Improvement Growth, Yield, and Seed Quality of Pea Plants Using Glass Fertilizers and Bio-Fertilizers.

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Abstract

A new glass fertilizer (GF) system of main composition $60\text{P}_2\text{O}_5 \cdot 30\text{K}_2\text{O} \cdot 0.35\text{ZnO} \cdot 3.5\text{MnO} \cdot 0.3\text{Fe}_2\text{O}_3$ was developed in response to the needs of pea plants with bio-fertilizers (*Rhizobium leguminosarum*, *B.v. viciae*, *Bacillus megaterium* var *phosphaticum*, *Bacillus circulans*). GF was prepared by the traditional melt quenching technique at 1150°C . Characterization of prepared system was done using FTIR spectra before and after immersion in a simulated actual agriculture medium like 2% citric acid and distilled water. During two winter seasons, two successful field experiments were conducted at Cairo University's Eastern Farm to determine the impact of chemical, glass, and bio-fertilizers on plant growth, yield attributes, and seed quality of pea plant. Control treatment were without any addition of recommended chemical fertilizers and other treatments were full dose of recommended chemical fertilizers (100% RDF), glass fertilizers at rate 60 kg fed^{-1} , Glass fertilizers at rate 30 kg fed^{-1} , 50% RDF, 100% RDF + bio-fertilizers, Glass fertilizers at rate 60 kg fed^{-1} + bio-fertilizers, glass fertilizers at rate 30 kg fed^{-1} + bio-fertilizers, 50% RDF + bio-fertilizers. Plots received 60 kg fed^{-1} glass fertilizers + bio-fertilizers show the highest significant increment in plant growth, number and weight of pods plant^{-1} , number of grain pods plant^{-1} , grain yield, biological yield, P%, K% in pea leaves and quality of pea seeds compared with plots without any addition (control) in both seasons.

1. Introduction

Pea (*Pisum sativum* L.) is an essential winter vegetable grown in Egypt and belongs to the Fabaceae family. It is an annual herbaceous plant that is either determinate or indeterminate and suited to wet climates [1,2]. It's a high-protein, high-carbohydrate vegetable that's also high in phosphorus, iron, magnesium, calcium, riboflavin, niacin, thiamine, and ascorbic acid [3]. Pea is an essential vegetable with its own physiological and morphological features [4], but all these varieties need better soil nutrients to support their development, as fertilization is the most successful methods of crop service and an important factors of production for its impact on an organization of biological functions, especially macronutrient nutrition [5]. In Egypt, 47951 feddan of garden peas were planted, yielding 180631 ton at an average yield of 3.8 ton per feddan. According to agricultural data from the Agriculture Ministry in 2012, dry pea had a yield of 162 fed and average productivity of $0.77 \text{ ton fed}^{-1}$. Small number of chemicals is produced by chemical fertilizers for crop fertilization which is dissolve quickly in humid soil. It provides large doses of chemicals to the plants [6]. Chemical compounds are required by plants during their growth stages to aid in their development. Chemical fertilizers are the chemical compounds that make up these substances. Artificial fertilizers are inorganic fertilizers with optimal macro and micronutrient concentrations. Nitrogen is a nutrient that is required for plant growth. The most often used water-soluble nitrogen source is urea (46 % N). Because of leaching, the nitrogen content of the soil decreases. As a result of leaching, the nitrogen content of the soil decreases.

To enhance plant nitrogen utilization in agriculture and in the same time minimizing negative environmental repercussions, urea-adapted hydroxyapatite particles are routinely employed [7].

Phosphorus is utilized in numerous biochemicals such as coenzymes, sugar phosphate, nucleic acids (DNA, RNA), nucleotides, and phospholipids. It helps for many functions in plant's root growth like seed creating, fruit set, and flourishing [8]. Also many physiological processes in plants involve phosphorus, like photosynthesis, transition and respiration, energy gathering, cell division and extension.

Potassium also is of large importance, it is necessary for nutrient uptake, water relation, photosynthetic process, sugar translocation, enzyme activation, stomatal opening, meristematic tissue growth, water relation.

It also helps in protein builder, disease retard, stem strengthener, root booster. It regulates breathing, and acts as chemical traffic crop. But in case of phosphorous and nitrogen absence, potassium becomes ineffective [9].

The usage of chemical fertilizers has recently resulted in a number of negative environmental consequences, including heavy metal deposition in soil and plant systems. [10]. As a result, to increase food production, modern fertilization ideas for vegetable crops are needed. Glass fertilizers (GF) are new types of eco-friendly slow-release fertilizers made from glass matrixes containing the most useful microelements for plants like macronutrients (Mg, S, K, P, Ca). Also incorporate some microelements (B, Fe, Mo, Cu, Zn, Mn) required for the growth and progress of crops or plants. In general, conventional glass fertilizers are made from oxide network formers such as SiO_2 , B_2O_3 and P_2O_5 , oxide glass fertilizers modifiers such as Na_2O and K_2O , glass fertilizers stabilizers such as CaO and Al_2O_3 , and other oxide additives such as Fe_2O_3 , ZnO and MnO [11]. Amongst these oxides that contribute to the structure and composition of a glass fertilizer, P_2O_5 and K_2O are considered macronutrients, whereas Fe_2O_3 , ZnO , MnO , and other oxides are micronutrients for plant growth. These oxide elements are commonly the sub-products of the different compounds (nitrates, carbonates, etc.) normally included in conventional fertilizers. The main benefit of glass fertilizers is the probability to modify their chemical composition by adding of novel elements in diverse amounts. Therefore, the kinetics and mechanism of the dissolution process can be tailored as needed [12]. In the case of plant nutrition, the release rates of GF components must be equivalent to the absorption rates of plants or microorganisms [13]. In this way, the possible harmful effects of elements gathering or shortage can be escaped. Thus, glass fertilizers can revenue a dual role. As the corrosion resistance of glass fertilizers increase, i.e., when applied to soil, the fertilizer is released very slowly, satisfying the best level of plant necessity with no waste. It is found that when such glass fertilizer is applied on tree-like mango, it remains 20-25 years at the root and it grows and gives fruits with a sole charge of fertilizer [14]. The main compensations of this new eco-friendly fertilizers against conventional fertilizers are, enlarged grade of integration by plants, do not relief insoluble compounds in soil, keep on in the soil through the total plant growth time, and do not contaminate the irrigating water [15, 16, 17, 18]. At the same time, these fertilizers controlled solubility in the time for many vegetable cycles. The possibility to include in the vitreous matrix of many valuable microelements [19, 20], do not contain toxic compounds, and do not release insoluble residues. [21] investigated the advantages of utilizing bio-fertilizers for phosphorus, nitrogen [22], and potassium [23] uptake [24]. They also boost plant growth and yield substantially as compared with untreated controls [23, 25, 26, 27]. [28] reported that two doses of the bio-fertilizer Phospherene substantially enhanced growth parameters at 30 and 95 days of age, as well as yield and its components, when compared to one dose and control (without bio-P fertilizer) treatments. In contrast to the 15.5 and 31 kg P_2O_5 fed-1 treatments, the addition of chemical P fertilizer at a rate of 46.5 kg P_2O_5 fed-1 resulted in a substantial increase in chickpea plant growth characters, yield, and its components. Bio-fertilizer had a major impact on chickpea yield per plant, pod weight per plant, and seed yield ha^{-1} and 100-seed weight, according to [29]. Furthermore, [30] reported that inoculated plants outperformed un inoculated plants in terms of number of nodules plant^{-1} , number of branches, plant height and seed yield plant^{-1} , 100-seed weight, and seed yield fed^{-1} . Inoculation had no effect on the quantity of seeds per pod, pod weight plant^{-1} , seed N content percent, or seed protein content percent. Our objectives were to determine the impact of using glass fertilizers on pea yield and quality, as well as to reduce the amount of chemical fertilizer recommended for environmental reasons.

2. Materials And Methods

Two field experiments conducted in the Eastern Farm of Cairo University's Faculty of Agriculture in Egypt during two winter seasons. A completely randomized block design with three replications was used to carry out the experiment. Pea seeds of the 'Super2' cultivar were directly sown in the slightly moist soil. Seeds were sown by hand in hills (3 seeds per hill) on two rows of each ridge (0.7 m width and 2 m length) at 10 cm intervals. The experiment consists of nine treatments as follows: (1) without Chemical fertilizers (control); (2) full dose of chemical fertilizers (100% RDF) ; (3) 60 kg fed^{-1} Glass fertilizers; (4) 30 kg fed^{-1} Glass fertilizers; (5) 50% chemical fertilizers; (6) 60 kg fed^{-1} Glass fertilizers + bio-fertilizers ; (7) 100% RDF + bio-fertilizers (8) 30 kg fed^{-1} Glass fertilizers + bio-fertilizers, and (9)

50% chemical fertilizers + bio-fertilizers. Fixation of N₂ bacteria (*Rhizobium leguminosarum* bv. *Viciae*), Phosphorus dissolving bacteria (*Bacillus megaterium* var *phosphaticum*), potassium dissolving bacteria (*Bacillus circulans*) were added immediately after planting, three weeks later, and six weeks later. The bio-fertilizer mixture was given to each plant in the amount of 6 mL. Using a knapsack pesticide sprayer, bio-fertilizers were applied as a liquid at a rate of 6 L fed⁻¹. In the Laboratory of Organic Agriculture in the Agriculture Centre Research, Giza, Egypt, bio-fertilizers were extracted from existing isolate samples. Chemical fertilizer (N, P, and K) is applied at the recommended rates. Two equal applications of fertilizer (ammonium sulphate "20.5 %t N") were added. The first before the first irrigation and the second before the second irrigation, with the exception of the control treatment. During soil preparation, 200 kg calcium super phosphate (15.5 percent P₂O₅) fed⁻¹ was used. 75 kg fed⁻¹ potassium fertilizer (potassium sulphate, "48.0 percent K₂O") Phosphorus and potassium were applied to all treatments except those that received glass fertilizers and the control treatment. Glass fertilizers were applied in three equal doses: the first during land planning, the second 30 after planting and the third 45 days after planting. Analysis of Experimental soil chemical and physical properties is presented in Table 1. All other farming activities were carried out. The farm soil type was clay loam.

Table 1
Experimental soil chemical and physical properties

Soil parameter	Value
Physical analysis	
Sand%	20
Silt%	43
Clay%	37
Texture class	Clay loam
Chemical analysis	
CaCO ₃ %	1.52
Organic matter%	2.22
EC(dcm ⁻¹)	1.34
PH	7.33
Available nutrients(macronutrients)	
K%	0.31
N%	1.2
P%	0.24
Soluble Cation(mL ⁻¹)	
Ca ⁺²	4.53
Na ⁺	3.35
Mg ⁺²	3.22
K ⁺	2.22
Soluble anions (mL ⁻¹)	
Cl ⁻¹	5.1
HCO ₃ ⁻¹	0.9
SO ₄	7.3
CO ₃ ⁻	-

2.1. Data recorded

2.1.1. Vegetative growth

After 50 days after sowing, ten plants from each experimental unit were randomly selected and measured for vegetative growth traits as such as plant height (measured from the soil surface to maximum leaf lit), number of leaves

per plant, plant fresh weight, and Plant dry weight (leaves and seeds samples were weighed and oven-dried at 70°C until a constant weight was obtained, then the dry matter was measured in g/plant).

2.1.2. Yield and its components

Each plot's green pods were harvested when they reached the proper maturity stage, and the following parameters such as average length of the pod, average pod weight, the average weight of pod plant⁻¹, number pod per plant, number of green seed per plant, the weight of 100 seeds, the total weight of pods fed⁻¹, total grain yield fed⁻¹ and biological yield fed⁻¹

2.1.3. Chemical Analysis

A 100 g sample of pea leaves after 50 days of sowing and green pods at the proper maturity stage were dried in the oven at 70°C until constant weight. 0.2 g crude dried held powder from each sample was wet digested with a mixture of concentrated sulphuric and perchloric acid to determine macro elements in the pods [31]. [32] defined Keldahl methods for determining nitrogen content (N percent). In the sulphuric system, the phosphorus content (P percent) was calculated colorimetrically using the chlorostannous reduce molybdo phosphoric blue colours process [32]. According to [33], the potassium content (K percent) in digested plant materials was calculated using a flame photometer, According to [34], micronutrients (Fe, Mn, Zn) were calculated. In addition, protein content was calculated by multiplying N percent by 6.25, total carbohydrates percentage [35], and ascorbic acid (mg/100g fresh weight) was measured using [36]

2.2. Preparation of glassy fertilizer:

The studied glassy fertilizer was prepared from mixture of pure materials like H₃PO₄, Fe₂O₃, K₂CO₃, MnO, ZnO. Batches were melted into porcelain crucibles in an electric SiC heated furnace (Vecstar, UK) at 1100°C for 60 minutes including frequent rotating the melts at intervals to reach complete mixing and homogeneity. Then the melts were poured into slightly warmed stainless steel molds of the required dimensions. The obtained amorphous material was fritted in water then ground to the grain size 0.5 and 1 mm.

2.3. FTIR spectral measurement

FTIR spectra were measured for the glasses using the KBr powder technique. A recording spectrometer (type Bruker 80V, FTIR, Germany) was used for the measurements within the range 400–4000 cm⁻¹. The measurements were repeated after immersion in distilled water and 2% citric acid.

2.4. Statistical analysis:

Using the "MSTATC" computer software program, all obtained data were statistically analyzed using the technique of analysis of variance for the fully randomized blocks design [37]. At a 5% level of probability, the LSD test was used to compare variations between treatment means [38].

3. Results And Discussion

3.1. Mechanism of phosphate glassy fertilizer:

The main reason for selecting phosphate glass as a glassy fertilizer is its structural nature. Ortho -phosphate ion (PO₄³⁻) polymerizes to form linear chains of P-O-P bonds. The last stage of condensation, chain polymers may also be formed [39]. Plant nutrients containing K⁺, Mg²⁺, Ca²⁺ or NH₄⁺ ions are neutralize phosphate chain which contain oxygen atoms with negative charge. Polymer chain contains these ions in the interstitial positions. The exchangeable ions have dual property. They can be soluble by cation exchange and almost insoluble in water. Slow hydrolysis of the

P-O-P group occurs [40] producing solubility of the cations. The solubility of polyphosphates containing all the macro- and micro- nutrient ions may be altered to match needed levels by controlling the degree of chain polymerization. The network construction model of the glass fertilizers with diverse corps nutrients is shown in Fig. 1 [41]

3.2. Chemical activity of glassy fertilizer:

The connect between surface of glass and the atmosphere gases or contacted chemical solutions is called corrosion or chemical activity of glass. In this process, glass attracts moisture so it is considered a hydrophilic material as shown in Figure 2 [42]. The hydrated layer increased in case of humidity and rainfall. This collection of water leads significantly to the destruction of glass surface. Generally, there are two phases to the chemical activity or corrosion procedure, happening together or separately. One of them is called leaching (ion exchange or alkali extraction or aqueous corrosion) which is occurred by moisture. In During this phase, alkali ions (Na⁺, K⁺) from the glass and hydrogen ions from the contact solution exchange ions. Although the other constituents of the glass remain same, the effectual surface area in contact with the solution is enhanced .This enhancement in surface area causes the metal ions in the glass fertilizers to be extracted or leached as nutrients. The chemical activity process is heavily influenced by the pH of the solution in contact with the glass surfaces. The quick increase in pH will cause the glass surface to break down quickly. Static and dynamic aqueous corrosion are the two types of aqueous corrosion. The entrapment of moisture on the surface of the glass causes static aqueous corrosion. In dynamic aqueous corrosion, moisture condensation replenishes the solution. In mass transfer controlled leaching processes, such as batch processes with constant mixing, the fluids are always in motion, indicating that the fluid flows in a turbulent state past a solid surface. However, because the fluid velocity at the particle surface is zero, a film of fluid must exist close to the surface. The following equation illustrates the process of mass transfer [43]

$$dM/dt = k'A(C_s - C) / b \dots \dots (1)$$

Where, A denotes the area of solid-liquid interface,

b denotes the effective thickness of the liquid film surrounding the particles,

C denotes the solute concentration in the solution bulk at time t,

C_s denotes the saturated solution concentration in contact with the particles

M denotes the mass of solute transferred in time t, and K` is the diffusion coefficient.

Physical, chemical, and dissolving characteristics were explored in relation to variations in the composition of the glass system in order to create the suitable glass fertilizer. Because phosphate functions as a former and macronutrient for plants, the phosphate system is better for fertilization.. For the application of eco-friendly glass-fertilizer, [44] choose K₂O-CaO-P₂O₅ glasses and studied the dissolution properties of these glasses using pH meter and ICP analyzer. The ICP analysis indicated that the dissolving rate was inversely related to the change in the K₂O/P₂O₅ ratio, and the results showed that pH values were dependent on the glass compositions. This is a key component in determining the chemical durability of glass fertilisers, and it can be influenced by the composition of the main glass matrix. As a result, the phosphate glasses are predicted to supply environmentally friendly, easy-to-produce, and widely applicable slow-release nutrient fertilizers. [44]. Figure 3[41] shows the glass fertilizer matrix's binding method with agriculture soil and plant roots, as well as its network structure.

3.3. Interpretation of FTIR results

The technique of infrared spectroscopy is a very useful examination that may be used in a variety of glass science applications. In glasses, it helps to distinguish structural building units. [45]. As a result, it can give a clear view about the effect of different conditions on the glass system by changing position and intensity of different peaks. In case of our prepared glass the main structural unit is the phosphate group beside some oxides present in minor quantities like ZnO, MnO, Fe₂O₃. Before immersion as shown in Fig. 4, one can notice that the peaks at 3410, 3479, 3550 cm⁻¹ are due to hydroxide, or water group [46]. The peak at 1618 cm⁻¹ is due P-OH vibration and molecular water vibrations [47]. The peak at 1281 cm⁻¹ can be related to the (PO₂) asymmetric stretching and doubly bonded oxygen vibrations P=O [48]. The band at 1100 cm⁻¹ can be assigned to a P–O stretching vibrations of the P–O–P bridging units [49,50]. Phosphate groups, particularly P-O-P asymmetric stretching with varied PO₂, PO₃, and PO₄ groups, are liable for the band at 890 cm⁻¹. [47]. 725 cm⁻¹ vibration band is due to P–O stretching coordinates of P–O–P linkages [49,51]. P-O-P bending vibrations cause the band at 586 cm⁻¹. [46]. The band at approximately 477 cm⁻¹ can be assigned to bending vibrations of O–P–O bond [52, 53]. The peaks move slightly to higher or lower wave number values after immersion in different soil simulating solutions like 2 % citric acid and distilled water. Due to the availability of alkali oxide, the multivalent micronutrient ions (Zn²⁺, Fe³⁺, Mn⁴⁺) may exist in high valence states, and their dissolution behaviour is expected to be influenced by bond breaking between the respective multivalent cations and oxygens, as well as their ease of solubility in the attacking solution. [54]. This could indicate that our produced glass structure is stable in a variety of agricultural environments. [47]

3.4. Effect of chemical fertilizers, Glass fertilizers, and Bio-fertilizers on vegetative growth characters.

After 60 days of sowing, analysis of variance revealed that the tested treatments had a significant impact on vegetative growth (Table 2). The highest plant height (69, 64, and 63 cm) was achieved from treatment received 60kg fed⁻¹ Glass fertilizers plus bio-fertilizers, 60 kg fed⁻¹ glass fertilizers, and 100%RDF plus bio-fertilizers in the first season, without any significant differences between them. Also, the highest plant height (69.23, 64.53 and 63.50 cm) were obtained from plots received 60kg fed⁻¹ plus bio-fertilizers, 60 kg fed⁻¹ glass fertilizers, and 100%RDF plus bio-fertilizers in the second season, without any significant differences between them. The highest number of leaves (39, 37, and 35) was produced from treatment 60kg fed⁻¹ plus bio-fertilizers followed by 60 kg fed⁻¹ glass fertilizers then 100%RDF plus bio-fertilizers in the first season. The highest number of leaves (38, 35, and 33.03) was recorded from treatment got 60kg fed⁻¹ plus bio-fertilizers followed by 60 kg fed⁻¹ glass fertilizers and 100%RDF plus bio-fertilizers in the second season. The highest value of fresh weight (98.76, 90, and 85.33 gm) was obtained from treatment 60kg fed⁻¹ glass fertilizers plus bio-fertilizers, 60 kg fed⁻¹ glass fertilizers, and 100%RDF plus bio-fertilizers. In the second season the highest value of fresh weight (97.67 and 88.67 and 84gm) from treatment 60kg fed⁻¹ glass fertilizers plus bio-fertilizers, 60 kg fed⁻¹ glass fertilizers, and 100%RDF plus bio-fertilizers. Regarding the effect of tested treatment on dry weight after 60 days of sowing date, the data showed that the highest dry weight (3.7, 3.1, and 2.13gm) were obtained from treatment 60kg fed⁻¹ glass fertilizers plus bio-fertilizers, 60 kg fed⁻¹ glass fertilizers, and 100%RDF plus bio-fertilizers in the first season. The highest dry weight (3.8, 3.23, and 2.33 gm) was observed from plots received 60kg fed⁻¹ glass fertilizers plus bio-fertilizers, 60 kg fed⁻¹ Glass fertilizers, and 100%RDF plus bio-fertilizers in the second season. The lowest values of plant height, number of leaves, fresh weight, and dry weight were recorded in untreated treatment compared to all other treatments in both seasons. Glassy fertilizers do not create soil acidification, poisonous gas, or hydro sulphuric acidification, which destroys plant roots. The glass fertilizer aids in increasing soil fertility and plant suitability for a variety of plants [55]. This finding is consistent with [50], who found that glass fertilizers improve maize plant growth parameters. By increasing available nutrients for plant growth, bio-fertilizers help to improve soil fertility. Foliar application can be seen as a cost-effective means of reducing fertilizer use. Furthermore, such technology could be developed in the sense of organic farming for long-term agriculture, which is a more environmentally friendly choice [56]. These findings matched those of [57] for chickpeas, [58] for peas, and [59] for cowpeas. Data recorded in table 3

indicate that the chlorophyll reading was affected by tested treatments in both seasons. Plots received 60 kg fed⁻¹ glass fertilizers + bio-fertilizers recorded the highest value of chlorophyll reading in leaves of pea plants compared to all other tested treatments. The highest chlorophyll content was recorded in 60 kg fed⁻¹ glass fertilizers with bio-fertilizers followed by 60kg fed⁻¹ glass fertilizers alone, and 100% RDF + bio-fertilizers in both seasons, without any significant differences between them. In both seasons, all treatment caused significant effects on N% in leaves compared to control plots. Whereas, the lowest concentration of N% in leaves recorded in control plots. The highest concentration of P% in leaves (0.99 % and 0.9 %) were recorded from treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers and glass fertilizers 60kg fed⁻¹ alone in the first season, without any significant difference between them. The highest value concentration of p% in leaves (1.02%) was recorded from treatment with 60 kg fed⁻¹ Glass fertilizers + bio-fertilizers followed by glass fertilizers 60 kg fed⁻¹ (0.87%) in the second season. The highest leaves K% were (1.99 and 1.88 %) from plots received 60 kg fed⁻¹ glass fertilizers + bio-fertilizers followed by treatment of glass fertilizers 60 kg fed⁻¹ in the first season, without any difference between them. Also, the highest leaves K% was (1.96 and 1.85 %) from the treatment of 60 kg fed⁻¹ glass fertilizers + bio-fertilizers followed by glass fertilizers 60 kg fed⁻¹ in the second season, without any difference between them. These findings matched those of [60], who found that glass fertilizers increased the supply of essential nutrients and the root-to-shoot ratio in 'The Fairy' rose was 1.6 times higher in the glass fertilizers treatment than in the control and compost treatments. [61] reported that phosphorus solvent bacteria can generate organic acids, increasing phosphorus solubility and availability to plants.

3.5. Effect of chemical fertilizers, Glass fertilizers, and Bio-fertilizers on yield and its attributes.

Results presented in table 4 show clearly that all treatments show a significant increment in all yield attributes compared to control treatment in both seasons. The highest average pod length (11.8 and 11cm) were obtained from plots got 60 kg fed⁻¹ glass fertilizers + bio-fertilizers followed by glass fertilizers at a rate of 60 kg fed⁻¹ at the same level of significant $p \leq 0.05$ in the first season. The highest average pod length (11.83 and 10.8 cm) was obtained from treatment 60 kg fed⁻¹ Glass fertilizers + bio-fertilizers and 60 kg fed⁻¹ Glass fertilizers at the same level of significant $p \leq 0.05$ in the second season. The highest pod yield plant⁻¹ (151 and 150.3) was recorded from the treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers in 1st and 2nd

seasons respectively. The highest number of pod plant⁻¹ (22.33 and 23) was obtained from treatment with 60 kg fed⁻¹ glass fertilizers + bio-fertilizers in the first season and second season respectively. The highest value number of seeds per pod (11 and 12) was recorded from treatment received 60 kg fed⁻¹ glass fertilizers + bio-fertilizers in the first and second seasons .respectively, followed by treatment received 60 kg fed⁻¹ glass fertilizers (9.33 and 10) in the first and second season respectively, compared to control treatment. As shown in table 5 all tested treatment had a significant increase in weight of 100 seeds, total fresh pod yield, total grain yield, and biological yield compared to control treatment. Glass fertilizers at a rate of 60 kg fed⁻¹ plus bio- fertilizers significantly increased and produced the highest values of all studied yield and its components as compared to other tested treatments in both seasons, followed by glass fertilizers at rate 60 kg fed⁻¹ then 100% RDF with bio-fertilizers. In contrast, the lowest mean values of all studied yield and its components were obtained from the control plots in both seasons. The highest weight of 100 seed (53 and 54 gm) was obtained from plots received 60 kg glass fertilizers + bio-fertilizers in the first and second season respectively. The highest value of total fresh pod yield (5.91 and 5.71 ton fed⁻¹) was obtained from treatment received 60 kg fed⁻¹ + bio-fertilizers in the first and second seasons respectively. The treatment of glass fertilizers 60kg fed⁻¹ + bio-fertilizers provided pod yield by 216.08% and 144.87% compared to control plots in 1st and 2nd seasons respectively. On the other hand,

the treatment of 60kg fed⁻¹ glass fertilizers induced increasing pod yield by 55.6% and 63.23% compared to 100% of the full dose of recommended chemical fertilizers in the first and second seasons respectively.

Table 2: Effect of chemical fertilizers, glass fertilizers, and bio-fertilizers on plant height, leaves number, fresh weight, and dry weight of pea plants.

Treatment	1 st seasons				2 nd Season			
	Plant height (cm)	leaves number	Fresh weight (gm)	Dry weight (gm)	plant height (cm)	leaves number	Fresh weight (gm)	Dry weight (gm)
Control	50.67	23.33	42.33	0.70	51.00	22.00	42.00	0.67
100%RDF	60.67	30.33	80.33	1.8	61.00	30.33	79.00	1.90
100%RDF+BF	63.00	35.00	85.33	2.13	63.50	33.03	84.00	2.33
GF 60kg fed-1	64.00	37.00	90.00	3.1	64.53	35.00	88.67	3.23
GF 60kg fed-1 +BF	69.00	39.00	98.67	3.7	69.23	38.00	97.67	3.8
50% RDF	56.00	26.00	66.67	1.13	56.67	26.67	65.33	1.200
50% RDF+ BF	58.00	29.00	75.67	1.53	58.33	30.00	75.33	1.600
GF 30kg fed-1	59.67	31.00	76.67	1.73	60.33	33.00	76.00	1.77
GF 30kg fed-1 + BF	61.87	33.33	80.00	2.167	64.20	30.67	79.67	2.30
LSD0.05	1.2	1.64	4.37	0.24	1.27	2.9	4.04	0.26

GF Glass fertilizers ,RDF Recommended doses fertilizers, BF Bio-fertilizers

Table 3: Effect of chemical fertilizers, glass fertilizers, and bio-fertilizers on chlorophyll reading and NPK(%) in leaves of pea plants .

1 st seasons					2 nd Season			
Treatment	Chlorophyll reading	N%	P%	K%	Chlorophyll reading	N%	P%	K%
Control	31.67	2	0.17	1.02	33.67	1.69	0.17	0.88
100%RDF	56	3.05	0.51	1.31	56.33	3.21	0.49	1.46
100%RDF+BF	60.00	3.38	0.75	1.57	61.00	3.51	0.72	1.69
GF 60kg fed-1	62	3.44	0.90	1.88	63.67	3.04	0.87	1.85
GF 60kg fed-1 + BF	68	3.50	0.99	1.99	70.00	3.50	1.023	1.96
50% RDF	39.33	2.03	0.41	0.68	39.67	2.03	0.40	0.72
50% RDF+ BF	47.00	2.26	0.46	0.82	47.33	2.42	0.44	0.83
GF 30kg fed-1	44.33	3.40	0.53	0.86	44.33	3.44	0.71	0.92
GF 30kg fed-1 + BF	49.00	3.41	0.67	0.95	50.33	3.54	0.73	1.28
LSD0.05	2.84	0.50	0.094	0.30	2.82	0.56	0.13	0.18

GF Glass Fertilizers, RDF Recommended Dose Fertilizers, BF Bio-fertilizers

Table 4. Effect of chemical fertilizers , glass fertilizers , and bio-fertilizers on yield attributes of pea plants .

Table 5: Effect of chemical fertilizers, glass fertilizers, and bio-fertilizers on yield of Pea plants.

The highest grain yield (361 and 372.9 kg fed⁻¹) was obtained from treatment received 60kg fed⁻¹ Glass fertilizers + bio-fertilizers in the first and second season respectively. The treatment of glass fertilizers 60 kg fed⁻¹+bio-fertilizers provided grain yield by 79.6% and 81.45% compared to control plots in the first and second seasons respectively. On the other hand, Plots received 60kg fed⁻¹ glass fertilizers + bio-fertilizers induced increasing grain yield by 24.48% and 27 % compared to 100% of the full dose of recommended chemical fertilizers in the first and second seasons respectively. The highest value of biological yield (1710 and 1673 kg fed⁻¹) was obtained from treatment received 60 kg fed + bio-fertilizers in the 1st and 2nd seasons respectively. Plots received glass fertilizers 60 kg fed⁻¹+bio-fertilizers provided biological yield by 66.18% and 63.25 % compared to control in 1st and 2nd seasons respectively. On the other hand, Plots received 60kg fed⁻¹ glass fertilizers +bio-fertilizers induced increasing biological yield by 19.58% and 16.58% compared to 100% of the full dose of recommended chemical fertilizers in 1st and 2nd seasons respectively. This is in line with the findings of [45], who found that glass fertilizer, hydrogel, and microorganisms increase faba bean production, seed nutrient quality, and irrigation water use performance under drought and salinity stress. Seed inoculation with rhizobium, phosphorus solubilizing bacteria, and organic amendments also increased the crop's seed production [62] These findings were in line with those of [29]. These findings are consistent with those of [30] who

Treatment	1 st seasons				2 nd Season			
	Average pod	Weight pod	Number of pods	Number of seed	Average pod	Weight pod	Number of pods	Number of seed
	length(cm)	/plant(gm)	/plant	/pod	length(cm)	/plant(gm)	/plant	/pod
Control	6.33	46.67	6.000	4.67	5.0	45.67	5.67	5.0
100%RDF	9.70	129.0	13.33	6.67	9.43	126.3	15.00	7.0
100%RDF+BF	10.00	135.0	16.67	8.33	10.20	139.7	17.00	8.0
GF 60kg fed-1	11.00	144.0	18.33	9.33	10.8	144.7	19.00	10.00
GF 60kg fed-1 +BF	11.80	151.0	22.33	11.00	11.83	150.3	23.00	12.00
50% RDF	8.67	110.7	10.00	5.33	6.33	81.00	11.00	5.67
50% RDF+ BF	10.43	120.7	12.33	7.0	9.2	91.00	14.00	7.67
GF 30kg fed-1	9.37	116.3	11.33	6.0	8.87	84.33	12.00	7.0
GF 30kg fed-1 +BF	10.67	122.3	14.00	8.000	9.77	116.0	13.67	8.0
LSD0.05	0.62	3.9	1.033	0.94	0.89	3.96	0.75	0.48

GF Glass Fertilizers, RDF Recommended Dose Fertilizers, BF Bio-fertilizers

found that inoculated peas outperformed un inoculated pea seeds in terms of seed yield plant⁻¹, 100-seed weight, number of pods plant⁻¹ seed yield fed⁻¹, pods weight plant⁻¹ and number of seed pod⁻¹.

3.6. Effect of chemical fertilizers, glass fertilizers, and bio-fertilizers on chemical constituents.

Results presented in Table 6 show that the lowest concentration of N% in pea seeds recorded in control treatment. On the other hand, Plants treated with glass fertilizers or chemical fertilizer (100 %RDF) with or without bio-fertilizers showed no significant variations in N % values. This could be owing to the synergistic effect of microorganisms fertilizers used. In addition to; all plots received the same level on nitrogen fertilizers. The highest concentration of P% in pea seeds (0.95 % and 0.98 %) was recorded from treatment received 60 kg fed⁻¹ glass fertilizers + bio-fertilizers in the first and second seasons respectively. As well as, the highest value concentration of k% in pea seeds (1.96%) was recorded from treatment with 60 kg fed⁻¹ glass fertilizers + bio-fertilizers and glass fertilizers 60 kg fed⁻¹ (1.83%) without any significant difference between them in the first season. The highest value concentration of k% in pea seeds (1.98%) was recorded from treatment with 60 kg fed⁻¹ Glass fertilizers with bio-fertilizers followed by glass fertilizers 60 kg fed-1 without bio-fertilizers (1.79%) in the second season. Concerning the micronutrient content in seeds of a pea, The highest concentration of Fe was (45.02 and 45 ppm) from the treatment of 60 kg fed⁻¹ glass fertilizers + bio-fertilizers and 60 kg fed⁻¹ in the first season, without any significant difference between them. Also, the highest value concentration of Fe was (42.33 and 42 ppm) from the treatment of 60 kg fed⁻¹ Glass fertilizers + bio-fertilizers and 60 kg

1 st seasons					2 nd Season			
Treatment	Weight 100 seed (gm)	Total pod Yield (ton fed- 1)	Total grain yield (Kg fed- 1)	Biological yield (Kg fed-1)	Weight 100seed (gm)	Total pod Yield (ton fed- 1)	Total grain yield (Kg fed- 1)	Biological yield (Kg fed-1)
control	21.00	1.87	201.0	1029	20.7	2.33	205.5	1024.8
100%RDF	38.00	3.80	290.0	1431	38.67	3.50	293.6	1435
100%RDF+BF	41.67	4.50	305.0	1489	42.33	4.43	308.1	1495
GF60kg fed- 1	44.33	5.10	331.7	1505	45.67	5.03	339.1	1557
GF 60kg fed- 1 + BF	53.00	5.91	361.0	1710	54.00	5.71	372.9	1673
50% RDF	28.33	2.45	221.3	1379	25.33	2.74	225.1	1382
50% RDF+ BF	37.00	3.31	233.0	1403	31.00	3.21	238.9	1401
GF 30kg fed- 1	35.00	2.82	241.0	1389	24.67	2.85	241.4	1393
GF 30kg fed- 1 + BF	37.60	3.460	266.3	1410	35.27	3.59	275.3	1417
LSD0.05	1.77	0.21	2.82	6.86	2.59	0.54	2.163	13.41

GF Glass Fertilizers, RDF Recommended Dose Fertilizers, BF Bio-fertilizers

fed⁻¹ alone, without any significant difference between them in the second season. The treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers recorded the highest content of Mn (32.67 and 32,1 ppm) in 1st and 2nd seasons respectively, followed by treatment 60 kg fed⁻¹ glass fertilizers (29.33 and 29.67 ppm) in 1st and 2nd seasons respectively. The best treatment of concentration of Zn in seeds (16.67 and 17 ppm) recorded in treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers in the first and second seasons respectively. The enhancement of micronutrient in pea seeds in plots received glass fertilizers with or without bio-fertilizers is due to the effect of glass fertilizers [54]. These findings were in line with those of [60], who found that glass matrix fertilizer had the highest concentrations of B, Mn, Cu, and Zn in Rose plant tissues.[63] discovered that using a combination of bio-fertilizers (phosphate dissolving bacteria, nitrogen fixation bacteria, and a spray liquid fertilizer containing 24 % potassium and 5 % nitrogen) in plots receiving 240N+ 33.6P+192K kg/ ha resulted in substantially higher concentrations of N, P, K, Fe, Mg, and Zn in potato tubers. These findings are consistent with those of [56] who found that combining chemical and bio-fertilizers significantly increased micronutrients like Fe and Zn in both Stover and maize grains. The results presented in table 7 shows clearly that all treatments show a highly significant increase of total carbohydrates % and ascorbic acid content in seeds compared to control in both seasons. The highest percentage of total carbohydrates (51.67, 48.33 and 47.33%) from treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers followed by the treatment 60 kg fed⁻¹ glass fertilizers and 100% RDF treatment with bio-fertilizers without any significant difference between them in the first season. On the other hand, the highest percentage of total carbohydrates (50.33, 47, and 45%) from treatment 60 kg fed⁻¹ glass fertilizers with bio-fertilizers followed by 100% RDF treatment with bio-fertilizers then the treatment 60 kg fed⁻¹ glass

fertilizers in the second season. [56] who found that combining chemical and bio-fertilizer effects are more successful on the percentage of carbohydrates percentage in maize grains. The highest concentration of ascorbic acid in seeds (5.67 and 5.33 mg/100 F.W) recorded by treatment 60 kg fed⁻¹ glass fertilizers + bio-fertilizers and 60 kg fed⁻¹ glass fertilizers alone without any significant difference between them in the first season. The highest content of ascorbic acid (5.8 and 5.13 mg/100 F.W) recorded by treatment 60kg fed⁻¹ glass fertilizers + bio-fertilizers followed by treatment of glass fertilizers 60 kg fed⁻¹ alone in the second season. Concerning to percentage of crude protein in seeds, Except for the treatment of 50% RDF with or without bio-fertilizers, all treatments show a significant increase compared to control in both seasons. Plants treated with glass fertilizers or chemical fertilization (100 %RDF) with bio-fertilizers did not show any significant variations in crude protein percent values. This could be owing to the crude protein content in seeds depends on the N% in seeds.

Table 6: Effect of chemical fertilizers, glass fertilizers, and bio-fertilizers on macronutrients and micronutrients in seeds of pea plants.

Year	Macronutrients %				Micronutrients (ppm)		
	Treatment	N%	P%	K%	Fe	Mn	Zn
1 st seasons	Control	1.29	0.13	0.85	30.3	16.67	7.0
	100%RDF	2.51	0.48	1.23	35.00	23.00	9.67
	100%RDF+BF	2.33	0.67	1.55	35.67	24.00	10.00
	GF 60kg fed-1	2.44	0.77	1.83	45.00	29.33	15.00
	GF 60kg fed-1 + BF	2.42	0.95	1.96	45.02	32.67	16.67
	50% RDF	1.66	0.33	0.66	33.00	21.67	9.00
	50% RDF+ BF	1.85	0.45	0.81	35.00	23.67	9.87
	GF 30kg fed-1	2.40	0.54	0.86	40.00	28.67	11.83
	GF 30kg fed-1 + BF	2.41	0.63	0.96	41.33	29.33	11.83
	LSD0.05	0.37	0.08	0.197	1.15	2.50	0.95
2 nd Season	Control	1.19	0.12	0.61	30.80	13.33	5.0
	100%RDF	2.45	0.47	1.27	33.83	17.47	8.3
	100%RDF+ BF	2.38	0.70	1.52	34.20	19.00	9.333
	GF 60kg fed-1	2.38	0.77	1.79	42.00	29.67	15.33
	GF 60kg fed-1 + BF	2.5	0.98	1.98	42.33	32.10	17.00
	50% RDF	1.59	0.35	0.65	32.30	17.23	8.200
	50% RDF+ BF	1.75	0.43	0.82	32.33	18.00	8.67
	GF 30kg fed-1	2.34	0.51	0.89	36.67	27.67	12.17
	GF 30kg fed-1 + BF	2.41	0.59	1.08	37.67	28.33	12.37
	LSD0.05	0.32	0.077	0.16	1.95	1.63	1.419

GF Glass fertilizers, RDF Recommended Dose Fertilizers, BF Bio-fertilizers

Table 7: Effect of chemical fertilizers, Agriglass, and bio-fertilizers on the total chemical content of pea seeds.

	1 st seasons			2 nd Season		
Treatment	Total carbohydrates%	Ascorbic acid mg/100g F.W	Crude protein%	Total carbohydrates%	Ascorbic acid mg/100g F.W	Crude protein%
Control	37.33	3.0	8.083	36.67	3.03	7.55
100%RDF	43.67	4.27	15.71	43.00	4.33	15.28
100%RDF+BF	47.33	4.63	14.58	47.00	4.73	14.88
GF 60kg fed-1	48.33	5.33	15.27	45.00	5.13	14.84
GF 60kg fed-1 + BF	51.67	5.67	14.11	50.33	5.8	15.52
50% RDF	39.00	3.70	10.40	39.67	3.5	9.99
50% RDF+ BF	41.33	4.07	11.54	41.00	4.2	10.93
GF 30kg fed-1	41.23	4.13	15.02	40.47	4.0	14.60
GF 30kg fed-1 + BF	43.60	4.53	15.04	43.00	4.4	15.04
LSD0.05	1.8	0.470	2.57	1.89	0.25	2.016

GF Glass fertilizers, RDF Recommended Dose Fertilizers, BF Bio-fertilizers

4. Conclusion

Nutrient accessibility in the root zone affects plant physiology, nutritional content, growth, and yield. The consumption of several vital nutrients is ensured with glass fertilizer with bio-fertilizers. From obtained results the rates of 60 kg fed⁻¹ glass fertilizer + bio-fertilizers enhance plant growth, yield attributes, and seed quality of pea plant. Glassy fertilizer was preferred to phosphorus and potassium mineral fertilizers, was environmentally acceptable, and had a long-term residual effect expected. From 60 kg fed⁻¹ glass fertilizers + bio-fertilizers, improvements in number of seed per pod, green pod yield, 100 seed weight, biological and grain yield were obtained. Bio-fertilizers can improve the biological properties of soil by lowering some values, such as fertilizer leaching, while raising others, such as nutrient uptake. Adding bio-fertilizers to glass fertilizers creates a new component capable of improving soil biological characteristics, resulting in increased crop production.

Declarations

Code Availability We did not use codes.

Author's Contributions All authors each made a significant contribution to the research reported and have read and approved the submitted manuscript.

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Data Availability. The datasets analyzed during the current study are available upon reasonable request from the corresponding author.

Ethics Approval 'Not applicable' for that section.

Consent to Participate 'Not applicable' for that section.

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Figures

Figure 1

glass fertilizers network structure

Figure 2

(a) Glass weathering process starting from a clean surface, (b) a formation of a water film, (c) a leached layer containing Hydrogen,(d) crystalline weathering products on the glass surface.

Figure 3

Binding way of glass fertilizers with soil

Figure 4

FTIR spectra of prepared glassy fertilizer before and after immersion in different solutions