Screening of coffee genotypes with tolerance/resistance to Bacterial Blight of Coffee in Chikamagalur Dist, Karnataka

Hossein Ramzan Nezhad, Rabin Chandra Paramanik, Achinto Paramanik

***Abstract*— Bacterial Blight of Coffee caused by Pseudomonas syringae pathovar garcae is a major concern due to high incidence and severity in Arabica coffee being responsible for crop losses of more than 30%. Although resistance to BBC was not factored in the breeding programs of elite varieties, disease resistant varieties reduce the cost of production and offer an environmentally safe management. The objective of the study was to identify coffee genotypes with resistance to BBC. Twenty four coffee genotypes were screened for resistance using 4 BBC isolates collected from different regions.Inoculation was done with a drop of approximately 10 µl of the isolates suspension (109 CFU/ml) using injection method on 4 months old seedlings. The experiment was carried out in a Complete Randomized Design. Disease symptoms were scored using a scale of 1 to 5 and the data subjected to analysis of variance and effect declared significant at 5% level. The results revealed significant difference among the coffee genotypes with Rume Sudan being the most resistant. There was no significant virulence effect observed on three isolates although one isolate was different.**

***Index Terms*— Pseudomonas syringae pathovar garcae, isolates, Coffea arabica, genotype.**

INTRODUCTION

Coffee is one of the most important agricultural commodities in international trade representing an important source of income for millions of people in coffee growing countries in Asia, Africa and Latin America (Mishra *et al.,* 2008). The Arabica coffee (*Coffea arabica*) varieties which are preferred for their superior beverage quality accounts for about 70% of the total world coffee production derived from either the "Typica" or "Bourbon" genetic base and are predominantly self-pollinating, which has resulted in low-genetic diversity among cultivated Arabicas (Gichuru *et al.,* 2008, Mishra and Slater, 2012). Coffee production in Kenya is constrained by diseases mainly Coffee Leaf Rust (CLR) caused by *Hemileia vastatrix,* Coffee Berry Disease (CBD) caused by *Colletotrichum kahawae* and Bacterial Blight of Coffee caused by *Pseudomonas syringae* pathovar *garcae* (Mugiira *et al.,* 2011). BBC has become a major concern in Kenya and other countries such as Brazil, Uganda and China due to high incidence and severity in Arabica coffee (Fekadu, 2013). It is responsible for crop losses mainly in windy and cooler cultivation areas. In Kenya, the disease was reported on coffee plantations soon after the crop was established but it was confined to the west of the Great Rift Valley (Kairu *et al*., 1985). However with changing climatic conditions, the disease has spread to Central and Eastern Kenya. Severe epidemics of the disease as often observed in coffee plantations impact a fire scorched appearance and in areas where BBC is endemic coffee trees are also affected by CBD (Kairu, 1995). Coffee growers have relied greatly on copper-based formulations to control BBC which accounts for up to 30% of the total cost of production but incidences of BBC can still be observed on copper sprayed farms. The infection may be attributed to poor timing of the spraying program, micro-distribution and erosivity effects of the formulation. The chemical control manages the disease to within economic levels but does not eradicate it. The occurrence of peak populations of *P. syringae* pv *garcae* and the incidence of BBC coincide with periods of high relative humidity of about 80% and cool temperatures of 18-20^{o}C (Masaba, 1998). This bacterioisis is more intense on coffee grown at higher altitudes, without wind protection and in cold regions (Ito *et al.,* 2008).

Disease resistant varieties not only have the potential to reduce the cost of production but offer an environmentally safe disease management approaches. The commercial variety known as Ruiru 11, which was released to growers in 1985, combines resistance to CBD and leaf rust with high yield, fine quality and compact growth amenable to high density planting (Omondi *et al*., 2001) although it has been reported to have a lower level of resistance to BBC (Ithiru *et al.,* 2013). Studies on the dynamics of *P. syringae* pv *garcae* multiplication in the foliage by Masaba (1998) indicated that the rate of multiplication, final populations, degree of colonization and severity of symptoms were lowest on Catimor, intermediate on SL34 and highest on SL28 (the latter two are traditional commercial varieties in Kenya selected on individual tree basis), implying that Catimor was potentially resistant to BBC. Although Catimor is one of the parents of Ruiru 11 hybrid, areas with high BBC severity in Kenya such as Nakuru and Kapsabet have shown infection on Ruiru 11 and the other traditional varieties under field conditions. The S_H1 gene found in the Arabica coffee genotypes Harar, Dilla & Alghe, S12 Kaffa and Geisha is said to confer simultaneous resistance to some races of *Hemileia vastatrix* and to *P.syringae* pv. *garcae* (Ito *et al.,* 2008). Those genotypes are not commercially grown in Kenya and it is also important to examine their level of resistance using the Kenyan BBC isolates. Other sources of resistance to BBC

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without S_H1 gene such as Icatu, Catucaí and Hibrido *de* Timor (HDT) have been identified indicating the presence of other genes that confer qualitative and quantitative resistances (Ito *et al.,* 2008). However some of those sources like Icatu and Catucai are not cultivated in Kenya and HDT does not meet other qualities of a commercial variety but has been utilized in breeding programs as a donor for disease resistance. Other coffee species such as *Coffea canephora* which is self-incompatible and has a wide geographic distribution has provided the major source of disease and pest resistance traits such as CLR, CBD, and root-knot nematode caused by *Meloidogyne spp*. that are lacking in *C. arabica* (Mishra and Slater, 2012). Other diploid species such as *C. liberica* and *C. racemosa* have been used as sources of resistance to CLR and coffee leaf minor respectively (Mishra and Slater, 2012). Field trials with several Arabica coffee genotypes identified Geisha as the most resistant to BBC.So far, selections for BBC resistance have not yielded a commercial variety in Kenya (Masaba, 1998). However, the new areas have reported high incidences of BBC especially Nakuru, Kitale, Mt. Elgon and Kapsabet areas. Since resistance to BBC was not factored in the breeding programs of elite varieties, the crop is subsequently faced with the challenge of infection. Identification and improvement of coffee varieties that are resistant to BBC is imperative to the commercial growing of coffee in Kenya and world over. This will reduce the huge cost associated to disease control or crop loss therefore improving the crop profitability and evade the risks associated with excessive use of copper sprays which has posed problems that include environmental pollution and phytotoxic effects on coffee trees (Kairu *et al.,* 1997).

MATERIALS AND METHODS

Test Materials: The test materials included 24 *Coffea arabica*, *Coffea canephora* and wild coffee genotypes (Table 1) available at coffee germplasm conservation fields. Many of the genotypes are elite cultivars that have been used with few wild introductions although the reaction of most genotypes to BBC had however not been known. Four BBC isolates from different regions of Chikamagalur,Karataka (Table 2) known for BBC infection were used for screening.

Table 1: Selected coffee genotypes with a description of their known characteristics

Sn	Genotype	Description
1	Batian 1	Commercial variety tolerant to CBD and CLR
2	Batian 2	Commercial variety tolerant to CBD and CLR
3	Batian 3	Commercial variety tolerant to CBD and CLR
4	SL 28	Commercial variety susceptible to CBD and CLR
5	SL 34	Commercial variety susceptible to CBD and CLR
6	K7	Commercial variety moderately tolerant to CBD and CLR
7	Ruiru 11	Commercial hybrid variety resistant to CBD and CLR
8	Robusta	Commercial *C. canephora* resistant to the CLR races affecting *C. arabica*
9	HDT	Spontaneous hybrid of *C. arabica* and *C.canephora*. Source of resistance to CLR
10	Rume sudan	Source of resistance to CBD
11	Catimor	Parent of Ruiru 11, resistant to CLR and known to be tolerant to BBC
12	Dilla alghe	Known to be tolerant to BBC
13	Bourbon	Known to be tolerant to BBC
14	Harar	susceptible to CBD and CLR
15	*C.euginiodes*	wild type species resistant to CBD and CLR
16	Wild type	Newly collected from West Pokot
17	Selection 6	S.274 x Kents a commercial variety introduced from India –ex Robavbica
18	Selection 5a	(Devamachi x S.881) introduced from India where it is a commercial variety
19	Sarchimor	Introduced from Colombia-Villarsachi x Hybrido de Timor
20	Geisha	Known to have some resistance to BBC
21	Caturra	Compact growth with increased productivity
22	Mokka 5	Dwarf, lowly productive and susceptible to CBD & CLR
23	San ramon	Dwarf, lowly productive and susceptible to CBD & CLR
24	Dilla	Has S_H1 gene known to confer resistance to *P. syringae* pv. *garcae*.

Coffee seeds from each selected genotypes were planted in germination boxes containing sterilized sand and watered regularly at room temperature. The germinated seedlings were transplanted at the eighth week when they had attained the cotyledonous leaves into black perforated polybags measuring 5" x 9" inches containing a potting media composed of soil, sand and manure at a ratio of 3:2:1 respectively. Triple Super Phosphate (TSP) fertilizer (125 g/15 kg of potting mixture) was added in the media. The seedlings were watered regularly and relative humidity maintained at 80-90% to allow seedlings produce new pair of true leaves approximately every four weeks. The BBC isolates were cultured in Sucrose Nutrient Agar (SNA) medium prepared by dissolving 8g of Nutrient agar and 20g of sucrose in 400ml of distilled water. The medium was sterilized in an autoclave at 120^{o}C, 15psi for 15 minutes, cooled to 45^{o}C and approximately 15-20ml poured into sterile petri-dishes. The bacteria spores from actively growing sites were streaked on the medium and incubated for 48 hours at 26^{o}C. Single colonies were sub-cultured to ensure pure cultures were obtained.

Table 2: The four isolates used in inoculation with their sites of collection

No.	Isolate	Source	County
1	Kisii-58/014	CRI, Kisii substation	Kisii
2	Mweiga-66/014	Mweiga Sasini estate	Nyeri
3	Nakuru-62/014	Nakuru-Little farm Bahati	Nakuru
4	Nyeri-69/014	Nyeri Hill, Githuri blk Kamwenja	Nyeri
5	Control	Distilled Water	

Inoculation: Actively growing bacteria colonies from each sample were collected using a sterile wire loop and put into labelled 50ml tubes with distilled water. The inoculum was standardized to a concentration of 10^9 CFU/ml by reverse dilution and culturing to count single colonies growing. Inoculation was done with a drop of approximately 10 µl of the isolates suspension (10^9 CFU/ml) using the injection method (Figure 1) described by Ithiru *et al.,* 2013 with a few modification where the target was the shoot primordial between the 1st and the 2nd nodes of 4 months old seedlings which had approximately 4 pairs of true leaves. A sterile needle was used to prick through each drop of the inoculum to create avenue for the pathogen to enter into the plant.

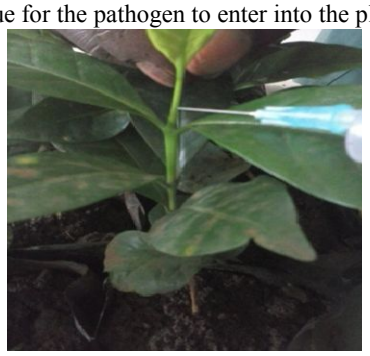

Figure 1: Inoculation of a coffee seedling at the 1st internode using the injection method

The inoculated seedlings were put in a controlled room arranged in a Complete Randomized Design (CRD) with three replication each having 10 seedlings. The temperature was set at 19-20^{0}C with the relative humidity maintained at approximately 75% by misting with water twice every day.

Data Collection and Analysis: Disease symptoms were scored using a scale of 1 to 5, from the least to the most described by Ito *et al.,* 2008 with modifications where: 1 = absence of the dark necrotic lesions, with yellow halo (bacterial blight); 2 = small black lesion; 3 = black lesion coalescing 4 =black coalesced lesion over 50% 5 = complete girdling around the meristem based on the degree of necrosis reached from day 14 from inoculation date and after every 7days. Each seedling was scored individually (Figure 2) for disease infection and a disease mean for each replication was used for analysis. The data was subjected to analysis of variance (ANOVA) using COSTAT version 2012 and confidence levels set at 95%. Least significance difference (LSD $_{5\%}$) was used to separate the means.

RESULTS

Some seedlings started showing signs of wilting and water soaking after 4-5days and necrosis after 7 days from inoculation as previously reported by Kairu *et al*., 1997. However, the observed disease symptoms could not be clearly measured in day 7 since only signs of wilting was observed. Disease symptoms mostly started to be visible from the site of inoculation and spread to other parts. The data on disease symptoms reflected a steady increase (Figure 3) from the 14th day to 21st day however; the rate of disease progression appeared to slow down towards day 28. Isolate 4, Nyeri-69/014 was the least virulent with a mean score of 1.5 on 21st day and 1.3 on the 28th day. The three most virulent isolates had a mean of approximately 4.2 on the 21st day and 4.4 on the 28th day. Most of the seedlings were in class four and five on the 28th day in most of the genotypes. All the selected genotypes appeared resistant to Isolate 4-Nyeri-69/014(1.46^b) which had significant difference to the other 3 isolates in all the varieties (Table 3). There was no significant variation ($P<0.05$) between the other three BBC isolates although isolate 3 Mweiga-66/2014 had the highest disease mean (4.22^a) followed by Isolate 1 Kisii-58/2014 (4.16^a) and Isolate 2 Nakuru-62/2014 (4.08^a) respectively.

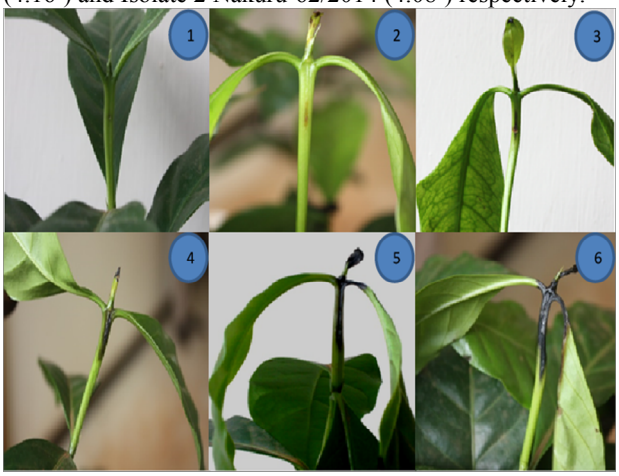

Figure 2: Classification of BBC disease symptoms after inoculation.

Key: 1 –no infection (class 1), 2- signs of water soaking with small scab or tiny brown lesions (class 2), 3- small black lesions (early class 3), 4- black lesion becoming wider and starting to coalesce (class 3), 5- black coalesced lesion over 50% (class 4), 6- complete girdling around the meristem (class 5).

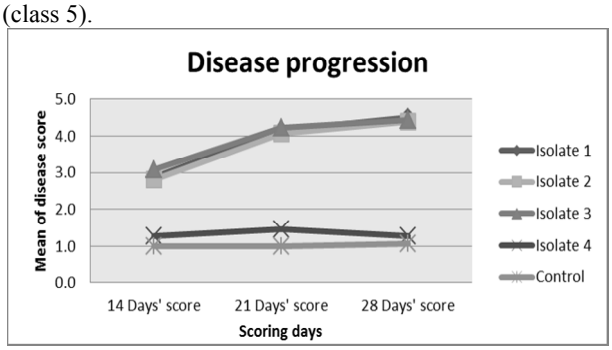

Figure 3: Means of disease progression of the coffee genotypes inoculated with the four isolates and the control.

Isolate 1:Kisii58/014, Isolate 2: Nakuru-62/014, Isolate 3: Mweiga-66/014, Isolate 4: Nyeri-69/014 and Isolate 5: Control-ddH_2O

Table 3: Disease infection means of the BBC isolates

Name	Mean	Rank
Isolate 3:Mweiga-66/2014	4.22[a]	1
Isolate 1:Kisii-58/2014	4.16[a]	2
Isolate 2:Nakuru-62/2014	4.08[a]	3
Isolate 4:Nyeri-69/2014	1.46[b]	4
Control	1[c]	5
LSD (0.05)	0.33	
CV	19.34%	

N= 72

Means marked with the same letter(s) are not significantly different at P<0.05

There was a significant increase in disease infection from day 14 to day 21 among all the genotypes although the change was not proportional. *Coffea euginiodes* had the smallest change (19.5%) followed by Robusta (*Coffea canephora* 20.7%) and Wild type coffee (24.7%) as illustrated in Figure 4. Geisha had the highest increase in disease score (47.1%) followed by Batian 3(46.4%) and selection 5a (45.0%). Nine genotypes had disease means increase of over 40% from day 14th to 21st.

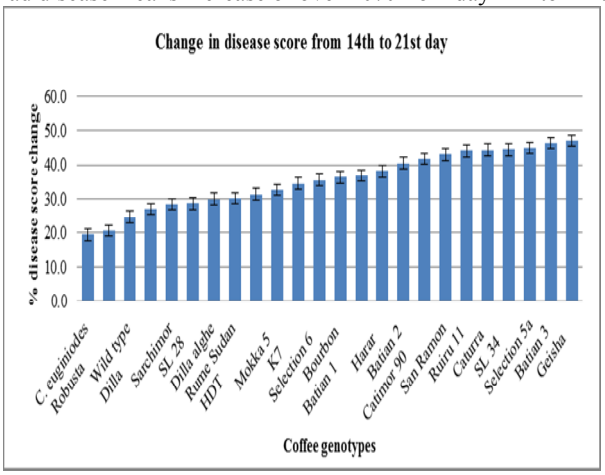

Figure 4: Disease progression in percentage on coffee genotypes against the BBC isolates from day 14th to 21st

Although Rume Sudan had a disease infection change of 30.2%, it was still the most resistant compared with the other genotypes. Mokka 5 had a change of 32.7% to reach the maximum disease score of 5. SL 28 had the smallest change of disease score (28.7%) when compared to the other commercially grown varieties while SL 34 had the highest change (44.5%). The data collected on 21st day from inoculation date gave the most realistic reaction of the coffee genotypes to BBC pathogen. The overall disease infection on all genotypes had reached a mean of 4.5 by the 28th day with most genotypes scoring between class 4 and 5.

Table 4: Coffee genotypes disease infection means against the 3 most virulent isolates

Genotype	Mean infection
Mokka 5	4.359[a]
Dilla	4.256[ab]
SL 28	4.233[ab]
Coffea eugenioides	4.122[abc]
Selection 6	4.093[abcd]
SL 34	4.052[bcde]
Harar	4.019[bcde]
San Ramon	3.970[bcdef]
Bourbon	3.915[cdef]
Catimor	3.907[cdef]
Dilla alghe	3.904[cdef]
Geisha	3.889[cdef]
Batian 1	3.889[cdef]
Ruiru 11	3.870[cdef]
Caturra	3.830[cdef]
Sarchimor	3.826[def]
Batian 2	3.804[defg]
West Pokot	3.785[efg]
Batian 3	3.715[fgh]
K7	3.707[fgh]
Selection 5a	3.511[gh]
HDT	3.426[h]
Robusta	3.422[h]
Rume Sudan	2.852[i]
LSD (5%)	**0.296**

Means marked with the same letter(s) are not significantly different at P<0.05

The inoculation results revealed significant (P<0.05) differences among the genotypes (Table 4) with Rume Sudan (2.852[i]) as the most resistant while Mokka 5 (4.359[a]) was the most susceptible. The commercial variety SL 28 which is susceptible to both CBD and CLR was the most susceptible (4.233[ab]) among the commercial varieties grown in Kenya with Batian 3 (3.715[fgh]) and K7 (3.707[fgh]) being among the most resistant in that category. There was no significant difference between Bourbon (3.915[cdef]), Catimor 90 (3.907[cdef]), Dilla alghe (3.904[cdef]), Geisha (3.889[cdef]), Batian 1 (3.889[cdef]), Ruiru 11 (3.870[cdef]) and Caturra (3.830[cdef]) which had a moderate resistance to BBC. The coffee species Robusta (*Coffea canephora)* which has T (C*k*-1) gene and is reportedly presenting significant variability in resistance to CBD (Gichimu *et al.,* 2014) was one of the most resistant genotype with a mean of 3.422[h] which compared well with one of its derivative, HDT (3.426[h]). *Coffea eugenioides* scored a mean of 4.122[abc] which was among the most susceptible genotypes. The three Batian lines were different, with Batian 1 having no significant difference with Ruiru 11 (3.889[cdef] and 3.870[cdef] respectively) while the others had 3.804[defg] (Batian 2) and 3.715[fgh] (Batian 3). The genotype West Pokot which is a wild type had a mean of 3.785[efg] which was closely behind Batian 3. Some genotypes like Batian 3 had a wide range of disease means score against the four BBC isolates (Figure 5) scoring a mean of 3.2 against isolate 1 Kisii-58/2014; 4.2 against isolate 3 Mweiga-66/2014 and 4.8 against isolate 2 Nakuru-62/2014 on day 21st. The reaction of the other two Batian lines against the BBC isolates was also quite different. However, the disease means score for Caturra,

Mokka 5, Selection 5a, Selection 6 and SL 28 on day 21st was almost similar for the three most virulent isolates (Mweiga-66/2014, Kisii-58/2014 and Nakuru-62/2014). Rume Sudan was the most resistant against isolates Kisii-58/2014 and Nakuru-62/2014 and was second against isolate Mweiga-66/2014 behind Robusta. SL 28 and SL 28 commercial varieties known for their high yields, adaptability and good quality appeared susceptible to BBC just as they are susceptible to both CBD and CLR both scoring above a mean of 4 against the three most virulent isolates. Ruiru 11 which is known for its resistant to both CLR and CBD had a high disease mean score of above 4 against isolate Nakuru-62/2014 and Mweiga-66/2014 although the mean was lower against isolate Kisii-58/2014. K7 was moderate in resistance against isolate Mweiga-66/2014 and Kisii-58/2014 but was quite susceptible to isolate Nakuru-62/2014. There appeared to be a similarity in resistance between Robusta and HDT against the isolates. Only four varieties scored a mean of 3.5 and below using the average disease means of the three most virulent isolates with Rume Sudan being the most resistant with a mean of 2.9 followed by Robusta and HDT each with 3.4 and Selection 5a with 3.5.

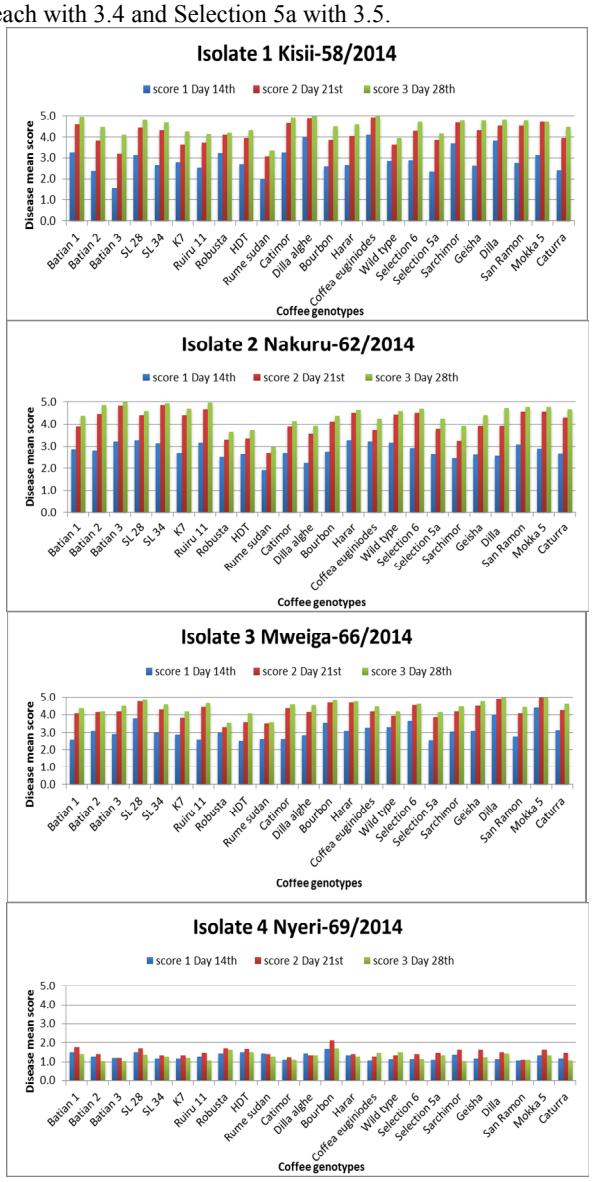

Figure 5: Comparison of progressive disease mean scores for the coffee genotypes using the four BBC isolates

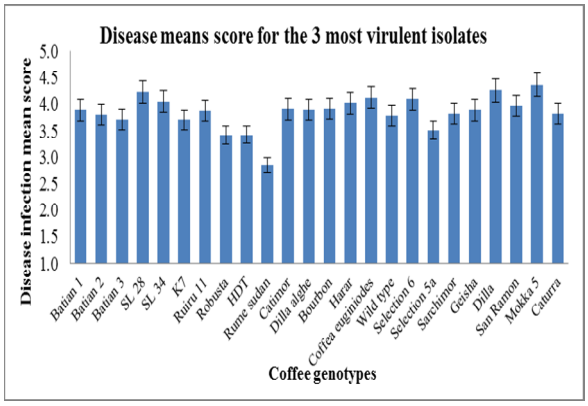

Figure 6 BBC disease means' score for the 3 most virulent isolates. Average mean for isolate Kisii-58/2014, Mweiga-66/2014 and Nakuru-62/2014 on the 24 coffee genotypes.

Varieties Mokka5(4.4), Dilla (4.3), SL 28(4.2), SL 34(4.1), *Coffea euginiodes* (4.1) and Selection 6 in that order were the most susceptible with a mean score of above 4.0 (Figure 6). Selection 5 which is a commercial variety introduced from India a derivative of Devamarchy was amongst the four genotypes that scored a disease mean of 3.5 or below against the three most virulent isolates. The performance of the genotype against the three isolates was very consistent. Genotypes K7 and Batian 3 had the lowest disease score (3.7) among the Kenyan commercial varieties. The genotypes that were considered to be partially susceptible were Bourbon, Catimor, Dilla alghe, Geisha, Batian 1, Ruiru 11, Caturra, Sarchimor and Batian 2 with a mean score of 3.804-3.915.

Discussion

Although it was possible to observe disease symptoms as early as 5th day from inoculation date, the symptoms could be clearly classified on 14th day and the genotypes appeared to differentiate well at day 21st. Beyond that day most of the varieties were pushed to susceptible class. The concentration of the inoculum appeared to have been quite high at 2 x 10^9 but it was better for selection of the resistant genotypes. Plants consistently resist certain pathogens but succumb to others; resistance is usually pathogen species or pathogen strain-specific. The tremendous diversity of hosts and disease symptomatology found in *P. syringae* pathovars species presents a unique opportunity to investigate the factors that determine host specificity (Michael *et al.,* 2005).The four isolates reaction against the coffee genotypes was different implying possible existence of different races of *P. syringae* pv *garcae* in Kenya. Many *P. syringae* pathovars contain several races characterized by their virulence on different host cultivars (Vinita *et al.,* 2005). The three Batian lines are the most recently released commercial true breeding varieties with tall stature and have been tested both in the laboratory and in the field and proven to be resistant to the two major (CBD &CLR) fungal diseases (Gichimu *et.,al* 2010) but was also reported by Ithiru *et al.,* 2013 to have a moderate resistance to BBC. They are also high yielding with good bean and liquor quality that compares to Ruiru 11 and SL28. The difference observed in their reaction to the four isolates indicates a possibility of existence of different strains of *Pseudomonas syringae* pathovar *garcae.*

Rume Sudan which is one of the widely used variety in Kenya as donor for resistance to the other major coffee diseases was

the most promising canditate for source of resistance to *P. s.* pv *garcae* scoring the lowest infection score against isolate Kisii-58/2014 and Nakuru-62/2014 and coming second after Robusta against Mweiga-66/2014 presenting a wide range of disease resistance. That consistence in resistance is a desirable trait towards breeding for resistance from a genotype which is highly resistant to CBD an has the dominant *R*- and the recessive *k*-genes (Gichimu *et al.,* 2014 and Agwanda *et al*., 1997). HDT which is a spontaneous interspecific hybrid of *C. arabica* and *C. canephora* also appeared to be a possible donor for resistance to BBC. The genotype had no significance difference with Robusta (*C. canephora*) and it is reported that clone 1349/269 of the variety HDT which was introduced in Kenya in 1960 from Portugal and its hybrid derivative Catimor carries one gene for CBD resistance on the *T*-locus with intermediate gene action (Gichimu *et al.,* 2014 and Agwanda *et al*., 1997). The results also confirms report by Ito *et al.,* (2008) that HDT could be a source of resistance without SH 1 gene. Different lines of HDT have been used worldwide to breed coffee varieties that are resistant to different pathogens (Kathurima *et al.,* 2011) including Ruiru 11 and Batian.

The screening results show that most of the Kenyan commercially grown coffee are susceptible or partially resistant to BBC which is a great threat to the coffee industry. K7 which is moderately resistant to CBD and it is reported to have the recessive *k*-genes (Agwanda *et al*., 1997) and Batian 3 which is amongst the newly released Batian lines were the most resistant genotypes among the commercial varieties in Kenya indicating possible quantitative resistance. There was no significance difference between Ruiru 11and Catimor which is one of its parents. Batian 3 appears to be more prospectus than the other Batian lines and Ruiru 11 in search for BBC resistance. The difference of the three Batian lines could be due to their pedigree where Batian 3 have the three major genes associated to CBD resistance namely *R* from Rume Sudan, *T* from HDT and *k* from K7. This could also explain the reason why there was no significant difference between Batian 3 and K7. The other two Batian lines had no K7 in their pedigree though Batian 2 had N39. Ruiru 11 is a composite F1 hybrid of variety Catimor (as the female) and breeders lines that yielded Batian most of which have HDT in their pedigree as the male selections (Kathurima *et al*., 2011). The breeding programmes to develop the male parents involved backcrossing and selfing at various selection stages which affected the amount of Robusta genome passed on to the next generation. This can explain the wide range of diversity observed between HDT and its derivatives (Catimor Line 90, Ruiru11 Batian 1, Batian 2 and Batian 3) confirming the report by Kathurima *et al.*(2011). Progenies of HDT and advanced inbred lines of its cross to *C. arabica* cv. Caturra (referred to as cv. Catimor), are used as donor parents for resistance to CBD and CLR in Kenya. Resistance to Coffee Berry Disease (CBD) in *Coffea arabica* cv. Ruiru 11 is known to be controlled by among others, the T (Ck-1) gene from Robusta coffee and is reportedly presents significant variability in resistance to CBD (Gichimu *et al.,* 2014). Although the disease appeared more severe on all the varieties possibly due to the high concentration (2×10^9) used in the inoculation the study confirms Masaba's (1998) report that Catimor was more resistant compared to SL 34 and SL 28. Though it had earlier been reported that SH1 gene found in the Arabica coffee genotypes Harar, Dilla & Alghe, S12 Kaffa and Geisha confers simultaneous resistance to some races of *Hemileia vastatrix* and to *Pseudomonas syringae* pv. *garcae* (Ito *et al.,*2008) these genotypes recorded a relatively high disease score and there was no significance difference amongst them. Selection 5a which is a derivative of Devamarchy a commercial variety in India performance was quite impressive. However the genotype has to undergo adaptability trials to evaluate its performance in Kenya coffee growing areas before it can be selected as a recurrent parent in breeding for BBC. While K7 is a Kent type commercial variety, other resistant donors (Hibrido *de* Timor, Rume Sudan) correspond to exotic germplasm where the valuable resistant genes are associated with undesirable traits (Agwanda *et al*., 1997). Utilization of commercial cultivars with desirable traits like Batian 3 in breeding for resistance to major coffee diseases is important.

CONCLUSION

The study confirmed that there exists diversity among coffee genotypes in relation to resistance to BBC. Vertical resistance is specific to certain races or strains of a pathogen species and is often controlled by single R genes and can be less durable. Horizontal or broad-spectrum resistance against an entire pathogen species is often only incompletely effective, but more durable, and is often controlled by many genes that segregate in breeding populations. Genotypes like Rumesudan and HDT that have been used in breeding for resistance varieties like Ruiru 11 and Batian have proved to be promising source of resistance to BBC and are therefore preferred as donor for resistance against the disease. Batian 3 which is an improved breeders' line that combines high yield, good quality and resistant to the other two major fungal diseases in Kenya is a suitable candidate as a recurrent parent in breeding for resistance towards BBC. Diversity of *Pseudomonas syringae* pv. *garcae* was observed and it is possible that there exist different strains of the pathogen affecting coffee in Kenya.

RECOMMENDATION

The possible existance of diverse strains of the *Ps.*pv.*garcae* pose a threat to coffee farming and therefore a breeding programme to introgres resistance gene into the commercial varieties through pyramiding of resistance genes could offer a durable resistance to the coffee. Further studies on characterisation of the pathogen to confirm its diversity should be prioritised to ensure a horizontal broad-spectrum resistance against the entire pathogen species is achieved.

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