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# Preliminary Screening of Maize Accessions Against Common Rust Disease (*Puccinia sorghi* Schw) in Arsi Negele District, Ethiopia

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**Abstract:** Maize is one of the most important crops in Ethiopia. The production of the crop is threatened by a number of biotic and a biotic factor. Among biotic factors, common rust caused by *Puccinia sorghi* Schw, is one of destructive foliar diseases of maize in Ethiopia. A study was conducted during the main cropping season (April to November, 2016) in the field at Arsi Negele research farm, Ethiopia with the objective of screening 92 maize accessions and 2 farmer's varieties checks against common rust disease. The experiment was laid out in augmented design with no replications. Disease assessment was done as percentage of leaf area infected on individual plant at 15 days intervals starting from 55 days after planting to cropping season for 5 times. The mean values of disease incidence, severity and AUDPC were calculated and yield recorded. The higher disease percent severity and AUDPC, least yield and thousand seed weight were observed from accessions, AN-239620, AN-9195, AN-9988, AN-9991, AN-15459, AN-15460, AN-16021, AN-18121, AN-18122 and Check-1 with mean values (63.94%, 1694.5%-in days, 3.04 to 3.69 t/ha and 240 to 297g) respectively and categorized in moderately susceptible group. Conversely, the minimum percent disease severity, AUDPC, higher yield and thousand seed weight were recorded from accessions, AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN2-4297, AN-913, AN-15325 AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-162383, with mean values of (31.01%, 720.4%-in days, 4.81 to 5.59 t/ha and 380 to 442g) respectively and grouped in resistant category. Therefore, accessions recorded low percent disease severity and AUDPC values could be used as the resistant varieties and source of resistance to common rust for varietal development of maize.

**Keywords:** Maize, Accession, *Puccinia sorghi*, Severity, AUDPC and Resistant

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## 1. Introduction

Maize (*Zea mays* L.) is one of the most important food crops world-wide. It is the principal component of human diet and feed constituent for domestic animals. It ranks third in production worldwide following wheat and rice and is grown in most parts of the world over a wide range of environmental conditions [1]. It occupies an important position in the world economy as food, feed, and industrial grain crop. It is a staple food for million people in the developing countries where they obtain their protein and calorie requirements from it.

In Ethiopia, maize is one of the most important cereal crops grown. Among cereal crops, maize ranks second to tef (*Eragrostis tef*) in area coverage but first in productivity and

total production [2]. Maize is currently produced by more farmers than any other crops. Although, improved cultivars have been largely included in the national extension package, the national average yield of maize is only 3.45tons/ha [3], which is below the world average of 5.5tons/ha.

The low yield is attributed to a number of factors such as biotic (diseases, insect pests, and weeds), a biotic (moisture, soil fertility, etc). Among biotic factors, foliar diseases such as leaf blight (*Exserhilum turcicum*), and common rust (*Puccinia sorghi* Schw) are generally among the important constraints in tropical maize production [4]. Common rust caused by *Puccinia sorghi* Schw is a destructive disease in the major maize growing high land areas of the country and causes from 12-61% yield loss in disease epidemic years [5].

The use of fungicide is beyond the access of resource

constrained farmers and moreover increases the production cost, hazardous to human health and has a negative impacts to environment.

The use of resistant varieties is effective for resource constrained farmers. This is the durable and economical means for disease management. This principle is equally important for an eco-friendly environment.

Therefore, this study was carried out to investigate the potential of 92 maize accessions against common rust disease which serve as a preliminary information that could help in developing *Puccinia sorghi* resistant and high yielding maize varieties under field conditions.

## 2. Materials and Methods

### 2.1. Description of the Study Area

Field experiment was conducted at Negele research farm site in Arsi Negele District, West Arsi Zone, Oromia Regional State, Ethiopia during the main cropping season of 2016. It is located at 7°21'N 38°42'E and at an elevation of 1940 m.a s l. It has a chromic and pellic vertisols with PH of 5-7. The annual rainfall of the location is 915 mm with 27±0.30°C mean daily temperature

### 2.2. Materials Used

Ninety two maize accessions obtained from Ethiopian Biodiversity Institute (Gene bank) and two farmer's varieties check named as check 1 and 2 were sown at Arsi Negele research farm site to evaluate against common rust disease at different plant growth stages during the main cropping seasons in 2016.

### 2.3. Experimental Design

92 maize accessions without replication along with 2 replicated checks were arranged in augmented design. Individual plot size measured 9m\*1.5m with 4 maize rows planted at a spacing of 75\*30 cm. All plots were planted manually with two seeds per hole. Fertilizers (DAP & Urea) and all agronomic practices were applied based on the recommendations.

### 2.4. Inoculation and Disease Assessment

Natural inoculation was relied up on in all experimental plots. Disease incidence and severity on 10 tagged plants was assessed on two weeks interval. Starting from the first appearance of disease symptoms (55 DAP) a total of five disease assessments were conducted throughout the cropping season. Disease assessment was made for the various accessions from the central two rows. Incidence of common rust was assessed by counting the number of plants on the middle two rows and expressed as percentage of total plants. Disease incidence was computed according to the following equation:

$$\text{Incidence (\%)} = \frac{\text{Number of diseased plant}}{\text{Total number of plants}} * 100$$

Disease severity (the percentage area of leaves damage per plant on 10 randomly pre-tagged maize plants in each plot) was rated following CIMMYT methods using 1-5 scoring scale [6]; where 1.0=Very slight to slight infection, one or two to few scattered lesions on lower leaves only; 2.0=Light infection, moderate number of lesions on lower leaves only, 3.0=Moderate infection, abundant lesions are on lower leaves, few on middle leaves, 4.0=Heavy infection, lesions are abundant on lower and middle leaves, extending to upper leaves, 5.0=Very heavy infection, lesions abundant on almost all leaves, plants prematurely dry or killed by the disease. The severity grades were converted into percentage severity index (PSI) for analysis [7].

$$PSI = \frac{\text{Sum of numerical rating}}{\text{No of plants observed (10) x maximum score scale(5)}} * 100$$

The disease progress rate (r) was calculated for each plot by using the linear logistic model and the calculated value was analyzed. These parameters were used in analysis of variance to compare the disease progress among the accessions. Apparent infection rate answers the question 'does disease develop more rapidly in plot of A than in plot of B' [8].

$$r = \frac{(\ln \frac{x}{1-x}) - (\ln \frac{x_0}{1-x_0})}{t}$$

Where, r = infection rate, x<sub>0</sub> = initial disease severity, x = final disease severity and t is the duration of the epidemic, ln = natural logarithm.

### 2.5. Area Under Disease Progress Curve (AUDPC)

To ensure disease evaluation in the field was consistent, a disease progress curve was made. By constructing a curve, symptom development and disease severity could be compared. The area under disease progress curve (AUDPC) was used to quantify disease progression from the beginning of the epidemic and the time until the rust and blight reached peak. AUDPC shows the level of disease that induces stress during the season and can be used as a predictor of yield. An area under the disease progress curve (AUDPC) was calculated for each plot using PSI values. The derived disease parameter, area under the disease progress curve (AUDPC), was calculated for each plot using the formula of [8]:

$$AUDPC_{i=1}^{n-1} = \sum \{ (Y_i + Y_{i+1}) / 2 \} \times (t_{i+1} - t_i)$$

Where, Y<sub>i</sub> = disease severity on the i<sup>th</sup> date,  
t<sub>i</sub> = time on which Y<sub>i</sub> was recorded and  
n = total number of observation.

### 2.6. Grain Yield and Thousand Seed Weight

At maturity, the yields of the 92 maize accessions and 2 farmer's varieties checks were harvested manually from each plot. The yield from the plots was converted into tone per hectare (t/ha<sup>1</sup>). And one thousand randomly taken seeds from each plot were weighed separately and thousand seed weight was measured in gram.

## 2.7. Data Analysis

Data on all disease parameters (disease incidence, disease severity, PSI, AUDPC and disease progression rate ( $r$ ), yield and thousand seed weight were subjected to analysis of variance (ANOVA) using Statistical Analysis System version 9.1 software (SAS Institute, 2002). Duncan's multiple range test (DMRT) was used for comparison among accessions means ( $P < 0.05$ ), where there is a significant difference. Regression analysis was used to examine the relationship between severity of foliage disease (independent variables) and change in yield and thousand grain weights (dependent variables).

## 3. Results and Discussion

### 3.1. Disease Incidence

Result of disease incidence revealed that no significant differences ( $P < 0.05$ ) was observed among accessions in final per cent disease incidence (Table A1).

### 3.2. Disease Severity

There were significant differences ( $p < 0.05$ ) among maize accessions for final percent disease severity. The least percent disease severity were recorded for AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN-24297, AN-913, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-162383 accessions with mean values of 31.01%. Conversely, the highest per cent disease severity was recorded for AN-239620, AN-9195, AN-9988, AN-9991, AN-15459, AN-15460, AN-16021, AN-18121, AN-18122 and check-1 with mean values of 63.94%. Moreover, based on the mean values of percent severity, the ninety two maize accessions and 2 checks could be categorized into three resistance groups, i.e. resistant (R), moderately resistant (MR) and moderately susceptible (MS). Among them, fifteen accessions, AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN-24297, AN-913, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-162383 with mean values (31.01%), were found resistant, while eight accessions, AN-16570, AN-15324, AN-15466, AN-15467, AN-15462, AN-15327, AN-15455 and AN-15328, (37.13 to 44%) were found moderately resistant (Table A1). Seventy accessions and check-2 were found moderately susceptible with mean values of (46.8 to 63.91%). (Table A1).

Similarly, genotypes were placed in reaction groups using CIMMYT scale, where 0 were placed in immune group, 0-10% in highly resistant group, 11-34% in resistant group, 35-44% in moderately resistant group, 45-69% in moderately susceptible category and genotypes with disease severity of more than 70% were placed in susceptible group [6].

### 3.3. Area Under Disease Progressive Curve (AUDPC)

The common rust symptoms appeared to start in all plots at about the same time with uneven distribution of the

pathogen. But gradually the disease severity varied within and among plots. The results of areas under disease progress curves were showed significantly different among the accessions ( $P < 0.05$ ).

The highest AUDPC were recorded for accessions, AN-239620, AN-9195, AN-9988, AN-9991, AN-15459, AN-15460, AN-16021, AN-18121, AN-18122 and check-1 with mean values (1694.5%-days). Conversely, the lowest AUDPC values with mean values (720.4%\_days %-days) was observed from accessions, AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN-24297, AN-9183, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-16233 with the value (Table A1)

On the other hand, the mean value of AUDPC provides adequate evaluation of the reaction of the accessions against common maize rust disease. The higher area under disease progress curves were observed on moderately susceptible accessions than resistant and moderately resistant groups.

Similarly AUDPC is directly related with the yield loss [9]. Therefore, selection of genotype having lower AUDPC is acceptable for practical purposes. Disease progress curve models also provide basic information for planning effective disease management practices for genotype with different types and levels of resistance [10].

### 3.4. Disease Progressive Rate ( $r$ )

Comparisons of the disease development rate among accessions using the logistic model showed that disease progressive rates significantly differed between accessions ( $P < 0.05$ ). The higher disease progressive rates were recorded from AN-239620, AN-9195, AN-9988, AN-9991, AN-15459, AN-15460, AN-16021, AN-18121, AN-18122 and check-1 with mean value (0.81). Likewise, the lowest disease progressive rate were recorded from accessions, AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN-24297, AN-9183, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-16233, with mean value (0.33).

### 3.5. Yield and Thousand Seed Weight

Grain yield and thousand seed weight varied significantly among accession ( $p < 0.05$ ). The highest grain yields of 15 maize accessions ranged from 4.81 to 5.59 t/ha and thousand seed weights of (380 to 442 g) were obtained from AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-18121, AN-24297, AN-9183, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-16233 respectively, in 2016 main cropping season. Conversely, the lowest grain yields along with thousand seed weight (3.04 to 3.69 t/ha) and (240 to 297g) were measured on accessions, AN-239620, AN-9195, AN-9988, AN-9991, AN-15459, AN-15460, AN-16021, AN-18121 and AN-18122 respectively (Table A1). Disease severity and AUDPC showed negative correlations with yield and thousand seed weight. Likewise, yield and thousand seed weight had positive correlations.

## 4. Conclusion

Rust disease is among devastating foliar fungal diseases of maize in Ethiopia. Evaluation of maize accessions against common rust was studied at Arsi Negele using 92 maize accessions and 2 farmers' varieties checks. There was significant difference among accessions against common rust disease in percent disease severity, AUDPC, infection rate, yield and thousand seed weight at Arsi Negele.

In conclusion, the maize accessions varied highly in common rust severity; screening of accessions seemed to be one of the important techniques for finding the sources of resistant. Hence, among the tested maize accessions, AN-16559, AN-9987, AN-16571, AN-18104, AN-18106, AN-

18121, AN-24297, AN-9183, AN-15325, AN-15326, AN-15461, AN-16276, AN-16278, AN-241584 and AN-16233, were found resistant against common rust disease.

Therefore, the present study provides crucial information in searching source of resistant varietal development and to confirm the disease reaction further investigation could be recommended.

## Acknowledgements

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## Appendix

**Table A1.** Final disease incidence percent, final severity percent, AUDPC percent in days, infection rate units per day, resistance category, thousand seed weight and yield per hectare in tone.

Accession name	Final disease incidence (%)	Final severity (%)	AUDPC (%-days)	Infection rate (units/day)	Resistance category	Thousand kernel weight (g)	Yield (t/ha)
AN-239620	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	264 <sup>edcf</sup>	3.34 <sup>edcf</sup>
AN-9195	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	292 <sup>ebdcef</sup>	3.69 <sup>ebdcef</sup>
AN-9988	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	260 <sup>edf</sup>	3.29 <sup>edf</sup>
AN-9991	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	252 <sup>ef</sup>	3.19 <sup>ef</sup>
AN-15459	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	297 <sup>ebdacf</sup>	3.76 <sup>ebdac</sup>
AN-15460	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	296 <sup>ebdacf</sup>	3.75 <sup>ebdac</sup>
AN-16021	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	244 <sup>f</sup>	3.09 <sup>f</sup>
AN-18121	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	260 <sup>edf</sup>	3.29 <sup>edf</sup>
AN-18122	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	308 <sup>ebdacf</sup>	3.90 <sup>ebdac</sup>
Check-1	100	63.91 <sup>a</sup>	1694.5 <sup>a</sup>	0.81 <sup>a</sup>	MS	240 <sup>f</sup>	3.04 <sup>f</sup>
AN -16262	100	62.98 <sup>a</sup>	1658.8 <sup>a</sup>	0.80 <sup>a</sup>	MS	276 <sup>edcf</sup>	3.49 <sup>edcf</sup>
AN-9989	100	62.98 <sup>a</sup>	1658.8 <sup>a</sup>	0.80 <sup>a</sup>	MS	276 <sup>ebdcef</sup>	3.49 <sup>edcf</sup>
AN-9992	100	62.98 <sup>aa</sup>	1658.8 <sup>a</sup>	0.80 <sup>a</sup>	MS	260 <sup>edf</sup>	3.29 <sup>edf</sup>
AN-15456	100	62.98 <sup>a</sup>	1658.8 <sup>a</sup>	0.80 <sup>a</sup>	MS	276 <sup>ebdcef</sup>	3.49 <sup>edcf</sup>
AN-15458	100	62.98 <sup>a</sup>	1658.8 <sup>a</sup>	0.80 <sup>a</sup>	MS	272 <sup>ebdcef</sup>	3.44 <sup>edcf</sup>
Check-2	100	61.8 <sup>ba</sup>	1629.3 <sup>ba</sup>	0.79 <sup>ba</sup>	MS	269 <sup>f</sup>	3.32 <sup>edcf</sup>
AN-18112	100	61.52 <sup>ba</sup>	1625.1 <sup>ba</sup>	0.79 <sup>ba</sup>	MS	244 <sup>f</sup>	3.09 <sup>f</sup>
AN-9990	100	60.70 <sup>ba</sup>	1597.6 <sup>ba</sup>	0.72 <sup>bac</sup>	MS	260 <sup>f</sup>	3.29 <sup>edcf</sup>
AN-16269	100	60.70 <sup>ba</sup>	1597.6 <sup>ba</sup>	0.72 <sup>bac</sup>	MS	336 <sup>ebdacf</sup>	4.25 <sup>ebdac</sup>
AN-16563	100	59.38 <sup>ba</sup>	1567.4 <sup>ba</sup>	0.71 <sup>bac</sup>	MS	260 <sup>edf</sup>	3.29 <sup>edcf</sup>
AN-16023	100	59.38 <sup>ba</sup>	1567.4 <sup>ba</sup>	0.71 <sup>bac</sup>	MS	332 <sup>ebdacf</sup>	4.20 <sup>ebdac</sup>
AN-16236	100	58.12 <sup>ba</sup>	1534.9 <sup>ba</sup>	0.64 <sup>bac</sup>	MS	344 <sup>ebdacf</sup>	4.35 <sup>ebdac</sup>
AN-18098	100	57.79 <sup>ba</sup>	1509.7 <sup>ba</sup>	0.61 <sup>bac</sup>	MS	324 <sup>ebdacf</sup>	4.10 <sup>ebdac</sup>
AN-9182	100	57.79 <sup>ba</sup>	1509.7 <sup>ba</sup>	0.61 <sup>bac</sup>	MS	320 <sup>ebdacf</sup>	4.05 <sup>ebdac</sup>
AN-16020	100	57.74 <sup>ba</sup>	1508.1 <sup>ba</sup>	0.61 <sup>bac</sup>	MS	324 <sup>ebdacf</sup>	4.10 <sup>ebdac</sup>
AN-18108	100	57.0 <sup>ba</sup>	1503.1 <sup>ba</sup>	0.61 <sup>bac</sup>	MS	372 <sup>bac</sup>	4.71 <sup>bac</sup>
AN-9994	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	380 <sup>bac</sup>	4.81 <sup>ba</sup>
AN-9191	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	328 <sup>ebdacf</sup>	4.15 <sup>ebdac</sup>
AN-16012	100	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	348 <sup>ebdacf</sup>	4.40 <sup>ebdac</sup>
AN-16567	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	280 <sup>edcf</sup>	3.54 <sup>edcf</sup>
AN-16582	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	328 <sup>ebdacf</sup>	4.15 <sup>ebdac</sup>
AN-18096	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	324 <sup>ebdacf</sup>	4.10 <sup>ebdac</sup>
AN-237684	100	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	312 <sup>ebdacf</sup>	3.95 <sup>ebdac</sup>
AN-9188	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	348 <sup>ebdacf</sup>	4.40 <sup>ebdac</sup>
AN-9984	80	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	332 <sup>ebdacf</sup>	4.20 <sup>ebdac</sup>
AN-9995	100	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	376 <sup>bac</sup>	4.76 <sup>bac</sup>
AN-16561	100	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	316 <sup>ebdacf</sup>	4.00 <sup>ebdacf</sup>
AN-237657	100	55.05 <sup>bac</sup>	1451.3 <sup>bac</sup>	0.59 <sup>bac</sup>	MS	376 <sup>bac</sup>	4.76 <sup>bac</sup>
AN-18114	80	54.52 <sup>bac</sup>	1424.0 <sup>bac</sup>	0.58 <sup>bac</sup>	MS	360 <sup>bac</sup>	4.55 <sup>ebdac</sup>
AN-16261	80	54.52 <sup>bac</sup>	1424.0 <sup>bac</sup>	0.58 <sup>bac</sup>	MS	316 <sup>ebdacf</sup>	4.00 <sup>ebdacf</sup>

Accession name	Final disease incidence (%)	Final severity (%)	AUDPC (%-days)	Infection rate (units/day)	Resistance category	Thousand kernel weight (g)	Yield (t/ha)
AN-9997	80	54.52 <sup>bac</sup>	1424.0 <sup>bac</sup>	0.58 <sup>bac</sup>	MS	344 <sup>ebdaf</sup>	4.35 <sup>ebdac</sup>
AN-16025	80	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	316 <sup>ebdaf</sup>	4.00 <sup>ebdaf</sup>
AN-18103	100	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	312 <sup>ebdaf</sup>	3.95 <sup>ebdac</sup>
AN-237597	80	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	316 <sup>ebdaf</sup>	4.00 <sup>ebdaf</sup>
AN-9192	80	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	336 <sup>ebdaf</sup>	4.25 <sup>ebdac</sup>
AN-9193	80	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	276 <sup>edcf</sup>	3.49 <sup>edcf</sup>
AN-9194	100	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	352 <sup>ebdaf</sup>	4.45 <sup>ebdac</sup>
AN-9998	80	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	368 <sup>bdac</sup>	4.66 <sup>bdac</sup>
AN-16279	100	53.99 <sup>bac</sup>	1379.1 <sup>bac</sup>	0.56 <sup>bac</sup>	MS	372 <sup>bac</sup>	4.71 <sup>bac</sup>
AN-9993	100	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	332 <sup>ebdaf</sup>	4.20 <sup>ebdac</sup>
AN-16226	80	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	368 <sup>bdac</sup>	4.66 <sup>bdac</sup>
AN-18100	100	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	328 <sup>ebdaf</sup>	4.15 <sup>ebdac</sup>
AN-228786	80	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	348 <sup>ebdaf</sup>	4.40 <sup>ebdac</sup>
AN-9181	100	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	328 <sup>ebdaf</sup>	4.15 <sup>ebdac</sup>
AN-15247	80	52.13 <sup>bac</sup>	1353.3 <sup>bac</sup>	0.54 <sup>bac</sup>	MS	320 <sup>ebdaf</sup>	4.0 <sup>ebdac</sup>
AN-9187	100	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	330 <sup>ebdaf</sup>	4.18 <sup>ebdac</sup>
AN-16234	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	360 <sup>bdac</sup>	4.55 <sup>ebdac</sup>
AN-98098	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	352 <sup>ebdaf</sup>	4.45 <sup>ebdac</sup>
AN-9985	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	328 <sup>ebdaf</sup>	4.15 <sup>ebdac</sup>
AN-239668	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	324 <sup>ebdaf</sup>	4.10 <sup>ebdac</sup>
AN-15457	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	288 <sup>edcf</sup>	3.64 <sup>edcf</sup>
AN-15463	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	344 <sup>ebdaf</sup>	4.35 <sup>ebdac</sup>
AN-9996	80	51.65 <sup>bac</sup>	1330.3 <sup>bac</sup>	0.53 <sup>bac</sup>	MS	376 <sup>bac</sup>	4.76 <sup>bac</sup>
AN-239645	80	50.63 <sup>bac</sup>	1303.8 <sup>bac</sup>	0.51 <sup>bac</sup>	MS	356 <sup>ebdaf</sup>	4.50 <sup>ebdaf</sup>
AN-18113	80	50.09 <sup>bac</sup>	1301.2 <sup>bac</sup>	0.51 <sup>bac</sup>	MS	388 <sup>bac</sup>	4.91 <sup>ba</sup>
AN-10000	80	49.12 <sup>bac</sup>	1268.8 <sup>bac</sup>	0.51 <sup>bac</sup>	MS	320 <sup>ebdaf</sup>	4.05 <sup>ba</sup>
AN-9986	80	49.12 <sup>bac</sup>	1268.8 <sup>bac</sup>	0.51 <sup>bac</sup>	MS	328 <sup>ebdaf</sup>	4.15 <sup>ebdac</sup>
AN-9999	80	48.81 <sup>bac</sup>	1241.7 <sup>bac</sup>	0.50 <sup>bac</sup>	MS	380 <sup>bac</sup>	4.81 <sup>bac</sup>
AN-16562	80	48.81 <sup>bac</sup>	1241.7 <sup>bac</sup>	0.50 <sup>bac</sup>	MS	316 <sup>ebdaf</sup>	4.00 <sup>ebdaf</sup>
AN-9190	80	47.8 <sup>bac</sup>	1199.4 <sup>bac</sup>	0.50 <sup>bac</sup>	MS	340 <sup>ebdaf</sup>	4.30 <sup>ebdac</sup>
AN-241616	80	46.8 <sup>bac</sup>	1183.0 <sup>bac</sup>	0.49 <sup>bac</sup>	MS	348 <sup>ebdaf</sup>	4.40 <sup>ebdac</sup>
AN-16570	80	44.0 <sup>bac</sup>	1116.8 <sup>bac</sup>	0.49 <sup>bac</sup>	MR	386 <sup>bac</sup>	4.88 <sup>ba</sup>
AN-15324	80	42.8 <sup>bac</sup>	1061.1 <sup>bac</sup>	0.47 <sup>bc</sup>	MR	336 <sup>ebdaf</sup>	4.25 <sup>ebdac</sup>
AN-15466	80	42.8 <sup>bac</sup>	1061.1 <sup>bac</sup>	0.47 <sup>bc</sup>	MR	386 <sup>bac</sup>	4.88 <sup>ba</sup>
AN-15467	80	41.99 <sup>bac</sup>	1032.3 <sup>bac</sup>	0.46 <sup>bc</sup>	MR	376 <sup>bac</sup>	4.76 <sup>bac</sup>
AN-15462	80	39.61 <sup>bac</sup>	972.3 <sup>bac</sup>	0.44 <sup>bc</sup>	MR	364 <sup>bdac</sup>	4.61 <sup>bdac</sup>
AN-15327	80	38.27 <sup>bac</sup>	928.0 <sup>bac</sup>	0.43 <sup>bc</sup>	MR	364 <sup>bdac</sup>	4.61 <sup>bdac</sup>
AN-15455	80	38.27 <sup>bac</sup>	928.0 <sup>bac</sup>	0.43 <sup>bc</sup>	MR	348 <sup>ebdaf</sup>	4.40 <sup>ebdac</sup>
AN-15328	80	37.13 <sup>bac</sup>	930.2 <sup>bac</sup>	0.43 <sup>bc</sup>	MR	340 <sup>ebdaf</sup>	4.30 <sup>ebdac</sup>
AN-16559	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	380 <sup>bac</sup>	4.81 <sup>bac</sup>
AN-9987	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	380 <sup>bac</sup>	4.81 <sup>bac</sup>
AN-16571	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	396 <sup>ba</sup>	5.01 <sup>a</sup>
AN-18104	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	400 <sup>a</sup>	5.06 <sup>a</sup>
AN-18106	80	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	396 <sup>ba</sup>	5.01 <sup>a</sup>
AN-18121	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	400 <sup>a</sup>	5.06 <sup>a</sup>
AN-24297	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	408 <sup>a</sup>	5.16 <sup>a</sup>
AN-9183	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	408 <sup>a</sup>	5.16 <sup>a</sup>
AN-15325	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	420 <sup>a</sup>	5.31 <sup>a</sup>
AN-15326	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	442 <sup>a</sup>	5.59 <sup>a</sup>
AN-15461	60	31.02 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	404 <sup>a</sup>	5.11 <sup>a</sup>
AN-16276	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	408 <sup>a</sup>	5.16 <sup>a</sup>
AN-16278	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	396 <sup>ba</sup>	5.01 <sup>a</sup>
AN-241584	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	408 <sup>a</sup>	5.16 <sup>a</sup>
AN-16233	60	31.01 <sup>c</sup>	720.4 <sup>c</sup>	0.33 <sup>c</sup>	R	400	5.06 <sup>a</sup>
Mean		52.01	1343	0.60		324.67	4.11
CV		16.69	19.14	16.98		11.33	11.31
LSD (5%)	ns	1.26	1.26			1.26	1.26

ns: none significant, CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance,

AUDPC: Area Under Disease Progress Curve, MS: Moderately Susceptible; MR: Moderately Resistant and R: Resistant

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