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Screening of Cowpea (*Vigna unguiculata* L. Walp) Genotypes for Rust (*Uromyces phaseoli* var. *vignae*) Resistance in Ghana

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Abstract: The demand for cowpea (*Vigna unguiculata* L. Walp) is higher than supply in Ghana due to low yields caused by pathogenic diseases, predominantly rust disease. The use of rust resistant cultivars is the most effective method to control cowpea rust. Genetic variations among cowpea genotypes may be potential sources of rust resistance to control cowpea rust and increase cowpea yield and production in Ghana. The study assessed rust disease incidence and severity among cowpea genotypes and determined resistance to cowpea rust under field conditions. Twenty-four cowpea genotypes were sowed in four agro-ecological zones in two cropping seasons in Ghana. Cowpea rust incidence, severity, area under disease progress curve (AUDPC) and relative area under disease progress curve (rAUDPC) were significantly ($p < 0.05$) higher in the semi-deciduous forest and minor cropping season compared with deciduous forest, coastal savannah, Sudan savannah and major cropping season. The cowpea genotypes also showed significant differences ($p < 0.05$) in response to rust infection. Positive and negative correlations existed in rust incidence, severity, AUDPC and rAUDPC within the agro-ecological zones and cropping seasons. The differences observed were due to variations in climatic conditions and genetic composition of the cowpea genotypes. Five cowpea genotypes were better slow rusting, eleven cowpea genotypes were slow rusting and eight cowpea genotypes were fast rusting. Interestingly, eleven cowpea genotypes showed resistance and eight cowpea genotypes showed moderate resistance to cowpea rust. The rust resistant cowpea genotypes identified in this work can be recommended for farmers to cultivate and used in breeding programmes to further improve the crop. This will maximize yields and increase cowpea production particularly in rust prone areas.

Keywords: Cowpea, Cowpea Rust, Rust Disease Incidence, Rust Disease Severity, Rust Resistance

1. Introduction

Cowpea (*Vigna unguiculata* L. Walp) is largely cultivated in about 20 countries in Africa including Ghana, Niger, Nigeria, Burkina Faso and Cameroon [1]. Sub-Saharan Africa (SSA) contributes about 96.4% of the global cowpea production, with more than 86.6% of Africa's production in West Africa. In Ghana, cowpea plays very important roles in small-holder farms for income, nutrition, food security, gender equity and sustainable natural resource management [2]. The crop is the second most cultivated legume after groundnut, and widely consumed with an estimated amount of 9 kg consumed per person per year [3]. However, cowpea yield in Ghana is among the lowest yields in the world and Africa, averaging 3.25% and 3.37% respectively [4, 5].

The marketable surplus production is geographically concentrated in the Northern belt of Ghana and accounts for 89.64% of the total production. The average percent growth rate of cowpea currently stands at -2.49% [5]. To date, Ghana remains a net consumer and importer of cowpea. The major constraint to cowpea production in Ghana is high rate of pathogen infections and their associated high management costs [6]. Cowpea rust infections caused by *Uromyces phaseoli* var. *vignae* are the most severe and devastating [7]. About 2,000 urediniospores of the pathogen are released per day during the dry season [8]. At the present, there is no single cost-efficient control measure to prevent rust infection particularly in different geographical areas [9].

Rust can appear on any part of the cowpea plant above ground and spreads rapidly to the middle and upper parts of the host especially during pod formation [10]. Cowpea rust interferes with normal root development and uptake of nutrients by plant roots, resulting in reduced seed size and considerable yield loss. However, chemical application is not safe and potentially hazardous to farm workers, traders and consumers as well as the environment. It also increases the costs of cowpea production. In this regard, the study was undertaken to assess incidence and severity of cowpea rust disease in cowpea germplasm and to identify resistant/susceptible genotypes on-field. Knowledge of the severity of rust disease is extremely important for rapid management interventions. The use of rust resistant cultivars is the cheapest and most effective method to control cowpea rust disease and subsequently increase cowpea yield and production in Ghana. It also serves as an environmentally safe and cost-effective disease management technique.

2. Materials and Methods

2.1. Study Area

The assessment of cowpea rust disease incidence and severity in cowpea genotypes was carried out in four agro-ecological zones in the Central and Upper East Regions of Ghana. These are University of Cape Coast Teaching and Research Farm (UCCTRF) in the coastal savannah, Asuansi (Ministry of Food and Agriculture [MoFA] station) in the deciduous forest, Ankaful, Abura and Jukwa in the semi-deciduous forest; and Manga (Council for Scientific and Industrial Research-Savanna Agriculture Research Institute [CSIR-SARI] station) in the Sudan savannah zone [11-16]. UCCTRF and Abura are areas within the Cape Coast Metropolis, located within latitudes 05°08' and 05°09' N, and longitudes 01°18' and 01°16' W respectively. Ankaful and Jukwa are coordinated on latitudes 05°09' and 05°20' N, and longitudes 01°20' and 01°23' W whilst Asuansi falls between latitude 05°18' N and longitude 01°15' W. Manga is also located between latitude 11°01' N and longitude 00°15' W.

The coastal savannah, deciduous forest and semi-deciduous forest zones are marked by double maximum rainfall (major and minor seasons). The major rainy season starts at the end of April, peaks at May-June and decline in July whilst the minor rainy season begins in September, reaches optimum at October-November and declines by mid-December. UCCTRF, Ankaful and Abura have mean annual rainfall of 750-1500 mm, Asuansi has 1100-1900 mm and Jukwa has 1750-2000 mm. Temperatures and relative humidities throughout the year are generally high, ranging between 22-36°C, and 75-100% respectively [11-14]. In contrast, Manga is characterised by a pronounced wet season (May-October). The total rainfall averages 800 mm per annum and the relative humidity ranges between 20-60%. Temperatures within the area are normally moderate at 26-28°C [15]. The entire study was carried out from August 2016 to February 2018. A temperature range of 26-27°C and 28-29°C was recorded for major season and minor season respectively (Table 1) [17]. The mean rainfall value was very low for the major season (47.75 mm) compared with the minor season (545.50 mm).

Table 1. *Weather condition during the study period*

Season	Temperature (°C)		Average Rainfall (mm)
	Minimum	Maximum	
Major	26	27	47.75
Minor	28	29	545.50

2.2. Sowing of Cowpea Seeds

Twenty-four (24) cowpea genotypes consisting of local land races, recombinant inbred lines (RILs) and International Institute of Tropical Agriculture (IITA) accessions were obtained from the Department of Molecular Biology and Biotechnology, University of Cape Coast for the study (Table 2). A plot of land was obtained at the various study areas, demarcated and cleared. The plot was then sprayed with Roundup (weedicide) at manufacturer's recommendation of 2% solution after two weeks of weed emergence and the land was divided into blocks (71 m x 3 m) with 1 m intervals. The blocks were subdivided into subplots (2 m x 3 m) with 1 m interval between two subplots. The experiment was laid out in a Randomised Complete Block Design (RCBD) with three replications. The cowpeas were sowed at two seeds per hole at a distance of 40 cm within rows and 60 cm between rows. Sowing was done in late June (Major cropping season), early November (Minor cropping season) and early July (Manga).

Table 2. *Cowpeas used for phenotypic evaluation of rust disease.*

SI. No.	Genotype	Source	SI. No.	Genotype	Source
1	UCC-11	UCC	13	UCC-490	UCC
2	UCC-24	UCC	14	UCC-513	UCC
3	UCC-32	UCC	15	UCC-523	UCC
4	UCC-153	UCC	16	UCC-Early	UCC
5	UCC-221	UCC	17	Padi-Tuya	SARI
6	UCC-241	UCC	18	Apagbaala	SARI
7	UCC-328	UCC	19	IT08K-125-107	IITA
8	UCC-366	UCC	20	IT08K-193-14	IITA
9	UCC-445	UCC	21	IT10K-817-3	IITA
10	UCC-466	UCC	22	IT10K-819-4	IITA
11	UCC-473	UCC	23	IT10K-832-3	IITA
12	UCC-484	UCC	24	IT97K-499-35	IITA

2.3. Assessment of Rust Disease in Cowpea

Rust disease incidence and severity were assessed in 24 cowpea genotypes at weekly intervals after seed germination till pod maturation. The severity of rust disease was assessed using a diagrammatic scale, and rated on a scale of 0 to 5, where 0 = 0%, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75% and 5 = 76-100% of leaf surface covered with pustules [18, 19]. The percent disease incidence (DI%) and disease severity (DS%) were calculated using equations (1) - (3) [20-22]. The area under disease progress curve (AUDPC) and relative area under disease progress curve (rAUDPC) for rust development on each cowpea genotype were determined using equations (4) and (5) [23, 24]. The cowpea genotypes were then classified as resistant (1-10%), moderately resistant (11-25%), moderately susceptible (26-50%) and susceptible (>50%) to cowpea rust (*Uromyces phaseoli* var. *vignae*) based on severity scores [20].

$$\text{Disease incidence, DI\%} = [\text{No. of plants infected} / \text{Total no. of plants}] \times 100 \tag{1}$$

$$\text{Disease severity, DS\%} = [\text{Sum of numerical ratings} / (\text{No. of plants examined} \times \text{maximum grade})] \times 100 \tag{2}$$

$$\text{Disease severity, DS\%} = [0.001 - (0.01076(\text{DI\%})) + (0.008376(\text{DI\%})^2) \tag{3}$$

$$\text{AUDPC} = [N_1((X_1+X_2)/2)] + [N_2((X_2+X_3)/2)] + [N_3((X_3+X_4)/2)] \tag{4}$$

Where X_1, X_2, X_3 and X_4 are the rust severities recorded on the first, second, third and fourth recording dates; and N_1, N_2, and N_3 are the day intervals between X_1 and X_2, X_2 and X_3, and X_3 and X_4 respectively.

$$\text{rAUDPC} = [\text{AUDPC of cowpea} / \text{AUDPC of susceptible cowpea}] \times 100 \tag{5}$$

2.4. Data Analyses

Descriptive and inferential statistical methods were used to analyse data obtained from the study. The incidence, severity, AUDPC and rAUDPC of rust recorded for the cowpea genotypes were tested in Minitab® Statistical Software 18 using One-way Analysis of variance (ANOVA) and Welch's test [25]. Means that showed significant difference ($p < 0.05$) were separated using Fischer's Least Significant Difference (LSD) at 5% significance level. The association between cowpea genotypes and cowpea rust was determined using Pearson's correlation coefficient at 5% significance level.

3. Results

3.1. Assessment of Rust Disease Incidence and Severity of Cowpea in Four Agro-ecological Zones

The incidence and severity of cowpea rust disease was assessed on-field on 24 cowpea genotypes in four agro-ecological zones in Ghana. Figure 1 shows rust disease in two cowpea genotypes. The highest incidence (63.03%) and severity (39.48%) of cowpea rust was found in the semi-deciduous forest (Table 3). Deciduous forest recorded the second highest incidence (32.64%) and severity (12.32%) of rust. Coastal savannah and Sudan savannah recorded disease incidence and severity values of 10.46% and 0.39% and 7.25% and 0.57% respectively (Table 3). Significant differences ($p < 0.05$) existed in the average incidence and severity of cowpea rust in the four agro-ecological zones. Fisher's LSD test revealed no significant differences ($p > 0.05$) in rust incidence and severity between coastal savannah, Sudan savannah and deciduous forest.

Moreover, there was significant difference ($p < 0.05$) between cowpea rust incidence and cowpea rust severity within the agro-ecological zones. Except coastal savannah which had a weak positive linear relationship ($r = 0.35$), there was a very strong positive linear relationship between rust incidence and severity in each agro-ecological zone ($r \geq 0.94$) (Table 3). Significant differences ($p < 0.05$) also existed in the linear relationship between rust incidence and severity in each agro-ecological zone.

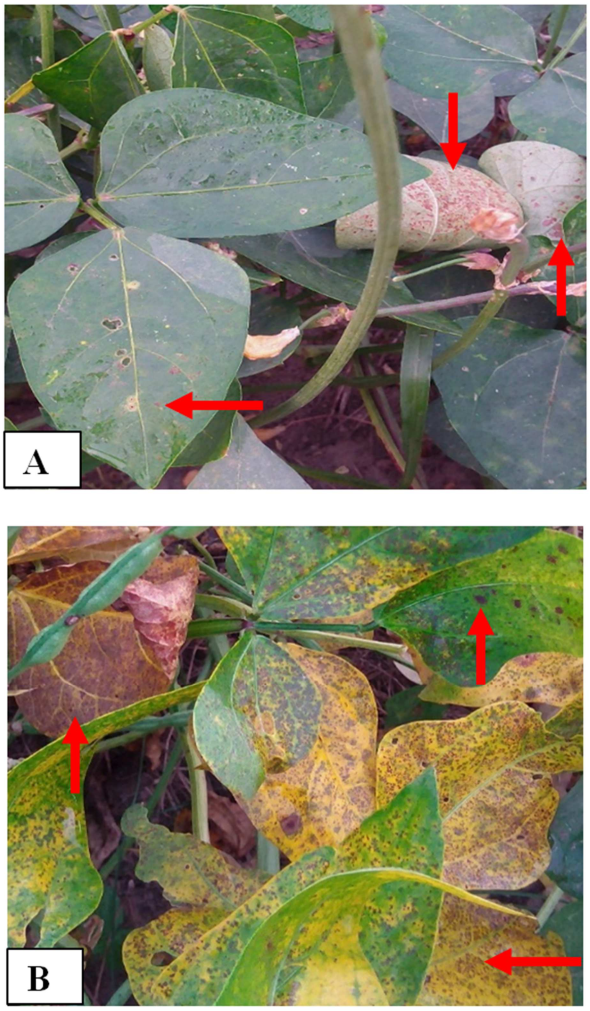

Figure 1. *Rust disease in cowpea. A) UCC-484, B) IT08K-817-3. Red arrows show rust pustules on cowpea leaves.*

Table 3. *Cowpea rust disease incidence and severity in four agro-ecological zones of Ghana.*

Agro-ecological zones	DI%	DS%	Mean	Correlation	
				r	P-value
Semi-deciduous Forest	63.03	39.48	51.26[a]	0.97	0.00
Deciduous Forest	32.64	12.32	22.48[b]	0.95	0.00
Coastal Savannah	10.46	0.39	5.43[c]	0.35	0.04
Sudan Savannah	7.25	0.57	3.91[c]	0.94	0.00
Mean	33.31[a]	16.29[b]	–	–	–
SEM ±	2.52	1.90	–	–	–

DI%: Rust disease incidence, DS%: Rust disease severity, r: Correlation coefficient, Means that share a letter within a row and a column are not significantly different ($p > 0.05$).

3.2. Assessment of Rust Disease Incidence and Severity of Cowpea in Major and Minor Cropping Seasons

The incidence and severity of cowpea rust disease were also assessed during the major and minor cropping seasons to determine the season suitable for rust development. The assessments were carried out in the semi-deciduous forest, deciduous forest and the coastal savannah agro-ecological zones. Cowpea rust disease incidence, severity, area under disease progress curve (AUDPC) and relative area under disease progress curve (AUDPC) recorded in the major and minor cropping seasons of 2017 is presented in Table 4. Significant differences ($p < 0.05$) were observed between cowpea rust incidence, severity, AUDPC and rAUDPC for the major and minor seasons. The mean incidence (4.85%), severity (0.55%), AUDPC (42.60) and rAUDPC (7.67) were very low among the cowpea genotypes in the major season (Table 4). Minor season recorded high rust incidence (58.52%), severity (21.30%), AUDPC (740.10) and rAUDPC (42.62). Significant differences ($p < 0.05$) were observed in the mean values recorded. However, Fisher's LSD test revealed no significant difference ($p > 0.05$) among cowpea rust incidence, severity and rAUDPC recorded in each season (Table 4).

IT08K-817-3 recorded the highest mean incidence (64.11%), severity (31.63%), AUDPC (1145.82) and rAUDPC (100.00) among the cowpea genotypes in both major and minor season. The lowest incidence (8.52%) was observed in IT08K-193-14 whereas the lowest severity was found in UCC-366 (3.83%). Eleven cowpea genotypes (UCC-523, UCC-484, Apagbaala, UCC-221, UCC-466, UCC-513, UCC-153, UCC-328, UCC-Early, IT97K-499-35 and IT10K-819-4) were slow rusting (rAUDPC < 30). UCC-473, UCC-366, IT08K-193-14, IT10K-125-107 and IT10K-832-3 were better slow rusting (rAUDPC < 10). However, eight cowpea genotypes (UCC-490, UCC-11, UCC-445, UCC-24, UCC-241, UCC-32, Padi-Tuya and IT08K-817-3) gave fast rusting response (rAUDPC > 30). A strong positive linear relationship was found between rust incidence, severity, AUDPC and rAUDPC in UCC-473, UCC-328, UCC-490, UCC-445, UCC-32, UCC-Early, IT10K-819-4, IT10K-832-3 and IT10K-817-3 ($r \geq 0.60$) and showed significant differences ($p < 0.05$) in the relationship except UCC-328 (Table 4).

UCC-523 and UCC-241 showed a moderate positive linear relationship ($0.40 < r < 0.60$). A weak positive and negative linear relationships were also recorded in 12 cowpea genotypes ($0.40 > r > -0.40$). UCC-221, UCC-513 and Padi-Tuya gave the same correlation values (± 0.02). In contrast, there was no correlation in rust incidence, severity, AUDPC and rAUDPC in UCC-366. The cowpea genotypes showed four types of response to cowpea rust (Table 4). Fifteen (15) cowpea genotypes including local and exotic lines, showed resistance to cowpea rust. Eight (8) cowpea genotypes were moderately resistant to cowpea rust. Only IT08K-817-3 was moderately susceptible to cowpea rust.

Table 4. *Incidence, severity, AUDPC and rAUDPC of cowpea rust disease in the major and minor cropping seasons.*

Cowpea Genotype	Major season				Minor season			
	DI%	DS%	AUDPC	rAUDPC	DI%	DS%	AUDPC	rAUDPC
UCC-473	0.00	0.00	0.03	0.01	17.86	9.81	87.97	5.07
UCC-523	6.60	0.30	8.22	1.48	56.45	16.38	749.60	43.17
UCC-366	1.40	0.00	0.43	0.08	22.22	7.66	103.58	5.97
UCC-484	2.54	0.03	0.28	0.05	60.71	18.45	634.69	36.55
Apagbaala	1.61	0.01	1.13	0.20	61.54	19.97	818.76	47.15
UCC-221	4.55	0.13	0.25	0.05	63.79	20.70	743.78	42.83
UCC-466	0.43	0.00	0.06	0.01	50.00	16.20	477.32	27.49
UCC-513	2.01	0.01	0.35	0.06	54.00	15.26	518.32	29.85
UCC-153	18.92	2.80	0.08	0.01	51.92	14.35	572.44	32.97
UCC-328	2.04	0.01	11.16	2.01	44.74	11.89	616.02	35.48
UCC-Early	6.30	0.27	156.05	28.10	46.67	16.01	421.40	24.27
IT08K-193-14	0.97	0.00	0.02	0.00	16.07	8.14	55.84	3.22
IT10K-125-107	0.51	0.00	0.03	0.01	33.33	9.47	306.16	17.63
IT10K-832-3	0.00	0.00	0.03	0.01	42.00	10.50	301.51	17.36

Cowpea Genotype	Major season				Minor season			
	DI%	DS%	AUDPC	rAUDPC	DI%	DS%	AUDPC	rAUDPC
IT97K-499-35	0.00	0.00	0.04	0.01	45.00	12.68	385.62	22.21
UCC-490	15.70	1.90	128.53	23.15	80.30	31.02	1126.25	64.86
Padi-Tuya	3.69	0.08	1.57	0.28	79.17	28.82	1133.40	65.27
UCC-11	1.15	0.00	0.01	0.00	81.25	30.54	1180.26	67.97
UCC-445	0.00	0.00	0.03	0.01	83.33	31.97	1202.69	69.26
UCC-24	4.07	0.10	6.53	1.18	78.33	29.72	1062.13	61.17
UCC-241	13.11	1.30	10.05	1.81	94.23	40.01	1546.44	89.06
UCC-32	1.03	0.00	122.77	22.11	79.55	30.52	1103.20	63.53
IT10K-819-4	1.44	0.00	19.50	3.51	62.12	24.72	878.39	50.59
IT08K-817-3	28.23	6.37	555.25	100.00	100.00	56.90	1736.39	100.00
Mean	4.85^b	0.55^b	42.60^a	7.67^b	58.52^d	21.30^d	740.10^c	42.62^d
SEM ±	1.46	0.29	24.10	4.35	4.71	2.41	92.20	5.31

Table 4. *Continued.*

Cowpea Genotype	Mean				Correlation		Host Response
	DI%	DS%	AUDPC	rAUDPC	r	P-value	
UCC-473	8.93	4.91	44.00	2.54	0.87	0.01	R
UCC-523	31.53	8.34	378.91	22.33	0.48	0.23	R
UCC-366	11.81	3.83	52.00	3.02	0.00	0.99	R
UCC-484	31.63	9.24	317.49	18.30	-0.05	0.90	R
Apagbaala	31.58	9.99	409.94	23.68	-0.18	0.68	R
UCC-221	34.17	10.41	372.02	21.44	0.02	0.97	R
UCC-466	25.22	8.10	238.69	13.75	-0.16	0.71	R
UCC-513	28.01	7.63	286.26	14.96	-0.02	0.97	R
UCC-153	35.42	8.57	286.26	16.49	-0.13	0.75	R
UCC-328	23.39	5.95	313.59	18.74	0.60	0.11	R
UCC-Early	26.48	8.14	288.73	26.19	0.98	0.00	R
IT08K-193-14	8.52	4.07	27.93	1.61	-0.22	0.60	R
IT10K-125-107	16.92	4.74	153.10	8.82	-0.12	0.78	R
IT10K-832-3	21.00	5.25	150.77	8.68	0.96	0.00	R
IT97K-499-35	22.50	6.34	192.83	11.11	-0.01	0.83	R
UCC-490	48.00	16.46	627.39	44.01	0.95	0.00	MR
Padi-Tuya	41.43	14.45	567.48	32.78	0.02	0.96	MR
UCC-11	41.20	15.27	590.13	33.99	-0.19	0.66	MR
UCC-445	41.67	15.98	601.36	34.63	0.98	0.00	MR
UCC-24	41.20	14.91	534.33	31.17	0.28	0.50	MR
UCC-241	53.67	20.66	778.24	45.44	0.45	0.27	MR
UCC-32	40.29	15.26	612.99	42.82	0.91	0.00	MR
IT10K-819-4	31.78	12.36	448.94	27.05	0.89	0.00	MR
IT08K-817-3	64.11	31.63	1145.82	100.00	0.99	0.00	MS
Mean	–	–	–	–	–	–	–
SEM ±	–	–	–	–	–	–	–

DI%: Rust disease incidence, DS%: Rust disease severity, AUDPC: Area under disease progress curve, rAUDPC: Relative area under disease progress curve, r: Correlation coefficient, R: Resistant, MR: Moderately Resistant, MS: Moderately Susceptible, Means that share a letter within a row are not significantly different ($p > 0.05$)

4. Discussion

The significant variations ($p < 0.05$) observed in the incidence and severity of cowpea rust disease in the four agro-ecological zones of Ghana conform to a similar study that reported rust disease in four districts of Western Hararghe Zone of eastern Ethiopia with variations in rust disease incidence and severity, ranging from 25 to 74% and 18 to 55% respectively, among the districts [26]. Significant difference ($p < 0.001$) in rust disease incidence and severity has also been reported across six agro-ecological zones of Uganda [27]. In the current study, semi-deciduous forest had the highest rust incidence of 63.03% compared with the deciduous forest, coastal savannah and Sudan savannah agro-ecological zones. This observation is similar to the study by [28] who reported highest rust incidence of 61.64% in Yardlong bean in India.

The significant variations in incidence and severity values recorded for cowpea rust in the semi-deciduous forest, deciduous forest, coastal savannah and Sudan savannah are closely associated with variations in rainfall and temperature of the agro-ecological zones. Semi-deciduous forest has the highest mean annual rainfall (1875 mm), relative humidity (77.5%) and temperature (28°C) among the four agro-ecological zones [14]. The deciduous forest generally has a high mean annual rainfall of 1500 mm whereas the coastal savannah has an annual rainfall of 875 mm [11, 12]. Sudan savannah is characterised by an average rainfall of 800 mm per annum and a modest temperature of 27°C and relative humidity rarely exceeding 20% [15]. The absence of significant difference ($p > 0.05$) in cowpea rust incidence and severity between the coastal savannah and Sudan savannah equally conforms to the similar climatic conditions of the zones. Rainfall, temperature, relative humidity and prolonged cloudy weather are the main climatic parameters for occurrence and epidemics of rust disease [29].

High amount of rainfall generally leads to cool and wet environmental conditions which cause cowpea plant to exhibit vegetative growth and increase in plant density, providing favourable conditions for rust development. Rust urediniospores land on cowpea leaf surface and in presence of water film and temperature of 15-30°C germinate, and produce appressoria and infection hyphae that penetrate the leaf through the stomata [29, 30]. Rust incidence increased in Yardlong bean (*Vigna unguiculata* sub sp. *Sesquipedalis*) due to higher plant densities which facilitated development of the disease [28]. Rust infection is particularly severe at high humid condition of 90% and temperature of 18-20°C [31].

Significant ($p < 0.05$) positive linear relationship existed between cowpea rust incidence and severity in the agro-ecological zones. Rust disease development was positively and significantly ($p < 0.05$) associated with maximum temperature (0.59), relative humidity (0.33), evaporation (0.33) and bright sunshine hours (0.55) [29]. The concept of the growing period is very important to agro-ecological zones, and ensures application of seasonality in sustainable crop production and yield [32]. Rust incidence, severity, area under disease progress curve (AUDPC) and relative area under disease progress curve (rAUDPC) for the cowpea genotypes differed significantly ($p < 0.05$) between the major and minor cropping seasons. Higher values of 58.52% (DI), 21.30% (DS), 740.10 (AUDPC) and 42.62 (rAUDPC) were observed in the minor season compared with 4.85% (DI), 0.55% (DS), 42.60 (AUDPC) and 7.67 (rAUDPC) observed in the major season (Table 4).

Similarly, high temperature and rainfall values were recorded for the minor season (545.50 mm and 29°C) compared with major season (47.75 mm and 27°C) (Table 1). This suggest that temperature and rainfall are positively associated with cowpea rust incidence, severity, AUDPC and rAUDPC. Studies have similarly reported that rust disease is greatly influenced by environmental factors [33, 34]. A study evaluated rust disease incidence in two growing seasons in the Southern transitional zone of India and reported different incidence levels ranging from 30.59-57.14% to 37.13-66.13%, with the latter season recording the higher value of rust incidence [28].

Five out of the 24 cowpea genotypes were better slow rusting, 11 cowpea genotypes were slow rusting whereas 8 cowpea genotypes showed fast rusting response in both major and minor cropping season (Table 4). Better slow rusting, slow rusting and fast rusting responses among 103 cowpea genotypes have been reported [35]. Cowpea genotypes that were better slow rusting have also been reported in Mexico [36]. Latent period is the principal component of slow rusting in plant cultivars [37, 38]. Studies in slow rusting cultivars are currently becoming popular in many crops because they remain effective for longer periods and allow some amount of disease development which leads to reduction in selection pressure for preferential development of previously undetected rust strains [39].

Except UCC-366, correlation existed in the incidence, severity, AUDPC and rAUDPC of cowpea rust disease recorded for the cowpea genotypes in the major and minor cropping seasons. This implies that cowpea rust disease is influenced by ecological conditions. A close association among incidence, severity and number of urediniospores produced per pustule of cowpea rust has been shown [35]. The 24 cowpea genotypes showed moderate susceptibility to resistance in response to cowpea rust infection (Table 4). Fifteen cowpea genotypes showed resistance to cowpea rust whereas eight cowpea genotypes showed moderate resistance to cowpea rust. In contrast, IT08K-817-3 was moderately susceptible to cowpea rust, and recorded highest incidence, severity, AUDPC and rAUDPC of cowpea rust compared with the resistant and moderately resistant cowpea genotypes. Earlier studies have reported higher AUDPC and rAUDPC values for cowpea rust in susceptible cowpea genotypes than resistant and moderately resistant cowpea genotypes [7, 35]. All the eighteen cowpea genotypes that showed resistance to cowpea rust can be recommended to farmers and also utilised in breeding programmes to develop resistance in susceptible cowpea lines.

5. Conclusions

Twenty four cowpea genotypes showed varied resistance responses to cowpea rust under field conditions. Rust disease was observed in the four agro-ecological zones and the major and minor cropping seasons with varying intensities due to environmental variability and genetic differences in the cowpea germplasm. Semi-deciduous forest recorded the highest incidence and severity of cowpea rust. The incidence, severity, AUDPC and rAUDPC of cowpea rust were also higher in the minor season compared with the major season. Positive and negative relationships were found among rust incidence, severity, AUDPC and rAUDPC within the agro-ecological zones and cropping seasons. The cowpea genotypes showed better slow rusting, slow rusting and fast rusting responses to cowpea rust.

Fifteen of the cowpea genotypes (UCC-153, UCC-221, UCC-328, UCC-366, UCC-466, UCC-473, UCC-484, UCC-513, UCC-523, UCC-Early, Apagbaala, IT08K-193-14, IT10K-125-107, IT10K-832-3 and IT97K-499-35) showed resistance to cowpea rust. Eight cowpea genotypes (UCC-11, UCC-24, UCC-32, UCC-241, UCC-445, UCC-490, Padi-

Tuya and IT10K-819-4) showed moderate resistance whereas only IT08K-817-3 was moderately susceptible to cowpea rust. The rust resistant cowpea genotypes can be cultivated by farmers to increase yield and production of the crop in Ghana. The slow rusting cowpea genotypes can be exploited in breeding for robust progenies to facilitate identification of races of cowpea rust and enhance genetic improvement and management strategies of the crop to rust.

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Conflict of Interest

The authors declare no conflict of interest.

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