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RESEARCH PAPER

Impact of organic amendments (vermicompost and fermented cow manure) on managing corn stalk rot disease caused by *Fusarium incarnatum*

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ABSTRACT

This study investigated the efficacy of organic amendments, specifically vermicompost (V) and fermented cow manure (C), at application rates of 625 and 1250 kg/dunam, in managing corn stalk rot disease caused by *Fusarium incarnatum*. Maize (*Zea mays* L.) is a globally vital crop, making the study of its diseases, such as stalk rot, essential for ensuring food security. Field experiments were conducted on five hybrid corn varieties (DKc6664, DKc6777, GS235982, GS235772 and 2341.Rayal) during the spring season of 2024 in Baghdad, Iraq. The results demonstrated that higher application rates (V. 1250 and C. 1250) significantly reduced disease severity and improved plant growth parameters, including plant height, vegetative mass, and yield components. Vermicompost at 1250 kg/dunam (V. 1250) was particularly effective in reducing disease severity in DKc6664 (16.67%) and DKc6777 (16.67%), while fermented cow manure at 1250 kg/dunam (C. 1250) enhanced root development and seed weight in DKc6777. In contrast, *F. incarnatum* inoculation consistently increased disease severity across all varieties, with the highest severity observed in GS235982 (91.61%). These findings highlight the potential of organic amendments, especially at higher application rates, to improve corn productivity and manage stalk rot disease, even under pathogen pressure.

Key words: disease management, maize stalk rots, organic amendments.

INTRODUCTION

Corn (*Zea mays* L.) is an essential crop for human nutrition, animal feed, and industrial application. In Iraq, maize cultivation covered approximately 88,812 ha in 2023, yielding 580,000 tons annually (FAO, 2024). During the growing season, several common fungal infections inflict substantial harm worldwide (Kenganal et al., 2017; Bawa, 2021; Pfordt & Paulus, 2025). Among these, corn stalk rots are particularly prevalent, occurring with varying degrees of severity each year. Plant pathogenic organisms, especially fungi, are the primary causal agents (Asiedu et al., 2024).

These diseases weaken the vascular tissues in corn stalks, impairing efficient water and nutrient transport (Song et al. 2024). Consequently, they cause premature plant death and reduced grain fill (Jian et al., 2024). Signs and symptoms of stalk rot typically do not appear until late in the season. Stalk rot is a severe disease in corn, characterized by brown streaks in the lower internodes, slowed growth, and rotting of leaf sheaths and internal stalk tissues (Han et al., 2023; Harish et al. 2023). The internal pith tissues of mature stalks become discolored, ranging from pink to salmon-pink (Shaner & Scott, 1998; Oldenburg et al., 2017).

Fusarium stalk rot is one of the most common forms of the disease, primarily caused by *Fusarium* spp. This fungus infects leaf nodes, roots, and stalks, and it is also responsible for Fusarium ear rot. Several *Fusarium* species are capable of causing stalk rot (Shin et al. 2014). The disease most frequently occurs during hot, dry years. The fungus is widespread and may even be present in otherwise healthy stalks, but infection progresses to rot only under favorable conditions. Proper soil drainage, adequate nutrient levels, and recommended planting densities help reduce plant stress (Song et al. 2024). These practices, combined with hybrids possessing partial resistance, can lower the incidence of corn stalk rot and support stronger stalk development. However, most genetic resistance in modern hybrids is specific to particular stalk rot pathogens (Asiedu et al. 2024).

Fermented cow manure, widely used in organic farming, contains beneficial microorganisms that act as biocontrol agents against plant pathogens such as

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Rhizoctonia bataticola, which causes root rot and wilt in corn (Radha & Rao, 2014). Its application enhances nutrient availability—particularly phosphorus—in the rhizosphere, improves uptake by plants, and stimulates the activity of beneficial microorganisms in seedlings (Fan et al., 2023).

Vermicompost has also been shown to mitigate drought stress, enhance plant growth, and improve resistance to soil-borne pathogens compared with untreated plants (Hodson et al., 2023). In addition, it improves plant anatomical features, such as increasing the thickness of the epidermis, cortex, and cambium ring, thereby enhancing resistance to pathogenic infections (Al-Enezi & Jamil, 2023; Al-Hlfie & Hussein, 2024). Using soil organic amendments, such as vermicompost, manure, and compost is a sustainable strategy for suppressing soil-borne pathogens, imporoving soil health, and enhancing crop yeilds (Naghman et al., 2023).

Therefore, this study aimed to evaluate the efficacy of organic amendments (vermicompost and fermented cow manure) in protecting corn plants from stem rot disease and to characterize the causative fungus both morphologically and molecularly.

MATERIALS AND METHODS

Corn Plant Materials and Isolation of *Fusarium* Species. Corn roots exhibiting symptoms of stalk rot were collected from corn fields in Baghdad Province, Iraq, during 2023 and 2024. Samples were transported to the laboratory in plastic bags, washed thoroughly with tap water, and cut into 5-mm pieces. Roots were surface-sterilized with 70% ethanol for 1 min, followed by 1% sodium hypochlorite for 5 min, and rinsed three times with sterile distilled water. The root pieces were individually placed on potato dextrose agar (PDA; prepared by dissolving 39 g of commercial PDA powder in 1 L of distilled water, autoclaved at 121 ºC for 15 min, and poured into sterile Petri dishes under laminar flow), amended with streptomycin (50 µg/mL), and incubated at 25 ºC for three days. The spore-streak plate method was employed by spreading spores on PDA plates, followed by incubation at 25 ºC. After 24 h, a single germinated spore was transferred to a fresh plate using a sterile needle. *Fusarium* isolates were stored at 4 ºC for further use in this study.

Morphological and Cultural Characteristics of *Fusarium* spp. Identification of *Fusarium* species was performed according to Leslie & Summerell (2008) and included: (i) microscopic examination of macroconidia morphology (dimensions, curvature, and septation patterns at 400× magnification), (ii) analysis of microconidia production (conidiophore type), and (iii) cultural characterization on PDA (growth rate, pigmentation, and colony morphology) after 7 days of incubation at 25 ºC under alternating light/dark cycles.

Pathogenicity Test of *Fusarium* spp. on Sorghum Seeds. Pathogenicity tests were conducted on local sorghum seeds. Water agar (WA) was sterilized and and poured into Petri dishes. WA plates were inoculated with Fusarium isolates and incubated at 25 ºC for three days. Sorghum seeds were surface-sterilized with 1% sodium hypochlorite, rinsed with sterile water, and air-dried. Ten seeds per plate were placed 1 cm from the edge of the fungal colony, with three replicates per isolate. Control dishes included plates containing only the pathogen or only seeds. Plates were incubated until seeds in the control dishes germinated. Germination percentage was calculated using the following formula (Gunasinghe et al., 2024):

$$G\ (\%) = \frac{n}{N} \times 100$$

G = Germination (%);
n = Number of sprouted seeds;
N = Total number of seeds.

Molecular Identification of *Fusarium* spp. The ITS region was used for molecular identification. Isolates were grown on PDA for five days to obtain mycelia, which were scraped into 2-mL tubes for DNA extraction following the methods of White et al. (1990) and Kareem et al. (2020). DNA quantity and quality were assessed using a NanoDrop spectrophotometer. The ITS region was amplified using primers ITS1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS4 (5'-TCCTCCGCTTATTGATATGC-3') in a 50-µL reaction mixture with Pfu DNA polymerase (Elpis, Daejeon, Korea) (Taha et al., 2023; Kakakhan & Shekhany, 2023). PCR products were purified and sequenced by Macrogen Inc. (Daejeon, Korea). Sequences (~500 bp) were analyzed using BLAST in the NCBI database. Reference sequences included Fusarium incarnatum isolates from India (MT367538, MW850464), Egypt, South Korea, Thailand, Mexico, Basra (southern Iraq), and Sulaymaniyah (northern Iraq) (MN480497, MF373444, KT587650, OR707898, MK174967, LC769967, OQ408107). ITS sequences were aligned using ClustalW in MEGA 7, and phylogenetic analysis was performed using the neighbor-joining method with 1000 bootstrap replicates.

Field Experiment. The field experiment was conducted at the Plant Protection Department Station B (33.31°N, 44.36°E), College of Agricultural Engineering, University of Baghdad, during the spring 2024 season. The study evaluated the efficacy of vermicompost and fermented cow manure, applied separately at two rates (625 and 1250 kg/dunam), in protecting corn against stalk rot and assessed the susceptibility of five hybrid cultivars: 2341.Rayal – Syngenta, DKc6664 – Syngenta, DKc6777 – Syngenta, GS235982 – Gentex Seeds, and GS235772 – Gentex Seeds.

A randomized complete block design (RCBD) with three replications was implemented in clay loam soil (pH 7.2). The field was plowed, leveled, and divided into three main blocks, each subdivided into six plots (2.5 m × 10 m) with 1-m buffer zones. Corn seeds were sown in rows spaced 25 cm apart (inter-row) and 20 cm within rows (intra-row). For pathogen inoculation, conidia from 7-day-old PDA cultures were suspended in sterile distilled water at 1×10^6 conidia/mL. Seeds were surface-sterilized and immersed in the conidial suspension for 30 min with intermittent agitation every 5 min. A non-inoculated control was maintained with sterile distilled water.

Standard agronomic practices were followed. Data were collected on germination percentage (30 days), plant height (end of season), SPAD chlorophyll (V6 stage), disease incidence/severity (0–4 scale), and yield components (kernels per ear). Statistical analysis was conducted using SAS 9.4 with two-way ANOVA and Tukey's HSD test ($P \leq 0.05$), with arcsine transformation applied to percentage data.

RESULTS AND DISCUSSION

Isolation of *Fusarium* Species. Seventeen *Fusarium* isolates were obtained from corn plants exhibiting symptoms of stalk rot in Baghdad Province during the 2023–2024 agricultural season. These plants showed symptoms including stalk and root rot, wilting, stunting, and leaf necrosis (Figure 1). The isolation of seventeen *Fusarium* strains aligns with findings by Kakakhan & Shekhany (2023), who documented *Fusarium* diversity in Iraqi corn fields. The observed symptomatology—wilting, stunting, and necrosis—corresponds with pathogenic mechanisms described by Al-Enezi & Jamil (2023).

Morphological and Cultural Characteristics of *Fusarium* spp. The *Fusarium* isolates exhibited mycelial growth with white to pink colonies and distinctive yellow reverse pigmentation on PDA at 25 ºC after six days. Two distinct conidial types were observed: (1) unicellular, hyaline microconidia (9–11 × 3–4 µm) with 0–1 septa, and (2) hyaline macroconidia (27–30 × 3–5 µm) with 4–5 septa. Macroconidia displayed characteristic curvature with tapering apical cells and foot-shaped basal cells, consistent with *F. incarnatum* morphology (Figure 2). These features are in agreement with descriptions by Ofi et al. (2023), supporting the identification of these isolates as *F. incarnatum*.

Pathogenicity Test of *Fusarium incarnatum* on Sorghum Seeds. Pathogenicity assays under in vitro conditions demonstrated significant variation among *F. incarnatum* isolates (Figure 3). Isolates FI 10c, FI 10b, and FI 14a exhibited the lowest germination rates at 20%, 25%, and 25%, respectively (Figure 4), significantly lower than other isolates. These differences in pathogenicity likely reflect genetic variability among isolates, influencing their ability to infect sorghum seeds (Gunasinghe et al., 2024). Highly aggressive isolates may produce more potent cell-wall degrading enzymes or mycotoxins, as reported for maize stalk rot (Harish et al., 2023; Oldenburg et al., 2017).

Molecular Identification Phylogenetic Analysis of *Fusarium* spp. DNA extracted from the isolates

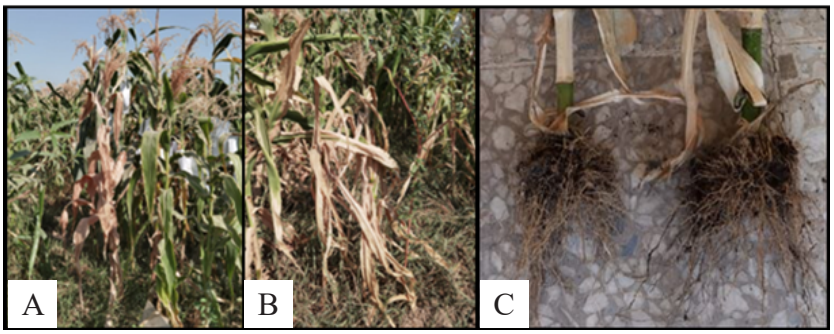

Figure 1. Symptoms of corn stalk and root rot disease. A–B. Wilting, stunting, and leaf death in corn plants; C. Root rot.

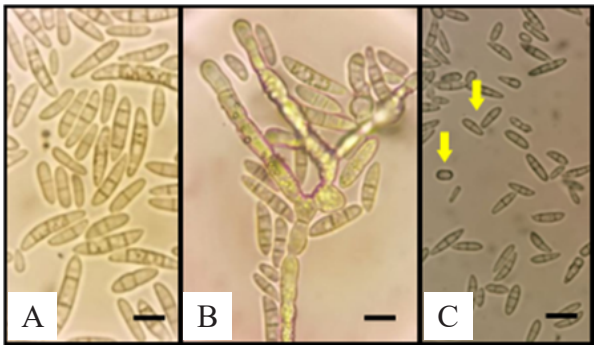

Figure 2. Morphological characteristics of *Fusarium incarnatum*. A. Macroconidia; B. Polyphialides; C. Microconidia. Scale bar = 10 µm.

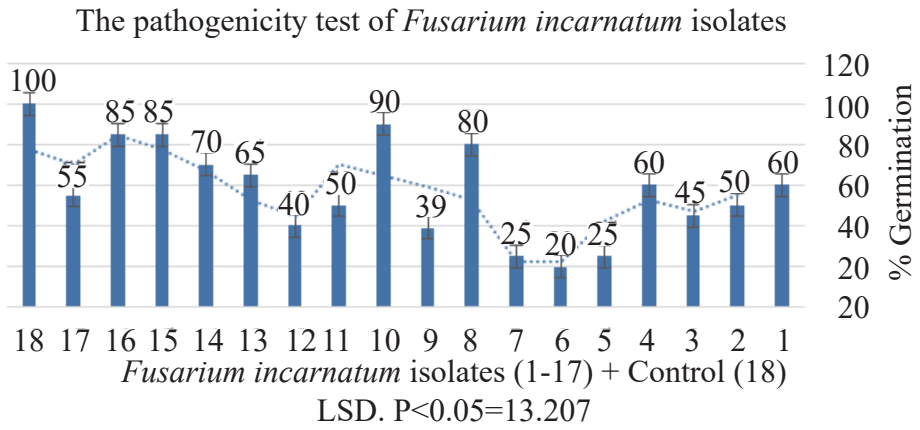

Figure 3. Pathogenicity test of *Fusarium incarnatum* isolates on sorghum seeds on WA medium.

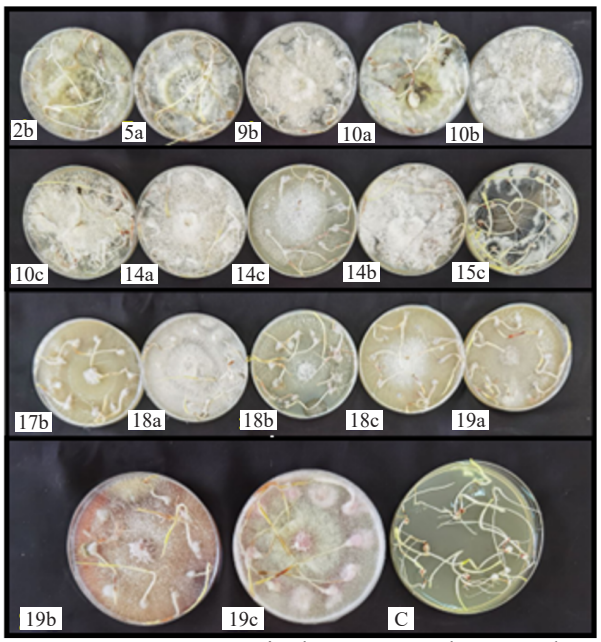

Figure 4. Pathogenicity test of *Fusarium incarnatum* isolates on sorghum seeds on WA medium. 1–17. *Fusarium incarnatum* isolates. C. Sorghum seed control.

was used to amplify the ITS region. BLAST analysis identified all isolates as *F. incarnatum*, suggesting it is primarily responsible for stalk rot in Baghdad corn fields. Phylogenetic analysis (Neighbor-Joining method; Figure 5) showed genetic affinity among the Baghdad isolates (FI 10c, FI 10b, FI 14a) and reference *F. incarnatum* sequences from GenBank, indicating a common ancestral origin. Significant divergence

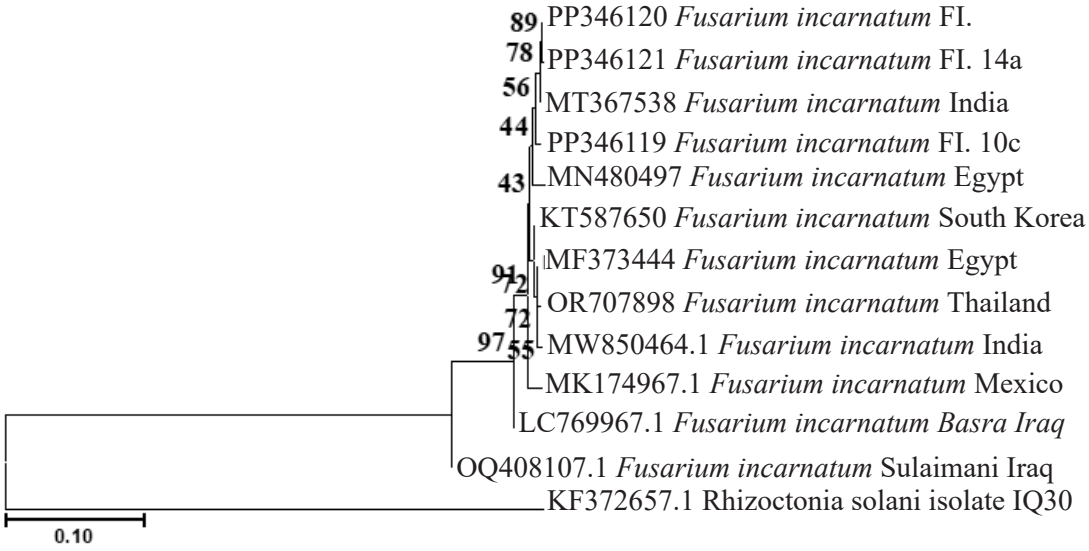

Figure 5. Phylogenetic tree constructed using the Neighbor-Joining method, illustrating the genetic relationships of *Fusarium incarnatum* compared with reference sequences available in the NCBI/GenBank database. Evolutionary analyses were performed in MEGA7 with a bootstrap test of 1000 replicates. Rhizoctonia solani isolate (KF372657.1) was used as the outgroup for the phylogenetic tree.

was observed between Baghdad isolates (PP346119, PP346120, PP346121) and isolates from Sulaymaniyah (OQ408107) and Basrah (LC769967), likely reflecting geographical and environmental influences on fungal differentiation (Ofi et al., 2023; Kakakhan & Shekhany, 2023).

Field Experiment.

GS235772 Hybrid Corn: Application of vermicompost and fermented cow manure at 625 and 1250 kg/dunam significantly affected stalk rot severity (Table 1). Treatments V.1250 and C.1250 reduced severity to 25% (disease degree index 1.0), compared with F. incarnatum (90.87%; degree index 3.7). C.1250 was the most effective treatment, reducing disease while improving plant height, vegetative mass, and 500-seed weight. V.1250 also enhanced disease suppression and root development.

DKc6664 Hybrid Corn: V.1250 achieved the lowest stalk rot severity index (16.67%), while *F. incarnatum* recorded the highest severity (58.34%) (Table 2). Vermicompost at 1250 kg/dunam also improved dry vegetative mass and seed count per row, whereas C.1250 enhanced cob development, reflected in the highest number of rows per cob and 500-seed weight. These effects are attributed to microbial consortia in the amendments, which provide biocontrol via rhizosphere colonization and siderophore-mediated iron sequestration. Results are consistent with Fan et al. (2023), but differ from Asiedu et al. (2024), highlighting functional specialization: vermicompost suppressed pathogens, while cow manure improved yield (Kakakhan & Shekhany, 2023).

DKc6777 Hybrid Corn: V.1250 was the most effective in reducing stalk rot and enhancing dry vegetative mass. C.1250 significantly improved root development and seed weight, producing the highest fresh root weight (123.1 g) and 500-seed weight (124.8 g) (Table 3). Conversely, *F. incarnatum* consistently underperformed in growth and yield traits. Biocontrol efficacy is linked to antibiotic-producing γ-Proteobacteria and Firmicutes within the amendments, which suppress pathogens through antimicrobial production and induction of systemic resistance (Al-Hlfie & Hussein, 2024).

GS235982 Hybrid Corn: V.625 reduced stalk rot and improved plant height, stalk width, and dry vegetative mass. V.1250 enhanced cob development, achieving the highest number of rows per cob (20) and seeds per row (30). In contrast, *F. incarnatum* caused the highest severity (91.61%) and reduced plant growth (Table 4). The biocontrol mechanisms of these amendments include systemic resistance induction, competitive exclusion, and antibiosis, mediated by diverse microbial communities (Hodson et al., 2023; Fan et al., 2023).

2341.Rayal Hybrid Corn: V.1250 enhanced vegetative growth, while C.625 improved seed quality (highest 500-seed weight) (Table 5). However, disease

Table 1. Evaluation of the efficiency of vermicompost and fermented cow manure at rates of 625 and 1250 kg/dunam in protecting corn crops from stalk rot disease, and assessment of the sensitivity of GS235772 hybrid corn variety to the disease

No	Treatments	Disease incidence		Vegetative mass			Root mass			Corn cob			
		Severity index	Degree index	% Germination	Chlorophyl	High (cm)	Stalk width (mm)	Fresh Weight (g)	Dry weight (g)	Fresh weight (g)	Row No.	Seeds No. in Row	Weight 500 S. (g)
1	V. 625	58.33	2.3	86.66	55	253	22.9	66.9	12.8	102.3	15.3	36.0	100.2
2	V. 1250	25.00	1.0	86.18	61	255	20.7	54.0	19.2	157.3	16.0	33.0	120.9
3	C. 625	75.00	3.0	85.71	50	254	22.4	55.4	5.4	80.1	14.0	29.0	118.3
4	C. 1250	25.00	1.0	90.46	60	268	22.3	99.3	23.0	88.4	16.7	34.0	139.3
5	*F. incarnatum*	90.87	3.7	94.30	54	245	23.8	83.6	14.2	54.1	15.7	24.0	64.4
6	Control	50.00	2.0	95.23	56	230	22.3	53.2	7.8	50.4	15.3	21.0	100.1
	LSD P≤0.05	4.16	0.53	14.90	0.15	6.68	2.90	9.67	1.79	13.84	1.22	1.39	1.88

* Each number in the table represents three replicates and Each replicate includes 7 plants. V= Vermicompost, C= Fermented cow manure.

Table 2. Evaluation of the efficiency of vermicompost and fermented cow manure at rates of 625 and 1250 kg/dunam in protecting corn crops from stalk rot disease, and assessment of the sensitivity of DKc6664 hybrid corn variety to the disease

	Treatments	Disease incidence		Vegetative mass			Root mass			Corn cob			
		Severity Index	Degree Index	% Germination	Chlorophyl	High (cm)	Stalk width (mm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Row No.	Seeds No. in Row	Weight 500 S. (g)
1	V. 625	50.00	2.0	85.71	57	266	18.8	53.2	12.1	90.9	16.3	22.7	73.6
2	V. 1250	16.67	0.7	75.13	45	245	20.2	72.2	17.8	81.8	15.7	32.0	82.4
3	C. 625	50.00	2.0	85.71	53	232	21.0	51.0	7.7	90.4	18.0	29.0	75.5
4	C. 1250	33.33	1.3	85.71	46	240	18.0	81.5	16.8	86.3	19.7	24.0	86.3
5	*F.incarnatum*	58.34	2.3	80.94	49	233	21.5	90.9	12.2	86.2	19.0	22.0	58.9
6	Control	50.00	2.0	90.46	44	232	21.0	90.7	14.2	98.8	19.3	29.3	87.4
	LSD P≤0.05	4.16	0.53	14.90	0.15	6.68	2.90	9.67	1.79	13.84	1.22	1.39	1.88

* Each number in the table represents three replicates and Each replicate includes 7 plants. V= Vermicompost, C= Fermented cow manure.

Table 3. Evaluation of the efficiency of vermicompost and fermented cow manure at rates of 625 and 1250 kg/dunam in protecting corn crops from stalk rot disease, and assessment of the sensitivity of DKc6777 hybrid corn variety to the disease

No	Treatments	Disease incidence		Vegetative mass			Root mass			Corn cob			
		Severity index	Degree index	% Germination	Chlorophyl	High (cm)	Stalk width (mm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Row No.	Seeds No. in Row	Weight 500 S. (g)
1	V. 625	50.00	2.0	76.51	37	258	19.9	48.6	12.5	74.6	16.7	25.0	94.4
2	V. 1250	50.00	2.0	90.46	55	252	18.8	42.1	11.8	88.1	20.0	30.0	83.6
3	C. 625	75.00	3.0	90.46	46	258	18.8	41.8	6.1	80.1	18.3	28.3	100.1
4	C. 1250	66.71	2.7	90.46	46	240	18.5	54.3	11.5	85.0	18.0	16.0	84.7
5	*F. incarnatum*	91.61	3.7	80.94	50	239	17.7	43.3	9.7	54.7	15.3	19.3	110.5
6	Control	75.00	3	95.23	45	231	19.1	46.1	5.0	52.7	15.7	21.0	106.9
	LSD P≤0.05	4.16	0.53	14.90	0.15	6.68	2.90	9.67	1.79	13.84	1.22	1.39	1.88

* Each number in the table represents three replicates and Each replicate includes 7 plants. V= Vermicompost, C= Fermented cow manure.

Table 4. Evaluation of the efficiency of vermicompost and fermented cow manure at rates of 625 and 1250 kg/dunam in protecting corn crops from stalk rot disease, and assessment of the sensitivity of GS235982 hybrid corn variety to the disease

No	Treatments	Disease incidence		Vegetative mass			Root mass			Corn cob			
		Severity index	Degree index	% Germination	Chlorophyl	High (cm)	Stalk width (mm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Row No.	Seeds No. in Row	Weight 500 S. (g)
1	V. 625	50.00	2.0	76.51	37	258	19.9	48.6	12.5	74.6	16.7	25.0	94.4
2	V. 1250	50.00	2.0	90.46	55	252	18.8	42.1	11.8	88.1	20.0	30.0	83.6
3	C. 625	75.00	3.0	90.46	46	258	18.8	41.8	6.1	80.1	18.3	28.3	100.1
4	C. 1250	66.71	2.7	90.46	46	240	18.5	54.3	11.5	85.0	18.0	16.0	84.7
5	*F. incarnatum*	91.61	3.7	80.94	50	239	17.7	43.3	9.7	54.7	15.3	19.3	110.5
6	Control	75.00	3	95.23	45	231	19.1	46.1	5.0	52.7	15.7	21.0	106.9
	LSD P≤0.05	4.16	0.53	14.90	0.15	6.68	2.90	9.67	1.79	13.84	1.22	1.39	1.88

* Each number in the table represents three replicates and Each replicate includes 7 plants. V= Vermicompost, C= Fermented cow manure.

suppression was limited, emphasizing growth-promoting effects rather than pathogen control.

Across varieties. Vermicompost at 1250 kg/dunam (V.1250) consistently enhanced vegetative growth (plant height, stalk width, biomass), while fermented cow manure at 625 kg/dunam (C.625) improved seed quality (Figure 6). In this trial, however, none of the treatments significantly reduced stalk rot incidence. These results suggest that organic amendments, particularly vermicompost, can improve corn growth and yield under disease pressure, even when disease control is limited. This aligns with Hodson et al. (2023) and Fan et al. (2023), though it contrasts with Asiedu et al. (2024).

Varietal Responses. Disease severity varied by genotype. GS23772 showed reduced severity with V.1250 (25%) and C.1250 (25%), whereas *F. incarnatum* increased severity to 90.87%. DKc6664 and DKc6777 showed the lowest severity with V.1250 (16.67%), while GS235982 remained highly susceptible (severity up to 91.61%). The 2341.Rayal variety displayed uniform severity (50%) across treatments, suggesting limited amendment effects. Overall, vermicompost at 1250 kg/dunam was the most effective in reducing severity (16.67–25%) across responsive varieties, supporting Asiedu et al. (2024) and confirming Fan et al. (2023) regarding the importance of high-rate vermicompost. These findings underscore the need for customized amendment strategies based on hybrid-specific responses.

CONCLUSION

This study evaluated the efficacy of organic soil amendments in suppressing corn stalk rot disease (*Fusarium incarnatum*) and their effects on maize (*Zea mays* L.) growth and yield. Quantitative assessments showed that vermicompost and fermented cow manure significantly ($p < 0.05$) reduced disease severity (by 17–79%) and enhanced agronomic performance, particularly at the 1250 kg/dunam application rate. Vermicompost demonstrated superior disease suppression in hybrids DKc6664, GS235772, and DKc6777, lowering severity indices to 16.67–25% compared with controls. At the same rate (V.1250), vermicompost also significantly improved vegetative traits, including plant height, stalk width, and fresh vegetative mass. In contrast, fermented cow manure at 625 kg/dunam (C.625) primarily enhanced seed quality, producing the highest 500-seed weight. Inoculation with *F. incarnatum* alone consistently increased disease severity (58–90%) across all cultivars. Overall, these findings highlight the potential of high-rate organic amendments, particularly vermicompost, as a sustainable strategy for managing Fusarium stalk rot and improving yield in maize production systems.

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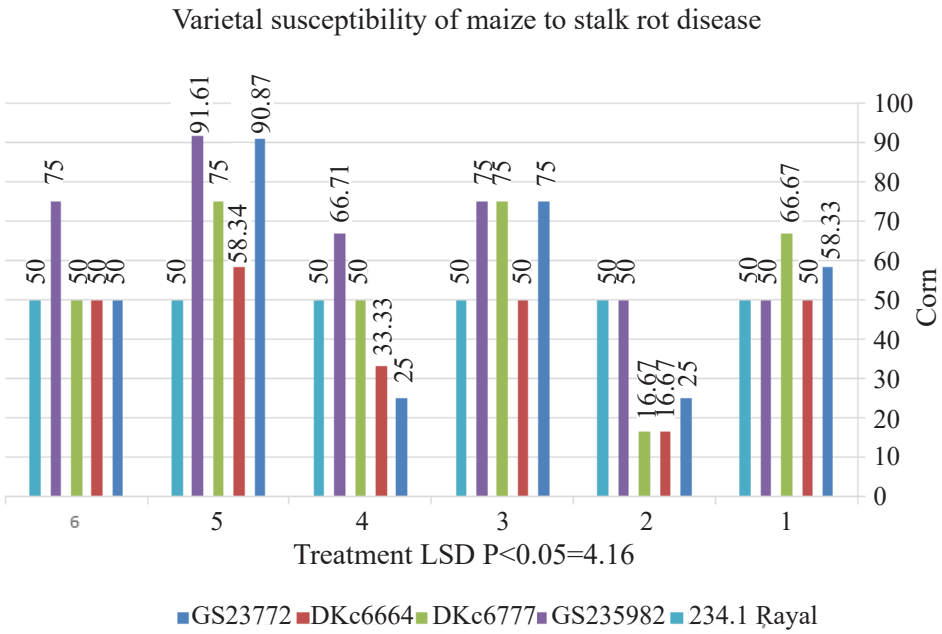

Figure 6. Corn variety susceptibility of corn stalk disease. (1-6: Treatments).

Table 5. Evaluation of the efficiency of vermicompost and fermented cow manure at rates of 625 and 1250 kg/dunam in protecting corn crops from stalk rot disease, and assessment of the sensitivity of 2341.Rayal hybrid corn variety to the disease

No	Treatments	Disease incidence		Vegetative mass			Root mass		Corn cob			
		Severity index	Degree index	% Germination	Chlorophyl	High (cm)	Stalk width (mm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Row No.	Seeds No. in Row	Weight 500 S. (g)
1	V. 625	50.00	2	80.94	59	255	21.0	60.0	13.3	110.9	16.3	34.3	77.2
2	V. 1250	50.00	2	100	53	299	23.7	68.4	12.5	83.2	16.0	30.7	77.2
3	C. 625	50.00	2	95.23	57	233	20.3	58.2	11.2	93.2	16.3	29.3	95.0
4	C. 1250	50.00	2	80.94	51	238	18.0	77.0	17.1	83.8	16.0	25.0	76.7
5	*F. incarnatum*	50.00	2	90.46	55	235	17.4	51.0	13.5	80.2	16.0	34.0	63.0
6	Control	50.00	2	95.23	57	231	23.2	52.2	13.4	81.0	15.3	20.7	93.0
	LSD P≤0.05	4.16	0.53	14.90	0.15	6.68	2.90	9.67	1.79	13.84	1.22	1.39	1.88

* Each number in the table represents three replicates and Each replicate includes 7 plants. V= Vermocompost, C= Fermented cow manure.

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AUTHORS' CONTRIBUTIONS

JDS and HMW conceived and designed the research. JDS, HMW, and KTA conducted experiments and collected data. KTA performed statistical analyses. JDS drafted the manuscript. HMW prepared figures and tables. All authors contributed to data interpretation, critically revised the manuscript, and approved the final version.

COMPETING INTEREST

The authors declare no conflicts of interest. This research was conducted independently, with no financial or personal influences affecting the study's design, execution, or outcomes.

REFERENCES

Al-Enezi AMA & Jamil DS. 2023. Phenotypic and molecular diagnosis of *Fusarium oxysporum* and *Macrophomina phaseolina* isolated from cucumis melon roots. *Caspian J. Environ. Sci.* 21(1): 75–84. https://doi.org/10.22124/CJES.2023.6197

Al-Hlfie RG & Hussein WA. 2024. Effect of organic fertilizers and nutrients on anatomical traits of red beetroots. *Iraqi J. Agric. Sci.* 55(Special): 151–161. https://doi.org/10.36103/ijas.v55iSpecial.1894

Asiedu DD, Akohoue F, Frank S, Koch S, Lieberherr B, Oyiga B, Kessel B, Presterl T, & Miedaner T. 2024. Comparison of four inoculation methods and three *Fusarium* species for phenotyping stalk rot resistance among 22 maize hybrids (*Zea mays*). *Plant Pathol.* 73(5): 1060–1071. https://doi.org/10.1111/ppa.13874

Bawa A. 2021. Yield and growth response of maize (*Zea mays* L.) to varietal and nitrogen application in the Guinea savanna agro-ecology

of Ghana. *Adv. Agric.* 2021(1): 1765251. https://doi.org/10.1155/2021/1765251

Fan Y, Lv G, Chen Y, Chang Y, & Li Z. 2023. Differential effects of cow dung and its biochar on *Populus euphratica* soil phosphorus effectiveness, bacterial community diversity and functional genes for phosphorus conversion. *Front. Plant Sci.* 14: 1242469. https://doi.org/10.3389/fpls.2023.1242469

FAO. 2024. *World Food and Agriculture – Statistical Yearbook 2024*. Rome. https://doi.org/10.4060/cd2971en. Accessed 31 July 2025.

Gunasinghe N, Vaghefi N, Shivas RG, Tan YP, Jordan D, Mace E, & Martin A. 2024. Diversity and pathogenicity of *Fusarium* spp. isolated from cultivated sorghum stems and roots in eastern Australia. *Plant Pathol.* 73(9): 2563–2573. https://doi.org/10.1111/ppa.13985

Han SL, Wang MM, Ma ZY, Raza M, Zhao P, Liang JM, Gao M, Li YJ, Wang JW, Hu DM, & Cai L. 2023. *Fusarium* diversity associated with diseased cereals in China, with an updated phylogenomic assessment of the genus. *Stud. Mycol.* 104(1): 87–148. https://doi.org/10.3114/sim.2022.104.02

Harish J, Jambhulkar PP, Bajpai R, Arya M, Babele PK, Chaturvedi SK, Kumar A, & Lakshman DK. 2023. Morphological characterization, pathogenicity screening, and molecular identification of *Fusarium* spp. isolates causing post-flowering stalk rot in maize. *Front. Microbiol.* 14: 1121781. https://doi.org/10.3389/fmicb.2023.1121781

Hodson ME, Brailey-Jones P, Burn WL, Harper AL, Hartley SE, Helgason T, & Walker HF. 2023. Enhanced plant growth in the presence of earthworms correlates with changes in soil microbiota but not nutrient availability. *Geoderma.* 433: 116426. https://doi.org/10.1016/j.geoderma.2023.116426

Jian H, Gao Z, Guo Y, Xu X, Li X, Yu M, Liu G, Bian D, Cui Y, & Du X. 2024. Supplemental irrigation mitigates yield loss of maize through reducing canopy temperature under heat stress. *Agric. Water Manag.* 299: 108888. https://doi.org/10.1016/j.agwat.2024.108888

Kakakhan HS & Shekhany KAM. 2023. Molecular detection of Fusarium species infected corn in Kurdistan region-Iraq. *Passer J. Basic Appl. Sci.* 5(2): 224–230. https://doi.org/10.24271/PSR.2023.375971.1190

Kareem TA, Hassan AK, Naemah RA, & Alsamir M. 2020. Morphological and molecular characteristics of fungal isolates causing onion neck rot disease. Biochem. *Cell. Arch*. 20(1): 403–408.

Kenganal M, Patil MB, & Nimbaragi Y. 2017. Management of stalk rot of maize caused by *Fusarium moniliform* (Sheldon). *Int. J. Curr. Microbiol. Appl. Sci.* 6(9): 3546–3552. https://doi.org/10.20546/ijcmas.2017.609.436

Leslie JF & Summerell BA. 2008. *The Fusarium Laboratory Manual*. John Wiley & Sons.New Jersey.

Naghman R, Bhatti MT, Najabat Z, Hyder S, Rizvi ZF, Gondal AS, Zafar Z, Malik S, Iqbal R, Hafeez A, Ali B, & Marc RA. 2023. Organic amendments: a natural way to suppress phytopathogens: a sustainable approach to go green. *Turk J of Agric Fores*. 47(5): 602–622. https://doi.org/10.55730/1300-011X.3113

Ofi BG, Abass MH, & Salih YA. 2023. The first record of the fungus *Fusarium incarnatum* (Desm.) Sacc., (1886) as a potential pathogen of leaf spot disease on the broad bean *Vicia faba* L. in Iraq. *IOP Conf. Ser.: Earth Environ. Sci.* 1262: 032029. https://doi.org/10.1088/1755-1315/1262/3/032029

Oldenburg E, Höppner F, Ellner F, & Weinert J. 2017. Fusarium diseases of maize associated with mycotoxin contamination of agricultural products intended to be used for food and feed. *Mycotoxin Res.* 33(3): 167–182. https://doi.org/10.1007/s12550-017-0277-y

Pfordt A & Paulus S. 2025. A review on detection and differentiation of maize diseases and pests by imaging sensors. *J. Plant Dis. Prot.* 132: 40. https://doi.org/10.1007/s41348-024-01019-4

Radha TK & Rao DLN. 2014. Plant growth promoting bacteria from cow dung based biodynamic preparations. *Indian J. Microbiol.* 54: 413–418. https://doi.org/10.1007/s12088-014-0468-6

Shaner GE & Scott DH. 1998. *Stalk Rots of Corn*. Ext. Publ. BP-59. Dept. of Botany & Plant Pathology, Purdue University. https://extension.purdue.edu/extmedia/BP/BP-59.html. Accessed

25 July 2025.

Shin JH, Han JH, Lee JK & Kim KS. 2014. Characterization of the maize stalk rot pathogens *Fusarium subglutinans* and *F. temperatum* and the effect of fungicides on their mycelial growth and colony formation. *Plant Pathol. J.* 30(4): 397–406. https://doi.org/10.5423/PPJ.OA.08.2014.0078

Song J, Liu Y, Guo R, Pacheco A, Muñoz-Zavala C, Song W, Wang H, Cao S, Hu G, Zheng H, Dhliwayo T, Vicente FS, Prasanna BM, Wang C, & Zhang X. 2024. Exploiting genomic tools for genetic dissection and improving the resistance to Fusarium stalk rot in tropical maize. *Theor. Appl. Genet.* 137: 109. https://doi.org/10.1007/s00122-024-04597-x

Taha AS, Jamel DS & Abdui-Razzak AK. 2023. Morpho-molecular identification and first report of *Trichoderma aggressivum* is causing green rot on white button mushroom in Iraq. *IOP Conf. Ser.: Earth Environ. Sci.* 1259(1): 012125. https://doi.org/10.1088/1755-1315/1259/1/012125

White TJ, Burns T, Lee S, & Taylor J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, & White, TJ (Eds.). *PCR Protocols: A Guide to Methods and Applications.* pp. 315–322. Academic Press, New York.