Combining CBD Resistance with High Yields and Good Cup Quality: Success case in Ruiru 11 Cultivar

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SUMMARY

Coffea arabica cv. Ruiru 11 is a composite of sixty six (66) F1 hybrid sibs each derived from a cross between a specific female and male population. The pedigree of Ruiru 11 consist of CBD resistance donors, Rume Sudan (*R* gene), Hibrido De Timor (*T* or *Ck-1* gene), Catimor (*T or Ck-1 gene*), K7 (*k* gene), SL4 and the high yielding, good quality but susceptible cultivars such as N39, SL28, SL34 and Bourbon. Ruiru 11 sibs reportedly present significant variability in terms of resistance to CBD, yields and quality. The objective of this study was to select for CBD resistance, high cherry yields and good quality within *Coffea arabica* L. cultivar, Ruiru 11. Thirty four hybrid sibs of Ruiru 11 cultivar grown in three different locations in Kenya were used for the study. The experiment was conducted between 2009 and 2011. Ripe cherries were harvested, bulked per replication, weighed and yield data recorded before subjecting them to wet processing, drying, hulling and grading. Beverage quality was determined following the sensory evaluation procedure of Specialty Coffee Association of America (SCAA). Evaluation of CBD resistance was conducted in the laboratory using hypocotyl inoculation method. The study confirmed earlier reports that Ruiru 11 sibs differ in quality aspects, yields and resistance to CBD but some sibs that combine all these desirable traits were identified.

Key words: Coffee, Ruiru 11 Sibs, Introgression, Kenya

INTRODUCTION

Coffee Berry Disease caused by *Colletotrichum kahawae* Waller and Bridge is one of the most important diseases of coffee limiting Arabica coffee production in Kenya and other countries in Eastern Africa (Gichimu *et al*., 2013). Growing of resistant cultivars is encouraged as the most economical method of managing the disease since chemical control is very expensive (Silva *et al*., 2006). Beverage quality is also an important attribute of coffee and acts as yardstick for price determination (Agwanda *et al*., 2003; Kathurima *et al*., 2009). Production and supply of coffee with excellent quality is therefore important for coffee exporting countries (Abadiga, 2010). Moreover, success of a new variety of Arabica coffee depends to a great extent on its bean and beverage quality (Agwanda *et al*., 2003). Many coffee producing countries thus consider the assessment of coffee quality as critical as disease resistance and productivity in their coffee variety development programmes (Abadiga, 2010).

A Kenyan cultivar, Ruiru 11, is a composite of about 60 F1 hybrid sibs each derived from a cross between a specific female and male population (Gichimu *et al*, 2013). The male parents are outstanding selections from a multiple cross programme involving CBD resistant donor parents such as Rume Sudan (R gene), Hibrido de Timor (T gene), K7 (k gene), and SL4 and the high yielding, good quality but susceptible cultivars such as N39, SL28, SL34 and Bourbon (Gichimu *et al.*, 2012). The female parents are advanced generations (F3, F4 and F5) of the cultivar Catimor, ex Colombia, which has Hibrido de Timor clone 1343/269 as one parent (Gichimu *et al*., 2012). The cultivar combines resistance to CBD and leaf rust with high yield and fine quality (Gichimu *et al*., 2012). However, Omondi *et al*. (2001) reported that resistance to CBD within this cultivar is fairly non-uniform. On the other hand, Ruiru 11 sibs reportedly present variability in terms of beverage quality (Ojijo, 1993; Kathurima *et al.* 2010). Other studies reported that the raw bean and liquor qualities of the cultivar Ruiru 11 is virtually similar to that of Kenyan traditional varieties (Owuor, 1988; Njoroge *et al.,* 1990; Omondi, 2008).

The varying parentage of Ruiru 11 sibs could be causing the reported variation in beverage quality and non-uniform resistance to CBD within the composite cultivar. The major source of resistance in Ruiru 11 comes from *C. canephora* introgressed mainly through Timor Hybrid (T gene). Robusta coffee has relatively poor bean and beverage quality (Gichimu *et al*., 2012) and therefore its genome introgression is expected to affect beverage quality in Ruiru 11 and related families. It was therefore deemed important to enhance selection for beverage quality and CBD resistance within the cultivar. Previous studies have tended to concentrate on evaluating the quality (Owuor, 1988; Njoroge *et al.,* 1990; Ojijo, 1993; Agwanda *et al*., 2003; Omondi, 2008; Kathurima *et al*., 2010) and disease resistance (Omondi *et al*., 2001) of Ruiru 11 sibs and leaving out the yield aspects. The objective of this study was to select for CBD resistance, high cherry yields and good quality within *Coffea arabica* L. cultivar, Ruiru 11.

MATERIALS AND METHODS

Description of study sites

The study was conducted in three different locations in Kenya namely Mariene in Meru county, Kisii in Kisii county and Koru in Kericho County. Mariene is located in the upper midland 2 agro-ecological zone at 0^0N, 37^0 35'E, at an elevation of 1524 m above sea level. Koru is located in the lower midland 3 agro-ecological zone at 0^0 07'S, 35^0 16'E and has an elevation of 1554 m above sea level. Kisii is found in the upper midland 1 at 0^0 41'S, 34^0 47'E at 1680 m above sea level (Jaetzold *et al.,* 2005).

Experimental Layout and Test Materials

The experiment was set up in existing coffee experimental plots that were established in April 1990 in Koru and Kisii and in April 1991 in Meru. Thirty four (34) Ruiru 11 sibs (Table 1) were evaluated in this study alongside two entries of SL28 used as checks. One entry of SL28 was sprayed with copper fungicides to control CBD and leaf rust. The other entry of SL28 was not sprayed. The plots were laid out in a Randomized Complete Block Design (RCBD) with three replications. Each replication consisted of 12 trees of each sib planted at a spacing of 2m by 1.5m. The experiment was conducted for 3 seasons between 2009 and 2011.

Data Collection

Ripe cherries were harvested, bulked per replication, weighed and yield data recorded before subjecting them to wet processing following the standard processing procedures. The parchment was then hulled and graded to seven grades based on size, shape and density. Only the premium grades AA and AB were used for the sensory evaluation. Roasting of the dry beans was done to attain a medium roast using a probat laboratory roaster. The samples were ground immediately after roasting using a probat laboratory grinder (Type 55 LM 1500). Each sib was ground separately and deposited into five cups, ensuring that the whole and consistent quantity of sample gets deposited into each cup. The ground samples were then infused in hot water using a predetermined ratio of 8.25ts g per 150 ml of water prior to cupping. Sensory evaluation was conducted following the sensory evaluation procedure of Specialty Coffee Association of America (SCAA) as described by Lingle (2001). Evaluation of CBD resistance was conducted through hypocotyl inoculation using the method developed by Van der Vossen *et al*. (1976). The first experiment was conducted in July 2010 and repeated in July 2011.

Table 1: Pedigree of Ruiru 11 sibs evaluated

	Female Parent						
Male Parent	Cat.86	Cat.88	Cat.90	Cat.124	Cat.127	Cat.128	Cat.134
SL28 x [(SL28 x RS) (B x HT)]	1,11,41	22,42	3,23	5	6	7	50
SL28 x [(K7 x RS) (SL34 x HT)]		52					
SL28 x [(N39 x HT) (SL4 x RS)]	71	72					80
SL28 x [(SL34 x RS) HT]	91,111, 121,131	112,142	93,103, 123,143	105,115, 125	106	107,117	100
SL34 x [(SL34 x RS) HT]				135		137	

Key: RS = Rume sudan, HT = Hibrido de Timor, Cat = Catimor, B = Bourbon

Data Analysis

All the data were subjected to Analysis of Variance (ANOVA) using XLSTAT Version 2012 statistical software and effects declared significant at 5% level. Least Significant Difference ($LSD_{5\%}$) was used to separate the means. Linear correlation was done to determine the association between cup quality and CBD resistance.

RESULTS

Yield Evaluation

Significant ($P \leq 0.05$) yielding differences were observed among the sibs in all the locations. Evaluated sibs were found to produce an average yield of between 3244 – 15996 grams per tree (Table 2). In all locations, SL28 sprayed with fungicides recorded slightly higher yields than the unsprayed SL28 in absolute terms but were not significantly different. Therefore, spraying SL28 against fungal diseases had no significant effect on yield. This was attributed to low disease pressure in all locations. At Kisii site, the yields of SL28 (both sprayed and unsprayed) were highly comparable to those of most Ruiru 11 sibs. The yields of sprayed SL28 were not significantly different from those of the first 30 Ruiru 11 sibs except R11-143, R11-107, R11-106 and R11-112 while the yields of unsprayed SL28 were not significantly different from those of all Ruiru 11 sibs except R11-112. At Koru, all Ruiru 11 sibs produced better yields than SL28 in absolute terms but 17 sibs recorded significantly ($P \leq 0.05$) higher yields than SL28. At Mariene, 8 Ruiru 11 sibs recorded significantly ($P \leq 0.05$) higher yields than SL28 (Table 2).

Table 2 also shows the most yielding sibs per location. The best sibs for Kisii that recorded above 10 kg of cherry were found to be R11-131, R11-52, R11-137, R11-117, R11-6, R11-7, R11-1, R11-111, R11-42, R11-41, R11-121, R11-50, R11-142 and R11-22. At Koru 16 sibs recorded above 10 kg of cherry per tree. These were R11-80, R11-107, R11-137, R11-117, R11-91, R11-142, R11-52, R11-100, R11-131, R11-11, R11-135, R11-115, R11-125, R11-105, R11-123 and R11-7. For Mariene, none of the sibs recorded average cherry yields of above 6 kg. The best performing sibs were R11-52, R11-1, R11-11, R11-135, R11-3, R11-22, R11-117 and R11-121 which were the only ones that yielded an average of above 5 kg of cherry per tree. The sibs were best discriminated at Mariene and the site was considered the best for yield selection followed by Kisii. The study further identified the sibs that consistently recorded high yields in all locations. These included R11-52, R11-117, R11-131, R11-11, R11-105, R11-142, R11-7, R11-100 and R11-121. Others that consistently recorded high yields in more than one location include R11-80, R11-135, R11-22, R11-72, R11-137, R11-115, R11-6 and R11-91.

Cup Quality/Sensory Evaluation

Ruiru 11 sibs recorded significant ($P \leq 0.05$) differences among them for different cup quality traits in different locations on different seasons. This was an indication of some level of variation between the sibs which are considered to be closely related. Although there was large variation in cup quality between sibs, all the sibs recorded an average overall cup quality of above 82 points with some recording better quality than SL28. Comparative performance of the sibs on varying locations enabled selection of the sibs which performed better in varying climatic conditions. The sibs that consistently recorded high quality in more than one location in varying seasons are R11-52, R11-117, R11-1, R11-131, R11-7, R11-137, R11-6, R11-142, R11-22, R11-121, R11-11, R11-72, R11-100, R11-107 and R11-115 (data not shown).

Variation among the genotypes was further demonstrated by the cluster dendrogram developed using the sensory variables (Figure 1). Four main classes (labelled 1, 2, 3 and 4 in the figure) were formed when the similarity index was considered for clustering. Class 1 contained two individuals, R11-52 and sprayed SL28, which consistently recorded high cup quality. Other individuals that recorded high cup quality were classified in class 2. Class 3 contained only R11-41 which was found to be highly unstable with its cup quality varying with locations and seasons. The rest of the genotypes which recorded relatively lower cup quality were classified in class 4. Within class diversity of 15.86% was recorded alongside a between classes diversity of 84.14%. The highest between class diversity was observed between class 1 which contained the genotypes with the best cup quality and class 4 consisting of genotypes with the lowest cup quality. Classes 1 and 2 which consisted of genotypes with moderate cup quality were the most closely related. The parentage of these sibs did not appear to play significant role in modifying the genetic diversity.

Table 2: Variation in cherry yields among Ruiru 11 sibs per location across all seasons

Kisii		Koru		Mariene	
Genotypes	Mean Cherry Yield (g/tree)	Genotypes	Mean Cherry Yield (g/tree)	Genotypes	Mean Cherry Yield (g/tree)
R11-1	11545.28 a-f	R11-1	7865.91 k-m	R11-1	5914.93 a
R11-3	7841.11 f-k	R11-3	7624.22 k-m	R11-3	5580.67 a-d
R11-5	9686.25 b-j	R11-5	7456.94 k-m	R11-5	4036.63 e-i
R11-6	11747.50 a-e	R11-6	9384.40 e-l	R11-6	4654.26 a-h
R11-7	11587.22 a-f	R11-7	10269.14 c-k	R11-7	4987.00 a-g
R11-11	8825.42 c-k	R11-11	11620.89 b-i	R11-11	5890.04 ab
R11-22	10142.78 b-j	R11-22	9569.67 d-l	R11-22	5323.28 a-e
R11-23	9507.08 b-j	R11-23	9125.94 f-l	R11-23	4270.07 d-i
R11-41	10655.86 a-i	R11-41	8880.03 g-l	R11-41	3773.70 g-i
R11-42	10817.64 a-h	R11-42	9350.75 f-l	R11-42	3823.26 g-i
R11-50	10587.08 a-i	R11-50	8370.11 h-l	R11-50	3583.89 hi
R11-52	12981.67 ab	R11-52	12032.70 b-g	R11-52	5976.15 a
R11-71	7588.33 g-k	R11-71	7451.14 k-m	R11-71	3788.44 g-i
R11-72	9867.50 b-j	R11-72	9677.07 c-l	R11-72	4518.41 c-i
R11-80	8058.47 e-k	R11-80	15995.37 a	R11-80	4482.04 c-i
R11-91	9202.64 b-k	R11-91	12886.57 a-e	R11-91	4000.74 e-i
R11-93	7503.33 g-k	R11-93	9040.70 f-l	R11-93	4187.93 e-i
R11-100	8387.36 e-k	R11-100	12016.00 b-g	R11-100	4827.81 a-h
R11-103	8661.94 d-k	R11-103	8731.01 g-l	R11-103	3244.48 i
R11-105	9948.75 b-j	R11-105	10351.90 c-k	R11-105	4525.30 c-i
R11-106	6461.39 jk	R11-106	7574.63 k-m	R11-106	4663.63 a-h
R11-107	6886.67 i-k	R11-107	14223.80 ab	R11-107	3711.15 g-i
R11-111	11015.00 a-g	R11-111	7800.23 k-m	R11-111	3891.11 f-i
R11-112	5573.33 k	R11-112	8033.38 j-m	R11-112	4335.44 c-i
R11-115	8988.75 c-k	R11-115	11407.59 b-j	R11-115	4822.93 a-h
R11-117	12437.08 a-d	R11-117	13038.19 a-d	R11-117	5270.78 a-e
R11-121	10604.86 a-i	R11-121	9951.22 c-k	R11-121	5173.85 a-f
R11-123	8261.67 e-k	R11-123	10295.81 c-k	R11-123	4551.48 b-i
R11-125	9198.75 b-k	R11-125	10888.70 b-k	R11-125	4410.22 c-i
R11-131	14115.97 a	R11-131	11765.36 b-h	R11-131	4823.04 a-h
R11-135	7995.14 e-k	R11-135	11494.28 b-j	R11-135	5640.22 a-c
R11-137	12671.94 a-c	R11-137	13115.73 a-c	R11-137	4531.41 c-i
R11-142	10238.75 a-j	R11-142	12423.47 b-f	R11-142	4484.33 c-i
R11-143	7012.78 h-k	R11-143	8122.30 i-m	R11-143	4767.89 a-h
SL28(NS)	10317.94 a-j	SL28(NS)	4737.24 m	SL28(NS)	3585.78 hi
SL28(S)	11208.06 a-g	SL28(S)	6169.75 l-m	SL28(S)	3652.52 g-i
Average	9670.31	Average	9965.06	Average	4547.36

Means followed by the same letter(s) within the column are not significantly different at P ≤ 0.05
Key: The hyphen (-) represents the alphabetical range between the letters

Laboratory evaluation of CBD resistance

Phenotypic variation of Ruiru 11 sibs in resistance to CBD was also highly significant (p<0.01). Some sibs recorded varying results during the two screening experiments (Table 3). This might have been caused by differences in CBD inoculum since a different inoculum was prepared for each experiment. The cultivar SL28 which was used as a susceptible control was the only genotype that was in the susceptible class (score 10-12) with average infection scores of 11.59

and 11.72 in first and second experiments respectively. Resistance in Ruiru 11 sibs ranged from moderately resistant to moderately susceptible but none of them fell in the resistant (score 1-3) and susceptible (score 10-12) classes. The most resistant was R11-143 with average infection scores of 4.55 and 4.71 in first and second experiments respectively. Other sibs that also recorded good resistance to CBD include R11-1, R11-3, R11-5, R11-22, R11-23, R11-42, R11-80, R11-93, R11-105, R11-107, R11-121 and R11-135 with average infection scores of 6.43, 5.85, 6.21, 6.46, 6.13, 6.17, 5.52, 6.26, 6.25, 6.49, 5.94 and 6.31 respectively. The rest of Ruiru 11 sibs were in the range of 7-9 and were therefore rated as moderately susceptible (Table 3).

Table 3: Variation in CBD infection on Ruiru 11 sibs

	Mean CBD Infection Score		
Genotypes	**Experiment 1**	**Experiment 2**	**Combined**
R11-1	7.33 g-j	5.55 no	6.43 h-j
R11-3	4.82 rs	6.89 g-l	5.85 kl
R11-5	6.15 l-o	6.27 l-n	6.21 i-k
R11-6	9.22 b	6.12 l-n	7.67 de
R11-7	7.45 f-j	7.83 b-f	7.64 de
R11-11	6.51 k-m	6.56 j-m	6.53 g-i
R11-22	6.40 k-m	6.53 lm	6.46 g-j
R11-23	8.13 c-f	4.14 p	6.13 i-k
R11-41	8.76 bc	8.56 b-d	8.66 b
R11-42	6.44 k-m	5.89 mn	6.17 i-k
R11-50	7.88 e-h	7.69 d-g	7.79 d
R11-52	8.14 c-f	7.46 f-j	7.80 d
R11-71	5.54 o-q	7.76 c-g	6.65 f-i
R11-72	7.63 e-i	6.71 h-m	7.17 ef
R11-80	6.54 k-m	4.51 p	5.52 l
R11-91	8.68 b-d	8.62 bc	8.65 b
R11-93	6.10 l-p	6.43 l-n	6.26 h-k
R11-100	9.22 b	8.46 b-e	8.84 b
R11-103	5.66 n-q	8.42 b-e	7.04 fg
R11-105	5.06 q-s	7.45 f-k	6.25 h-k
R11-106	6.31 l-n	7.73 c-g	7.02 fg
R11-107	5.38 p-r	7.59 e-h	6.49 g-j
R11-111	8.04 d-g	7.56 e-i	7.80 d
R11-112	7.29 h-j	8.69 b	7.99 cd
R11-115	8.23 c-e	8.57 b-d	8.40 bc
R11-117	7.49 f-j	6.89 g-l	7.18 ef
R11-121	6.03 m-p	5.84 mn	5.94 j-l
R11-123	8.63 b-d	6.75 h-m	7.69 de
R11-125	7.55 e-i	6.72 h-m	7.15 ef
R11-131	8.73 b-d	6.54 k-m	7.63 de
R11-135	5.94 m-p	6.66 i-m	6.31 h-k
R11-137	7.10 i-k	6.51 lm	6.80 f-h
R11-142	6.79 j-l	6.48 lm	6.63 f-i
R11-143	4.55 s	4.71 op	4.63 m
SL28	11.59 a	11.72 a	11.65 a

Means followed by the same letter(s) within the column are not significantly different at $P \leq 0.05$
Key: The hyphen (-) represents the alphabetical range between the letters

Figure 2 shows the relationship between cup quality and CBD susceptibility/resistance in Ruiru 11. Taking a CBD infection score of less than 6 and cup quality above 83 points, some promising sibs that appeared to combine good cup quality with high CBD resistance were identified (unshaded bars in Fig. 2). These were R11-1, R11-105, R11-107, R11-11, R11-121, R11-135, R11-143, R11-22, R11-23, R11-3, R11-42, R11-5, R11-80 and R11-93.

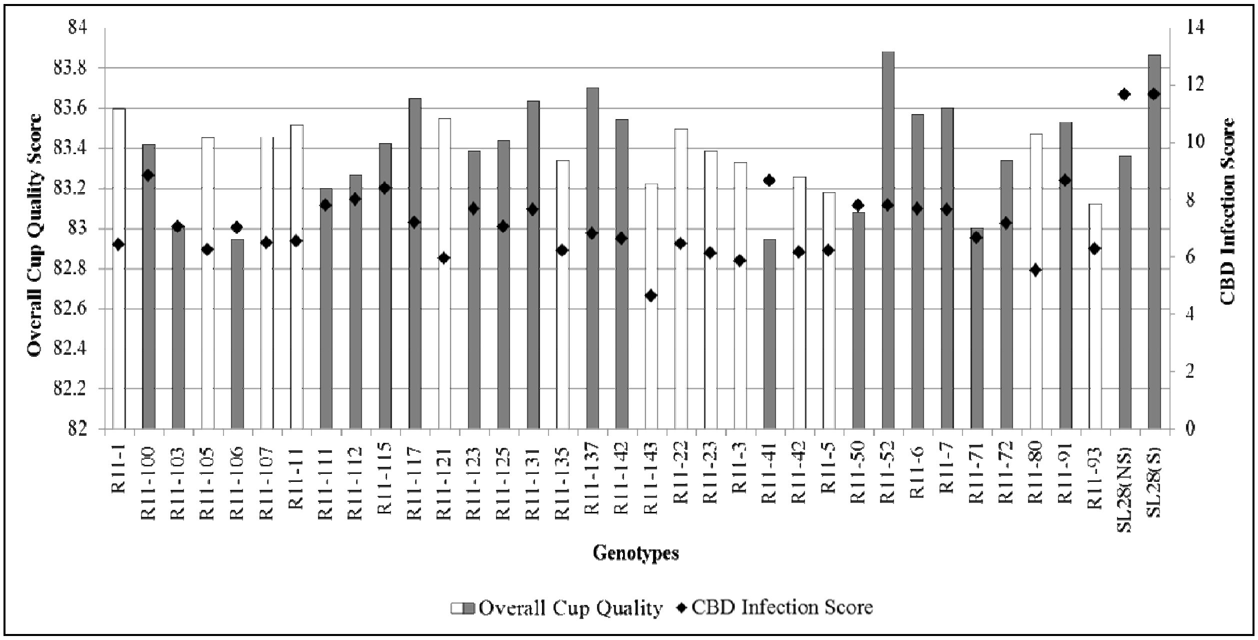

Fig. 2: Relationship between overall cup quality and CBD infection. Unshaded bars represent the most promising sibs that appeared to combine good cup quality with good CBD resistance.

Out of the fourteen (14) sibs that recorded good resistance to CBD, eleven (11) were also found to be high yielding and of good bean and cup quality in different locations. Specifically, the sibs that combined good CBD resistance with high yields and good quality for the different locations were identified as follows: R11-1, R11-3, R11-11, R11-22, R11-121 and R11-135 for Mariene, R11-11, R11-80, R11-105, R11-107, R11-135 and R11-137 for Koru and R11-1, R11-22, R11-42 and R11-121 for Kisii. Other promising sibs that were found to combine high yields and good quality though with relatively lower resistance to CBD included R11-6, R11-52, R11-100, R11-117, R11-131 and R11-142.

DISCUSSION

Although some studies have been carried out to assess variation in quality of Ruiru 11 sibs (Ojijo, 1993; Agwanda *et al*., 2003; Omondi, 2008; Kathurima *et al*., 2010) and disease resistance (Omondi *et al*., 2001), there is little information about their variation in yield. Ruiru 11 sibs evaluated were found to differ significantly in yields. This was an indication of agronomic variation between Ruiru 11 sibs. Similar results were obtained by Wamatu *et al*. (2003) when evaluating related coffee clones some of which have been utilized as Ruiru 11 male parents. The study identified the sibs that consistently recorded high yields in all locations. Some of these sibs including R11-52, R11-117, R11-131, R11-107, R11-121, R11-11, R11-137 and R11-22 have also been found to have high bean and cup quality with good stability (Gichimu *et al*., 2012). Kathurima *et al*. (2010) also recorded high cup quality from R11-41, R11-11, R11-91 and R11-131 in a multi locational study involving ten Ruiru 11 sibs. Such sibs can be recommended to farmers for adoption and also be exploited in future breeding programmes.

Ruiru 11 sibs evaluated were found to differ significantly in cup quality. This concurred with the findings of Ojijo (1993) and Kathurima *et al*. (2010) that the composite Ruiru 11 cultivar presents significant variability in terms of quality. All the sibs evaluated had an overall score of more than 82 points. The cup quality of Ruiru 11 is therefore of premium grade. Other previous studies had reported that the cultivar Ruiru 11 is virtually similar to the traditional varieties in terms of cup quality (Owuor, 1988; Njoroge *et al.,* 1990). The study identified several sibs that are best suited for each of the three locations. These sibs should be recommended to farmers in the respective locations for production of high quality Ruiru 11 coffee. The study further identified Ruiru 11 sibs that consistently produced high quality coffee in varying climatic conditions. These included R11-52, R11-117, R11-137, R11-131, R11-6, R11-7 and R11-1. These consistently recorded good quality in more than one location and season. Such sibs can be used in future improvement of Ruiru 11 and its derivatives to expand their agronomic adaptability. Kathurima *et al*. (2010) also recorded high cup quality from R11-41, R11-11, R11-91 and R11-131 in a multi locational study involving ten (10) Ruiru 11 sibs.

Variation in CBD resistance was observed among different Ruiru 11 sibs. This confirmed the report of Silva *et al*. (2006) that differences in resistance of coffee trees to CBD are frequently observed under field and laboratory conditions. The observed variability in CBD resistance among Ruiru 11 sibs concurred with the findings of Omondi *et al*. (2001) that although the composite cultivar, Ruiru 11 generally contains good resistance to CBD, this resistance is not uniform among the sibs. Thirteen Ruiru 11 sibs with good resistance to CBD were identified namely R11-143, R11-1, R11-3, R11-5, R11-22, R11-23, R11-42, R11-80, R11-93, R11-105, R11-107, R11-121 and R11-135. These sibs are recommended to farmers in CBD prone agro-ecological zones especially on higher altitudes. The sibs can also be exploited in future breeding programmes.

CONCLUSION

The study demonstrated the existence of significant variations in cherry yields, cup quality and CBD resistance among the Ruiru 11 sibs. There is therefore high potential of intra-cultivar selection for agronomic improvement of Ruiru 11. The most promising Ruiru 11 sibs that appeared to combine high yields with good quality and resistance to CBD were identified. These sibs are recommended to farmers in for adoption and can also be exploited in future breeding programmes for improvement of Ruiru 11. The sibs that combined high yields and good quality though with relatively lower resistance to CBD are recommended to breeders for further improvement of their resistance to CBD since they already have other desirable traits.

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