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Impact of Some Soil Amendments on Productivity and Insect Infestation of Cowpea under Water Stress in New Lands

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ABSTRACT

An urgent food security problem is emerging in Egypt caused by rapidly increasing food demand exacerbated by intensifying fresh water scarcity. Hence, the study objective is to enhance cowpea production by using soil amendments under water stress in new agricultural soil. In this study, different water stress regimes were applied and soil amendments (biochar and compost, and biochar and compost) with application rate of 2 ton/ feddan were used. The rice straw biochar (RSB) was synthesis by using the slow pyrolysis process and the compost (COM) was composted from agriculture waste. The characterizations of RSB and COM have been investigated. In addition, the experiment has been designed through two successive seasons 2021 and 2022 at the Shandweel Agricultural Research Station, Sohag, Egypt, for cultivating cowpea under a drip irrigation system with three replicates. During the experiments, insect infestation (*Aphis craccivora*, *Liriomyza trifolii* and *Empoasca decipiens*), some plant traits and soil properties were examined. The findings showed that cowpea production was significantly reduced as a result of water stress. In addition, using COM, RSB and COM+RSB can be alleviating the water stress impact on some plant and soil properties. Thence, the result leads to a preliminary recommendation for the use the mixture between biochar and compost to reduce the negative effect of water stress on cowpea and soil properties in new reclaimed soil. Thence, these amendments can be applied as a tool to suppress the populations of *A. craccivora*, *L. trifolii, and E. decipiens* in future cowpea IPM operations.

Keywords: cowpea, compost, biochar, insect, water stress.

1. Introduction

In Egypt, cowpeas (*Vigna unguiculata* L.) are one of the most commonly grown grain legumes. The two main elements that make cowpea plantations successful are fertilizer and irrigation, particularly in Egypt's sand-filled reclaimed soil areas. One of the main issues restricting crop production is a lack of water, which slows down plant growth and makes the cowpea crop less efficient at using water (Hayatu *et al*., 2014; El-kassas *et al*., 2017 and Geeth, 2019). As well as, plant–insect interactions are affect by environmental factors such as biotic and abiotic stresses, soil levels of various nutrients can have significant effects on pest infestation as indirect effects of the amounts of these nutrients in the plant (Facknath and Lalljee, 2005). Many authors demonstrated that the water regime affected on insect infestation (Çıkman and Civelek, 2006; Simpson *et al*., 2012 and Malik *et al*., 2013). In addition, water stress caused salinity increasing in soil and affected soil chemical and physical properties.

Different tools were used to overcome the yield reduction of cowpea and enhance soil properties under water deficit such as the application of biochar (Sohi *et al*., 2010; Pudasaini *et al*., 2016 and El-Hassanin *et al*., 2022) and compost (Davodi *et al*., 2020 and Doaa and Ashmawi 2022).

Biochar is produced by pyrolysis, thermal decomposition of biomass in partial or total absence of oxygen and at temperatures between 300 and 600°C.Any organic material such as bark, wood, crop residues or other waste of agricultural or livestock origin can be used for biochar production (Elsayed

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et al., 2021). Compost is commonly prepared by decomposing plant and food waste as plant fertilizer. Biochar and compost application positively improve soil properties and enhance cowpea productivity (Prapagdee and Tawinteung, 2017; Phares *et al.*, 2020 and Kannan *et al.*, 2021).

In addition to the effects of compost and biochar amendments on soil proprieties and crop yield, there are many observed effects on insect infestation (Shalaby *et al.*, 2012; Mogahed *et al.*, 2018; Waqas *et al.*, 2018; Chen *et al.*, 2019; Ullah *et al.*; 2019; Bakhat *et al.*, 2021; Chen *et al.*, 2020 and Mohamadou *et al.*, 2023). They suggested that the two soil amendments may due to inducing plant resistance. The unwise usage of pesticides and synthetic fertilizers considered as a major factors in environment deteriorating (Kaosol, 2009).

Therefore, the present work aimed to investigate the impact of compost and biochar as soil amendments on productivity and insect infestation of cowpea and soil properties under three water stress regimes in new lands.

2. Materials and Methods

2.1. Experimental design:

The experiment was done during 2021 and 2022 growing summer seasons by the cowpea cultivar Sakha 1 at Lysimeters of Shandweel Agricultural Research Station, Sohag, Egypt, (31 42 E, 26 33 N, and 61 maltitude). Sandy soil (87.6% sand, 8.2% silt, and 4.2% clay) was placed into lysimeters of 2.0 m x 1.0 m x 1.6 m, with the intention of simulating reclaimed soil. The study included 12 treatments, which were the combination between three water regimes and four soil amendments. Three stages of irrigation were included in the applied water schedule: deficit irrigation (75%) half-level irrigation (50%) and completely managed, non-stressed control (100%). For the growth seasons of 2021 and 2022, the ETo was calculated using information from the meteorological station owned by the Sohag Government. The ETo of the cowpea was then established using the CROPWAT model. A method was employed to calculate the irrigation needs (IR), or the volume of water required for crop (Ali *et al.,* 2023). In addition to control (mineral fertilization), three soil amendments were applied: compost, rice straw biochar, and a combination of the two. Three duplicates of each of the earlier treatments were placed in a split plot using a fully randomized block design. While the soil amendments were put at random in the sub plots, the main plots were utilized for water regimes. Each experimental unit has dimensions of 1 m wide by 2 m long. In both seasons, seeding took place on April 15th, with three seeds per hill spaced 15 cm apart. Plants/hills were created by thinning out seedlings. Throughout the duration of the trial, conventional agricultural methods were employed and no insecticidal treatments were applied.

2.2. Biochar production (RSB)

Rice straw was collected throughout the rice-harvesting season. The gathered straw was cleaned with tap water to get rid of any dust that stuck to it. Following washing, the rice straw was sun-dried and then ground into a fine powder using a standard commercial blender. Before being moved to a pyrolysis furnace that was heated by 5^{o} C min^{-1} to 350^{o} C under anaerobic conditions and then maintained for an hour until no more smoke exhaust was produced, the dried rice straw material was placed in tightly sealed containers to create an oxygen-limited environment during the biochar production (Reza *et al*., 2020). Following an hour, the pyrolysis furnace was let to cool to between 40 and 50 degrees Celsius before the produced biochar was collected and ground into tiny particles before applied. Table (1) explores the some properties of rice straw biochar (RSB).

Table 1: Physical and chemical properties of rice straw biochar (RSB) used in the experiment.

Item	pH	C%	H%	S%	O%	N%	K%	P%	WHC (g/g)	BET Surface Area (m^2/g)
Value	8.1	45.6	4.7	-	44.8	0.8	1.5	2.6	1.72	31.2

2.3. Compost production (COM)

In this study, compost material was created by composting a combination of different agricultural wastes and cattle dung over a period of 12 weeks. Table (2) displays the results of the compost's physical, chemical, and biological analyses. Raw materials' chemical and physical characteristics were ascertained (Black, 1965).

Table 2: Physical and chemical properties of compost (COM) used in the experiment.

Character	Unit	COM
	Physical analysis	
Density	kg/ m^3	594
Moisture content	%	17.7
Dry matter	%	82.3
pH (1:10)		7.51
EC (1:10)	dS/m	3.75
	Chemical analysis	
Ammonia	ppm	51.7
Nitrate	ppm	277.3
Total nitrogen	%	1.36
Organic matter	%	54.80
Organic carbon	%	31.78
Ash	%	45.20
C/N ratio		23.4 : 1
Total phosphorus	%	0.69
Total potassium	%	0.58

2.4. Collected data

2.4.1. Insect data

Cowpea plants were left for natural insect infestation. Samples started after two weeks from planting date (at the end of April), and then continued at weekly intervals to the end of both seasons of the study (at the end of August). For the leafhopper, *E. decipiens*, 10 randomly leaves per plot were examined in the field and the numbers of adults and nymphs were recorded. In regard to aphid, *A. craccivora* and leafminer, *L. trifolii*, ten randomly selected leaves from the bottom, middle, and upper levels of cowpea plants were used to create the samples. The samples were then transported in plastic bags to the laboratory, where the number of aphids and mines caused by leafminers were tallied.

2.4.2. Horticultural data

2.4.2.1. Stem length

To measure the stem length (in centimeters), ten randomly selected plants from each plot were sampled at the harvest time of each season.

2.4.2.2. The seed yield and its components

Ten plants were selected at random from each plot to serve as samples in order to count the quantity of seeds per pod, pod filling percentage (by dividing the number of seeds per pod by the length of the whole pod multiplied by 100), pod length (cm), the number of pods plant^{-1}, weight of 100 dry seeds (gm), and dry seed yield (kg) was calculated in both seasons.

2.4.3. Soil properties

Soil samples (0–30 cm depth) representing all treatments from the experimental site were obtained after soil preparation, prior to fertilization, and at harvest time in order to evaluate the impact of water stress on soil chemical characteristics under various experimental settings. The samples went through 2 mm sieve holes after being air dried. Several soil parameters, including pH, EC, and the principal cations and anions, were determined by analyzing soil sample data (Page *et al*., 1982).

2.5. Statistical analysis

All the collected data were analyzed using MSTAT-C computer software package. When 'F' value was significant, the least significant differences test (LSD) was used to compare means according to Gomez and Gomez (1984).

3. Results and Discussion

3.1. Insect infestation

The results in Table (3) represent the main influence of WR and soil amendments on infestation of cowpea plants with *A. craccivora*, *L. trifolii* and *E. decipiens* during the two growing seasons of 2021 and 2022. The differences between the three water regimes (50%, 75% and 100%) and between the four soil treatments (control, COM, RSB and COM +RSB) were significant in both seasons.

3.1.1. Impact of Water regimes (WR)

It is clear that the increase in water amount resulting increase in insect infestation by the three studied pests in both seasons. The lowest and the highest infestation were shown in WR 50% and WR 100%, respectively, in both seasons.

The infestation with *A. craccivora* decreased from 37.62 and 25.38 aphids/ 10 leaves in WR 100% at the two seasons, respectively, to 26.31 and 23.48 aphids/ 10 leaves in WR 75% at the two seasons, respectively, and 18.06 and 20.05 for cowpea plants irrigated by WR 50% recorded at the two seasons, respectively. Also, for *L. trifolii*, the cowpea plants irrigated by WR 100% recorded 5.15 and 3.78 mines/ 10 leaves at the two seasons, respectively, compared to 4.03 and 2.88 mines/ 10 leaves in WR 75% at the two seasons, respectively, and 2.62 and 2.05 mines/ 10 leaves in WR 50%, recorded at the two seasons, respectively. The same trend was obtained in regard to *E. decipiens*, the cowpea plants irrigated by WR 100% recorded 4.34 and 5.50 leafhoppers/ 10 leaves at the two seasons, respectively, compared to 3.59 and 5.00 leafhoppers/ 10 leaves in WR 75% at the two seasons, respectively, and 2.70 and 3.66 leafhoppers/ 10 leaves in WR 50% recorded at the two seasons, respectively.

Data illustrated in Figure (1) show that the infestation with *A. craccivora*, *L. trifolii* and *E. decipiens* were reduced by 36.49%, 47.45% and 35.62%, respectively, in cowpea plots irrigated with WR 50%, however, the reduction percentages of 18.78%, 22.85% and 13.19% were recorded in cowpea plots irrigated with WR 75% for the previous pests, respectively.

In the same line, Çikman and Civelek (2006) reported that the increasing in irrigation level increased the number of living *L. cicerina* larvae and adult on *Cicer arietinum* L. Simpson *et al.* (2012) found that the number of aphid, *Myzus persicae* Sulzer on cabbage plant was strongly and positively related to the soil moisture content. Also, Malik *et al.* (2013) showed that free amino acids and polyamine levels in Satsuma leaves differed significantly under water stress.

Table 3: Effect of water regimes and soil amendments on infestation with *A. craccivora*, *L. trifolii* and *E. decipiens* during 2021 and 2022 seasons.

Main effect	**Mean number/ 10 leaves**					
	A. craccivora		***L. trifolii* (mines)**		***E. decipiens***	
Season	**2021 season**	**2022 season**	**2021 season**	**2022 season**	**2021 season**	**2022 season**
Water regimes						
WR 50%	18.06	20.05	2.62	2.05	2.70	3.66
WR 75%	26.31	23.48	4.03	2.88	3.59	5.00
WR 100%	37.62	25.38	5.15	3.78	4.34	5.50
L.S.D. 0.05	7.0985	1.0054	0.4423	0.2336	0.3514	0.2838
Soil amendments						
Control	32.71	27.42	4.79	3.66	5.82	5.94
COM	23.22	19.50	3.82	2.71	3.24	4.60
RSB	27.44	21.87	3.54	2.62	2.62	4.18
COM+RSB	25.94	23.09	3.58	2.62	2.50	4.14
L.S.D. 0.05	2.4600	1.3462	0.3476	0.1148	0.2485	0.3589

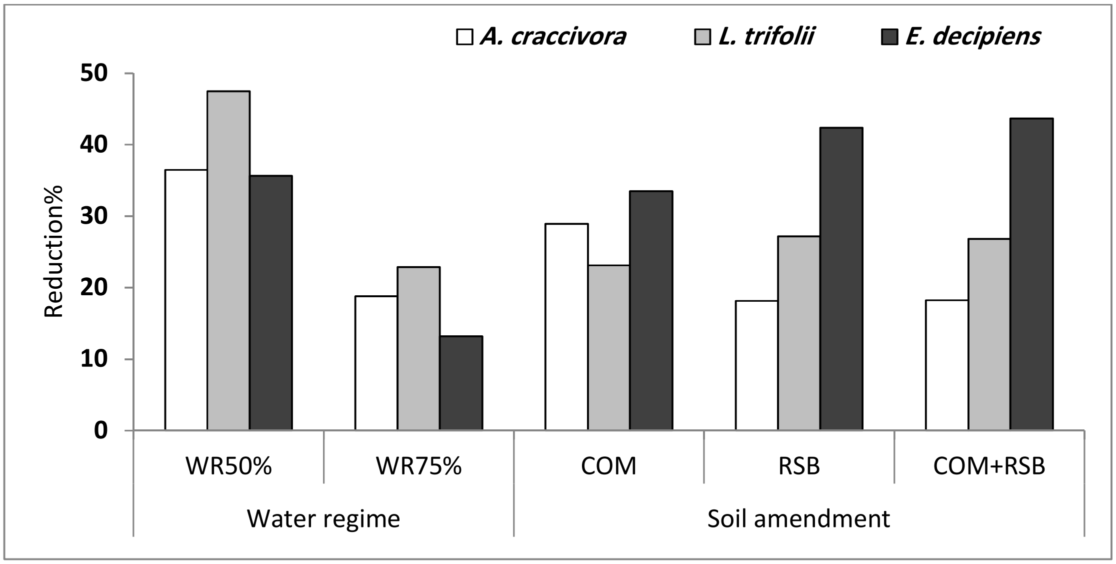

Fig. 1: Reduction percentage on *A. craccivora*, *L. trifolii* and *E. decipiens* infestation due to water regimes and soil amendments in average of both 2021 and 2022 seasons.

3.1.2. Impact of soil amendments

As shown in Table (3), when cowpea plants fertilized with the COM, RSB or mix of both them, the infestation with the three studied insect pests reduced significantly compared to control (mineral fertilization only) in the two studied seasons.

For *A. craccivora*, the lowest infestation was observed in COM plots with mean numbers of 23.22 and 19.50 aphids/ 10 plants in the two seasons, respectively, followed significantly by RSB with 27.44 and 21.87 aphids/ 10 plants in the two seasons, respectively, and COM+RSB with 25.94 and 23.09 aphids/ 10 plants in the two seasons, respectively, with insignificant differences between the last two. However, the highest infestation was observed in control with 32.71 and 27.42 aphids/ 10 plants in the two seasons, respectively.

For *L. trifolii*, control plots gave the highest mean number of mines of 4.79 and 3.66 mines/ 10 leaves in 2021 and 2022 seasons, respectively, however, cowpea plants fertilized with COM, RSB or mix of both them recorded 3.82, 3.54 and 3.58 mines/ 10 leaves, respectively in 2021 season, and 2.71, 2.62 and 2.62 mines/ 10 leaves, respectively in 2022 season, by insignificant differences between them in both seasons of the study.

In regard to *E. decipiens*, control plots gave the highest mean number of 5.82 and 5.94 leafhoppers/ 10 leaves in 2021 and 2022 seasons, respectively, however, cowpea plants fertilized with COM+RSB recorded the lowest mean number of 2.50 and 4.14 leafhoppers/ 10 leaves in 2021 and 2022 seasons, respectively, followed insignificantly by RSB with mean number of 2.62 and 4.18 leafhoppers/ 10 leaves in 2021 and 2022 seasons, respectively.

It is clear that the use of COM, RSB or COM+RSB can reduce *A. craccivora* infestation by 28.94%, 18.17% and 18.23%, respectively, *L. trifolii* infestation by 23.11%, 27.17% and 26.82%, respectively, and *E. decipiens* infestation by 33.49%, 42.39% and 43.67%, respectively (Figure 1).

In a similar way, Shalaby *et al*. (2012) found that compost tea reduced insect infestation when compared to the control, while Mogahed *et al.* (2018) discovered that soybean plants fertilized with a combination of COM and chemical fertilizer had a lower insect infestation than the control. Ullah *et al.* (2019) discovered that the application of various COM treatments reduced the incidence of citrus leafminer, *Phyllocnistis citrella*, when compared to the control.

Regarding biochar, Waqas *et al.* (2018) found that when *Sogatella furcifera* Horvath infested, rice plants acquired large quantities of jasmonic acid due to RSB. According to Chen *et al.* (2019), applying RSB amendments to soils decreased the *Sitobion avenae* aphid's ability to reproduce on wheat. This impact may have been caused by biochar treatments that induced plant defenses.

According to Chen *et al.* (2020), RSB dramatically decreased the infestation of brinjal by leafhoppers (*Amrasca biguttulabiguttula* (Ishida)). This might be explained by plants absorbing silicon more effectively. According to Bakhat *et al.* (2021), RSB amendments reduce the effectiveness of stylet penetration activities on host plants, potentially due to changes in the host's nutrient contents. This has an impact on the feeding habits of aphids, *Sitobion avenae* on wheat, and planthoppers, *Laodelphax striatellus* on rice.

3.1.3. Interaction between water regimes and soil amendments effects

Data in Table (4) indicated that the interaction between the three soil amendments and the four water regimes was significant in both seasons for *A. craccivora* and *E. decipiens*, however, it was insignificant in regard to *L. trifolii* in both seasons of the study.

Control plots (mineral fertilization only) irrigated with WR 100% with suffered the highest infestation by *A. craccivora* with mean numbers of 46.42 and 31.63 aphids/ 10 leaves in 2021 and 2022 seasons, respectively, and by *E. decipiens* with mean number of 7.30 leafhoppers/ 10 leaves in both seasons.

Plots fertilized with COM under WR 50% regime gave the lowest mean numbers of 16.05 and 16.92 aphids/ 10 leaves in the two seasons respectively, followed insignificantly by RSB and COM+RSB in both seasons and second seasons, respectively, under the same regime. For *E. decipiens*, COM+RSB (1.93 and 3.45 leafhopper/ 10 leaves in the two seasons, respectively) and RSB (1.95 and 3.25 leafhopper/ 10 leaves in the two seasons, respectively) under WR 50% regime recorded the lowest infestation in 2021 and 2022 seasons, respectively, with insignificant differences between them on side and with COM (2.35 and 3.43 leafhopper/ 10 leaves in the two seasons, respectively) under the same regime on the other side.

Our results in partial agreement with Inbar *et al.* (2001) who reported that leafminer feeding and oviposition rates were higher on tomato plants treated with optimum water and fertilization, they suggested that may due to negative association between plant growth and chemical defense.

Table 4: Effect of the interaction between water regimes and soil amendments on infestation with *A. craccivora*, *L. trifolii* and *E. decipiens* during 2021 and 2022 seasons.

Water regime	Soil amendments	Mean number/ 10 leaves					
		A. craccivora		*L. trifolii* (mines)		*E. decipiens*	
		2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
WR 50%	**Control**	21.88	23.82	3.37	2.70	4.57	4.50
	COM	16.05	16.92	2.42	1.90	2.35	3.43
	RSB	17.85	18.15	2.28	1.75	1.95	3.25
	COM+RSB	16.47	21.32	2.42	1.85	1.93	3.45
WR 75%	**Control**	29.83	26.80	4.68	3.73	5.60	6.03
	COM	24.07	20.60	3.88	2.60	3.43	4.95
	RSB	26.45	22.87	3.80	2.55	2.65	4.63
	COM+RSB	24.88	23.65	3.73	2.63	2.68	4.37
WR 100%	**Control**	46.42	31.63	6.33	4.53	7.30	7.30
	COM	29.55	20.98	5.15	3.63	3.93	5.42
	RSB	38.03	24.58	4.55	3.57	3.25	4.65
	COM+RSB	36.48	24.32	4.58	3.38	2.88	4.62
L.S.D. 0.05		**4.2609**	**2.3317**	**-----**	**-----**	**0.4304**	**0.6216**

3.2. Horticultural Data

3.2.1. Water regimes effects (WR)

Data are presented in Table (5) showed that increasing water regimes (WR) from 50% to 100% was an increase in all studied traits of cowpea plants. The full irrigation treatment 100% lead to the maximum increases in stem length (36.46 and 39.33 cm), pod length (15.71 and 16.29 cm), pod filling % (55.55 and 57.18 %), number of seeds pod^{-1} (8.75 and 9.33 seeds), number of pods plant^{-1} (19.54 and 22.00 pods), weight of 100 dry seeds (23.89 and 25.41 gm) and dry seed yield fed^{-1} (883.02 and 895.48

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Table 5: Effect of the water regimes (WR) and soil amendments on stem length, pod length, number of seeds pod^{-1}, pod filling %, dry 100 seeds weight, number of pods plant^{-1} and weight of dry seed yield (kg fed^{-1}) in cowpea during 2021 and 2022 summer seasons

Traits	Stem length		Pod length		No. of seeds pod^{-1}		Pod filling %		Dry 100 seeds wt.		No. of pods plant^{-1}		Dry seed yield (kg fed^{-1})	
Season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
Water regimes														
WR 50%	27.31	28.92	11.83	13.17	5.38	6.25	44.95	47.26	20.32	21.36	8.83	10.63	290.47	301.55
WR 75%	33.63	36.67	14.00	15.67	6.67	7.54	47.63	48.00	23.02	23.73	17.58	19.75	781.658	795.417
WR 100%	36.46	39.33	15.71	16.29	8.75	9.33	55.55	57.18	23.89	25.41	19.54	22.00	883.02	895.48
L.S.D. 0.05	0.84	0.75	0.77	0.77	0.25	0.23	3.00	0.96	0.39	0.90	1.14	0.77	25.18	25.83
Soil amendments														
Control	27.17	30.89	12.33	13.89	5.67	6.56	45.20	46.70	20.04	21.77	13.67	15.83	576.59	589.02
COM	37.67	40.39	13.72	15.11	7.22	8.00	51.58	52.32	22.54	23.58	15.22	17.89	669.01	681.54
RSB	31.03	32.61	13.67	14.44	7.11	7.78	51.63	53.86	22.34	23.04	14.83	16.67	615.23	626.98
COM+RSB	34.00	36.00	15.67	16.72	7.72	8.50	49.10	50.36	24.73	25.51	17.56	19.44	746.02	759.06
L.S.D. 0.05	0.88	0.50	0.52	0.31	0.32	0.33	2.70	2.11	0.35	0.47	0.65	0.44	19.66	19.56

kg) in both seasons, respectively. The treatment of WR 75% was significant increases as compared with WR 50% in all traits except pod filling during 2021 and 2022 summer seasons.

Increased water stress levels may have a detrimental impact on stem length, branches number, dry weight per plant and pod number which could explain the decline in dry seed production and all of its components. (Gheeth, 2019) Water scarcity is one of the main biotic stresses that negatively impacts plant growth and output, according to Abdul-Jaleel *et al.* (2009). The aforementioned modifications primarily pertain to modifications in metabolic processes, outcomes stemming from heightened floral abscission rates, and pod abortion-related factors like decreased synthesis of photosynthetic pigments. Consequently, the degree of variation in photosynthetic pigment synthesis is intimately linked to the biomass yield of plants. On the other hand, the fact that irrigation water is an essential part of plant life may account for the increase in vegetative growth characteristics with higher irrigation treatments. Thus, the presence of sufficient soil moisture provided a good supply of irrigation water, improved the characteristics of plant roots, and temperature positively enhanced plant physiological and biochemical activities, increasing the availability, absorption, and utilization of important nutrients, all of which led to an increase in plant growth (Eldewini *et al.*, 2023).

3.2.2. Soil amendments effect

It is clear from the data found in Table (5) that all soil amendments significantly increased all traits under investigation in two summer seasons in comparison to the control treatment. In addition to treating cowpea with COM produced the longest plants of the study (37.67 and 40.39 cm), while the treatment of RSB showed the highest values of pod filling percentage (51.63 and 53.86%) with no significant difference between it and the treatment of COM (51.58 and 52.32 %) for the 1st and 2nd seasons, respectively. COM+RSB showed the highest significant effects on dry seed yield (746.02 and 759.06 kg fed^{-1}) , pod length (15.67 and 16.72 cm), number of seeds pod^{1} (7.72 and 8.50 seeds), weight of 100 dry seeds (24.73 and 25.51 gm) and number of pods $plant^{-1}$ (17.56 and 19.44 pods) of cowpea plants in both seasons, respectively. Thus this study clearly brought out that soil amendments COM, RSB and COM+RSB play a crucial role in increasing the dry seed yield and its components in two summer seasons. The reason for this is that applying organic matter increases the cation exchange capacity, which in turn causes nutrients to be absorbed more readily and reduces nutrient losses. Nutrients are released gradually when organic matter is applied. As a result, plant nutrients will be available for a long time and in sufficient quantities. This will allow the plant to absorb the necessary nutrients in accordance with its needs, leading to improved components of yield, growth and development. The incorporation of organic matter enhances the structure, porosity, water-holding capacity, bulk density, and chemical properties of the soil, including accessible nutrients and soil organic carbon. All of these consistently support crop growth, yield, and soil health (Fazulla *et al*., 2017).

3.2.3. Interaction between water regimes and soil amendments effects

Regarding to the effect of the interactions between soil amendments and water regimes of the cowpea plants on stem length, dry seed yield and its components, the results at Table (6) and Fig. (2) indicate that the interaction between the COM+ RSB treatment with the WR 100% had the superior effect on most traits i.e. pod length (17.67 and 18.17 cm), weight of 100 dry seeds (26.52 and 28.26 gm), number of pods $plant^{-1}$ (22.00 and 23.67 pods) and dry seed yield (990.50 and 1003.43 kg fed^{-1}) in the two summer seasons, respectively, comparing with the other interactions. While, the soil amendment of COM with WR 100% recorded the best values of stem length (43.00 and 46.00 cm), pod filling percentage (63.53 and 61.15%) in the 1st and the 2nd season, respectively. This may be an indication of the beneficial effects of soil organic amendments like COM and RSB combined with soil moisture on the roots' ability to absorb nutrients and distribute them throughout the cowpea plant.

Table (6) displays data indicating significant effects between the interactions among the COM+ RSB treatment with WR 75% and between control treatment with WR 100% of pod length, weight of 100 seeds, number of pods $plant^{-1}$ and dry seeds yield fed^{-1} in both seasons and stem length in the first season. In addition to significant effects among the interactions of COM treatment with WR 75%, and between control treatment with WR 100% on stem length and weight of 100 seeds in both seasons and pod length in the second season. Additionally, a significant difference was found between interaction the RSB and the WR 75 % and between control treatment with WR 100 % of stem length in both seasons

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Table 6: Effect of the interaction between water regimes and soil amendments on stem length, pod length, number of seeds pod^{-1}, pod filling %, dry 100 seeds weight, number of pods plant^{-1} and weight of dry seed yield (kg fed^{-1}) in cowpea during 2021 and 2022 summer seasons

Water regime	Soil amendments	Stem length		Pod length		No. of seeds pod^{-1}		Pod filling %		Dry 100 seeds wt.		No. of pods plant^{-1}		Dry seed yield (kg fed^{-1})	
		2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
WR 50%	Control	25.00	26.00	11.00	12.00	4.00	5.00	36.01	41.39	18.04	20.19	7.67	9.17	249.80	260.07
	COM	29.00	31.17	12.00	13.00	5.00	6.00	41.39	45.94	20.52	21.21	8.00	10.33	284.17	295.23
	RSB	28.25	29.50	11.33	12.67	6.00	7.00	52.80	55.18	21.11	21.66	9.00	10.00	266.37	277.33
	COM+RSB	27.00	29.00	13.00	15.00	6.50	7.00	49.60	46.51	21.61	22.38	10.67	13.00	361.53	373.57
WR 75%	Control	28.00	33.00	12.00	14.33	6.00	7.00	49.77	48.72	20.46	22.04	15.67	18.00	701.40	715.17
	COM	41.00	44.00	14.00	16.00	7.00	8.00	49.83	49.87	23.09	24.20	18.00	20.67	798.33	811.77
	RSB	32.50	35.33	13.67	15.33	6.33	7.00	45.95	45.56	22.47	22.78	16.67	18.67	740.87	754.57
	COM+RSB	33.00	34.33	16.33	17.00	7.33	8.17	44.98	47.86	26.06	25.88	20.00	21.67	886.03	900.17
WR 100%	Control	28.50	33.67	14.00	15.33	7.00	7.67	49.83	50.00	21.61	23.06	17.67	20.33	778.57	791.83
	COM	43.00	46.00	15.17	16.33	9.67	10.00	63.53	61.15	24.01	25.63	19.67	22.67	924.53	937.63
	RSB	32.33	33.00	16.00	15.33	9.00	9.33	56.13	60.83	23.43	24.67	18.83	21.33	838.47	849.03
	COM+RSB	42.00	44.67	17.67	18.17	9.33	10.33	52.72	56.72	26.52	28.26	22.00	23.67	990.50	1003.43
L.S.D. 0.05		1.52	0.87	0.89	0.54	0.55	0.57	4.68	3.65	0.61	0.82	1.13	0.77	34.06	33.88

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and weight of 100 seeds in the first season. However, revealed the data in the same table that no significant effects between the interaction with the COM treatment with WR 75%, and between control treatment with WR 100% on number of pods plant^{-1}, number of seeds pod^{-1} and dry seeds yield fed^{-1} in both studied seasons. According to Zhang *et al*. (2014), RSB improved soil moisture and significantly raised soil microbial activity, both of which have an impact on the decay of soil organic matter. The addition of RSB to soil results in higher levels of organic matter and carbon/nitrogen (C/N) ratios, both of which improve soil fertility (Ingold *et al*., 2015).

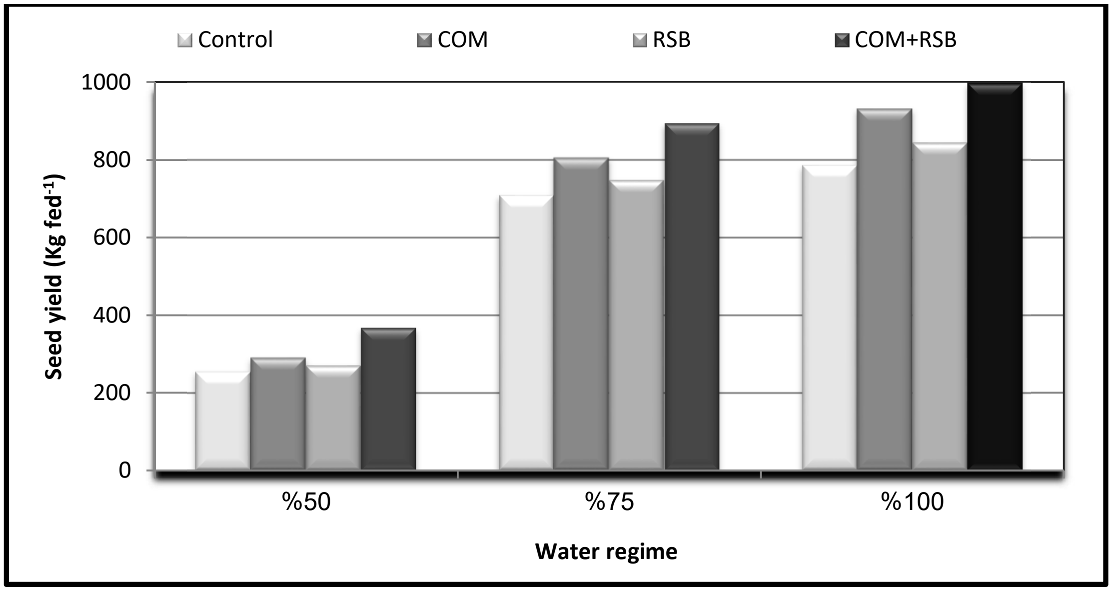

Fig. 2: Dry seed yield (kg fed^{-1}) as affected by the interaction between water regimes and soil amendments on cowpea plants as the average of 2021 and 2022 summer seasons.

3.3. Soil properties

Water stress had a significant influence on soil characteristics; however, because drip irrigation is an efficient method and soil supplements have a high water-holding capacity, utilizing them in conjunction with a drip irrigation system might lessen the impact of water stress on soil properties and plant output. Water stress has a highly significant impact on EC, soil organic matter, major cations, and anions, but has a small influence on pH, according to Table 7 data, which show soil attributes in both seasons. Water stress therefore adversely affects the chemical characteristics of soil (Parvaiz and Satyawati, 2008).

However, soil amendments have an impact on the physical and chemical characteristics of the soil. The hydrological properties of soil, such as its moisture content, water holding capacity, water retention, hydraulic conductivity, and water infiltration rate, are greatly influenced by COM and RSB. These properties are inextricably linked to bulk density, surface area, porosity, and aggregate stability. Furthermore, the addition of soil amendments resulted in a rise in the following soil parameters: pH, CEC, organic carbon, accessible P, C, N, and K. Increases in CEC values (Liang *et al.*, 2006); cations adsorption (Freddo *et al.*, 2012); and control of polluted organic and inorganic chemicals in soil are possible mechanisms by which COM and RSB have a positive impact on soil chemical characteristics (Ogbonnaya and Semple, 2013).

Additionally, as Table (7) illustrates, the combination of RSB and COM has a greater favorable impact on the chemical characteristics of soil. The results in Table (7) showed that the treatment had a highly significant effect on the characteristics of the soil at harvest. Additionally, because of their capacity to adsorb water molecules through their functional groups, COM and RSB have a significant impact on the availability of nutrients N, K, and P in both normal and water-stressed conditions. Accordingly, the negative impact of water stress on soil production was lessened by COM and RSB (Gunarathne *et al*., 2020).

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Table 7: Some properties of soil samples under study season 2021 and 2022

Season	Water regime	Soil amendments	OM	pH	EC	meq/L							P g/kg	K g/kg	N g/kg
						Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{3-}	Cl^{-}	SO_4^{2-}			
2021	WR 50%	Control	0.23	7.9	1.45	2.15	0.64	10.75	1.40	4.10	8.04	2.95	6.00	14.7	12.50
		COM	0.52	7.9	1.40	2.10	0.60	10.30	1.40	4.00	8.03	2.50	6.50	18.50	14.80
		RSB	0.60	8.0	1.50	2.20	1.10	10.90	3.70	4.15	8.60	3.10	7.00	20.80	17.50
		COM+RSB	0.62	7.9	1.45	2.15	0.60	10.75	1.40	4.10	8.04	2.95	7.50	21.50	18.50
	WR 75%	Control	0.23	7.9	1.42	2.10	0.63	10.50	1.42	4.07	8.02	2.60	6.00	14.4	12.00
		COM	0.54	7.8	1.39	2.08	0.59	10.20	1.39	4.00	8.00	2.55	7.20	19.9	15.20
		RSB	0.61	7.9	1.44	2.22	0.64	10.60	1.5	4.07	8.10	2.80	7.30	21.85	17.50
		COM+RSB	0.64	7.9	1.43	2.2	0.62	10.45	1.45	4.1	8.12	2.62	7.60	22.00	18.50
	WR 100%	Control	0.24	7.9	1.30	1.50	0.70	9.90	1.30	3.80	7.70	2.20	5.80	18.50	16.10
		COM	0.55	7.8	1.29	1.49	0.65	9.90	1.28	3.70	7.70	2.20	6.8	19.90	17.6
		RSB	0.65	7.9	1.35	2.00	0.65	10.75	1.30	3.60	7.20	2.80	7.50	22.20	18.2
		COM+RSB	0.68	7.8	1.32	1.55	0.72	9.95	1.32	3.85	7.72	2.25	8.00	22.7	19.50
	F test 0.05		*	NS	*	*	**	**	**	NS	**	*	*	*	*
2022	WR 50%	Control	0.21	7.8	1.40	2.10	0.60	10.30	1.40	4.00	8.03	2.50	6.42	15.70	13.40
		COM	0.54	7.7	1.38	2.06	0.55	10.10	1.35	3.85	7.90	2.50	6.45	19.80	15.90
		RSB	0.64	7.9	1.42	2.10	0.60	10.30	1.40	4.00	8.03	2.50	7.49	22.30	18.70
		COM+RSB	0.66	7.8	1.40	2.10	0.60	10.30	1.40	4.00	8.03	2.50	8.00	23.00	19.80
	WR 75%	Control	0.21	7.8	1.38	2.05	0.54	10.10	1.35	3.85	7.90	2.50	6.40	15.40	12.80
		COM	0.56	7.8	1.36	2.00	0.50	9.95	1.30	3.80	7.80	2.40	7.70	21.30	16.30
		RSB	0.63	7.9	1.40	2.10	0.59	10.32	1.40	4.00	8.03	2.50	7.80	23.40	18.70
		COM+RSB	0.67	7.9	1.39	2.07	0.58	10.29	1.41	3.95	8.00	2.45	8.10	23.54	19.80
	WR 100%	Control	0.22	7.9	1.32	1.55	0.65	9.95	1.32	3.90	7.80	2.30	6.20	19.80	17.20
		COM	0.58	7.7	1.28	1.47	0.62	9.80	1.90	3.70	7.65	2.10	7.30	21.30	18.80
		RSB	0.68	7.9	1.33	1.56	0.67	10.00	1.34	3.95	7.82	2.35	8.10	23.75	19.50
		COM+RSB	0.71	7.9	1.31	1.54	0.64	9.90	1.32	3.90	7.80	2.30	8.60	24.30	20.90
	F test 0.05		*	NS	NS	*	**	NS	*	NS	NS	*	*	**	*

4. Conclusion

Our findings generally showed that, when cowpea plants were irrigated by WR of 75% with COM or COM+RSB applied, the seeds yield increased by 2.53% and 13.74 %, on average, over the course of two seasons, respectively, compared to the control treatment with WR of 100%. This resulted in a 25% reduction in irrigation water consumption. From the previous results, it could be recommended to use COM or RSB as soil amendments to enhance cowpea yield and yield components. Also, these fertilizers can be used in future cowpea IPM programs as a tool to suppress the *A. craccivora*, *L. trifolii* and *E. decipiens* populations.

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