Middle East Journal of Agriculture Research
Volume: 12 | Issue: 04| Oct. – Dec.| 2023

EISSN: 2706-7955 ISSN: 2077-4605
DOI: 10.36632/mejar/2023.12.4.67
Journal homepage: www.curresweb.com
Pages: 1001-1015

Enhance Soil Quality and Cowpea Productivity using Different Types of Soil Improvement Materials includes compost, Biochar, and potassium feldspar under Sandy Soil Conditions

Doaa M. Khalifa[1], Sammar F. Zahran[1], Nebal S. Abd Elhamied[3] and Amr R. Rabie[3]

[1]Soil Chemistry and Physics Res. Dept., Soil, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
[2]Soil Fertility and Plant Nutrition Dept., Soil, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
[3]Forestry Dept., Horticulture Res. Inst., Agricultural Research Center (ARC), Giza, Egypt.

Received: 10 Oct. 2023 **Accepted:** 15 Dec. 2023 **Published:** 30 Dec. 2023

ABSTRACT

Purpose: Cowpea (*Vigna unguiculata*) is a vital legume crop in Egyptian agriculture, contributing to food security and soil fertility enhancement. Egypt is forced to import potassium fertilizers due to the lack of natural raw materials needed to manufacture K fertilizers, which is necessary to improve the quality of grain crops and helps with stand abiotic and biotic stresses. The present study investigates effects of three different soil improvement materials includes compost (Comp), Biochar (Bioch), and potassium feldspar (KFd) on cowpea productivity and enhances sandy soil quality properties. **Methods:** A field experiment was conducted over two summer growing seasons of 2020 and 2021 at Isma3elia agricultural research station farm using cowpea cultivar *Dokki 126* in a randomized complete block (RCB) statistical design. Eight treatments were tested, including control, individual amendments, and combined applications of KFd, Bioch and Comp, Soil physical and chemical properties, plant growth parameters, and NPK nutrient content were determined. **Results:** The combined trio application of Comp, Bioch and KFd significantly improved soil structure by reducing bulk density (from 1.62 g/cm³ in control to 1.28 g/cm³) and increased total porosity (from 47.5% to 39.3%). Soil organic matter content (SOMC) was the highest in the trio combined treatment (0.71%) compared to control (0.50%). Additionally, mineral nitrogen (MN) 49.10 mg kg^{-1}), available phosphorus (AP) (6.62 mg kg^{-1}), and exchangeable potassium (EK) (187 mg kg^{-1}) were maximized under the same treatment. Cowpea plant growth parameters showed remarkable improvement, with extra growth reaching 305 cm in height compared to 144.3 cm in the control. Pod characteristics, including pod length (24.23 cm vs. 17.45 cm in control) and fresh weight (12.33 g vs. 7.29 g), were also significantly enhanced. Photosynthetic pigments and carbohydrate content in seeds increased, further supporting higher productivity. **Conclusion:** The combination of Comp, Bioch and KFd proved to be the most effective soil improvement combination, enhancing soil fertility, plant growth, and cowpea yield. These findings suggest that integrating organic and primary materials as soil amendments can improve productivity while reducing dependency on synthetic fertilizers in Egyptian agriculture.

Keywords: Cowpea, plant length, vegetative growth, potassium feldspar, biochar, compost, sandy soil, organic matter, bulk density, total porosity.

Introduction

A promising field crop known as cowpea (*Vigna unguiculata* ssp. *unguiculata*) has been introduced to Egyptian agriculture. It is a short-duration legume crop that requires little water, has a high nutritional content, and is widely consumed by humans in southern Asia and Africa (Elsobky & Hassan, 2021). In Egypt, cowpeas will face competition from other summer crops that have a dominant position. Another application for cowpeas is as a vegetable crop because of its cooked green pods; however, the Egyptian

Corresponding Author: Doaa M. Khalifa, Soil Chemistry and Physics Res. Dept., Soil, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt.
E-mail: dr.doaaamousa@gmail.com

crop structure does not support the production of cowpeas as a vegetable crop, although unconventional methods like intercropping may be applied in this regard (Lateef *et al.,* 2020). Soils are more susceptible to degradation as a result of increased agricultural mechanization. The first step in this deterioration is soil compaction, which then lowers the amount of organic matter in the soil. Adding both organic and non-organic materials to the soil is one of the many strategies used to address these issues. To increase crop output per unit area and make up for K losses in soils caused by crop uptake, runoff, leaching, and soil erosion, Egypt should utilize a lot of K chemical fertilizers (Wu *et al.*, 2022).

Furthermore, rising production costs and environmental contamination are caused by the high cost of these fertilizers. The application of natural potassium fertilizer and/or biofertilizer is an inexpensive method of giving plants K, and it can serve as a substitute for more costly K-chemical fertilizers (Jena *et al.,* 2019 & Longfeng *et al.,* 2022). The primary natural sources of K come from the weathering of minerals (K- feldspar, leuctie, and K-mica (Heisey *et al*., 2022) Numerous writers have suggested that K-feldspar could be useful as an inexpensive and low-releasing potassium source (Demnitz *et al.,* 2022 & Liu *et al.*, 2020). Compost is regarded as a type of fertilizer that is created by the decomposition of plant material or organic wastes (Wright *et al.,* 2022). Application of organic biowaste compost as organic fertilizer is currently available, and agricultural use of compost has some advantages in improving soil quality. Adding compost into the soil makes the soil rich in nutrients and organic matter, which has a positive effect on the physical, chemical and biological properties of the soil (Heisey *et al.,* 2022).

In recent years, biochar, a product of biomass pyrolysis, has been considered an obvious soil conditioner because it is present in the soil's carbon pool and can remain in the soil. Biochar is considered an important soil amendment that can reduce the effects of climate change due to its ability to store excess carbon (Pierre-Adrien, 2022). Evidence shows that it is used to amend soil by affecting the physical, chemical and biological properties of the soil (Chen *et al.,* 2022; Nuanhchamnong *et al.,* 2022 & Supraja *et al.,* 2023). Additionally, the effect of biochar application on other physical properties of the soil (such as PR, hydraulic conductivity, bulk density, and soil structure) has not been fully evaluated (Zhao *et al.,* 2022; James *et al.,* 2022 and Lehmann *et al.,* 2021).

In this study, applying feldspar, compost, and biochar all at once should enhance soil quality; however, this effect can be modified by varying the amount and composition of them. The purpose of this study is to assess the effects of different soil improvement materials on the productivity of cowpeas as well as the characteristics of reclaimed sandy soils in Egyptian agricultural environments. We look into the efficacy of three popular supplements: biochar, compost, and feldspar and our analysis of these amendments' effects on soil characteristics and cowpea output will provide important context for understanding their potential for Egypt's sustainable agriculture.

2. Materials and Methods

The present work was carried out at the Ismailia Agriculture Research Station farm, Ismailia Governorate, Egypt located at (30 o 35 ' 41.9 " N latitude and 32 o 16 ' 45.8 E longitude), during two successive summer growing seasons of (2020 and 2021). The cowpea cultivar used (*Vigna unguiculata* ssp. *unguiculata*) is Dokki 126 variation to assess the effectiveness of feldspar (KFd), compost (Comp) and Biochar (Bioch) on soil soil characteristics. Soil bulk density (BD), total porosity (TP), hydraulic conductivity (Ksat), field capacity (FC), wilting point (WP), accessible water (AW), soil pH, electrical conductivity (EC), organic matter (OM), and nutrient content (NPK) and cowpea productivity in sandy loam soil. Initial treatment is management (no treatment).

In Table 1, shows physical and chemical characteristics of the soil under investigation were evaluated by taking soil samples at a depth of 0 to 30 cm both before and after planting (Page *et al.,* 1982). Soil before sowing was identified from soil analysis which showed that the soil was sandy and lacked fertility in the presence of macronutrients.

Table 1: Some physical and chemical characteristics of the investigated surface layer of soil (0-30 cm).

Soil characteristics		**Values**
Physical properties		
Particle size distribution	Sand (%)	65.69
	Silt (%)	9.04
	Clay (%)	25.27
	Soil texture	Sandy soil
Available water %		7.16
Wilting point (%)		1.92
Field capacity (%)		9.07
Organic matter (%)		0.43
Bulk density (g cm–3)		1.57
Total porosity %		47.62
Saturation percentage (%)		21.21
Calcium carbonate (%)		5.90
*pH (Soil paste)		7.60
**EC (dS m–1)		1.29
Chemical properties		
Soluble Cations (meq L^{-1})	Ca^{++}	5.51
	Mg^{++}	2.75
	Na^{+}	10.69
	K^{+}	1.03
Soluble Anions (meq L^{-1})	CO_3^{--}	7.70
	HCO_3	3.20
	Cl^{-}	14.80
	$SO_4{}^{2}$	2.91
Available nutrients (mg kg^{-1})	Nitrogen	44.2
	Phosphorus	4.99
	Potassium	171.0

* Determined in 1:2.5 soil and water suspension, **Determined in soil paste extract

The physical and chemical features of the used compost (Comp) as well as the amount of certain critical plant nutrients it contained were tested utilizing methodologies specified by Page *et al.* (1982) and the obtained data are recorded in (Table 2).

Table 2: Some physical and chemical properties of tested compost

Compost properties		**Values**
Physical properties		
Water holding capacity %		31.30
Moisture content %		25.70
Organic matter (%)		38.16
Bulk density (g cm–3)		0.500
Chemical properties		
C:N ratio		32.7
*pH (Sus.1:10dSm-)		7.5
*EC (1:10 Extract)		2.29
Available nutrients		
Macronutrients (%)	N	1.13
	P	0.63
	K	0.77
Micronutrients (mg kg-1)	Fe	268.0
	Mn	24.0
	Zn	15.0

In addition, (Table 3) showed some physical and chemical properties of biochar (Biochar is made from Eucalyptus camaldulensis and Casuarina equistefolia trees) (Bioch) according to Page et al. (1982). Biochar analysis at a final temperature of 500°C and a holding time of 2 hours. Biochar samples were ground and sieved to a diameter of <0.5 mm. Biochar was applied simultaneously to the soil at a rate of 4 tones fed^{-1} (Fadden = 0.42 ha).

Table 3: Some physical and chemical properties of Biochar

Biochar properties		**Values**
Physical properties		
Moisture content %		25.70
Organic matter (%)		46.37
Bulk density (g cm–3)		0.17
Chemical properties		
C, %		82.46
N, %		0.71
H, %		1.34
*pH (Sus.1:10dSm-)1:2.5 : water suspension		6.86
*EC (dSm^{-1}) (1:10 bio char water suspension)		0.84
Available nutrients		
Macronutrients (%)	N	1.54
	P	0.66
	K	8.11

Potassium feldspar rock (KFd) as a natural local potassium rock powder was produced by Al Ahram for mining Co., Ltd., Egypt. The chemical properties of the used feldspar rock according to Soltanpour, (1985) are presented in (Table 4).

Table 4: Some physical and chemical properties of potassium feldspar (KFd) used in the experiment.

Feldspar properties	Values
Al_2O_2	15.11%
K_2O	10.61%
MgO_2	7.04%
Na_2O	1.90%
Fe_2O_2	0.07%
P_2O_2	0.06%
CaO	0.35%
Cl	0.04%
TiO_2	0.01%
MnO_2	0.01%
$CaCO_3$	0.41%
SiO_2	64.35%
*pH (Sus.1:10)	8.20
**EC (dSm^{-1})	0.53

* Suspension 1:10 KFd: water, ** Suspension 1:2 KFd: water

2.1. Bacterial strains

Before planting, cowpea seeds are inoculated with rhizobium bacteria (*actinorhizobium species*). Potassium solubilizing bacteria (KSB) Bacillus circulenes. Phosphate solubilizing bacteria (PSB) B. megaterium. Inoculants were purchased from soil Microbiology Department at soils, Water and Environment Institute Research Institute (ARC), Egypt.

2.2. Fertilization

Every treatment was added in the amounts as recommended rates for cowpea plants After 15, 30, 45, and 60 days after cowpea seeding, nitrogen was fertilized in the form of ammonium nitrate (33.5% N) at rate50 kg N fed^{-1}, divided into four equal dosages Superphosphate (15.5 % P_2O_5) was incorporated at a rate of 30 kg P2O5 equal to 200 kg fertilizer fed^{-1} prior to cultivation. Potassium sulfate (50% K_2O) was added at a rate of 50 kg fed^{-1} in two equal doses (12.5% K_2O each), the first at planting and the second 30 days after sowing.

2.3. Experimental treatments

This experiment study included 8 treatments, which were the combinations between three soil amendments with rate: Biochar (7.350 m^3 fed^{-1}), Compost (15.750 m^3 fed^{-1}) and KFd applications with soil inoculation of both phosphate and potassium dissolving bacteria (3.150 m^3 fed^{-1}).

1- Control treatment without any addition with supplying the full recommended dose of phosphorus (200 kg fed-1 of single calcium supper phosphate, 15.5 % P2O5), The full dose of potassium (50 kg fed-1 of potassium sulfate, 50 % K2O) and nitrogen (50 kg fed-1 of 150 kg fed-1 of ammonium nitrate, 33.5 % N) for all experimental plots.
2- Potassium feldspar (KFd),
3- Biochar (Bioch).
4- Compost (Comp).
5- KFd + Bioch+ Comp.
6- KFd + Bioch,
7- KFd + Comp.
8- Bioch + Comp.

2.4. Examined parameters

2.4.1. Soil analysis

In accordance with Cottenie *et al.* (1982), soil samples were collected at the conclusion of the growing season from depths of soil (0–30 cm), air-dried, ground, well mixed, sieved to pass through a 2 mm sieve, stored, and submitted to the following examination of certain soil chemical parameters:

1- Soil bulk density (BD)
2- Total porosity (TP)

3- Hydraulic conductivity (Ksat)
4- Field capacity (FC)
5- Wilting point ((WP)
6- Accessible water (AW)
7- Field Soil water extract's electrical conductivity (EC) dS m^{-1} at a ratio of 1:5
8- In 1:2.5 soils to water suspensions, the pH of the soil was measured
9- The percentage of organic carbon (OC) and organic matter (OM)
10- N, P, and K (mg kg-1) those are available

The Page *et al*. (1982) method was used to calculate the bulk density, total porosity, and percentage saturation of the soil.

2.4.2. Plant growth

The plant determined was plant length (A), number of branches (B), number of leaves(C), plant fresh weight (D), and plant dry weight(E).

2.4.3. Photosynthetic pigments

Using the Niroula *et al*. (2019) approach, photosynthetic pigments (total chlorophyll and carotenoid) were quantified in plant leaves at 30- and 60-day intervals. The pigment concentration was represented as mg g^{-1} Fw, and the computations were perfor(med using formulas developed by Hendry and Grime (1993).

2.4.4. Harvest pigments

At harvest, plants were taken to evaluate yield and yield components plant length (cm) biological yield (BY), straw (St), and seeds (Sd) were evaluated. Pod were collected and determine then length (A), pod diameter (B), fresh weight(C) and dry weight (D) . Plant samples were weighed and oven dried at 70°C until constant dry weight, then ground and digested using an H_2SO_4 and H_2O_2 mixture as described by Page *et al*. (1982). The digested samples were then subjected to the evaluation of nutrients (N, P and K) according to the method described by Cottenie *et al*. (1982) and the total content of nutrients was calculated as kg fed^{-1} in both straw and seeds of cowpea plants.

2.5. Statistical Analysis

Duncan's multiple range test was used to compare treatment means, and the analyses of variance approach described by (Duncan, 1955) was used to tabulate and analyze the data. level of 5% for one factor at a time (one way analysis) using CoStat 6.45 program (Costat 1985). The obtained data were statistically analyzed according to complete randomized block design (Snedecor and Cochran, 1982). The individual comparisons between the obtained values were carried out at the 5% level of LSD.

3. Results

3.1. Soil analysis

3.1.1. Effects of KFd, Bioch and Comp on the soil characteristics

The study's findings, which span two growing seasons, show how Comp, Bioch, and KFd effect on several soil characteristics. Soil bulk density (BD), total porosity (TP), hydraulic conductivity (Ksat), field capacity (FC), wilting point (WP), accessible water (AW soil pH, electrical conductivity (EC), organic matter (OM), and nutrient content (NPK) were all significantly affected by the treatments, according to the data. The combination of KFd + Bioch+ Comp produced the lowest bulk density in Table 5 (1.29 g cm^{-3} in the second growing season and 1.34 g cm^{-3}in the first growing season). This treatment also showed comparable hydraulic conductivity (8.19 cm h^{-1} and 40.1% in the first growing season and 39.1% in the second growing season), as well as the highest total porosity in Table 5.

3.1.2. Field capacity, wilting point, and available water

Effect of the treatments of soil improvements on available water (AW), wilting point (WP), and field capacity (FC) are shown in Table 6. The highest FC and WP values were found in KFd and charcoal treatments, suggesting that they were able to hold more water than the other treatments. With AW values of 7.51% and 7.81% over the course of the two growing seasons, the addition of KFd, Bioch and Comp demonstrated balanced increases in the quantity of water accessible for plants. These results suggest improved water retention, which is advantageous for plant growth, particularly in situations where water is scarce.

Table 5: Effect of KFd, Bioch and Comp on soil (BD), (TP) and (Ksat) in the two growing seasons.

Treatments	First growing season			Second growing season		
	BD, g cm^{-3}	TP, %	Ksat, cm h^{-1}	BD, g cm^{-3}	TP, %	Ksat, cm h^{-1}
Control	1.63g	46.8g	8.37f	1.66g	47.8f	**8.36f**
KFd	1.44d	39.9f	8.291e	1.42e	41.9e	**8.25c**
Bioch.	1.47e	41.1c	8.21bc	1.43e	41.1c	**8.19b**
Com.p	1.50f	40.5b	8.20ab	1.47f	40.5b	**8.18b**
KFd+ Bioch.	1.34c	42.3d	8.32c	1.38c	41.4c	**8.31e**
KFd+ Comp.	1.35b	42.4d	8.31cd	1.33b	42.1d	**8.29d**
Bioch + Comp.	1.35b	42.50e	8.31c	1.34b	41.9b	**8.29d**
KFd+ Bioch. + Comp.	1.34a	40.1a	8.19a	1.21a	39.1a	**8.15a**
LSD. at 0.05	0.39	2.18	1.57	0.32	2.12	**0.31**

Table 6: Effect of KFd, Bioch and Comp for soil physical properties of (FC), (WP) and (AW) during the two growing seasons after harvesting time.

Treatments	First growing season			Second growing season		
	FC, %	WP,%	AW, %	FC, %	WP,%	AW, %
Control	11.12g	2.15g	9.01f	11.61g	2.26e	**9.40g**
KFd	12.96e	5.59c	7.44a	13.28d	5.63b	**7.71d**
Bioch.	13.17b	5.64b	7.60c	13.66b	5.71b	**7.92f**
Comp	13.06c	5.61c	7.52b	13.42c	5.67b	**7.81e**
KFd+ Bioch.	13.04d	5.18d	7.92d	13.28d	5.35c	**7.87c**
KFd+ Comp.	12.10c	4.53f	7.65c	12.15e	5.04d	**7.18d**
Bioch + Comp.	12.91f	4.81e	8.16e	12.98f	5.35c	**7.70d**
KFd+ Bioch. + Comp.	13.28a	6.37a	7.54b	13.92a	6.43a	**7.52b**
LSD. at 0.05	2.71	3.95	1.57	2.31	4.26	**2.34**

3.1.3. Soil pH, EC, and OM.

The Soil pH, EC, and OM content differed among treatments application, as shown in Table 7. With the highest values (0.67% and 0.72% at OM throughout the two growing seasons respectively the combination of KFd, Bioch and Comp had the most positive effect on OM followed by Biochar treatments. Although the soil's pH stayed mostly constant throughout the treatments, the addition of KFd, Bioch and Comp caused the pH to drop slightly smaller than the control. Particularly for plants that thrive in slightly alkaline environments, lower pH levels can enhance nutrient availability.

3.1.4. NPK Content

Table 8 show effects of soil improvement treatments on available levels of NP and K nutrients In both growing seasons, the highest NPK values were found due to combination treatment of KFd, Bioch and Comp; the values reached significant differences for the first growing season as 50.5mg kg^{-1} for N, 5.84 mg kg^{-1} for P, and 187.76 mg kg^{-1} for K respectively whereas in the second season, these levels reached as high as 51.56 mg kg^{-1} for N, 6.88 mg kg^{-1} for P, and 189.81 mg kg^{-1} for K respectively. This implies that by making vital nutrients more accessible, these additions significantly improve soil fertility. However, the control had far lower NPK values (N4.73 mg kg^{-1}, P529 mg kg^{-1}, K 166 mg kg^{-1}) demonstrating the significance of applying soil amendments for improved nutrient management

Table 7: Effect of KFd, Bioch and Comp for soil pH, EC and OM during the two growing seasons in the tested soil after harvesting time.

Treatments	First growing season			Second growing season		
	pH	EC, dS m^{-1}	OM, %	pH	EC, dS m^{-1}	OM, %
Control	7.81e	1.30d	0.51e	7.87f	1.32e	**0.54f**
KFd	7.72c	1.16b	0.57d	7.68c	1.14b	**0.60e**
Bioch	7.74d	1.19c	0.61c	7.71e	1.16c	**0.67d**
Comp	7.73c	1.17c	0.64b	7.72e	1.15b	**0.693c**
KFd+ Bioch	7.72c	1.16c	0.63b	7.60d	1.17d	**0.71b**
KFd+ Comp	7.65b	1.17b	0.62c	7.62b	1.17c	**0.68d**
Bioch + Comp	7.64b	1.16b	0.65b	7.61b	1.15b	**0.69c**
KFd + Bioch + Comp	7.62a	1.12a	0.67a	7.60a	1.10a	**0.72a**
LSD. at 0.05	0.04	0.14	0.08	0.05	0.18	**0.09**

Table 8: Effect of KFd, Bioch and Comp for on NPK during the two growing seasons in the tested soil after harvesting time.

Treatments	First growing season			Second growing season		
	N, mg kg^{-1}	P, mg kg^{-1}	K, mg kg^{-1}	N, mg kg^{-1}	P, mg kg^{-1}	K, mg kg^{-1}
Control	41.16e	45.94e	173.57d	47.37	5.29g	**168.49e**
KFd	46.73d	5.46d	177.6c	49.55b	6.01e	**185.75b**
Bioch	48.20c	4.79b	181.69b	49.25c	6. 74c	**173.57d**
Comp	47.36c	4.78b	185.75a	48.41c	5. 79f	**181.78c**
KFd+ Bioch	49.25b	5.78c	183.72b	40.55b	6. 82b	**185.75b**
KFd+ Comp	48.41c	5.67c	186.86a	49.14c	6.81b	**187.88b**
Bioch + Comp	49.46b	5.83b	184.73a	49.46b	6.36d	**185.75b**
KFd+ Bioch + Comp	50.51a	5.84a	187.78a	51.56a	6. 88a	**189.31a**
LSD. at 0.05	2.73	0.80	3.38	2.46	0.78	**2.33**

3.2. Plant analysis

The results presented in the document focus on the effects KFd, Bioch, and Comp on various growth and physiological parameters of cowpea plants across the two growing seasons. These treatments significantly influenced pigment content, carbohydrate concentraو, plant morphological characteristics, and nutrient levels in the cowpea plant.

3.2.1. Pigment Content

According to statistics on the pigment content of cowpea leaves (Fig. 1) (carotenoids, chlorophyll a, and chlorophyll b), the application of KFd, Bioch, and Comp together resulted in the highest amounts of pigment in both growing seasons. In particular, when all three treatments were combined, chlorophyll an in the second season increased to 20.86 mg 100g^{-1}, while in the control, it was only 13.1 mg 100g^{-1}. Carotenoids and chlorophyll b showed a similar pattern, suggesting that the combination treatment greatly increased the plant's ability to photosynthesize. Because higher chlorophyll content indicates improved light collection and energy conversion, which results in better growth, this is significant for plant productivity (Fig. 1).

3.2.2. Carbohydrate Content

In terms of carbohydrate accumulation in dry seeds of cowpea (Fig 2), the combination of KFd, Bioch, and Comp led to the highest carbohydrate levels (64.8 g 100g^{-1} in the second season), which was significantly higher than the control (59.99 g 100g^{-1}). This suggests that the combined treatment improves the energy reserves in seeds, which is vital for seed quality (Fig. 2).

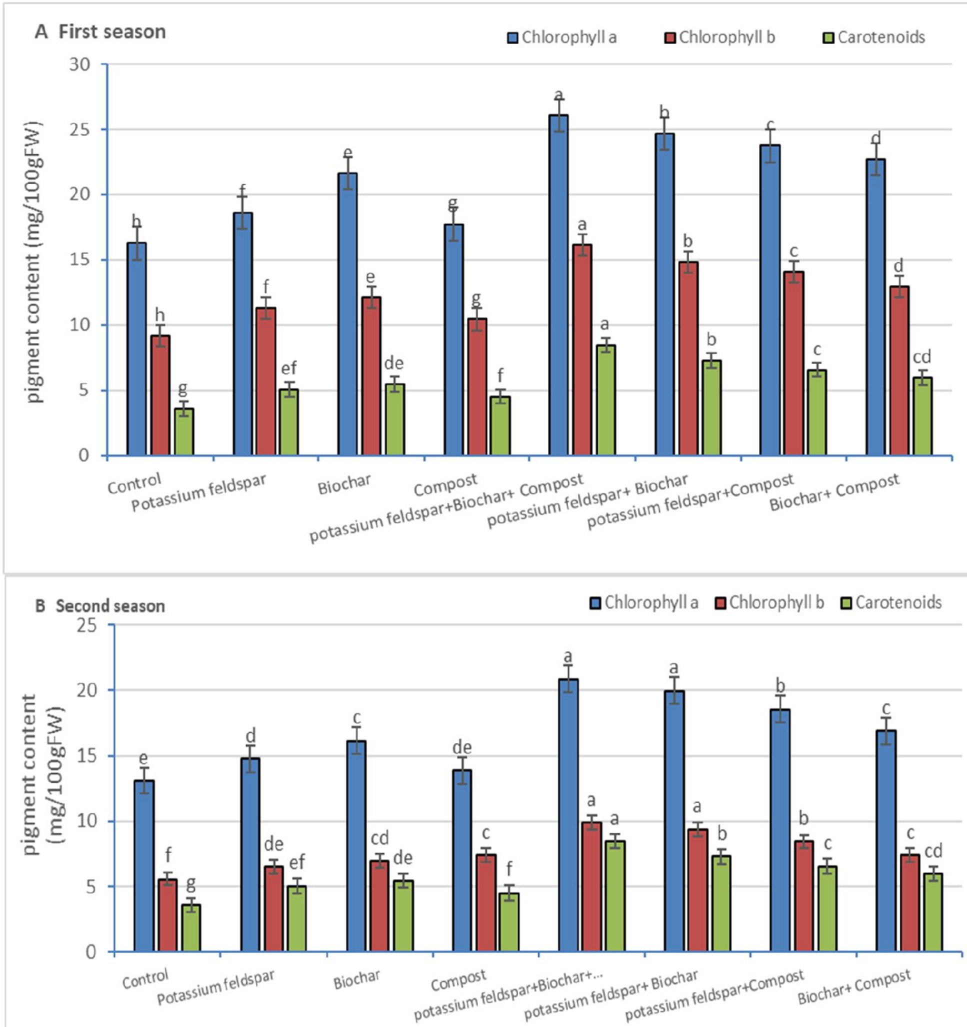

Fig. 1: Effect of KFd, Bioch, and Comp on pigment contents in leaves of cowpea plant in the two growing seasons (first A, second B).

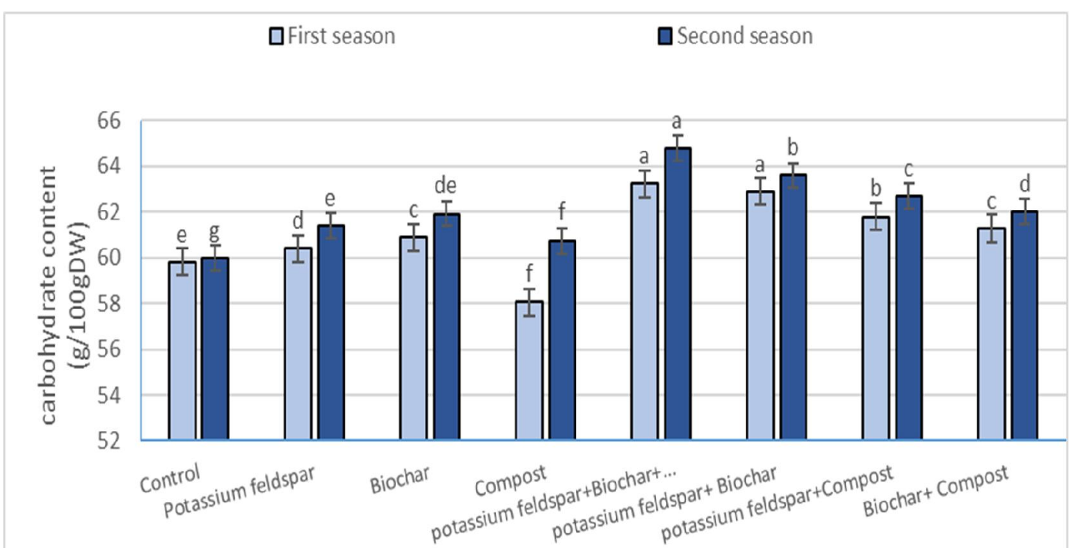

Fig. 2: Effect of KFd, Bioch, and Comp on carbohydrate contents of dry seeds of cowpea plant in the two growing seasons.

Middle East J. Agric. Res., 12(4): 1001-1015, 2023
EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2023.12.4.67*

3.2.3. Plant Growth Parameters

Plant growth indicators, such as plant length, branch count, and leaf count, were significantly impacted by the combined application of KFd, Bioch, and Comp. The combination treatment resulted in a plant length of 305 cm in the second season, which was far longer than the control (144.3 cm). The number of leaves and branches followed a similar trend, with the combined treatment yielding more leaves (84.67) and branches (5) compared to the control. These improvements in growth parameters highlight the beneficial effects of the treatments on vegetative development (fig. 3).

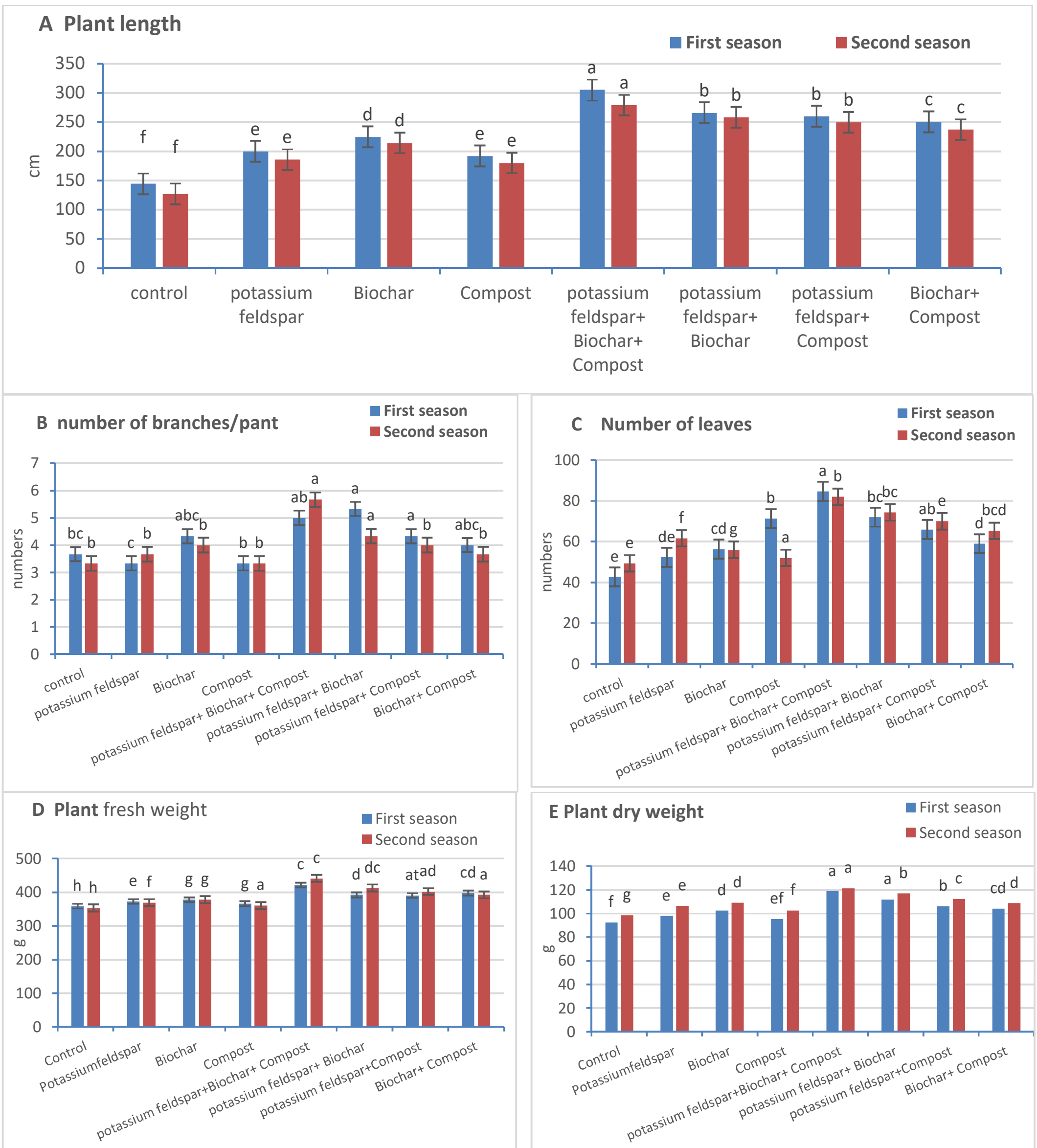

Fig. 3: Effect of KFd, Bioch, and Comp on plant criteria of cowpea plant in the two growing seasons (A plant length, B number of branches, C number of leaves , D plant fresh weight and E plant dry weight).

3.2.4. Pod Characteristics

Pod-related traits such as length, diameter, fresh weight, and dry weight also benefited from the combined treatments. For instance, in the second season, the pod length reached 24.23 cm, and pod fresh weight was 12.33 g under the combined treatment, both significantly higher than the control.

Middle East J. Agric. Res., 12(4): 1001-1015, 2023
EISSN: 2706-7955 ISSN: 2077-4605 DOI: 10.36632/mejar/2023.12.4.67

These results suggest that the combination of KFd, Bioch, and Comp not only improves vegetative growth but also enhances the reproductive output of cowpea plants, leading to higher yields.

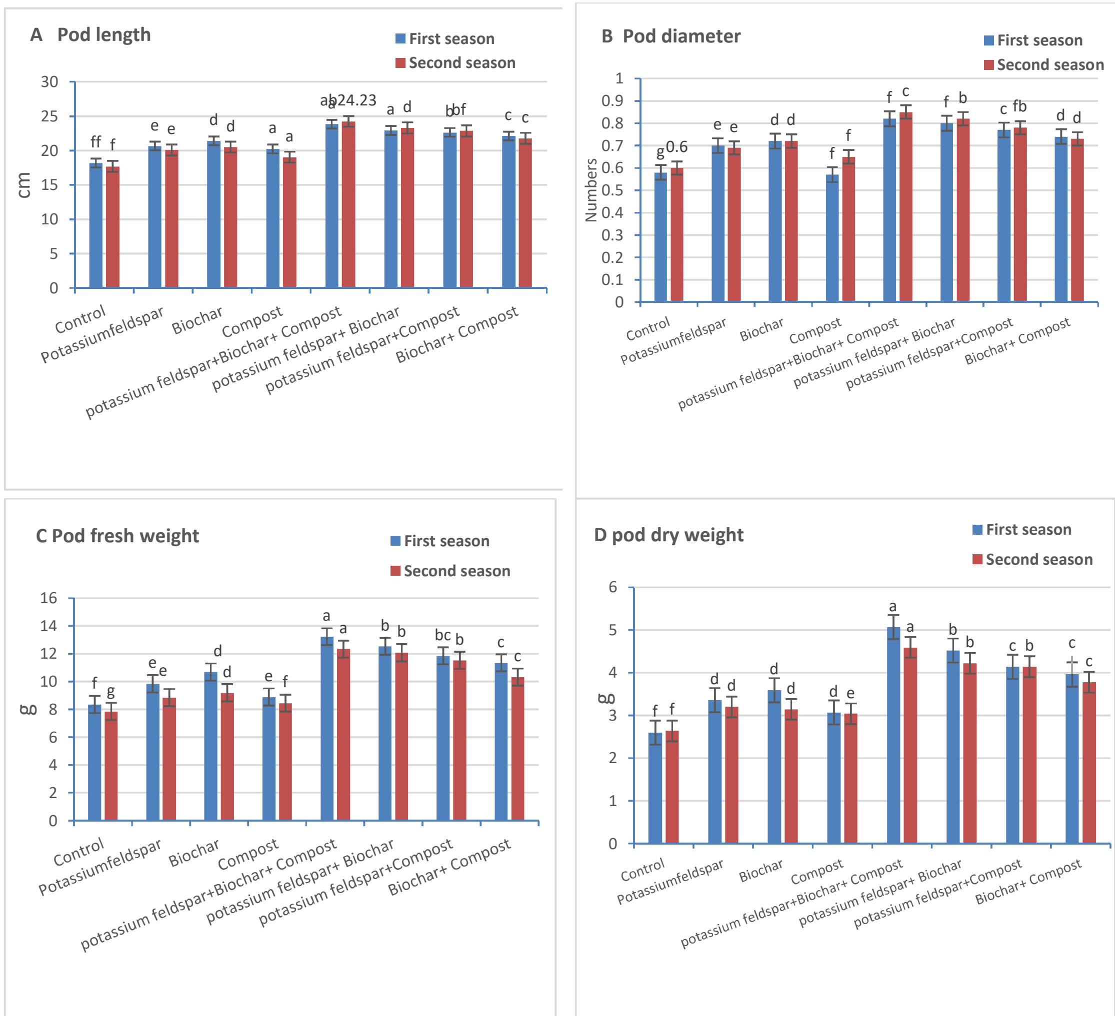

Fig. 4: Effect of KFd, Bioch, and Comp on pod criteria of cowpea plant in the two growing seasons (A pod length, B pod diameter, C pod fresh weight, and D pod dry weight)

3.2.5. Nutrient Content (NPK).

Nutrient analysis of cowpea seeds revealed that the combination of KFd, Bioch, and Comp significantly increased nitrogen (N), phosphorus (P), and potassium (K) levels compared to the control. In the second season, content reached 5.09 mg/g, 0.67 mg/g, and 1.21 mg/g under the combined treatment. This indicates improved nutrient uptake and utilization, which is essential for plant growth, pod development, and seed quality (fig. 5).

Overall, the results clearly demonstrate that the combined use of potassium feldspar, biochar, and compost has a synergistic effect on cowpea plant growth, improving pigment content, carbohydrate, plant, and yield-related traits. These findings suggest that the integration of these soil amendments can significantly enhance soil fertility, leading to better crop performance. This has implications for sustainable agricultural practices, as these treatments could help improve productivity in nutrient-poor soils while reducing the need for synthetic fertilizers.

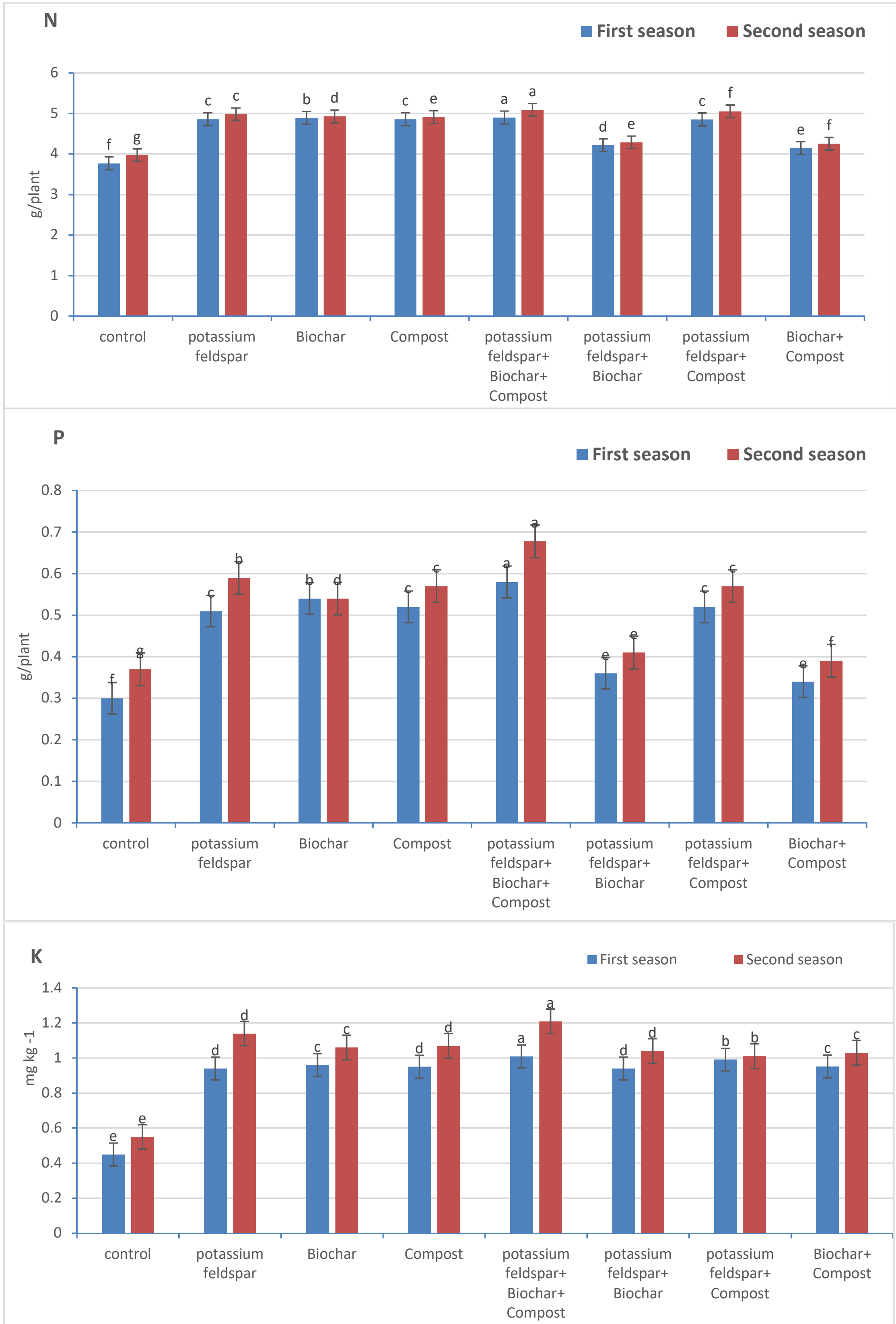

Fig. 5: Effect of KFd, Bioch, and Comp on NPK contents in seeds of cowpeas two growing seasons.

4. Discussion

The results of this study highlight the significant impact of soil amendments specifically potassium feldspar, biochar, and compost on cowpea productivity and the properties of reclaimed sandy soil in Egyptian agriculture. Cowpeas (*Vigna unguiculata*) are increasingly recognized for their role in improving soil fertility and contributing to food security, particularly in regions with challenging agricultural conditions (El-Sayed *et al.,* 2021). The combination of potassium feldspar, biochar, and compost demonstrated remarkable improvements in various soil physical and chemical properties. Notably, the reduction in bulk density and the increase in total porosity and hydraulic conductivity indicate enhanced soil structure, facilitating better water and air movement (Wright *et al.,* 2022. &, Heisey *et al.,* 2022). This is crucial for root development and overall plant health, especially in arid regions where water retention is vital (Pierre-Adrien *et al.,* 2022).

The study's findings corroborate existing literature that emphasizes the benefits of organic amendments. Compost, a well-known organic fertilizer, enriches soil with nutrients and improves its biological activity (Bucka *et al.,* 2019). The increased organic matter content observed in this study aligns with previous research indicating that organic amendments contribute to higher soil fertility and improved nutrient cycling. Biochar's role as a soil amendment has gained attention for its ability to enhance soil properties by increasing water retention, nutrient availability, and microbial activity (Kranz *et al.,* 2020). The synergistic effects observed in this study, where the combined application of biochar, compost, and potassium feldspar resulted in the highest nutrient levels (NPK), further substantiate its effectiveness. Biochar's porous structure likely aids in trapping nutrients and improving soil aeration, thus promoting healthier plant growth (Kubinova *et al.,* 2021).

The results also indicate a significant increase in available nitrogen, phosphorus, and potassium levels in the soil treated with the combination of amendments. This enhancement is critical, as nutrient deficiencies are common in sandy soils, which are prevalent in Egypt. The reliance on chemical fertilizers has raised concerns about environmental sustainability and soil health (Kumar *et al.*, 2022). By integrating organic amendments like compost and biochar with natural mineral sources like potassium feldspar, farmers can mitigate these issues, improving soil fertility while potentially lowering input costs. Additionally, the stability of soil pH observed in this study suggests that these amendments can buffer the soil, maintaining conditions favorable for nutrient availability and microbial activity. The slight decrease in pH associated with the combined treatment may enhance the solubility of essential nutrients, particularly phosphorus (Pierre-Adrien *et al.,* 2022). This is especially important in alkaline soils, where nutrient availability can be severely limited. From an agronomic perspective, the marked increase in vegetative growth parameters, including plant height, leaf number, and biomass, aligns with findings from similar studies that reported enhanced crop yields following the application of organic amendments (Adekiya *et al.,* 2021).

The improved physiological traits of cowpea, attributed to better nutrient and water availability, reinforce the potential of these amendments to support sustainable crop production practices in Egyptian agriculture (Fig 6).

This is an indication that the taller the plant the more likely it is to have more leaves and greater the opportunity for more chlorophyll content in leaves and the greater the chance for photosynthesis to occur leading to vegetative growth. This agrees with report by Heisey *et al.* (2022) that tall plants are likely to have more green areas for more photosynthetic activities that facilitate increase in growth and grain yield of crops.

5. Conclusion

The application of potassium feldspar, biochar, and compost not only enhances cowpea productivity but also significantly improves the physical and chemical properties of sandy clay loam soils. These findings contribute to the growing body of evidence supporting the use of integrated soil fertility management practices as a sustainable solution to improve agricultural output and soil health. Future research should focus on long-term impacts and the economic viability of implementing these practices on a larger scale, especially in regions facing similar agricultural challenges.

	N seed	P seed	K seed	Plant length	No. of leaves	of branche/pl	Plant FW	Pod DW	Plant DW	Pod length	Pod diameter	Pod FW	Carbohydrat	Chla
N seed	1.00													
P seed	0.96	1.00												
K seed	0.75	0.70	1.00											
Plant length	0.35	0.31	0.64	1.00										
No. of leave	0.39	0.43	0.61	0.84	1.00									
No. of branc	0.17	0.24	0.37	0.78	0.71	1.00								
Plant FW	0.27	0.33	0.56	0.90	0.84	0.82	1.00							
Pod DW	0.27	0.27	0.54	0.97	0.86	0.83	0.91	1.00						
Plant DW	0.34	0.42	0.66	0.83	0.81	0.78	0.89	0.85	1.00					
Pod length	0.35	0.32	0.64	0.98	0.86	0.79	0.93	0.96	0.84	1.00				
Pod diamete	0.31	0.32	0.63	0.91	0.73	0.81	0.90	0.92	0.92	0.93	1.00			
Pod FW	0.19	0.17	0.46	0.96	0.80	0.83	0.89	0.98	0.79	0.96	0.91	1.00		
Carbohydrat	0.22	0.30	0.55	0.78	0.66	0.81	0.87	0.81	0.95	0.80	0.94	0.78	1.00	
Chla	0.11	0.04	0.26	0.84	0.62	0.75	0.67	0.85	0.49	0.80	0.69	0.90	0.48	1.00
Chl b	0.07	-0.02	0.11	0.67	0.46	0.58	0.44	0.68	0.24	0.60	0.46	0.73	0.23	0.94
Carot	0.33	0.36	0.62	0.96	0.88	0.87	0.95	0.97	0.92	0.97	0.95	0.95	0.88	0.77
BD	-0.48	-0.42	-0.82	-0.90	-0.74	-0.60	-0.82	-0.84	-0.79	-0.90	-0.86	-0.80	-0.75	-0.60
TP%	-0.71	-0.68	-0.91	-0.69	-0.70	-0.45	-0.60	-0.58	-0.63	-0.66	-0.56	-0.51	-0.47	-0.37
Ksat	-0.79	-0.83	-0.70	-0.31	-0.41	-0.24	-0.31	-0.21	-0.37	-0.27	-0.21	-0.11	-0.20	-0.05
FC %	0.66	0.54	0.91	0.74	0.63	0.40	0.53	0.62	0.58	0.71	0.63	0.58	0.46	0.47
WP%	-0.10	-0.07	0.06	0.39	0.41	0.47	0.36	0.37	0.40	0.35	0.30	0.39	0.33	0.32
AW %	0.09	0.13	-0.18	-0.54	-0.44	-0.40	-0.45	-0.47	-0.38	-0.48	-0.36	-0.49	-0.29	-0.46
pH	-0.50	-0.48	-0.76	-0.81	-0.72	-0.47	-0.78	-0.76	-0.73	-0.81	-0.74	-0.69	-0.66	-0.47
EC	-0.72	-0.67	-0.95	-0.73	-0.67	-0.42	-0.64	-0.64	-0.65	-0.71	-0.65	-0.56	-0.54	-0.40
OM	0.45	0.45	0.81	0.69	0.69	0.42	0.69	0.61	0.76	0.68	0.65	0.53	0.64	0.25
N soil	0.51	0.52	0.83	0.70	0.72	0.52	0.67	0.68	0.81	0.70	0.73	0.59	0.67	0.36
P soil	0.22	0.27	0.55	0.49	0.45	0.39	0.63	0.45	0.78	0.53	0.67	0.40	0.80	0.02
K soil	0.47	0.45	0.73	0.77	0.80	0.50	0.71	0.75	0.61	0.80	0.63	0.70	0.51	0.55

	Chl b	Carot	BD	TP%	Ksat	FC %	WP%	AW %	pH	EC	OM	N soil	P soil	K soil
Chl b	1.00													
Carot	0.57	1.00												
BD	-0.41	-0.85	1.00											
TP%	-0.24	-0.64	0.76	1.00										
Ksat	-0.01	-0.31	0.36	0.82	1.00									
FC %	0.36	0.64	-0.82	-0.91	-0.60	1.00								
WP%	0.22	0.39	-0.15	-0.34	-0.17	0.26	1.00							
AW %	-0.34	-0.45	0.36	0.46	0.21	-0.41	-0.85	1.00						
pH	-0.29	-0.77	0.94	0.71	0.39	-0.69	-0.07	0.31	1.00					
EC	-0.29	-0.69	0.88	0.91	0.69	-0.90	-0.02	0.21	0.84	1.00				
OM	0.05	0.68	-0.77	-0.86	-0.59	0.80	0.51	-0.59	-0.74	-0.78	1.00			
N soil	0.15	0.73	-0.77	-0.75	-0.54	0.73	0.22	-0.33	-0.73	-0.76	0.79	1.00		
P soil	-0.25	0.58	-0.64	-0.41	-0.18	0.40	0.20	-0.15	-0.62	-0.49	0.70	0.58	1.00	
K soil	0.43	0.73	-0.84	-0.76	-0.37	0.75	0.19	-0.32	-0.83	-0.79	0.68	0.62	0.36	1.00

Fig. 6: The correlation analysis revealed that plant length, number of leaves, carbohydrate, and chlorophyll content had positive correlation to growth and yield production in cowpea.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article.

References

Adekiya, O. A., T. M. Agbede, W. S. Ejue, C.M. Aboyeji, O. Dunsin, C. O. Aremu, A. O. Owolabi, B. O. Ajiboye, O. F. Okunlola and O. O. Adesola, 2020. Biochar, poultry manure and NPK fertilizer: sole and combine application effects on soil properties and ginger (*Zingiber officinale* Roscoe) performance in a tropical Alfisol. Open Agriculture, 5(1):30-39. https://doi.org/10.1515/opag-2020-0004

Bucka, F.B., A. Kölbl, D. Uteau, S. Peth, and I. Kögel-Knabner, 2019. Organic matter input determines structure development and aggregate formation in artificial soils. Geoderma, 354, 113881. https://doi.org/10.1016/j.geoderma.2019.113881

Chen, L., Y. Zhang, L. Wang, S. Ruan, J. Chen, H. Li, J. Yang, V. Mechtcherine, D.and C.W. Tsang, 2022. Biochar-augmented carbon-negative concrete. Chemical Engineering Journal Volume 431, Part 1, 133946 . https://doi.org/10.1016/j.cej.2021.133946

Demnitz, M., S. Schymura, J. Neumann, M. Schmidt, T. Schäfer, T. Stumpf, and K. Müller, 2022. Mechanistic understanding of Curium(III) sorption on natural K-feldspar surfaces Science of the Total Environment, citations by CoLab: 3. 843:156920

El-Sayed, E.A. El-Sobky, K. Hend and H.M. Hassan, 2021. Optimizing Cowpea Productivity by Sowing Date and Plant Density to Mitigate Climatic Changes. Egypt. J. Agron. 43(3): 317-331.

Elsobky, E.E., and H.H. Hassan, 2021. Optimizing cowpea productivity by sowing date and plant density to mitigate climatic changes. Egypt. J. Agron. 43: 317–331.

Heisey, S.R., R. Ryals, Tai McClellan Maaz, and N. H. Nguyen, 2022. A Single Application of Compost Can Leave Lasting Impacts on Soil Microbial Community Structure and Alter Cross-Domain Interaction Networks. Front. Soil Sci., (2). https://doi.org/10.3389/fsoil.2022.749212

Hendry, A.F. and J.P. Grime, 1993. "Methods in Comparative Plant Ecology". A Laboratory Manual. (Chapman and Hall: London), UK. 120-145.

James, A., A. Sánchez, J. Prens, and W. Yuan, 2022. Biochar from agricultural residues for soil conditioning: Technological status and life cycle assessment. Curr. Opin. Environ. Sci. Heal., 25, 100314. https://doi.org/10.1016/j.coesh.2021.100314

Jena, S.K., N. Dash, A.K. Samal, and P.K. Misra, 2019. Competency of chlorination roasting coupled water leaching process for potash recovery from K-feldspar: Mechanism and kinetics aspects. Korean J. Chem. Eng., 36: 2060–2073.

Kranz, C.N., R.A. McLaughlin, A. Johnson, G. Miller, and J.L. Heitman, 2020. The effects of compost incorporation on soil physical properties in urban soils-A concise review. Journal of Environmental Management, 261, 110209. https://doi.org/10.1016/j.jenvman.2020.110209

Kubinova, R., M. Neumann, and P. Kavka, 2021. Aggregate and pore size distribution of the soil sediment eroded on steep artificial slopes. Applied Sciences,10,4427. https://doi.org/10.3390/app1110442710.3390/app11104427

Kumar, S., G. Kaushik, M.A. Dar, M. Nanda, and M. Ahmed, 2022. Biochar in agriculture: The role of biochar in enhancing nutrient use efficiency and crop productivity. Journal of Plant Nutrition, 45(3): 387-401.

Lateef, E.M.A.E., A.E.M. Eata, A.M. Wali, and M.S.A. El-Salam, 2020. Evaluation of Mungbean (*Vigna radiata* L. Wilczek) as Green Pod and Seed Crop under Different Cropping Systems in Egypt. Asian J. Crop Sci. 12: 115–123. https://doi.org/10.3923/ajcs.2020.115.123

Lehmann, J., Cowie, A., Masiello, C.A. et al. Biochar in climate change mitigation. Nat. Geosci. 14, 883–892. https://doi.org/10.1038/s41561-021-00852-8

Liu, S., C. Han and J.M. Liu 2020. Process optimization of potassium release from K–Feldspar by combining calcination and hydrothermal method. Chemistry Select. 5:522–527. doi: 10.1002/slct.201904278.

Nuanhchamnong, C., K. Kositkanawuth and N. Wantaneeyakul, 2022. Granular waterworks sludge-biochar composites: Characterization and dye removal application. Results in Engineering, 14, 100451. https://doi.org/10.1016/j.rineng.2022.100451

Niroula, A., S. Khatri1, R. Timilsina, D. Khadka, A. Khadka, and P. Ojha, 2019. Profile of chlorophylls and carotenoids of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) microgreens, J. Food Sci. Technol. 56 (5): 2758–2763.

Page, A.L., R.H. Miller, and D.R. Keeney, 1982. Methods of soil analysis, part 2. Chem. Microbiol. Prop. 2: 643–698

Pierre-Adrien, R., J. Dorina , N. Attila , M. András, B. Gyöngyi, U. Nikolett , R. Márk and F. Csilla, 2024. Short-term effects of compost amendments to soil on soil structure, hydraulic properties, and water regime .Journal of Hydrology and Hydromechanics. https://doi.org/10.3389/fsoil.2022.749212

Snedecor, G.W. and W.G. Cochran, 1982. Statistical Methods. 7th Edition, Iowa State University Press, Towa, 511.

Supraja, K.V., H. Kachroo, G. Viswanathan, V.K. Verma, B. Behera, et al., 2023. Biochar production and its environmental applications: recent developments and machine learning insights Bioresource Technology, 387, 129634. https://doi.org/10.1016/j.biortech.2023.129634

Wright, J., K. Scott , L. Bret 2022. Utilization of Compost as a Soil Amendment to Increase Soil Health and to Improve Crop yields. Open Journal of Soil Science ,12(6). DOI: 10.4236/ojss.2022.126009

Wu, Y., L. Li, X. Liu Y. Wang and M. Li, 2022. Decomposition of K-feldspar by potassium hydroxide solution in the hydrothermal system. Minerals Engineering, 178, 107392. https://doi.org/10.1016/j.mineng.2022.107392

Zhao, L., Z. Sun, C. Zhang, J. Nan, N. Ren, D. Lee, and C. Chen, 2022. Advances in pretreatment of lignocellulosic biomass for bioenergy production: challenges and perspectives Bioresour. Technol., 343, 123-126.