b	7.12 a	6.04 a

S_2 (Sandy soil)	3.3 b	4.09 b	3.76 b	4.09 b	3.81 c
S_3 (Calcareous soil)	4.56 b	4.95 b	4.58 b	5.05 b	4.78 b
Mean	4.26 b	5.35 a	4.49 ab	5.42 a	

T_1: Control (no treatment), **T_2:** Addition of farmyard manure (FYM) to the soil, **T_3:** Foliar application of spirulina (SP), and **T_4:** Combined treatment (FYM+SP).

3.4. Grain yield and chemical traits

Figure 1, illustrate the impact of farmyard manure and *spirulina*, applied either individually or in combination, on the straw and grain yield of wheat cultivated in three soil types (clay, sandy, and calcareous) during the 2020-2021 and 2021-2022 seasons. Figures 2, 3, 4, and 5 depict the effect of the studied treatments on protein, nitrogen, phosphorus, and potassium levels in both grain and straw. The results demonstrate that wheat productivity and the chemical composition of grain and straw (N, P, K) were highest in plants cultivated in clay soil, followed by those in calcareous soil, and finally those in sandy conditions. Remarkably, the combined treatment (FYM+SP) proved most effective in enhancing wheat productivity and the chemical composition of grain and straw (N, P, K). Subsequently, the addition of FYM alone to the soil ranked second in efficacy, followed by the foliar application of Spirulina alone, while the control group exhibited the least improvement. Fig.1 (a,b) showed different grains and straw yield assortment; the mean of clay soil gave the highest grains worth, calcareous was moderate and sandy soil gave the lowest (2244.99, 1935.78 and 1798.825 of Kgfed^{-1}), respectively. Application of FYM gave grains at rate 2069.63 Kgfed^{-1} and jointly had a good wheat grains at rate of 2101.58 Kgfed^{-1} and straw gave 3621.07 Kgfed^{-1} compared with control (1990.17 and 3377.48. Kgfed^{-1}) grains and straw, respectively.

Fig. 2 (a & b) showed farmyard manure, spirulina and both treatments effect on Protein grains and straw content compared with control treatment on three soils types at 2021 and 2022 seasons. Protein content grains and straw of wheat of clay soil was towering than sandy and calcareous. On the other hand, Fig. 3, 4 and 5 (a & b) showed farmyard manure, spirulina and both treatments effect on N, P and K of grains and straw content compared with control treatment on three soils types at 2021 and 2022 seasons. N, P and K contents of grains and straw of wheat of clay soil was a great more than sandy and calcareous. N, P and K – content of grains and straw of wheat cultivated in clay soil gave the best value (3.59, 2.16, 0.26, 0.175, 1.14 and 8.03 ppm^{-1}), respectively. Dual application of FYM and SPE rise the N, P and K content compared with control.

Fig 1; showed sub main treatments farmyard manure, *spirulina*, and mix of both compared with control treatment effect on straw and grain yield wheat production of three soils types during seasons of 2020-2021 and 2021-2022

Fig 2; showed submain treatments farmyard manure, *spirulina*, and mix of both compared with control treatment effect on straw and grain protein content of wheat production of three soils types during seasons of 2020-2021 and 2021-2022

Fig 3; showed submain treatments farmyard manure, *spirulina*, and mix of both compared with control treatment effect on straw and grain nitrogen content of wheat production of three soils types during seasons of 2020-2021 and 2021-2022

Fig 4; showed submain treatments farmyard manure, *spirulina*, and mix of both compared with control treatment effect on straw and grain phosphorus content of wheat production of three soils types during seasons of 2020-2021 and 2021-2022

Fig 5; showed submain treatments farmyard manure, *spirulina*, and mix of both compared with control treatment effect on straw and grain potassium content of wheat production of three soils types during seasons of 2020-2021 and 2021-2022

4. Discussion:

These binding agents decrease the bulk density of the soil by improving soil aggregation and hence increase the porosity (Bhatia and Shukla 1982) and kunj et al. (2018). Increase in total porosity with inorganic fertilization has also been reported by Schjonning et al., (1994) and kunj et al. (2018). The higher total porosity of the soil particularly of the surface layer helps in ready exchange of O_2 and CO_2 between the soil and the atmosphere, thereby, promoting better root growth in the soil. A positive effect of FYM on P availability was also observed by Roy et al. (2001) and kunj et al. (2018).

Combined use of organic and inorganic sources of nutrient could be attributed to better synchrony of nutrient availability to the wheat crop, which was reflected in higher grain yield and biomass production and also the higher nutrient use efficiency kunj et al. (2018). Table 2, 3 and 4 showed some chemical and physical characterization of the studied soils before planted. Electric connectivity of the clay soil increased from the up to down with increasing the depth of samples. On the other hand, EC of Calcareous and sandy soils where decrease with increasing the depth. pH, Cations (Na^+, K^+, Ca^{++}, and Mg^{++}) and anions ($CO^{3=}$, HCO^{3-}, Cl^- and $SO^{4=}$) showed different value depend on the depth of the sample and the soil type. Available macro-elements (N, P and K mg kg^{-1}) and microelements (Zn, Fe and Mn ppm^{-1}) showed variety of value depending on the depth of sampling and soils type.

4.1. EC, pH, SAR

The observed trends in soil properties in response to different application treatments can be attributed to several scientific reasons. The inherent composition of different soil types (clay, sandy, calcareous) affects their properties such as electrical conductivity (EC), pH, and sodium absorption ratio (SAR). Clay soils typically have higher EC and SAR values due to their higher clay content, which increases the soil's ability to conduct electricity and retain soluble salts. Conversely, calcareous soils tend to have higher pH values due to the presence of calcium carbonate, which acts as a natural buffer against changes in pH. Farmyard manure (FYM) treatments contribute organic matter and nutrients to the soil, which can influence soil properties. Organic matter enhances soil structure, water retention, and nutrient availability, leading to improved soil pH and reduced EC and SAR values. Additionally, the nutrients provided by FYM and SP may stimulate microbial activity, further enhancing soil health and fertility. The addition of organic amendments like FYM and SP can influence ion exchange processes in the soil. Organic matter contains negatively charged functional groups that can adsorb positively charged ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+), thereby reducing their availability for exchange with sodium (Na^+), which contributes to lower SAR values. Additionally, organic matter can buffer changes in soil pH by releasing hydrogen ions (H^+) during decomposition, leading to a reduction in pH. The application of organic amendments can stimulate microbial activity in the soil, leading to increased decomposition of organic matter and nutrient cycling. Microorganisms play a crucial role in maintaining soil pH and nutrient availability through processes such as mineralization, nitrification, and denitrification. Enhanced microbial activity can promote the conversion of soluble salts and reduce their accumulation, contributing to lower EC and SAR values. Overall, the observed responses in soil properties to different application treatments are influenced by complex interactions between soil composition, nutrient availability, ion exchange processes, and microbial activity. The addition of organic amendments like FYM and SP can effectively modify these factors, resulting in improved soil health and fertility. Similar trends were observed across both seasons tion. The obtained results are in harmony with those of **(Kumar *et al.* 2020; Abd El-Shedeed *et al.* 2022**; **Ghazi *at al.* 2022; Seğmen and Özdamar-Ünlü, 2023).**

4.2. Organic matter (OM), available nitrogen (A-N), phosphorus (A-P) and potassium (A-K)

Scientific analysis reveals underlying reasons for the observed trends in soil fertility indicators. The soil fertility hierarchy observed, with clay soil exhibiting the highest fertility followed by calcareous soil, and then sandy soil, can be attributed to differences in soil composition and nutrient availability. Clay soils typically have higher organic matter content and nutrient retention capacity due to their fine texture and higher cation exchange capacity (CEC), resulting in elevated levels of OM, A-N, AP, and A-K. Conversely, sandy soils have lower organic matter content and nutrient retention capacity, leading to lower fertility levels. Calcareous soils often contain calcium carbonate, which can influence nutrient availability and pH, affecting soil fertility. The combined treatment of FYM and Spirulina (FYM+SP) emerged as the most effective in enhancing soil quality, as indicated by the highest values of OM, A-N, AP, and A-K. This effectiveness can be attributed to synergistic effects between FYM and Spirulina. FYM contributes organic matter and nutrients to the soil, improving soil structure, water retention, and nutrient availability. Spirulina supplementation enhances soil microbial activity, nutrient cycling, and plant nutrient uptake, further enhancing soil fertility. The FYM treatment ranked second in efficacy, followed by the Spirulina treatment alone. FYM application improves soil organic matter content and nutrient levels, while Spirulina supplementation enhances microbial activity and nutrient availability, albeit to a lesser extent compared to FYM. The control group exhibited the least improvement in soil fertility indicators, highlighting the importance of soil amendments in enhancing soil quality and fertility.Overall, the observed trends underscore the importance of soil management practices, such as the application of organic amendments like FYM and supplementation with Spirulina, in improving soil fertility and enhancing agricultural productivity. Similar patterns were observed across both seasons under investigation. The obtained results align closely with findings reported by previous studies **(Kumar *et al.* 2020; Abd El-Shedeed *et al.* 2022**; **Ghazi *at al.* 2022; Seğmen and Özdamar-Ünlü, 2023).**

4.3. Grain yield and chemical traits

The observed trends in wheat productivity and the chemical composition of grain and straw across different soil types and treatment applications can be attributed to several scientific factors. Clay soil typically possesses better water retention capacity, higher nutrient availability, and improved soil structure compared to sandy soil. This facilitates better root development, nutrient uptake, and overall plant growth, resulting in higher wheat productivity and better chemical composition of grain and straw. Similarly, calcareous soil may provide a more favorable environment for plant growth due to its higher pH and calcium content, which can enhance nutrient availability. Farmyard manure (FYM) applications contribute essential nutrients and organic matter to the soil, promoting soil health and fertility. FYM improves soil structure, water retention, and nutrient availability, leading to enhanced plant growth and productivity.

The observed enhancements in wheat productivity and the chemical composition of grain and straw, particularly with the foliar application of Spirulina (*Spirulina platensis*), can be attributed to its vital role in promoting plant growth and development through various scientific mechanisms. When applied as a foliar spray, Spirulina delivers essential nutrients directly to the plant leaves, facilitating rapid absorption and utilization. Spirulina contains high levels of proteins, vitamins, and minerals, which serve as important growth-promoting factors for plants. These nutrients contribute to enhanced photosynthesis, chlorophyll synthesis, and enzyme activation, leading to increased biomass accumulation and improved yield potential. Furthermore, Spirulina's bioactive compounds, such as phytohormones and antioxidants, play a crucial role in regulating plant growth processes and mitigating oxidative stress, thereby promoting overall plant health and resilience to environmental factors. The foliar application of Spirulina represents an efficient and sustainable approach to enhance crop productivity and quality while reducing reliance on synthetic fertilizers and pesticides, highlighting its significance in modern agricultural practices. The same trend was found for both studied seasons. The findings obtained in this study are consistent with previous research conducted by **Kumar *et al.* (2020); Abd El-Shedeed *et al.* (2022); Ghazi *et al.* (2022);Seğmen and Özdamar-Ünlü (2023).** These studies have also reported similar outcomes regarding the effects of various treatments on soil fertility, crop productivity, and the chemical composition of grains and straw. This consistency across multiple studies underscores the reliability and validity of the observed results and further strengthens the evidence supporting the effectiveness of interventions such as farmyard manure, Spirulina application, and their combinations in enhancing agricultural sustainability and productivity.

Conclusion

it may be concluded that integrated use of farmyard manure at 10 tonnes ha^{-1} and foliar with SPE consisted of 2.4 L during the vegetative growth stages on wheat resulted in the significant improvement in the physical, biological and chemical properties of soil, i.e. decrease in bulk density, penetration resistance and decrease EC, SAR and increase soil organic carbon, increase in macro- nutrient compared to alone use of fertilizer NPK. It was also observed that integrated use of farmyard manure and SPE led to improvement in crop growth para meters, viz., root length density, leaf area duration, and resulted in higher nitrogen uptake and higher grain, straw yield. So integrated use of farmyard manure at 10 tonnes ha^{-1} and with SPE may be practiced in soil to improve soil physical environment and enhance carbon sequestration and for achieving higher productivity through efficient utilization of water and nutrients in wheat and improve beneficial microbial community. Based on the obtained findings, several recommendations can be made to improve soil quality and enhance wheat productivity in Egypt. Firstly, farmers should consider incorporating organic amendments such as farmyard manure (FYM) into their soils, particularly in sandy and calcareous soil types, to enhance soil fertility and nutrient availability. Additionally, foliar application of spirulina (SP) can be adopted as a supplementary approach to further boost plant growth and productivity, especially when combined with FYM. It's also crucial to promote the adoption of sustainable agricultural practices that focus on soil conservation and management to preserve soil fertility in the long term. Moreover, continued research and extension efforts are needed to educate farmers about the benefits of soil amendments and foliar applications, as well as to provide them with guidance on proper application methods and dosage to maximize their effectiveness. By implementing these recommendations, farmers in Egypt can enhance soil quality, increase crop yields, and ultimately contribute to addressing the nutrition gap in the region.

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