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Field evaluation of some cowpea genotypes for resistance to the Cercospora leaf spot disease in Northern Ghana

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Abstract

Cercospora leaf spot infection during flowering, podding, and pod filling stages of cowpea has been reported to cause as high as 80% yield losses among susceptible genotypes. The objectives of this study were to evaluate selected cowpea genotypes for resistance to Cercospora leaf spot disease under field conditions and to determine the impact of the disease on yield and its associated components on cowpea. Twenty-five (25) cowpea genotypes were evaluated for resistance to the Cercospora leaf spot disease under field conditions in Northern Ghana. The experiment was laid out in a Randomized Complete Block Design with three replications at both Nyankpala and Yendi. Agronomic data and cercospora disease scores were taken. The results revealed that four genotypes; IT10K-817-3, IT13K-1070-2, IT14-2112-1 and IT86D-610 were slightly resistant to the disease. IT14K-1682-2 and IT14K-1682-3 were susceptible to the disease whilst the remaining nineteen genotypes were moderately resistant to the Cercospora leaf spot disease. IT14K-1682-3 can be considered a tolerant line as it yields appreciably although it showed susceptibility to the disease. The different categories of resistance identified among the cowpea genotypes will be useful in breeding for resistance to Cercospora disease in cowpea.

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Introduction

Cowpea (*Vigna unguiculata* (L). Walp) contains higher nutritional values which make it a very important commodity in achieving food and nutritional security. It is known to contain high nutrient content of 20-30% protein, 50-67% carbohydrate, and other nutrients (Kirse and Karklina, 2015; Khalid and Elharadallou, 2016). It is therefore a key grain crop in minimizing poverty and food insecurity in most rural areas of the African continent (Langyintuo *et al.,* 2003). West Africa with 10.7-million-hectare annual production is responsible for 85% of Africa's production (FAOSTAT, 2017). Ghana produces an average of 143,000 MT annually (ICRISAT, 2012) making Ghana the 5th highest producer of cowpea in Africa. In Ghana, over 90% of annual national cowpea output is realized in the Northern, Upper East, Upper West regions (MOFA-SRID, 2011). Cowpea is grown based on the selection of yields, days to maturity grain size, and color (MOFA, 2013). Cowpea among other leguminous crops, because of its high level of nutrients it is widely known to be greatly affected by several weeds, insect pests, bacterial, viral, and fungal diseases among others throughout its growth period (Fatokun, 2002; Akpalu *et al*., 2014; Gomes *et al*., 2019). Among the diseases, the most prominent and persistent are the Cercospora leaf spot, cowpea bacterial blight, cowpea wilt, stem rot, and the root-knot nematode caused by (*Meloidogyne* spp.). According to the IITA, disease infestation in cowpea can cause up to 90% yield loss if not managed properly (IITA, 2000). Among these diseases, the Cercospora leaf spot, caused by the fungi; *Cercospora canescens* Ellis and Martin and *Mycospharella cruenta* Lanthanus (Akande, 2007) has been reported to cause severe yield loss in cowpea. According to Schneider *et al.* (1976); Ferry *et al.* (1977), Cercospora in susceptible varieties can cause a yield loss of up to about 42%. According to Ajibade and Amusa (2001), field observation in 1999 and 2000 among 75 cowpea lines revealed that about 40% of the genotypes were susceptible and recorded about 80% disease severity during the experiment. Booker and Pathmanathan (2007) also asserted that the Cercospora leaf spot can also be responsible for about 42% of crop loss. In West Africa, cowpea undergoes considerable damage due to frequent terminal drought as a result of climate change. Cercospora leaf spot infection at the flowering, podding, and pod filling stage of the crop can cause as high as 80% yield losses among susceptible genotypes (Agbicodo *et al..,* 2009). This menace calls for the employment of economic, environmentally friendly and effective strategies to curb the effects of the menace. Breeding for Cercospora resistant genotypes of cowpea could be an effective means to minimize the economic losses due to the disease. This will further yield an appreciable success in food security and reduction of poverty among resource-poor rural farmers. The adaptation of strategic research, therefore, remains essential, especially breeding resistant varieties to Cercospora leaf spot for farmers. The first step in any breeding intervention is the identification of resistant sources. This study, therefore, seeks to evaluate the cowpea genotypes for resistance to the Cercospora leaf spot disease under field conditions and to determine the impact of the Cercospora leaf spot disease on yields of the cowpea genotypes.

Materials and methods

The experiment was conducted at two experimental fields of the CSIR-Savanna Agricultural Research Institute (CSIR-SARI); Nyankpala and Yendi, under natural and rainfed conditions. Nyankpala and Yendi are located in the Northern region of Ghana with coordinates 9.3965° N, 0.9892° W and 9.4450° N, 0.0093° W respectively. Three (3) released varieties and twenty-two (22) elite lines were obtained from the Cowpea Improvement programme of the CSIR-SARI for the experiment. The twenty-five (25) genotypes were laid in a Randomized Complete Block Design (RCBD) with three replications at both Nyankpala and Yendi. The experimental materials were established on a 4 m × 4 rows plot with a 0.75 m × 0.2 m planting distance. Pendimethalin was applied at 1 kg /ha as a pre-emergence herbicide. NPK fertilizer 15-15-15 was applied at 100 kg/ha at two weeks after planting to improve vegetative growth at the initial stages. Weed control was done manually

when necessary. K-Optimal (Cyhalothrine 15 g + Acetamippride 20 g) and (Cypermethrine + Dimethoate) were applied at a rate of 500 ml/ha at vegetative, flowering, and podding stages to control insect pests.

Data collection and analysis

The disease was scored using a 6-point modified scale of Park (1987) in terms of leaf coverage by the Cercospora leaf spot. where 0 = no visible symptom and 5 = more than 80% of the leaf lamina covered by the spot with possible defoliation. According to this scale, the resistance level of the 25 genotypes were interpreted as 0 = highly resistant, 1 = resistant, 2 = slightly resistant, 3 = moderately resistant, 4 = susceptible, 5 = highly susceptible.

The formula used to compute disease severity was

$$= \frac{\text{Sum of individual ratings}}{\text{Number of Plants Assessed x Highest Rating in the Scale}} \times 100$$

Modified Awurum and Emechebe (2001) scale was used to categorized genotypes into highly resistant (HR), resistant (R), slightly resistant (SR), moderately resistant (MR), susceptible(S), and highly susceptible (HS) after disease severity computation. Disease rating was done 60 days after planting.

Agronomic parameters such as days to 50% flowering, days to 95% pods maturity, grain yield and 100 seed weight were determined. The means of all parameters measured from the two locations (Nyankpala and Yendi) were computed and subjected to analysis of variance (ANOVA) to query the variabilities and significant differences between the means among the genotypes. Where there were significant differences ($P < 0.05$), treatment means were compared using LSD at 5% using Genstat statistical package (12th Edition).

Results

Days to 50% flowering

Days to 50% flowering was significantly ($P < 0.001$) different among genotypes in both Nyankpala and Yendi.

Table 1. Modified scale of Awurum and Emechebe 2001.

Rating	Mean Disease Severity
Highly resistant	0%
Resistant	1 - 10%
Slightly resistant	11 - 20%
Moderately resistant	21 -40%
Susceptible	41 - 65%
Highly susceptible	More than 65%

The result revealed that most genotypes attained 50% flowering earlier in Yendi than in Nyankpala. In Yendi, twenty-two out of twenty-five genotypes reached 50% flowering before 50 DAP whilst only three genotypes reached 50% flowering after 50DAP. In Nyankpala, Padi-tuya and IT14K-2030-2 were the first to attain 50% flowering at 47.67 and 48 DAP respectively, while Kirkhouse Benga was the last to attain 50% flowering at 54.33 DAP in Nyankpala (Fig. 1). In Yendi, IT07K-303-1 attained 50% flowering at 48 DAP, making it the first while IT14K-1913 was the last to attain 50% flowering at 54 DAP in Yendi (Fig. 1).

Days to 95% pod maturity

Cowpea genotypes exhibited significant differences in days to 95% maturity ($P < 0.001$) at both Nyankpala and Yendi. Days to 95% maturity ranged from 68.67 to 78.67 DAP and 66.67 to 78.33 DAP at Nyankpala and Yendi respectively (**Error! Reference source not found.**). In Nyankpala, the early maturing genotypes were IT13K-1329-10, IT13K-1329-8 and SARI-2-50-80, whiles IT14K-2112-1 was the last to attained 95% pod maturity (**Error! Reference source not found.**). Two genotypes; IT11K-61-82 and IT84S-2049 were the earliest reaching 95% maturity at 66.67 DAP while IT14K-1913 was late

maturing (78.33 DAP) in Yendi. In Nyankpala, IT13K-1329-10, IT13K-1329-8 and SARI-2-50-80 were the earliest with maturity periods between 65 and 70 DAP. Genotypes IT09K-456 and IT14K-2112-1 attained 95% pod maturity after 75 DAP whilst the remaining twenty genotypes attained 95% pod maturity between 71 and 75 DAP and therefore fall within the medium duration range. In Yendi, IT10K-817-3, IT13K-1070-2, IT14K-1683-2, IT14K-2035-2, IT11K-61-82 and IT84S-2049 are early maturing as they reached maturing within the range of 65 and 70 DAP. IT14K-1913 and IT13K-1424-12 reached maturity after 75 DAP and are therefore late maturing for this location whilst the remaining seventeen genotypes reached maturity from 71 to 75 DAP (**Error! Reference source not found.**).

Table 2. Variation in 100 seed weight of cowpea genotypes at different locations.

	100 Seed weight (g)		
Genotypes	Nyankpala	Yendi	Means
IT99 K-1122	15.67 d-h	16.33 e-h	16 ef
IT07K-303-1	15.33 e-i	17.67 d-h	16.5 bcd
IT08K-150-12	16.99 c-g	17.33 d-h	17.16 ef
IT09K-456	15.33 e-i	17.33 d-h	16.33 ab
IT10K-815-5	15.67 d-h	18.67 c-g	17.17 c-f
IT10K-817-3	17.67 cde	17.67 d-h	17.67 b-e
IT10K-837-1	17.67 cde	19.67 b-e	18.67 b-e
IT13K-1070-2	14 ghi	15 h	14.5 ef
IT13K-1160-3	15 e-i	17.33 d-h	16.165 ef
IT13K-1297-9	18.67 bcd	22.33 ab	20.5 bc
IT13K-1329-10	13.33 hi	16 fgh	14.665 f
IT13K-1329-8	13 hi	15.33 gh	14.165 f
IT13K-1424-12	23 a	24 a	23.5 a
IT14K-1682-3	12.33 i	15.33 gh	13.83 f
IT14K-1683-2	15.67 d-h	16.33 e-h	16 abc
IT14K-1913	19.33 bc	20.67 bcd	20 a
IT14K-2030-2	23.33 a	24.33 a	23.83 ab
IT14K-2035-2	16 d-h	19 c-f	17.5 b-f
IT14K-2112-1	17.33 c-f	17.67 d-h	17.5 ab
IT1K-61-82	14 ghi	15.33 gh	14.665 def
IT84S-2049	17.33 c-f	17 e-h	17.165 b-e
IT86D-610	14.33 f-i	16.67 e-h	15.5 b-f
Kirkhouse Benga	16.67 c-g	19 b-f	17.835 b-e
Padi-tuya	21 ab	21.67 abc	21.335 ab
SARI-2-50-80	19.67 bc	21.67 abc	20.67 bc
Mean	16.73	18.37	17.44
CV (%)	9.7	9.7	8.8

Means followed by the same letters in a column are not significantly different at $P < 0.05$.

Hundred Seed weight

The variation among the cowpea genotypes for 100 seed weight was significant ($P < 0.001$) at both Nyankpala and Yendi. For Nyankpala, the highest hundred seed weight was recorded by IT14K-2030-2 (23.33 g) while IT14K-1683-2 recorded the lowest hundred seed weight (12.33 g) (Table). In Yendi, IT14K-2030-2 recorded the highest 100 seed weight (24.33 g) and was significantly different from IT13K-1070-2 which recorded 15.00 g (Table). Based on the mean computation of 100 seed weight for the two locations, the highest 100 seed weight was obtained for IT13K-1424-12 (23.50 g) while IT14K-1682-3 had the lowest (13.83 g) (Table).

Grain yield

The genotypes showed significant ($P < 0.05$) differences for grain yield at both Nyankpala and Yendi. Comparing the two locations, IT14K-2035-2 had the highest average grain yield (2126.5 kg/ha) whilst Padi-tuya had the lowest (855.5 kg/ha). The highest grain yield in Nyankpala was 2113 Kg/ha for IT13K-1297-9 (2113 kg/ha) while IT84S-2049 had the lowest (909 kg/ha) (**Error! Reference source not found.**).

Table 3. Grain yield for the cowpea genotypes at different locations.

	Grain Yield (kg/ha)		
Genotypes	Nyankpala	Yendi	Means
IT99K-1122	1012 cd	1497 bc	1254.5 cd
IT07K-303-1	1171 a-d	1559 bc	1365 bcd
IT08K-150-12	1505 a-d	1847 abc	1676 bcd
IT09K-456	1446.46 abc	1625 bc	1535.733 bcd
IT10K-815-5	1748 abc	1416 bc	1582 bc
IT10K-817-3	1113 a-d	1938 ab	1525.5 bcd
IT10K-837-1	1446 abc	1828 abc	1637 cd
IT13K-1070-2	1332 a-d	1850 abc	1591 bcd
IT13K-1160-3	1449 a-d	1844 abc	1646.5 bc
IT13K-1297-9	2113 a	2057 ab	2085 a
IT13K-1329-10	1798 abc	1681 bc	1739.5 ab
IT13K-1329-8	1080 bcd	2518 ab	1799 bc
IT13K-1424-12	1396 a-d	1517 bc	1456.5 bcd
IT14K-1682-3	1184 a-d	2184 ab	1684 cd
IT14K-1683-2	1299 a-d	1619 bc	1459 bc
IT14K-1913	1411 a-d	1689 bc	1550 bc
IT14K-2030-2	2005 ab	2038 ab	2021.5 ab
IT14K-2035-2	1379 a-d	2874 a	2126.5a
IT14K-2112-1	1379.53 a-d	1587 bc	1483.26 bcd
IT11K-61-82	1317 a-d	2078 ab	1697.5 bcd
IT84S-2049	901 cd	1718 bc	1309.5 cd
IT86D-610	1377 a-d	1690 bc	1533.5 bc
Kirkhouse Benga	1504.83 abc	1664 bc	1584.41 bc
Padi-tuya	951 cd	760 c	855.5 cd
SARI-2-50-80	1726 abc	1726 bc	1726 cd
Mean	1322.68	1792.16	1557.42
CV (%)	37.4	32.5	25.2

Means followed by the same letters in a column are not significantly different ($P > 0.05$).

In Yendi, IT14K-2035-2 had the highest grain yield of 2874 kg/ha. This was significantly different from the yield obtained by Padi-tuya (760 kg/ha) which was the lowest (**Error! Reference source not found.**).

Disease assessment

Cercospora leaf spot disease occurred in all study areas (**Error! Reference source not found.**). All the 25 cowpea genotypes responded differently to the disease both at Nyankpala and Yendi. IT14K-1683-2 had the highest mean disease severity (50%) with genotypes IT10K-817-3, IT13K-1070-2, IT14K-2112-1 and IT86D-610 having the least (20%). In Nyankpala, IT14K-1683-2 had the highest disease severity (60%) whilst fourteen genotypes; IT07K-303-1, IT08K-150-12, IT10K-817-3, IT13K-1070-2, IT13K-1160-3, IT13K-1329-8, IT14K-2030-2, IT14K-2035-2, IT14K-2112, IT11K-61-82, IT84S-2049, IT86D-610, Kirkhouse Benga, Padi-tuya, and SARI-2-50-80 had the lowest disease severity (20%). In Yendi, genotype IT08K-150-12 had the highest disease severity (60%) whilst IT10K-817-3, IT13K-1070-2, IT13K-1297-9, IT13K-1424-12, IT14K-2112-1 and IT86D-610 had the least disease severity (20%). Out of the 25 cowpea genotypes, the average disease severity mean reveals that two genotypes IT14K-1683-2 and IT14K-1682-3 were susceptible to the Cercospora leaf spot disease. Four other genotypes IT10K-817-3, IT13K-1070-2, IT14K-2112-1 and IT86D-610 were slightly resistant to the disease whilst the remaining eighteen

genotypes were moderately resistant to the disease. However, three genotypes IT10K-837-1, IT14K-1682-3, and IT14K-1683-2 were susceptible to the disease in Nyankpala. Genotypes IT99K-1122, IT09K-456, IT10K-815-5, IT13K-1297-9, IT13K-1329-10, and IT13K-1424-12 were moderately resistant while the remaining sixteen were slightly resistant. In Yendi, IT99K-1122, IT07K-303-1 and IT08K-150-12 were susceptible to the Cercospora leaf spot disease. Six genotypes, IT10K-817-3, IT13K-1070-2, IT13K-1297-9, IT13K-1424-12, IT14K-2112-1, and IT86D-610 were slightly resistant to the disease whiles the remaining 16 are moderately resistant to the disease (**Error! Reference source not found.**).

The mean disease severity for the two locations of this study however has revealed that four genotypes, IT10K-817-3, IT13K-1070-2, IT14-2112-1 and IT86D-610 were slightly resistant to the disease. Based on disease scores, IT14-1682-2 and IT14-1682-3 were susceptible to the disease whilst the remaining nineteen genotypes were moderately resistant to the Cercospora leaf spot disease (**Error! Reference source not found.**).

Table 4. Disease severity assessment of cowpea genotypes for resistance to the Cercospora leaf spot disease at different locations.

	Disease Severity (%)					
Genotypes	DS% Nyankpala	Remarks	DS% Yendi	Remarks	DS% Mean	Remarks
IT99K-1122	33.33 ab	MR	46.67 ab	S	40 bcd	MR
IT07K-303-1	20 a	SR	46.67 ab	S	33.33 abc	MR
IT08K-150-12	20 a	SR	60 b	S	40 bcd	MR
IT09K-456	33.33 ab	MR	26.67 a	MR	30 ab	MR
IT10K-815-5	26.67 a	MR	40 ab	MR	33.33 abc	MR
IT10K-817-3	20 a	SR	20 a	SR	20 a	SR
IT10K-837-1	46.67 bc	S	33.33 ab	MR	40 bcd	MR
IT13K-1070-2	20 a	SR	20 a	SR	20 a	SR
IT13K-1160-3	20 a	SR	33.33 ab	MR	26.66 ab	MR
IT13K-1297-9	33.33 ab	MR	20 a	SR	26.66 ab	MR
IT13K-1329-10	26.67 a	MR	26.67 a	MR	26.67 ab	MR
IT13K-1329-8	20 a	SR	33.33 ab	MR	26.67 ab	MR
IT13K-1424-12	26.67 a	MR	20 a	SR	23.33 a	MR
IT14K-1682-3	53.33 c	S	40 ab	MR	46.67 cd	S
IT14K-1683-2	60 c	S	40 ab	MR	50 d	S
IT14K-1913	20 a	SR	33.33 ab	MR	26.67 ab	MR
IT14K-2030-2	20 a	SR	33.33 ab	MR	26.67 ab	MR
IT14K-2035-2	20 a	SR	33.33 ab	MR	26.67 ab	MR
IT14K-2112-1	20 a	SR	20 a	SR	20 a	SR
IT1K-61-82	20 a	SR	33.33 ab	MR	26.67 ab	MR
IT84S-2049	20 a	SR	26.67 a	MR	23.33 a	MR
IT86D-610	20 a	SR	20 a	SR	20 a	SR
Kirkhouse Benga	20 a	SR	33.33 ab	MR	26.67ab	MR
Padi-tuya	20 a	SR	26.67 a	MR	23.33 a	MR
SARI-2-50-80	20 a	SR	40 ab	MR	30 ab	MR
Mean	26.4		32.27		29.33	
CV (%)	31.6		43.6		26.7	

Disease Severity (DS); Highly resistant (HR) = 0%; Resistant (R) = 1-10%; Slightly resistant (SR) = 11-20%; Moderately resistant (MR) = 21-40%; Susceptible (S) = 41- 65%; Highly susceptible (HS) = more than 65%.

Discussion

Cercospora leaf spot has been one of the common diseases observed on cowpea farms in Ghana. Cercospora leaf spot under severe conditions has been reported to reduce the number of pods per plant, average number of seeds per pod, and 100-seed weight of susceptible cowpea variety (Sinsiri *et al.*, 2006; Plantwise, 2010). In this study, despite some

genotype's ability to exhibit some levels of resistance, there were significant variations ($P < 0.001$) among the genotypes with respect to days to 50% flower, days to 95% maturity and 100 seed weight at both Nyankpala and Yendi. The genotypes, however, exhibited no significant differences in total grain yield at both locations. In green plants, the ability to grow, develop and reproduce is directly proportional to its ability to undergo photosynthesis provided all other conditions are adequately met (Ozay and Oztas, 2003). The inability of the Cercospora leaf spot to have any significant impact on most yield parameters is usually attributed to the fact that the leaves of the plants were not yet affected enough by the Cercospora leaf spot to interfere with the photosynthetic ability and processes and the utilization of its product (Awurum and Emechebe, 2001).

This could also be attributed to the fact that Cercospora leaf spot damage occurred late in the growing season when the crop's vegetative and reproductive parts were fully developed (Awurum and Emechebe, 2001) and may have a significant negative impact on its fodder yield instead of grain yield.

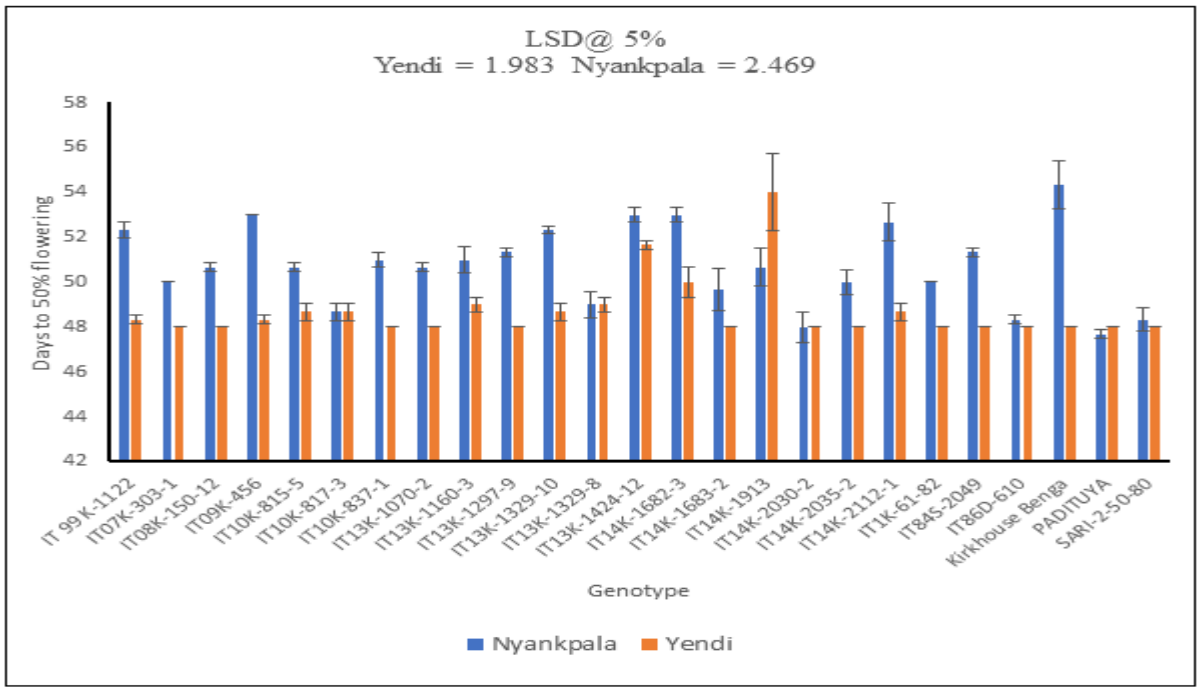

Fig. 1. Variation in days to 50% flowering among cowpea genotypes at different locations.

Seed weight is a very important parameter in measuring productivity in cowpea. According to Memon *et al.* (2005), 100 seed weight does not only depend greatly on the genetic composition of the crop, other factors such as disease incidence and severity also play an inevitable role.

These figures are higher as compared to that of Nahunnaro and Ayuba (2012) who reported an average seed weight of 13 – 18 g in Nigeria. 100 seed weights in Yendi were comparatively higher than what was observed in Nyankpala. This difference could be due to variations in the environmental conditions of the two locations. This agrees with Memon *et al.* (2005) who reported that an environmental factor such as soil fertility had a significant impact on 100 seed weight. The average 100 seed weights of the two locations ranged between 13.83 and 23.55 g.

These are comparatively higher as compared to that of Tengey *et al.* (2021) who recorded a 100 seed weight between 12.4 and 20.9 g when they evaluated studied 21 cowpeas for yield stability. This difference could be attributed to variation in the genetic makeup of the cowpea genotypes, soil fertility, and disease resistance (Awurum and Emechebe, 2001; Memon *et al.*, 2005; Idahosa *et al.*, 2010; Gerrano *et al.*, 2015).

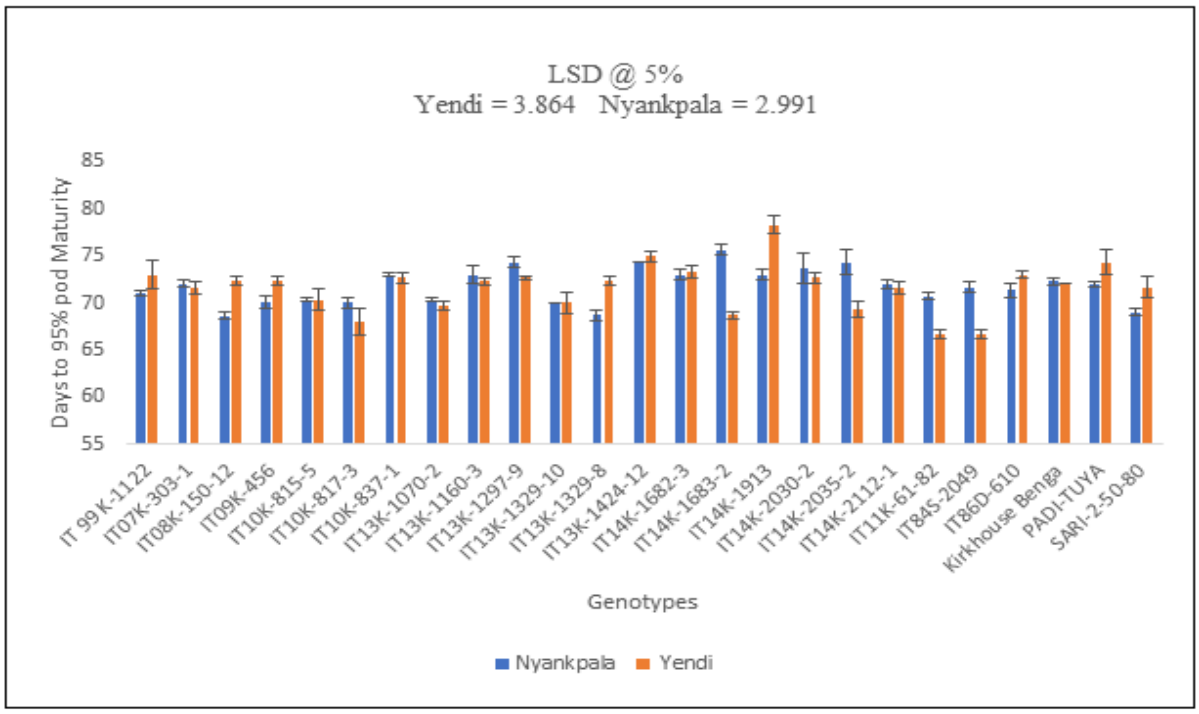

Fig. 2. Variation in days to 95% pod maturity of cowpea genotypes at different locations. Error bars represent SEM.

Grain yield is mostly considered as the main product in pulses. In this study, grain yield ranged from 905 kg/ha to 2113 kg/ha in Nyankpala and 760 kg/ha to 2874 kg/ha in Yendi. However, the mean grain for the two locations ranged from 855.5 to 2126.5 kg/ha. Booker and Pathmanathan (2007) have reported that Cercospora leaf spot disease caused up to 40% yield loss in cowpea.

Cercospora disease severity ratings revealed that the 25 cowpea genotypes in this study reacted differently in their levels of resistance to the Cercospora leaf spot disease at both Nyankpala and Yendi. This agrees with Nahunnaro and Ayuba (2012) who postulated that different cowpea genotypes responded differently to Cercospora leaf spot when studied in two locations in Nigeria. Furthermore, Sinsiri *et al.* (2006) also postulated that different cowpea genotypes exhibited different levels of resistance to the disease at different levels due to differences in their genetic make-ups. This study revealed different levels of susceptibility and resistance of the 25 genotypes to the disease (**Error! Reference source not found.**). Apart from the variations in the genetic make-up of the genotypes, the difference in the susceptibility levels among the genotypes across Nyankpala and Yendi could also be attributed to variations in other environmental factors. Akande (2007) in a similar experiment observed that environmental conditions such as initial inoculum of the Cercospora pathogen, warm temperature, and higher humidity greatly affected the incidence and severity of Cercospora leaf spot. The knowledge and availability of resistant varieties may be very useful to farmers and crop breeders in their selection of cowpea varieties for different locations at different times. In the present study, IT13K-1297-9 recorded the highest grain yield in Nyankpala where it was moderately resistant to the disease. Again, IT14K-2035-2 obtained the highest grain yield in Yendi where it was slightly resistant to the disease. Ajibade and Amusa (2001) in a similar study also observed that 40% of 75 cowpea genotypes evaluated in 1999 and 2000 produced higher yields in that year where they were less susceptible to the disease and vice versa.

Conclusion

Most of the genotypes evaluated were slight to moderately resistant to cercospora disease whilst IT14K-1682-3 was tolerant. In terms of yield, IT13K-

1297-9 and IT14K-2030-2 were the top performers. In terms of seed weight, IT14K-2030-2 and 1T14K-1424-2 were the highest. The results from this experiment will help in future breeding interventions.

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Conflict of interest

The authors have not declared any conflict of interest.

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