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COMPARATIVE EFFICACY OF SELECTED FUNGICIDES AGAINST CUCUMBER FRUIT ROT DISEASE UNDER FIELD CONDITIONS

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SUMMARY

Cucumber (*Cucumis sativus* L.) production in Nigeria is constrained by fruit rot disease, which reduces yield and market quality under field conditions. This study evaluated the comparative efficacy of selected fungicides and their residue levels in cucumber. Field experiments were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Ogun State, during the 2023 late and 2024 early planting seasons using two hybrid varieties Amarisa Super F1 and Oliver Bold F1. Three fungicide treatments, Five Star (azoxystrobin 200 g/L + difenoconazole 125 g/L SC), Dew Force (pyraclostrobin 40 g/L + dimethomorph 72 g/L EC), Ridomil Gold (metalaxyl 40 g/kg + mancozeb 640 g/kg), and an untreated control, were evaluated in a randomized complete block design with three replications. Fungicides were applied weekly from two weeks after sowing. Disease incidence, severity, and yield were analyzed using ANOVA, while residue levels were determined by UV-visible spectrophotometry and compared with the Codex maximum residue limits. Season significantly influenced disease development, with higher incidence (34.38%) and mean severity score (1.31) in the late season. Fungicides reduced disease. Five Star recorded the lowest incidence (15.00%), severity (0.67), and highest yield (10,539 kg/ha), followed by Ridomil Gold (25.75%, 0.69, 7,973 kg/ha) and Dew Force (28.86%, 1.11, 7,913 kg/ha) compared with the control (37.94%,1.42, 5,133.75 kg/ha). Variety significantly influenced yield, with Amarisa Super F1 (9,706 kg/ha) outperforming Oliver Bold F1 (6,073 kg/ha). Residues were metalaxyl (0.000068–0.000071), mancozeb (0.000047–0.000049), azoxystrobin (0.000046–0.000049), difenoconazole (0.000032–0.000034), pyraclostrobin (0.000051–0.000053), and dimethomorph (0.000036–0.000038 mg/kg), below Codex MRLs of 0.5, 2.0, 1.0–3.0, 2.0, 0.5, and 1.5 mg/kg, respectively. Five Star provided superior control without compromising food safety.

Keywords: cucumber, fruit rot, fungicide efficacy, disease incidence, disease severity, pesticide residues, yield

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable crop cultivated widely in tropical and temperate regions. The crop is valued for its nutritional composition, including vitamins such as vitamin C and vitamin K, minerals including potassium and magnesium and bioactive compounds such as flavonoids, phenolic compounds and carotenoids (1). Its high-water content also contributes to its fresh and refreshing characteristics (2). In Nigeria, cucumber cultivation has expanded because the crop matures quickly and provides economic

returns to farmers (3). The fruits are consumed fresh, used in salads, and marketed within Nigeria. Despite its importance, cucumber production is constrained by diseases that affect leaves, stems, and fruits, resulting in yield and quality losses under field conditions (4). Among these diseases, fruit rot is particularly important because of its direct impact on harvestable yield and post-harvest quality. Fruit rot is caused by several fungal pathogens such as *Fusarium* spp., *Rhizoctonia solani*, *Botrytis cinerea*, and *Choanephora cucurbitarum*, as well as oomycete pathogens such as *Phytophthora capsici* and *Pythium* spp. (5)(6), that infect fruits under warm and humid conditions, resulting in water-soaked or sunken lesions, tissue discoloration, soft or watery tissue decay on affected fruits, and eventual fruit collapse or complete fruit loss if not properly managed (6). The warm and humid tropical climate of Nigeria favors rapid fungal growth and spore dissemination, thereby increasing the prevalence and severity of fruit rot diseases in cucumber fields. Apart from reducing the quantity of cucumbers produced, fruit rot also lowers fruit quality, increases post-harvest losses, and reduces market value, thereby negatively affecting the income and livelihoods of farmers and rural households (5). To minimize these losses, farmers largely depend on chemical fungicides as a major disease management strategy. Different contact, systemic, and combination fungicides are applied at various stages of crop growth to suppress disease incidence and severity while improving fruit quality and yield. Fungicides play a significant role in disease control and productivity enhancement; their use requires consideration of food safety because chemical residues may remain on harvested fruits.

Studies have reported pesticide residues in vegetables, including cucumbers, with some exceeding the maximum residue limits considered safe for human consumption (7). The Codex Alimentarius Commission, established jointly by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), provides internationally recognized Maximum Residue Limits (MRLs) for pesticide residues in food commodities, including vegetables such as cucumber. These limits are established to ensure that pesticide residues resulting from approved agricultural use remain within levels considered acceptable for consumer protection (8). Therefore, there is a need to evaluate fungicide use not only for disease management and yield improvement but also food safety and regulatory compliance. This study was conducted to evaluate the comparative efficacy and safety of three selected fungicides in the management of cucumber fruit rot under field conditions in Nigeria.

MATERIALS AND METHODS

Study Area and Experimental Seasons

The experiments were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria (Latitude 7°20′N, Longitude 3°23′E). Two field trials were conducted during the 2023 late planting season (September–November) and the 2024 early planting season (April–June).

Planting Materials and Fungicide Treatments

Two hybrid cucumber varieties, Amarisa Super F1 (V1) and Oliver Bold F1 (V2), were obtained from Solokad Multiventures, Ibadan. Two seeds were sown per hill at a spacing of 1 m × 1 m and thinned to one healthy plant per stand at two weeks after sowing. The plots were kept weed-free by routine hand weeding.

Three treatments were evaluated: Five Star (azoxystrobin 200 g/L + difenoconazole 125 g/L SC), Dew Force (pyraclostrobin 40 g/L + dimethomorph 72 g/L EC), Ridomil

Gold (metalaxyl 40 g/kg + mancozeb 640 g/kg), and an untreated control. The fungicides were applied as foliar sprays weekly from two weeks after sowing for four weeks at the manufacturer-recommended rates: Five Star, 1.2 mL/L; Dew Force, 2.4 mL/L; and Ridomil Gold, 6 g/L.

Experimental Design and Data Collection

The experiment was laid out in a Randomized Complete Block Design with a split-plot arrangement: varieties in main plots (2 m × 14 m) and fungicide treatments in subplots (2 m × 2 m), each replicated three times. Disease incidence and severity were recorded weekly from three weeks after sowing (WAS) by visual observation using a 0–4 scale, where 0 = no infection, 1 = 1–25% tissue affected, 2 = 26–50% tissue affected, 3 = 51–75% tissue affected, and 4 = >75% tissue affected,

Mean disease severity score = Σ individual disease severity scores / Number of plants assessed

Disease incidence was calculated as:

Disease incidence (%) = (Number of diseased plants / Total number of plants assessed) × 100

Fruit yield was determined by number and weight of marketable fruits per plot. Fruit yield was expressed in kg/ha:

Yield (kg/ha) = [Fruit weight per plot (kg) / Plot area (m^2)] × 10,000

Residue Extraction and Analysis

Mature fruits were harvested, homogenized, and 5 g of each sample were weighed using a digital Mettler weighing balance and transferred into a 100 mL beaker. Pentane (50 mL) was added, and the sample was homogenized in a Waring blender for 10 min. The extract was filtered through Whatman No. 42 filter paper. Isopropyl alcohol (50 mL) was added to the filtrate, which was transferred to a 250 mL separatory funnel and shaken to separate the pentane layer. The extraction was repeated twice. The pentane extracts were combined, transferred to a 50 mL volumetric flask, and made up to volume with pentane.The residues of metalaxyl, mancozeb, difenoconazole, azoxystrobin, pyraclostrobin, and dimethomorph were quantified by UV–visible spectrophotometry. For metalaxyl determination, 5 mL of the extract were treated with 2 mL methyl sulphonyl chloride, and the absorbance was measured at 450 nm. Working standards ranging from 10–50 µg/mL were prepared from a 100 µg/mL stock solution. For mancozeb determination, 5 mL of the extract were treated with 3 mL dimethyl sulphoxide, and the absorbance was measured at 435 nm. For difenoconazole determination, 5 mL of the extract were treated with 3 mL phenazinemethosulphate (PMS) solution, and the absorbance was measured at 415 nm. For azoxystrobin determination, 5 mL of the extract were treated with 1 mL nitroblue tetrazolium (NBT) solution, and the absorbance was measured at 380 nm. For pyraclostrobin determination, 5 mL of the extract were treated with 3 mL PMS solution, and the absorbance was measured at 485 nm. For dimethomorph determination, 5 mL of the extract were treated with 3 mL dimethyl sulphoxide, and the absorbance was measured at 435 nm. Working standards of 10–50 µg/mL were prepared from a 100 µg/mL stock solution for each active ingredient and treated under the same conditions as the samples. Absorbance of the samples and standards was measured using a Cecil 2843 spectrophotometer, with pentane used as the blank. Residue concentration was calculated from the absorbance response and gradient factor obtained from the respective calibration curve using the laboratory-specified assay calculation:

Residue (µg/kg) = [Absorbance of sample extract × Gradient factor × 1000] / Weight of sample taken (g)

The residue concentrations obtained in µg/kg were converted to mg/kg by dividing by 1000 and compared with the corresponding Codex Alimentarius maximum residue limits (MRLs).

Statistical Analysis
Data were subjected to analysis of variance using SAS version 9.3. Means were separated using Duncan's Multiple Range Test at the 5% probability level.

RESULTS

Effect of Season, Cucumber Variety, and Fungicide on Fruit Rot Incidence and Severity
Season significantly affected fruit rot incidence and mean severity score. The late planting season recorded higher incidence (34.38%) and mean severity score (1.31) than the early planting season, which recorded 19.40% incidence and a mean severity score of 0.64. Differences between cucumber varieties were not significant. Oliver Bold F1 recorded 31.90% incidence and a mean severity score of 1.00, whereas Amarisa Super F1 recorded 21.88% incidence and a mean severity score of 0.94. Fungicide treatments significantly reduced disease relative to the untreated control, which recorded the highest incidence (37.94%) and mean severity score (1.42). Five Star recorded the lowest incidence (15.00%) and mean severity score (0.67). Ridomil Gold recorded 25.75% incidence and 0.69 mean severity, while Dew Force recorded 28.86% incidence and 1.11 mean severity.

Table 1. Effect of season, cucumber variety, and fungicide on incidence and severity of cucumber fruit rot disease.

Factor	Level	Fruit rot incidence (%)	Mean severity score
Season	Early	19.40 b	0.64 b
	Late	34.38 a	1.31 a
Cucumber variety	Amarisa Super F1	21.88 a	0.94 a
	Oliver Bold F1	31.90 a	1.00 a
Fungicide	Control	37.94 a	1.42 a
	Dew Force	28.86 ab	1.11 ab
	Five Star	15.00 b	0.67 b
	Ridomil Gold	25.75 ab	0.69 b

Means followed by the same letter within a column are not significantly different at the 5% probability level according to Duncan's Multiple Range Test.

Effect of Fungicides on Cucumber Yield
Season had no significant effect on marketable fruit number or marketable fruit weight. The early season recorded 3,219.67 g per subplot, equivalent to 8,049.18 kg/ha, while the late season recorded 3,092.04 g per subplot, equivalent to 7,730.10 kg/ha. Cucumber variety significantly influenced yield. Amarisa Super F1 produced 5.17 marketable fruits and 3,882.33 g per subplot, equivalent to 9,705.83 kg/ha, compared with 3.50 fruits and 2,429.38 g per subplot, equivalent to 6,073.45 kg/ha, for Oliver Bold F1.

Fungicide treatments also improved marketable yield relative to the untreated control. The control produced 3.33 marketable fruits and 2,053.50 g per subplot, equivalent to 5,133.75 kg/ha. Five Star produced the highest marketable fruit number (5.33) and weight (4,215.50 g per subplot), equivalent to 10,538.75 kg/ha. Ridomil Gold recorded 4.50 fruits and 3,189.25 g per subplot, equivalent to 7,973.13 kg/ha, while Dew Force recorded 4.17 fruits and 3,165.17 g per subplot, equivalent to 7,912.93 kg/ha.

Table 2. Effect of fungicide on fruit yield of cucumber.

Factor	Level	Marketable fruits	Yield (kg/ha)
Season	Early	4.21 a (80%)	8,049.18
	Late	4.46 a (71%)	7,730.10
Cucumber variety	Amarisa Super F1	5.17 a (81%)	9,705.83
	Oliver Bold F1	3.50 b (68%)	6,073.45
Fungicide	Control	3.33 b (65%)	5,133.75
	Dew Force	4.17 ab (72%)	7,912.93
	Five Star	5.33 a (85%)	10,538.75
	Ridomil Gold	4.50 ab (77%)	7,973.13

Means followed by the same letter within a column are not significantly different at the 5% probability level according to Duncan's Multiple Range Test.

Fungicide Residue Levels in Cucumber Fruits

Fungicide residue analysis showed that the detected residues in cucumber fruits of both varieties were substantially below the applicable Maximum Residue Limits (MRLs) established by the Codex Alimentarius Commission (FAO/WHO) (Table 3). Metalaxyl residues were 0.000068 mg/kg in Amarisa Super F1 and 0.000071 mg/kg in Oliver Bold F1, compared with a Codex MRL of 0.5 mg/kg. Mancozeb residues were 0.000049 and 0.000047 mg/kg in Amarisa Super F1 and Oliver Bold F1, respectively, compared with an MRL of 2.0 mg/kg. Similarly, azoxystrobin residues were 0.000049 and 0.000046 mg/kg, compared with an MRL of 1.0 mg/kg, while difenoconazole residues were 0.000032 and 0.000034 mg/kg, compared with an MRL of 2.0 mg/kg. Pyraclostrobin residues were 0.000053 and 0.000051 mg/kg, compared with an MRL of 0.5 mg/kg, whereas dimethomorph residues were 0.000038 and 0.000036 mg/kg, compared with an MRL of 1.5 mg/kg. Thus, all detected residues were substantially below their respective Codex MRLs.

Table 3. Fungicide residue concentrations in cucumber fruits and comparison with Codex MRL values.

Fungicide active ingredient	Amarisa F1 (mg/kg)	Oliver Bold F1 (mg/kg)	Codex MRL (mg/kg)
Metalaxyl	0.000068	0.000071	0.5
Mancozeb	0.000049	0.000047	2.0
Azoxystrobin	0.000049	0.000046	1.0–3.0
Difenoconazole	0.000032	0.000034	2.0
Pyraclostrobin	0.000053	0.000051	0.5
Dimethomorph	0.000038	0.000036	1.5

Source: Codex Alimentarius Commission (FAO/WHO, 2024)

DISCUSSION

Fungicide application significantly reduced fruit rot incidence, severity and yield loss compared with the untreated control. Among the treatments, Five Star consistently produced the lowest incidence and severity across seasons and cucumber varieties. Its superior performance may be associated with the complementary activity of azoxystrobin and difenoconazole. Azoxystrobin is a QoI fungicide in FRAC Group 11 that inhibits mitochondrial

respiration at the Qo site of complex III, whereas difenoconazole is a DMI fungicide in FRAC Group 3 that inhibits sterol biosynthesis required for fungal cell membrane development (9). The combination of these different target sites may have contributed to the greater disease suppression observed with Five Star. The effectiveness observed with Five Star is consistent with the findings (10), who reported that the combination of azoxystrobin and difenoconazole provided effective field control of Alternaria brown spot, with the two active ingredients showing complementary activity against spore germination and mycelial growth. Dew Force (pyraclostrobin + dimethomorph) and Ridomil Gold (metalaxyl + mancozeb) showed moderate effectiveness, although they belong to different fungicide groups. Dew Force combines a QoI fungicide (pyraclostrobin, FRAC Group 11) with a CAA fungicide (dimethomorph, FRAC Group 40), whereas Ridomil Gold combines a phenylamide fungicide (metalaxyl, FRAC Group 4) with a multi-site fungicide (mancozeb, FRAC Group M03) (9). Their comparable performance suggests that the differences in mode of action did not produce differences in disease suppression under field condition.Fungicide performance can be influenced by pathogen sensitivity, disease pressure, application timing and environmental conditions. Similar comparable responses among fungicides have been reported in Nigerian vegetable disease studies. Comparable reductions in tomato early blight incidence among several fungicides at the same application rate have been reported [11], while (12) reported effective disease suppression with different fungicide treatments against cocoyam leaf blight.

Season significantly influenced disease development, as disease incidence and severity were higher during the late planting season than during the early planting season. The higher disease levels recorded may be associated with the wetter conditions that characterized this period, particularly frequent rainfall, high relative humidity, and prolonged leaf wetness. These conditions favour pathogen infection, sporulation, and disease spread. In Nigeria cucumber fruit rot became more pronounced following prolonged rainfall and high humidity under field conditions as reported by (13) Similarly, (14). reported significant variation in cucumber disease incidence and severity with planting time. Their findings support the role of planting period and environmental conditions in influencing cucumber disease development.

The reduction in disease incidence and severity following fungicide application was associated with improved yield performance. Fungicide-treated plots produced more fruits than the untreated control, while Five Star recorded the highest yield. The greater yield obtained with Five Star may be related to its stronger suppression of disease, which reduced disease-associated damage and allowed greater fruit production. This finding agrees with (15) who reported that management practices that reduced disease pressure were associated with improved cucumber growth and yield. Similarly, (13) observed that treatments that reduced cucumber fruit rot incidence and severity also improved yield performance.

Residues of metalaxyl, mancozeb, azoxystrobin, difenoconazole, pyraclostrobin and dimethomorph were detected in cucumber fruits, but their concentrations were below the corresponding maximum residue limits (MRLs) established by the Codex

Alimentarius Commission [5]. This indicates that the detected residues did not exceed the established regulatory limits under the conditions of the present study. The finding is comparable with (16), who detected paraquat residues in Nigerian vegetables and fruits at concentrations below the applicable limits. However, the presence of detectable residues demonstrates the need for proper pesticide management. Variations in residue levels may result from differences in pesticide type, application rate, environmental conditions and the interval between application and harvest. Therefore, adherence to recommended application rates and pre-harvest intervals remains important for minimizing pesticide residues in harvested cucumber fruits

CONCLUSION

This study demonstrated that cucumber fruit rot occurred under field conditions and that disease development varied between planting seasons, with greater disease incidence and severity recorded during the wetter late planting season. Fungicide application significantly reduced disease incidence and severity compared with the untreated control and was associated with improved fruit yield. Among the fungicides evaluated, Five Star, containing azoxystrobin and difenoconazole, provided the most effective disease suppression and recorded the highest yield under the conditions of the study. Residue analysis detected metalaxyl, mancozeb, azoxystrobin, difenoconazole, pyraclostrobin and dimethomorph in harvested cucumber fruits, although the concentrations were below the corresponding Codex maximum residue limits. This finding should be interpreted as evidence that the measured residues did not exceed the established regulatory limits and not as a recommendation for fungicide-treated cucumber consumption. The findings highlight the need for responsible fungicide use, adherence to recommended application rates and pre-harvest intervals, and further evaluation of organic, biological and other sustainable disease-management approaches for cucumber fruit rot.

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