UNDER PEER REVIEW

Original Research Article

Field Reactions of Pepper (Capsicum spp.) Lines and Accessions to Anthracnose Disease in Makurdi, Benue State, Nigeria.

Abstract

Nursery and field experiments were conducted in 2012 and 2013 at the experimental site of the Federal University of Agriculture, Makurdi in the Southern Guinea Savannah of Nigeria (7° 45'N, 8° 35' E) to evaluate the field reactions of twenty eight pepper lines and accessions to pepper anthracnose. Fifteen exotic pepper lines developed at the World Vegetable Center (AVRDC) Taiwan (AVPP- 0013, 0802, 9809, 9905(Susceptible Check), 0401, 9814, 9807, 0403, 0706, 0513, 0412, 0114, 9801, 9813, 9612) and thirteen accessions sourced locally (Ex-kunkunu, Cayenne, GHA, Prof fintashi, N-M-Iddi, Tugantashi, Bor kono tsifidi, M'daku, African Birdeye pepper, Atarodo, Tatashe, Sombo, Nsukka yellow) were screened for resistance to pepper anthracnose. The experiment was laid out in Randomized Complete Block Design with three replications. Fifteen pepper lines/accessions which had better establishment were further selected to screen for resistance to pepper fruit anthracnose caused by *Colletotrichum capsici* under natural conditions. The results showed that African birdeye pepper, AVPP 0706 and Nsukka yellow had the lowest mean anthracnose severity of 6.50%, 10.75% and 19.20% respectively and were classified as resistant. Nine pepper lines/accessions namely AVPP 0013, AVPP 0802, AVPP 9809, AVPP 9905, Cayenne, Ex-Kunkunu, GHA, Prof fintashi, N-M-Iddi were moderately resistant to pepper anthracnose while the remaining three M'daku, Bor kono tsifidi, Sombo were moderately susceptible to the disease. Ex-kunkunu was tolerance to pepper anthracnose. Correlation results showed positive significant correlation (r = 0.53) between nursery disease and fruit anthracnose.

Keywords: Screening, resistance, anthracnose, pepper, accessions.

1. INTRODUCTION

Pepper (*Capsicum spp*) is considered to be one of the most important crops in the tropics. In Nigeria, pepper is regarded as the third most important vegetable after onions and tomatoes [1, 2]. It is known as one of the commodities with great potential for commercialization in Nigeria [3]. It is cultivated mainly in the Northern Guinea Savanna with about 60% of the total national output [4]. Pepper was ranked seventh in North Central Nigeria and listed among the commodities with returns greater than US$1 billion over a period of 17years [3].

UNDER PEER REVIEW

Anthracnose disease of pepper characterized by fruit lesions evident by concentric rings produced by the acervuli is the most economical disease of pepper caused by *Colletotrichum capsici* [5]. *Colletotrichum* spp. is capable of causing disease on many of the chilli plant parts during any stages of growth. However, fruit lesions are the most economically important aspect of this disease [5]. Incidence of the anthracnose disease in the nursery and on the field is a problem in most pepper growing regions of Nigeria, where conditions are conducive for disease development especially in years recording high rainfall and humidity. Anthracnose is one of the serious diseases on pepper that causes yield loss and reduces the quantity and marketability of fruits by reducing the dry weight and lowering quantities of capsaicin and oleoresin indicative of reduced fruit quality. Infected seeds usually turn rusty while infected fruits often lose their pungency and taste [6].

Infected fruits showing blemishes are generally considered unfit for human consumption and may be toxic to humans and animals [6]. Small anthracnose lesions on pepper fruits have been reported to reduce their marketable value [7].

Crop protection achieved through host plant resistance is a preferred option, especially for the resource-poor farmers. The introduction of better adaptable, well performing varieties with tolerance/resistance to nursery and field diseases could be used to boost pepper production and quality of pepper in Nigeria. Identifying sources of resistance for economic diseases is important for effective and long term control of such diseases.

Although some sweet pepper varieties were earlier screened for tolerance/resistance to pepper anthracnose by [8] resistant varieties were not identified. There is the need to screen more exotic breeding lines and local pepper varieties of the sweet and hot pepper types for resistance to pepper anthracnose disease. The identification and introduction of pepper varieties with high yield and

UNDER PEER REVIEW

resistance/tolerance to anthracnose is important for effective and long term control of the disease. The selected high yielding exotic lines and local accessions with moderate yield were screened for resistance to anthracnose under natural infection with the aim of identifying promising varieties that could be bred by combining desirable traits such as high yield and resistance to anthracnose.

This study therefore seeks to evaluate some hot, sweet exotic and local varieties of pepper for resistance/tolerance to pepper anthracnose in the seedling and mature stages in order to select varieties of economic importance that can adapt well to the Dystric Ustropept [9] environment in Makurdi, North Central Nigeria.

2. MATERIALS AND METHODS

2.1 Pepper Varieties

Fifteen exotic breeding lines viz AVPP 0013, AVPP 0401, AVPP 9814, AVPP 9809, AVPP 9807, AVPP 0403, AVPP 0706, AVPP 0802, AVPP 0513, AVPP 0412, AVPP 0114, AVPP 9801, AVPP 9813, AVPP 9905, AVPP 9612 were collected from the Genetics Resources and Seed Unit of The World Vegetable Center (AVRDC) Taiwan in 2012. Seven varieties namely GHA, Tugantashi, Bor kono tsifidi, M'daku, Prof fintashi, N-M-Iddi and Ex kunkunu were obtained from the Institute of Agricultural Research (IAR) Zaria, Nigeria. The remaining six varieties namely African Birdeye pepper, Atarodo, Tatashe, Sombo, Nsukka yellow and Cayenne were sourced locally.

A viability test was conducted in the laboratory using a total of 1400 seeds (at the rate of 50 seeds per pepper line and accession). The experiment was a Completely Randomized Design replicated three times. Incubated seeds were examined for the presence of *C. capsici*. Infected seeds were counted and recorded as percentages.

UNDER PEER REVIEW

After the initial nursery planting, five exotic pepper varieties namely AVPP 0013 (Chilli pepper), AVPP 0706 (Chilli pepper), AVPP 0802 (Chilli pepper), AVPP 9809 (Sweet pepper), AVPP 9905 (Chilli pepper) and six local accessions namely Bor kono tsifidi, Ex- Kunkunu, Prof fintashi, GHA, M'daku, N-M-Iddi, Birdeye, Nsukka yellow and Sombo which had high percentage germination were further evaluated for field resistance/tolerance to anthracnose in Makurdi.

2.2 Nursery Screening

The nursery preparation involved the application of poultry dung (applied three weeks before planting) to the top soil in the ratio 3:2 in beds 1m x 2.5m wide. The seeds of fifteen pepper varieties were treated with Seed Plus 30WS (a.i Imidactoprid 10% (Systemic insecticide) + Metalaxyl 10% (systemic fungicide) + Carbendazim 10% WS (systemic fungicide) at the recommended rate of 30ml/2kg seed and placed in drills. Fifty seeds of each variety were planted in drills 10cm apart and at 1cm depth on nursery beds 1m x 2.5m wide on the 10th of April, 2012 and 17th April, 2013. The experiment was a Completely Randomized Design replicated three times. The beds were watered and mulched with dry grass. Mulch was removed after seedling emergence and shade was removed at 3WAP to harden seedlings in preparation for transplanting at 4WAP.

2.3 Field screening

Two field trials were conducted in 2012 and 2013 cropping seasons at the experimental site of the University of Agriculture, Makurdi in the Southern Guinea Savannah of Nigeria (7° 45'N, 8° 35' E). Top soil (0-15cm) for the nursery and field sites used for the experiment were analyzed for physical and chemical properties.

UNDER PEER REVIEW

Seedlings of the different varieties were transplanted to mini plots of 2.5m x 1.5 m size. The gross land area (37.50m x 22.5m) was 0.084 ha with one metre between blocks. The experiment was Randomized Complete Block Design with three replications for each variety. The experiment was laid out on a plot measuring 12m x 21m (252m^2) with mini plots measuring 2.5 x 0.75m (1.88m^2). Six weeks old pepper seedlings were transplanted on 26th of May 2012 and 1st June 2013.

2.4 Data collection

Data were collected on environmental conditions (Agroclimatological Indices) from Nigerian Meteorological Agency, Makurdi and on some important growth parameters and yield characters**.** Data on seedling establishment was calculated as the percentage of seedlings established 4WAT. Seedling height at 30 days after planting (DAP) was measured from the ground level to shoot apex of the plant with a ruler. Arc sine transformation was applied to incidence data while square root transformation was done for germination percentages before analysis. Correlation coefficients between laboratory, nursery and field parameters were determined across the two seasons at 5% probability. Data were subjected to Analysis of Variance (ANOVA) using Genstat 10 statistical software and SAS version 9.2 Edition [10]. Significant treatment means were separated using DNMRT at 5% level of significant [11].

Disease Assessment: The incidence of anthracnose infection (percentage calculated on the basis of diseased plants over the total plants assessed) was recorded.

Using the disease scale the mean disease reaction class of each variety across the two years was determined as described by [12] as shown below:

UNDER PEER REVIEW

R=Resistant (1-20%), MR = Moderate resistant (21 -40%), MS= Moderately Susceptible (41 - 60%), S = Susceptible (61 -80%), HS = Highly Susceptible (81-100%).

3. RESULTS

3.1 Soil properties and Meteorological data of experimental site

Results of the nursery and field soil analysis are presented in Table 1. The result of the soil physical and chemical analysis showed that the soil of the experimental sites was sandy loam and slightly acidic with a pH of 6.24 and 6.33 for the nursery and field sites respectively. Phosphorus was higher in the field (4.5 mg kg^{-1}) than in the Nursery (0.38 mg kg^{-1}).

Table 1: Physical and chemical properties of the soil of the experimental sites

Soil Properties	**Percent composition**	
	Nursery site	**Field site**
Particle size distribution (%)		
Sand	80.08	83.50
Clay	10.92	7.20
Silt	9.00	9.28
Textural class	Sandy loam	Sandy loam
pH (H_2O)	6.24	6.33
Exchangeable bases(Cmol/kg)		
Potassium	0.33	0.38
Magnesium	2.40	1.93
Sodium	0.21	0.57
Calcium	3.20	3.52
Chemical properties (%)		
Organic carbon	1.30	2.61
Organic matter	2.24	4.52
Nitrogen	0.08	0.07
Phosphorus (mg kg^{-1})	0.38	4.50

Figure 1 shows the trend of temperature (^{o} C), relative humidity (%) and rainfall (mm) for the 2012 and 2013 cropping season. Temperature and relative humidity was favourable for anthracnose development during the time the experiment was carried out in both years.

UNDER PEER REVIEW

Temperature differed slightly during the two cropping seasons with temperature varying between 26 – 29°C, relative humidity ranged between 62% and 80% and monthly rainfall between 123-352mm. Total annual rainfall for 2012 was 1392.30mm while for 2013 was 1287.80mm. Relative humidity of 80% was recorded in August (13 WAT) for both years corresponding to the fruiting stage in pepper when anthracnose infected pepper fruits.

In 2012, the peak rainfall (352 mm) was observed in July (9 WAT) at the flowering and fruiting stage coincided with the flooding experienced at the location during the 2012 cropping season. The high rainfall during this growth period may have resulted in high cloud cover which reduced the rate of photosynthesis and subsequently reduced yield. In 2013 the rainfall had its peak in September (285 mm) which was the harvesting period (17 WAT) when fruit anthracnose occurred.

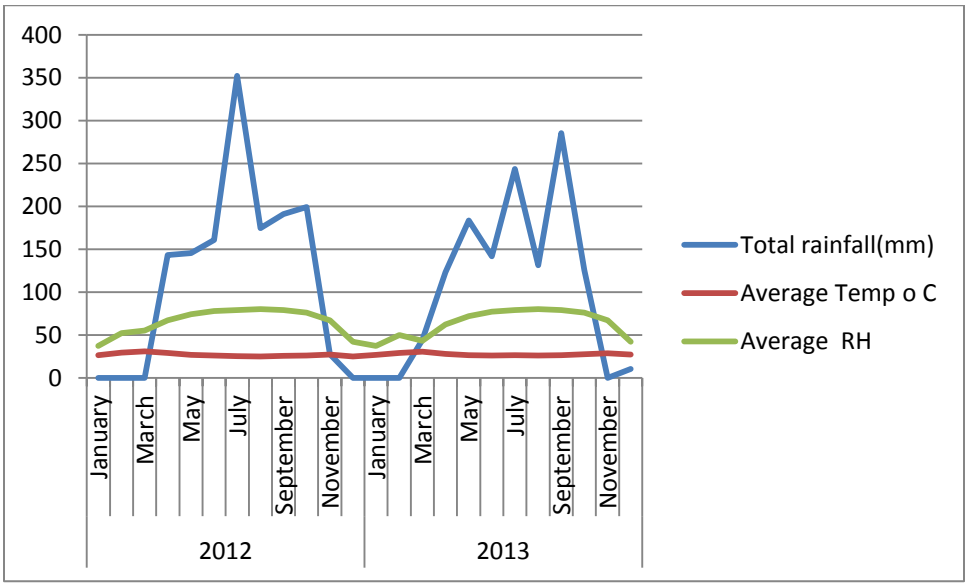

Figure 1: Meteorological data of the 2012 and 2013 cropping season for Makurdi, Nigeria

UNDER PEER REVIEW

4.2 Incidence of *Colletotrichum capsici* on pepper seeds

The result presented in Table 3 shows the percentage incidence of *Colletotrichum capsici* on pepper seeds. The incidence of *C. capsici* was significantly higher ($p<0.05$) on Prof fintashi seeds with an incidence of 35% followed by AVPP 9809 with 25% incidence, AVPP 9905, Ex kunkunu and Birdeye seeds recorded 15% incidence while N-M-Iddi had 5% incidence. All other varieties had no incidence of *C. capsici* on their seeds before planting.

Table 3: Percentage incidence of *Colletotrichum capsici* isolated from pepper seeds in the laboratory

Variety	Percentage Incidence
AVPP 9905	15^{c}
AVPP 9809	25^{b}
N-M-Iddi	5^{d}
Prof fintashi	35^{a}
Ex kunkunu	15^{c}
Birdeye	15^{c}

The germination of twenty eight breeding lines and varieties determined in the laboratory and in the nursery is presented in Table 4. The variability test showed high germination percentages for exotic lines but they exhibited low establishment. In 2012, the exotic lines germinated better than the local varieties. Percentage germination ranged between 10 and 100% with Bor Kono tsifidi having the least germination (10%), AVPP 0013, 9814, 0706, 0802, and 9905 with 100% germination. AVPP 0802 reached 100% germination eleven days after planting. The tallest seedling height of 11.4cm and 20.7cm was recorded by Prof fintashi and Ex-kunkunu varieties in 2012 and 2013 respectively while the shortest seedling height of 3.1cm and 10.8cm was recorded by Sombo and Nsukka yellow respectively for the two cropping seasons.

UNDER PEER REVIEW

Table 4: Seed viability, Germination percentages and Average seedling height of twenty eight pepper lines and accessions

Breeding line/Accession	Seed Viability (%)	% Nursery Germination 2012	% Nursery Germination 2013	Average seedling height (cm) 2012	Average seedling height (cm) 2013
AVPP 0013	100.0^{a}	59.0^{de}	36.0^{f}	9.0^{d}	14.5^{e}
AVPP 0706	100.0^{a}	74.0^{b}	20.0^{h}	10.7^{b}	15.0^{e}
AVPP 0802	100.0^{a}	70.0^{b}	50.0^{d}	5.8^{gh}	16.8^{d}
AVPP 9809	70.0^{dc}	56.0^{e}	12.0^{i}	6.2^{g}	18.0^{c}
AVPP 9905	100.0^{a}	22.0^{j}	50.0^{d}	4.6^{k}	12.8^{f}
AVPP 9814	100.0^{a}	62.0^{dc}	6.0^{j}	9.0^{d}	8.5^{h}
AVPP 0513	90.0^{ab}	8.0^{lm}	0.0^{k}	5.0^{ijk}	0.0^{i}
AVPP 9813	90.0^{ab}	0.0^{n}	0.0^{k}	0.0^{n}	0.0^{i}
AVPP 0403	90.0^{ab}	40.0^{g}	0.0^{k}	5.4^{hi}	0.0^{i}
AVPP 9807	90.0^{ab}	0.0^{n}	0.0^{k}	0.0^{n}	0.0^{i}
AVPP 0114	80.0^{bc}	64.0^{c}	0.0^{k}	6.2^{g}	0.0^{i}
AVPP 9612	70.0^{dc}	24.0$^{i.j}$	0.0^{k}	3.4^{lm}	0.0^{i}
AVPP 0401	70.0^{dc}	62.0^{dc}	0.0^{k}	9.0^{cd}	0.0^{i}
AVPP 9801	60.0^{de}	22.0^{j}	0.0^{k}	3.7^{l}	0.0^{i}
AVPP 0412	60.0^{de}	12.0^{kl}	0.0^{k}	5.8^{gh}	0.0^{i}
Tugantashi	30.0^{gh}	4.0^{nm}	0.0^{k}	4.9^{jk}	0.0^{i}
Atarodo	40.0^{fg}	50.0^{f}	44.0^{e}	5.1^{ij}	8.5^{h}
Tatashe	35.0^{gh}	50.0^{f}	36.0^{f}	7.0^{f}	14.5^{e}
Birdeye	30.0^{gh}	92.0^{a}	24.0^{g}	7.5^{e}	15.2^{e}
Bor kono tsifidi	10.0^{i}	14.0^{k}	50.0^{d}	9.1^{cd}	20.0^{ab}
Cayenne	25.0^{h}	40.0^{g}	60.0^{c}	7.9^{e}	17.7^{cd}
Ex Kunkunu	40.0^{fg}	28.0^{i}	40.0^{f}	9.5^{c}	20.7^{a}
GHA	40.0^{fg}	28.0^{i}	42.0^{e}	3.6^{l}	18.2^{c}
M'daku	50.0^{ef}	22.0^{j}	44.0^{e}	7.8^{e}	19.5^{b}
N-M- Iddi	70.0^{dc}	26.0^{ij}	70.0^{a}	8.9^{d}	18.2^{c}
Nsukka yellow	80.0^{bc}	42.0^{g}	38.0$_{f}$	5.3^{ij}	10.8^{g}
Prof fintashi	40.0^{fg}	34.0^{h}	44.0^{e}	11.4^{a}	20.0^{ab}
Sombo	35.0^{gh}	88.0^{a}	66.0^{a}	3.1^{m}	18.8^{d}

Means followed by the same alphabet along the column are not significantly different from one another according to Duncan New Multiple Range test at 5% probability level.

UNDER PEER REVIEW

Table 5 shows the percentage incidence of leaf spot for fifteen varieties of pepper screened for resistance to anthracnose pepper diseases at 6WAP for two cropping seasons in Makurdi. AVPP 0706, 0802, 9809, Bor Kono tsifidi, Cayenne and Nsukka yellow were classified as resistant while the remaining lines and accessions were classified as moderately susceptible.

Table 5: Percentage incidence of leaf spot for fifteen varieties of pepper screened for resistance to anthracnose pepper diseases at 6WAP for two cropping seasons in Makurdi.

Variety	**Disease incidence (%)**			
	2012	**2013**	Mean disease incidence	Reaction class
AVPP 0013	1.0^{f}	97.4^{b}	49.2^{d}	MS
AVPP 0706	1.0^{f}	1.0^{k}	1.0^{m}	R
AVPP 0802	1.0^{f}	34.0^{i}	17.5^{j}	R
AVPP 9809	33.2^{a}	1.0^{k}	17.1^{k}	R
AVPP 9905	15.4^{c}	100.0^{a}	57.7^{a}	MS
Birdeye	1.0^{f}	93.0^{e}	47.0^{h}	MS
Bor kono tsifidi	1.0^{f}	24.0^{j}	12.5^{l}	R
Cayenne	1.0^{f}	1.0^{k}	1.0^{m}	R
Ex Kunkunu	1.0^{f}	77.0^{g}	39.0^{i}	MR
GHA	1.0^{f}	96.0^{d}	48.5^{f}	MS
M'daku	1.0^{f}	97.0^{c}	49.0^{e}	MS
N-M- Iddi	11.0^{e}	96.0^{d}	53.5^{b}	MS
Nsukka yellow	1.0^{f}	1.0^{k}	1.0^{m}	R
Prof fintashi	12.7^{d}	92.0^{f}	52.4^{c}	MS
Sombo	28.3^{b}	67.0^{h}	47.7^{g}	MS

Means followed by the same alphabet along the column are not significantly different from one another according to Duncan New Multiple Range test at 5% probability level.

UNDER PEER REVIEW

4.3 Seedling establishment

The percentage seedling establishment for fifteen varieties of pepper screened for resistance to anthracnose for 2012 and 2013 cropping season is presented in Table 6. Thirteen pepper lines and accessions died off in all the replications in the nursery indicating that they did not adapt to the Southern Guinea Savannah agro ecology of Nigeria.

Percentage establishment was not significantly different among the remaining fifteen pepper lines and accessions screened in 2012. However, highest seedling establishment of 93.33% was recorded by Cayenne and Ex- kunkunu while the least seedling establishment of 60% was recorded by Nsukka yellow, birdeye and AVPP 0706 in 2012. There was significant difference in seedling establishment among varieties in 2013. Borkono tsifidi, Cayenne, Ex-kunkunu, Prof fintashi and Sombo had the highest seedling establishment of 100% in 2013 while the lowest seedling establishment of 40% was recorded by AVPP 0706, AVPP 9809 and birdeye in 2013.

Table 6: Percentage field establishment of fifteen varieties of pepper screened for resistance to anthracnose for 2012 and 2013 cropping season in Makurdi

Variety	**Percent establishment**	
	2012	**2013**
AVPP 0013	80.0[a]	100.0[a]
AVPP 0706	60.0[a]	40.0[e]
AVPP 0802	73.3[a]	93.3[b]
AVPP 9809	86.7[a]	40.0[e]
AVPP 9905	73.3[a]	93.3[b]
Birdeye	60.0[a]	40.0[e]

UNDER PEER REVIEW

Bor kono tsifidi	86.7[a]	100.0[a]
Cayenne	93.3[a]	100.0[a]
Ex Kunkunu	93.3[a]	100.0[a]
GHA	73.3[a]	86.7[c]
M'daku	66.7[a]	93.3[b]
N-M- Iddi	66.7[a]	86.7[c]
Nsukka yellow	60.0[a]	53.3[d]
Prof fintashi	86.7[a]	100.0[a]
Sombo	80.0[a]	100.0[a]

Means followed by the same alphabet along the column are not significantly different from one another according to Duncan New Multiple Range test at 5% probability level.

4.4. Screening of pepper breeding lines and accessions for fruit anthracnose

Data on the incidence of fruit anthracnose for 2012 and 2013 is presented in Table 7. The incidence of pepper fruit anthracnose was significantly ($P \leq 0.05$) higher in 2013 compared with 2012. In 2012, anthracnose incidence was significantly higher in AVPP 9809 (31.14 %) compared with GHA (1.44 %) and bird's eye (2.43 %). In 2013, anthracnose incidence increased significantly in Bor kono tsifidi and Sombo (38.44 %) and decreased in AVPP 0706 (1.00 %) and Nsukka yellow (1.90 %). The mean fruit anthracnose incidence was classified as resistant in all the varieties screened except AVPP 9809, Bor kono tsifidi, Prof fintashi and Sombo which were classified as moderately resistant. GHA variety had the least percentage incidence for anthracnose (2.13 %) and this was not significantly different ($P \geq 0.05$) from the anthracnose recorded in Bird's eye variety (2.89 %).

The data on the mean severity of fruit anthracnose for 2012 and 2013 is presented in Table 4. The severity of pepper anthracnose was significantly lower ($P \leq 0.05$) in bird's eye variety (8.33 %) in 2012 and (4.67 %) in 2013 compared with all other varieties. Variety AVPP 0706, Bird's eye and Nsukka yellow were rated as resistant based on severity of fruit anthracnose. Bor kono

UNDER PEER REVIEW

tsifidi, M'daku and Sombo were classified as moderately susceptible while the remaining varieties were classified as moderately resistant.

Table 7: Effect of Pepper Variety on the Incidence of Pepper Anthracnose in 2012 and 2013 in Makurdi

Variety	2012	2013	Variety mean	Reaction
AVPP 0013	4.93^{e}	14.59^{d}	9.76^{cd}	R
AVPP 0706	9.49^{c}	1.00^{g}	5.25^{e}	R
AVPP 0802	2.69^{fg}	22.85^{b}	12.77^{bc}	R
AVPP 9809	31.14^{a}	11.56^{e}	21.35^{a}	MR
AVPP 9905	19.71^{b}	6.86^{f}	13.29^{b}	R
Bird's eye	2.43^{fg}	3.35^{g}	2.89^{f}	R
Bor kono tsifidi	5.66^{e}	38.44^{a}	22.05^{a}	MR
Cayenne	3.80^{ef}	18.15^{c}	10.98^{c}	R
Ex Kunkunu	2.43^{fg}	17.22^{c}	9.83^{cd}	R
GHA	1.44^{g}	2.82^{g}	2.13^{f}	R
M'daku	7.67^{d}	22.94^{b}	15.31^{b}	R
N-M- Iddi	3.76^{ef}	26.83^{b}	15.30^{b}	R
Nsukka yellow	10.96^{c}	1.90^{g}	6.43^{e}	R
Prof fintashi	9.00^{cd}	34.22^{b}	21.61^{a}	MR
Sombo	5.15^{e}	38.44^{a}	21.80^{a}	MR

Means followed by the same alphabet along the column are not significantly different from one another according to Duncan New Multiple Range test at 5% probability level.

Data presented in Table 8 shows the severity of pepper fruit anthracnose on naturally infected pepper varieties in 2012 and 2013 in Makurdi.

The highest disease severity was recorded on Bor kono tsifidi variety. The lowest severity was recorded by birdeye for both years. The exotic breeding lines were moderately resistant to

UNDER PEER REVIEW

anthracnose infection. AVPP 0706, GHA and Bird's eye had resistant reaction to pepper anthracnose.

Table 8: Effect of Pepper Variety on the Severity of Pepper Anthracnose in 2012 and 2013 in Makurdi

Variety	**2012**	**2013**	**Variety Mean**	**Reaction**
AVPP 0013	31.67[ab]	44.22[d]	25.30[bc]	MR
AVPP 0706	21.00[ab]	0.50[j]	10.75[d]	R
AVPP 0802	25.33[ab]	41.22[d]	33.28[abc]	MR
AVPP 9809	40.00[a]	8.07[h]	24.04[cd]	MR
AVPP 9905	41.67[a]	8.07[h]	24.87[bc]	MR
Bird's eye	8.33[c]	4.67[i]	6.50[d]	R
Bor kono tsifidi	50.00[a]	50.55[c]	50.28[a]	MS
Cayenne	17.67[abc]	36.48[e]	27.08[bc]	MR
Ex Kunkunu	21.67[abc]	30.91[f]	26.29[bc]	MR
GHA	25.00[abc]	38.44[de]	31.72[abc]	MR
M'daku	25.00[abc]	59.29[a]	42.15[a]	MS
N-M- Iddi	20.00[abc]	53.73[b]	36.87[ab]	MR
Nsukka yellow	20.00[abc]	18.40[g]	19.20[cd]	R
Prof fintashi	16.67[abc]	53.73[b]	35.20[abc]	MR
Sombo	43.33[a]	53.73[b]	48.53[a]	MS

Means followed by the same alphabet along the column are not significantly different from one another according to Duncan New Multiple Range test at 5% probability level.

R=Resistant (1-20%), MR = Moderate resistant (21 -40%), MS= Moderately Susceptible (41 - 60%), S = Susceptible (61 -80%), HS = Highly Susceptible (81-100%)

UNDER PEER REVIEW

Figure 2: Incidence of Pepper anthracnose on two exotic pepper lines

Mean yield of fifteen varieties of pepper screened for disease resistance for two consecutive years in Makurdi is presented in table 9. Ex- kunkunu had the highest mean yield of yield of 2.24t/ha while GHA had the lowest mean yield of 0.68t/ha. The differences in fruit yield recorded in the two cropping seasons in this study agrees with the report of Idowu–Agida *et al*. (2010) which reported significant effect of season on the yield of different pepper accessions with a higher yield in the second season than in the first season.

Table 9: Mean yield of fifteen varieties of pepper screened for disease resistance for two consecutive years in Makurdi.

Variety	**Yield (tons/ha)**		**Mean yield (tons/ha)**
	2012	2013	
AVPP 0013	1.54^{bcd}	0.71^{cd}	1.13^{bc}
AVPP 0706	1.31^{bcd}	1.02^{bcd}	1.17^{abc}
AVPP 0802	1.99^{abc}	1.73^{ab}	1.86^{ab}
AVPP 9809	2.24^{ab}	0.53^{d}	1.39^{abc}
AVPP 9905	0.64^{d}	1.15^{bcd}	0.90^{bc}
Birdeye	0.85^{d}	1.04^{bcd}	0.95^{bc}
Bor kono tsifidi	1.31^{bcd}	0.59^{d}	0.95^{bc}

UNDER PEER REVIEW

Cayenne	0.73[d]	0.94[bcd]	0.84[bc]
Ex Kunkunu	2.84[a]	1.64[abc]	2.24[a]
GHA	0.72[d]	0.64[ab]	0.68[c]
M'daku	1.07 [bcd]	1.87[ab]	1.47[abc]
N-M- Iddi	1.46 [bcd]	1.62[abc]	1.54[abc]
Nsukka yellow	1.01 [bcd]	0.93[bcd]	0.97[bc]
Prof fintashi	1.92 [abc]	1.22[abcd]	1.57[abc]
Sombo	0.68 [d]	2.18[a]	1.43[abc]

Table 10 shows correlation coefficient between laboratory and field parameters for fifteen breeding lines and accessions. The result indicates moderate significant and positive correlation between nursery leaf spot infection and fruit anthracnose for both years (r = 0.53 and r = 0.47). Conversely, negative correlation was obtained between nursery germination and yield, seedling height and fruit anthracnose in 2012.

Table 10: Correlation coefficient between germination, growth, yield and disease parameters of fifteen breeding lines and accessions in Makurdi for 2012 and 2013 cropping season.

Parameters	Correlation coefficient(r)	
	2012	2013
Laboratory germination vs nursery germination	0.23	0.38*
Laboratory germination vs yield	0.32	0.03
Nursery germination vs nursery disease	0.02	0.45*
Nursery germination vs yield	-0.15	0.58*
Nursery disease vs fruit anthracnose	0.53*	0.47*
Seedling height vs fruit anthracnose	-0.10	0.66*

4. DISCUSSION

Pepper lines and accessions evaluated in this study had good seed germination percentages of 75% to 100% during the laboratory germination test but had reduced seedling emergence in the

UNDER PEER REVIEW

nursery. The differences in the seed germination and seedling emergence could be attributed to the differences in water holding capacity of the growth media and temperatures in the laboratory and nursery. This is in line with the report of [14] which observed that germination tests done in the laboratory do not represent field germination due to differences in environmental conditions. According to [14] laboratory germination tests using filter paper had a higher germination percentage of grass seeds than grass seeds planted in the soil on the field. The incidence of *C. capsici* on the pepper seeds suggests the possibility of nursery-to-field infection due to the seed borne nature of *C. capsici*. This agrees with the report of [15] in which a carry-over of nursery-initiated infections was reported on the field for some pathogens including *Colletotrichum gloeosporioides*. According to [16], seed contamination contributed to initial infections on tomato transplants. Furthermore [17] observed that disease estimation under controlled condition such as in the laboratory may be unreliable and may not be applicable to field conditions due to environmental fluctuations on the field. Although [18] observed that laboratory germination was not significantly correlated with field emergence of wheat lines, [19] however reported that good laboratory performance produced good field emergence in rice genotypes. [20] reported differences among kenaf genotypes for twenty one traits studied and recommended the selection of the traits for improvement based on the large variability of the genotypes.

The varying viability and germination percentages of pepper varieties screened for resistance to anthracnose may be attributed to the presence of fungi in the seeds before planting. The presence of C. *capsici* on pepper seeds in this study may be responsible for the low germination of seeds. [21] attributed poor germination to fungal infection and noted that seed borne fungal infection results in seedling diseases under the right environmental conditions and may lead to poor yield. Similarly, Seed borne fungi could retard seed germination and seedling viability resulting in poor

UNDER PEER REVIEW

stand establishment [22]. Also, [23] observed that poor quality seeds will result in low field emergence producing seedlings that are more sensitive to plant diseases with reduced quality and yield.

The number of plants established in the field relative to number sown is the final analysis of success of the planting operation. Planting of pepper seeds was more successful in 2013 than in 2012 because of the higher seedling establishment. Successful crop establishment involves the germination and emergence of plants with strong seedling vigour. The report of [24] attributed poor performance of pepper to poor early growth while [25] noted that healthy plant varieties that germinate fast are considered the strongest and are better able to tolerate pathogens.

The significant effect of seedling height in this study shows the vigorous nature of seedling growth in this study. This is in line with the report of [26] which reported plant height as the strongest morphological trait used to identify vigorous seedlings of *Acacia senegal*.

The higher severity of anthracnose on pepper fruits in 2013 may be attributed to high rainfall and high humidity during the harvesting stage which provided the favourable environment for disease development. This is in line with the findings of [27] in which high rainfall was attributed to increased fruit rot among pepper accessions of South West Nigeria. This agrees with the report of [13, 28] in which severe sorghum anthracnose disease was recorded in areas with high rainfall and intermediate temperature. The report observed a strong influence of rainfall on anthracnose development. Anthracnose infection of pepper lines and accessions is likely to have affected pepper yield in this study. [13] noted that anthracnose severities greater than 20% could impact sorghum yield. [25] also attributed variations in the incidence and severity of plant diseases to host genotypes and planting environment.

UNDER PEER REVIEW

The variation in yield could be due to different dry matter partitioning ability of pepper plants [29]. The work of [27] indicated that different accessions of pepper performed differently in different seasons due to the varying environmental factors that either enhance or limit productivity. The lower yield recorded in GHA and Bird's eye which were resistant could be attributed to their small fruit sizes. [8] and [12] had earlier reported that varieties with smaller fruits produced less weighty fruits per hectare. Also, [30] reported low incidence of pepper anthracnose in the southern part of Benue State where Bird's eye pepper was predominantly cultivated. [31] associated resistance to anthracnose disease with high concentrations of capsaicin in some chili varieties.

Although Ex- kunkunu recorded moderate anthracnose incidence and severity, its yield was higher compared with other lines and accessions indicating it's tolerant to anthracnose. This resistance/tolerance can be attributed to inherent resistance to infection by *C. capsici* as reported by [32].

5. CONCLUSION AND RECOMMENDATION

This study revealed two local pepper accessions and one exotic breeding line that was resistant to pepper anthracnose under field conditions. The resistant local accessions identified in this study can be used in the development of improved *Capsicum* spp. varieties resistant to *Colletotrichum capsici* by crossing these identified accessions with exotic lines with desirable traits to produce pepper fruits with resistance to anthracnose and greater yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

UNDER PEER REVIEW

REFERENCES

1. Agbogidi OM, Okonmah UL. Performance of sweet pepper (C*apsicum annuum*) as influenced by weeding frequency. International Journal of Advanced Biological Research. 2011; 1(1): 119-122.
2. Asawalam EF, Emeanor KC, Okezie JC. Control of pests of some *Capsicum* species (Pepper) cultivars using soil amendments in Umudike- Nigeria. Electronic Journal of Environmental Agricultural and Food Chemistry. 2007; 6(4):1975-1979.
3. Manyong VM, Ikpi A, Olayemi, JK. Agriculture in Nigeria: Identifying opportunities for increased commercialization and Investment. A summary report by IITA, USAID and University of Ibadan. 2004: 28pages.
4. Alao SEL. Pepper based stem rot and wilt disease. The story so far and available control options. NOMA. 1998; 12:1-7.
5. Roberts PD, Pernezny KL, Kucharek TA. Anthracnose caused by *Colletotrichum sp*. on pepper. 2001: http://edis.ifas.ufl.edu.document.PP104.
6. Nayaka SC, Shankar ACU, Niranjana SR, Prakash HS, Mortensen CN. Anthracnose disease of chili pepper. Technical Bulletin published by Asian Seed Health Centre Karnataka, India and Danish Seed Health Centre for Developing Countries, Denmark. 2009:14pp.
7. Lubna M, Ali A, Shahzad A, Sofi TA. Cultural, Morphological and Pathogenic Variability in *Colletotrichum capsici* causing Die-back and Fruit Rot of Chilli. Asian Journal of Plant Pathology. 2013; 7: 29-41.
8. Ekefan EJ, Olukotun FG, Nwankiti AO. Incidence of anthracnose and its effect on yield of sweet pepper (*Capsicum annuum* L.) in Makurdi, Nigeria. Nigerian Journal of Botany. 2010; 23(2):297-306.
9. Alhassan GA, Kalu BA, Egbe OM. Influence of planting densities on the performance of intercropped bambara groundnut with Cowpea in Makurdi, Benue State, Nigeria. International Journal of Development and Sustainability. 2012; 1(3): 860-879.
10. SAS Institute Inc. SAS/STAT Guide for personal computers, Version 9.2 edition. SAS Institute Cary, NC.USA; 2009.
11. Obi IU. Statistical methods of detecting differences between treatment means and research methodology issues in laboratory and field experiments 2nd edition AP Express Publishers, Nsukka. 2002; 117pp.
12. Asian Vegetable Research and Development Center (AVRDC). Taiwan, China. 2003; AVRDC Progress Report for 2002.
13. Chala A, Bruberg MB, Tronsmo AM. Incidence and severity of sorghum anthracnose in Ethiopia. Plant Pathology Journal. 2010; 9:23-30.
14. Frasier GW**.** Characterization of seed germination and seedling survival during the initial wet-dry periods following planting. Journal of Range Management. 1989; 42(4):299-303.

UNDER PEER REVIEW

15. Barnard EL. Diseases of seedlings in forest tree nurseries in Florida: History and status. Paper presented at the third meeting of IUFRO Working Party 57.03-04 (Diseases and Insects in Forest Nurseries). Orlando-Gainesville, Florida, USA. May 19-24, 1996; 1-15.

16. Makelo MN. Assessment of seed borne pathogens for some important crops in Western Kenya, Machakos, Kenya. 2010; 1-7.

17. Idowu OTH., Popoola AR, Adeoti AYA, Salami AM. Reaction of *Sorghum bicolor* (L.) Moench cultivars to *Colletotrichum graminicola* (Cesati) Wilson in South – West Nigeria. Nigerian Journal of Plant Protection. 2011; 25(1): 43-54.

18. Anjorin ST, Mohammed M. Effect of seed borne fungi on germination and seedling vigour of watermelon (*Citrullus lanatus* thumb). African Journal of Plant Science. 2014; 8(5): 232-236.

19. Mehrotra RS, Aggarwal A. Plant Pathology. Teta Mc Graw-hill Publishing Company New Delhi second edition. 2003; 254.

20. Taye W, Laekemariam F, Gidago G. Seed germination, emergence and seedling vigor of maize as influenced by pre-sowing fungicides seed treatment. Journal of Agricultural Research and Development. 2013; 3(3): 35-41.

21. Ibrahim HM, Olasantan FO, Oyewale RO. Age of seedling at transplanting influenced growth and fruit yield of sweet pepper (C*apsicum annum* L. cv. Rodo). Net Journal of Agricultural Science. 2013; 1(4):107-110.

22. Ashilenje DS. Learn how to grow pepper. Phoenix publishers Limited Nairobi, Kenya. (2013); 37.

23. Zubairu SU. The influence of seed pre treatment on seed germination and seedling vigour in *Acacia senegal* in the nursery. Journal of Biology, Agriculture and Healthcare. (2014); 4(12):57-62.

24. Kehinde TO, Adebisi MA, Esuruoso OA, Akinrinde GO, Famakinde O. Assessment of seedling vigour characteristics in Kenaf (*Hibiscus cannabinus* L.) Genotypes. Applied Tropical Agriculture. 2015; 20(2): 24-31.

25. Adebisi MA, Okelola FS, Alake CO,Ayo- Vaughan MA, Ajala MO. Interrelationship between seed vigour traits and field performance in new rice for Africa (NERICA) Genotypes (*Oryza sativa* L.). Journal of Agricultural Science and Environment. 2010; 10(2): 15-26.

26. Neya A, Normand M. Responses of Sorghum genotypes to leaf anthracnose (*Colletotrichum graminicola*) under field conditions in Burkina Faso. Crop Protection. 1998; 17: 47- 53.

27. Idowu- Agida OO, Adetimirin VO, Nwanguma EI, Makinde AA. Effects of Seasonal variability on the Performance of Long Cayenne Pepper Collected from South- western Nigeria. *Researcher*. 2010; 2(10): 85-92.

UNDER PEER REVIEW

28. Ngugi HK, King SB, Abayo GO, Reddy YVR. Prevalence, incidence and severity of sorghum diseases in Western Kenya. Plant Disease. 2002; 86:65-70.

29. Seleshi D. Evaluation of elite hot pepper varieties (*Capsicum* species) for growth,dry pod yield and quality under Jimma condition, South West Ethiopia. Master of Science Thesis submitted to Department of Horticulture, Jimma University, Ethiopia. 2011; 58pp.

30. Ekhuemelo C, Ekefan EJ, Nwankiti AO. Morphological, Pathological and Molecular Characterization of *Colletotrichum capsici* Causal Agent of Pepper Anthracnose in Benue State, Nigeria. Nigerian Journal of Plant Protection. 2016; 30: 1-12.

31. Wilawan K, Somsiri S, Sutevee S. Effect of Capsaicin on germination of *Colletotrichum capsici* conidia. Kasetsart Nature Science Journal. 2008; 42(3): 417-422.

32. Parey MA, Razdan VK, Sofi TA. Comparative study of different fungi associated with fruit rot of chilli and screening of chilli germplasm against *Colletotrichum capsici*. International Journal of Agricultural Crop Science. 2013; 5 (7): 723- 730.