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Research Article

Evaluation of the Sensitivity of Thirteen (13) Promising Cassava Varieties to Diseases (Viruses-Bacteria) and Pests (Mealybugs-Mites) in Central Côte d'Ivoire

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Abstract

Cassava (*Manihot esculenta*), a plant with starch-rich roots, plays a crucial role in global food security. For producers, it has become both a subsistence and cash crop. In Côte d'Ivoire, it ranks second among crops after yam. However, cassava is severely affected by bacteria, fungi, viruses, mites, and mealybugs, causing yield losses ranging from 20% to 90%. This study was conducted at the Food Crop Research Station (FCRS) of the National Center for Agronomic Research (NCAR) in Bouake in central Côte d'Ivoire. The plant material consisted of thirteen varieties of cassava of the *Manihot esculenta* species, from the national cassava collection. It aimed to assess the performance of thirteen promising cassava varieties, originating from the national cassava collection, against these diseases and pests under natural infestation conditions. The results revealed that the Yacé variety showed the highest sensitivity to viruses, with an incidence (I) of 96.25% and a severity index (IGS) of 2.8. In contrast, the Yavo variety was the least sensitive, with an incidence of 11.50% and a severity index of 1.3. All varieties studied demonstrated high sensitivity to bacterial blight and mite attacks, with high incidence rates observed in Bocou1 (71.25%) and Bocou3 (68.75%). However, mealybug infestation was relatively low, ranging from 8.75% (Yavo) to 33.75% (Bocou2). Except for mosaic disease, the severity indices for diseases and pests were similar across all varieties.

Keywords

Varieties, Diseases, Pests, Natural Infestation, Incidence, Severity Index

1. Introduction

Cassava (*Manihot esculenta Crantz*) is a starchy root crop native to South America. It ranks fourth in global agricultural production after maize, rice, and wheat, with worldwide production in 2022 estimated at 330 million tons, of which 68.76% came from Africa [7]. In West Africa, cassava production in 2022 was around 122 million tons, marking a 34% increase compared to 2021 [8]. Cassava is a hardy crop, highly resilient to current climate changes [12]. It can with-

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stand prolonged droughts and irregular rainfall [23], making it a key player in poverty alleviation in the face of climate uncertainty. Cassava has become a strategic crop for food security [13], given its adaptability across different agroecological zones. It thrives in low-fertility soils and has the advantage of flexible harvest periods [5].

In Côte d'Ivoire, cassava is primarily produced in the southern, western, and central regions [19], with a national output of 6.3 million tons [8]. A wide variety of cassava cultivars are grown in these areas, offering a range of local food products such as attiéké, couscous, bread, toh, flour, gari, etc., which are also marketed locally and regionally [20]. Cassava leaves are highly valued as a vegetable in many cassava-producing countries, serving as an important dietary supplement [15, 16].

Despite cassava's nutritional and economic benefits, the crop faces several biotic constraints that limit its production in Africa. The most harmful constraints are bacterial, fungal, and viral infections, along with pests, which can cause yield losses ranging from 20 % to 90 % [11, 24]. To mitigate these losses, numerous cassava varieties have been developed by agricultural research institutions like the International Institute of Tropical Agriculture (IITA) and the National Center for Agronomic Research (NCAR). These institutions aim to provide farmers with cassava varieties that are tolerant or resistant to diseases and pests.

In this context, the present study seeks to evaluate the performance of thirteen (13) promising cassava varieties against diseases (viruses and bacterial blight) and pests (mealybugs and mites).

2. Materials and Methods

2.1. Study Site

This study was conducted at the Food Crop Research Station (FCRS) of the National Center for Agronomic Research (NCAR) in Bouaké (Figure 1). It is located between 7°69' North latitude and 5°03' West longitude, at an altitude of 376 m [18]. The climate in the study area is tropical humid, with four seasons: a long dry season (November to February), a long rainy season (March to June), a short dry season (July to August), and a short rainy season (September to October). These periods have become less distinct in recent years [3]. The soils are ferrallitic and gravelly, moderately saturated, shallow, with a sandy-clay texture [6]. The average annual rainfall is 1200 mm, with an average temperature of 25.73 °C and annual sunshine duration of 2200 hours [25].

2.2. Plant Material

The plant material consists of thirteen (13) varieties belonging to the species Manihot esculenta. These varieties were sourced from NCAR's national cassava collection. Table 1 presents the agronomic and technological characteristics of the cassava varieties used.

Table 1. *Agronomic and technological characteristics of cassava varieties used as plant material [4].*

Variety Name	Usage Type	Cycle (Months)	Characteristics
Bocou1	Foutou, attiéké, placali, toh, gari	12-20	Good adaptation to different ecologies, Mild taste, Excellent canopy cover, High dry matter content (39%) and stable, Yield (25 t/ha)
Bocou2	Attiéké	11-18	Good adaptation to different ecologies, Bitter taste, Good canopy cover, High dry matter content (38%), Presence of provitamin A (6 ppm), Yield (25 t/ha)
Bocou3	Attiéké, placali, toh	12-20	Good adaptation to different ecologies Mild taste High starch content Yield (25 t/ha)
Bocou4	Foutou, attiéké, placali, toh, gari	12-18	Good adaptation to different ecologies, Mild taste,

Variety Name	Usage Type	Cycle (Months)	Characteristics
			Dry matter content: 39.43%, Starch content: 19.14%, Yield (28 t/ha)
Bocou5	Versatile	11-18	Good adaptation to different ecologies, Mild taste, High dry matter content (40%), High starch content, Yield (30 t/ha)
TMS4(2)1425	Versatile	11-20	Good adaptation to different ecologies, Mild taste, Excellent canopy cover, Tolerant to root rots, Yield (30 t/ha)
Yavo (=TME7)	Versatile	12-20	Good adaptation to different ecologies, Mild taste, High dry matter content (40%), Yield (25 t/ha)
Yac é	Atti ék é, placali, toh	11-20	Good adaptation to different ecologies, High dry matter content (40%), High starch content, Reference for atti ék é, Yield (20 t/ha)
01/1663	Atti ék é, placali, toh, gari; pain; g âteaux	11- 20	Good adaptation to different ecologies, High provitamin A potential, Colored flesh, Yield (34 t/ha)
01/1277	Atti ék é, placali, toh, gari; pain; g âteaux	11-20	Good adaptation to different ecologies, High provitamin A potential, Colored flesh, Yield (28 t/ha)
01/1380	Atti ék é, placali, toh, gari; pain; g âteaux	11-18	Good adaptation to different ecologies, High provitamin A potential, Colored flesh, Highyield (50 t/ha)
Toum-toum	Versatile	12-20	Good adaptation to different ecologies, Mild taste, Good culinary properties when boiled, White flesh, Low yield (17 t/ha)
Bonoua 2	Versatile	12-20	Good adaptation to different ecologies, Mild taste, High dry matter content (41%), good culinary properties when boiled, Yield (20 t/ha)

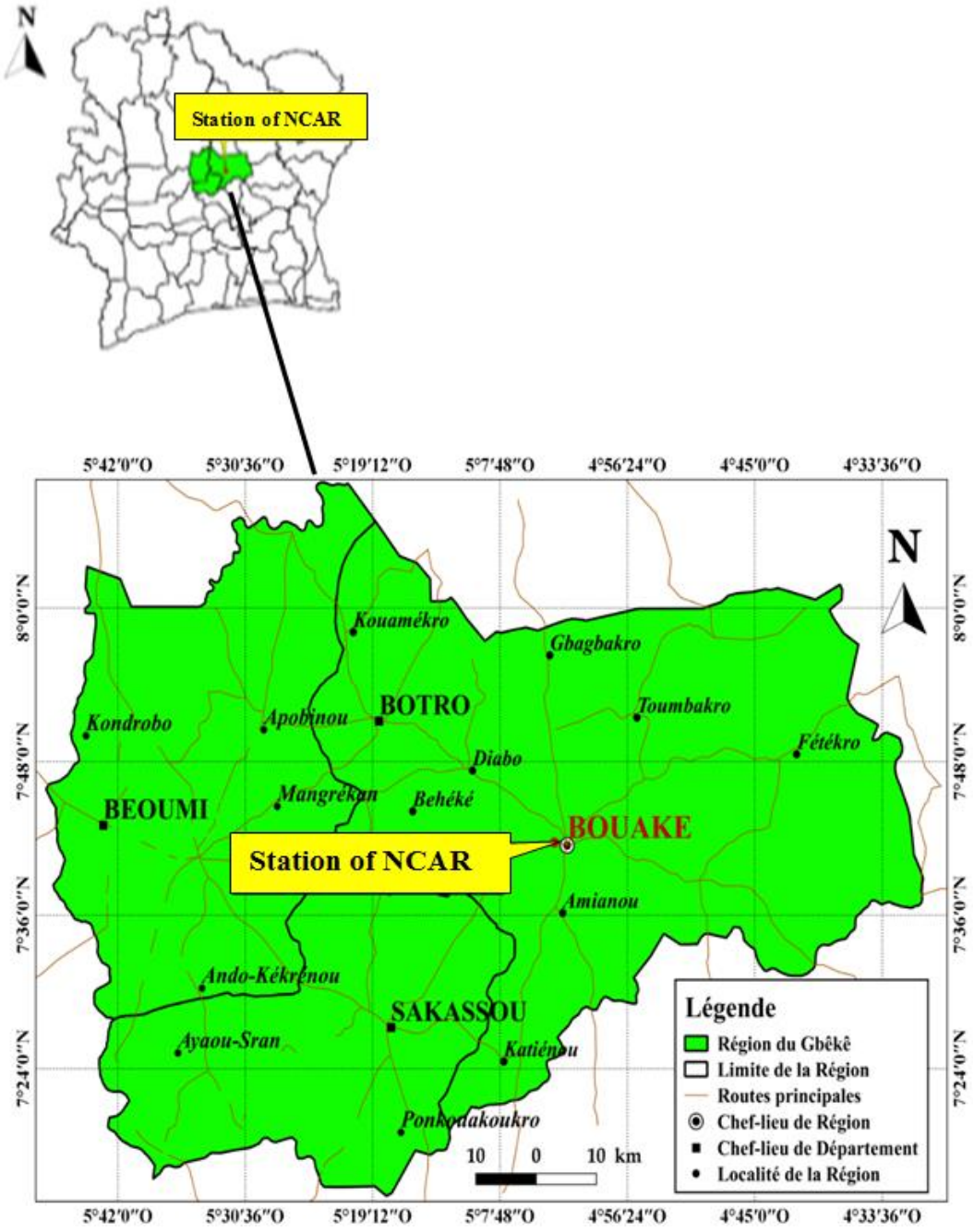

Figure 1. *Map of the Gbêkê region indicating the study area.*

2.3. Technical Equipment

The technical equipment used included machetes for cutting cassava cuttings, hoes for digging planting holes, and a planting rope for spacing. To measure the experimental plot dimensions, a measuring tape was used. For data collection, a notebook, pencil, eraser, digital camera, and portable tablet were employed.

2.4. Experimental Design

The trial was set up using a randomized complete block design with a single factor (variety). The plot was divided into two repetitions, each consisting of thirteen (13) rows separated by 2 meters. Each row corresponded to a variety and contained five (5) plants. The spacing between plants was 0.8 meters, and the rows were spaced 1 meter apart. The total number of plants per repetition and for the entire experimental plot was 65 and 130 plants, respectively.

2.5. Data Collection

Data collection began one month after planting and continued until harvest at twelve months, with eleven (11) months

of health monitoring. This study was conducted over three years, from 2018 to 2020.

2.6. Evaluation of the Incidence of Diseases and Pests

The incidence of diseases (I) refers to the proportion of infected plants in each population and helps assess the disease's spread. It was estimated using the following formula:

$$\text{I}(\%) = \frac{\text{Number of infected plants}}{\text{Total number of observed plants}} \times 100$$

2.7. Evaluation of the Severity Index for Diseases and Pests

The severity index (or Symptom Severity Index, SSI) assesses the degree of disease or pest damage. It was estimated using the following formula:

$$\text{SSI} = \frac{\sum \text{scores of infected plants}}{\text{Number of infected plants}}$$

SSI = Symptom Severity Index

The severity index for diseases and pests was evaluated using a standard scale from 1 to 5, as described by Hahn et al., 1980 [9, 2, 1]. Healthy plants were scored 1, while infected plants had scores ranging from 2 to 5, representing increasing severity.

2.7.1. Symptom Severity Index for Cassava Mosaic Disease (CMD)

The degrees of severity for cassava mosaic disease (CMD) were assigned based on the characteristic symptoms observed on each plant. CMD manifested as irregular yellow-green or white patches on the leaves, accompanied by leaf deformation and, in severe cases, plant stunting (Figure 2). The severity scale was as follows:

1. No visible symptoms on the leaves
2. Light chlorotic spots on the leaves
3. Chlorotic spots on nearly all leaves (2/3) without leaf deformation
4. Chlorotic spots on most leaves, accompanied by leaf deformation and reduced leaf area
5. Severe chlorosis, twisted and deformed leaves, almost reduced to veins, with stunted plant growth

Score 1 Score 2 Score 3 Score 4 Score 5

Figure 2. *Scores of symptoms characteristic for Cassava Mosaic Disease (CMD).*

2.7.2. Symptom Severity Index for Bacterial Blight

The severity of cassava bacterial blight was evaluated based on characteristic symptoms. These included angular leaf spots that appeared water-soaked or translucent, leaf burn, wilting due to toxin production, lesions on the stems with exudate, defoliation of shoots, and drying of plant tops [14]. These symptoms were more visible during the rainy season than the dry season. The first assessment was conducted around the middle of the rainy season. The severity scale was as follows:

1. No visible symptoms
2. Presence of angular leaf spots only
3. Limited leaf burn, wilting, defoliation, and presence of gum exudate on stems and petioles
4. Extensive leaf burn, wilting, defoliation, and stem necrosis
5. Complete defoliation and stem necrosis; stunting and necrosis of lateral branches

Score 1 Score 2 Score 3 Score 4 Score 5

Figure 3. *Scores of symptoms characteristic of bacterial blight.*

2.7.3. Symptom Severity Index for Pests

Pests are species harmful to plants that feed on cassava stems and leaves, causing damage. Their effects can be visible [10].

Mealybugs

Cassava mealybugs (*Phenacoccus manihoti*) attacked the growing tips of cassava plants, the undersides of the leaves, and stems, covering them with a thick waxy secretion [11]. Symptoms included shortened internodes, tufted leaves, and a bushy top appearance. Severe infestations led to stem deformation, leaf desiccation, and defoliation [11]. Damage was more visible and severe during the dry season. The assessment was conducted during the peak of the dry season. The severity scale was as follows:

1: No visible symptoms

2: Slight bushy top appearance and slight reduction in leaf area and internode length

3: Moderate bushy top symptoms with significant reduction in leaf area and internode length

4: Severe bushy top symptoms, visible shortening of internodes, and significant leaf area reduction

5: Candle-like appearance, severe shortening of internodes, defoliation, and complete drying of young shoots

Score 1 Score 2 Score 3 Score 4 Score 5

Figure 4. *Scores of symptoms characteristic of mealybug attacks.*

Mites

Cassava green mites (*Mononychellus tanajoa*) are tiny pests that live on the undersides of young cassava leaves. Symptoms included small chlorotic yellow spots on the upper leaf surface, smaller and narrower young leaves, and terminal leaf drop, giving the shoot tips a "candle" appearance [11]. Damage was more severe during the dry season. Severity was assessed during the transitional periods between rainy and dry seasons. The severity scale was as follows:

1. No visible symptoms
2. Moderate damage, no reduction in leaf area, sparse chlorotic spots on young leaves
3. Severe chlorosis with slight reduction in leaf area
4. Severe chlorosis and significant reduction in leaf area of young shoots
5. Extreme chlorosis, severe leaf area reduction, and generalized defoliation; "candle" appearance of young shoots.

2.8. Statistical Analysis

The collected data were analyzed using the STATISTICA 7.1 software. A one-way analysis of variance (ANOVA 1) was used to assess both the incidence rate and the average severity of cassava mosaic, bacterial blight, mite, and mealybug attacks across the thirteen (13) cassava varieties. When significant differences were found, Fisher's LSD test was conducted at the 5% significance level ($\alpha = 0.05$) to group the

means into homogeneous groups.

Score 1 Score 2 Score 3 Score 4 Score 5

Figure 5. *Scores of symptoms characteristic of mite attacks.*

3. Results

3.1. Evaluation of the Incidence of Diseases and Pests

3.1.1. Incidence of Cassava Mosaic Disease (CMD)

Figure 6 shows the average incidence of cassava mosaic disease across the thirteen (13) cassava varieties. The incidence of CMD varied significantly among the cassava varieties, ranging from 11.50% to 96.25%. The highest incidence was recorded in the Yacé variety (96.25%), followed by Bocou4, 01/1380, Toum-toum, Bocou2, Bonoua2, and Bocou1, with rates exceeding 50%. In contrast, the lowest incidence was observed in 01/1663, Yavo, 01/1277, Bocou3, TMS4(2)1425, and Bocou5, with rates of 11.50%, 16.25%, 28.75%, 34.82%, 40.70%, and 42.50%, respectively. These varieties demonstrated some tolerance to CMD.

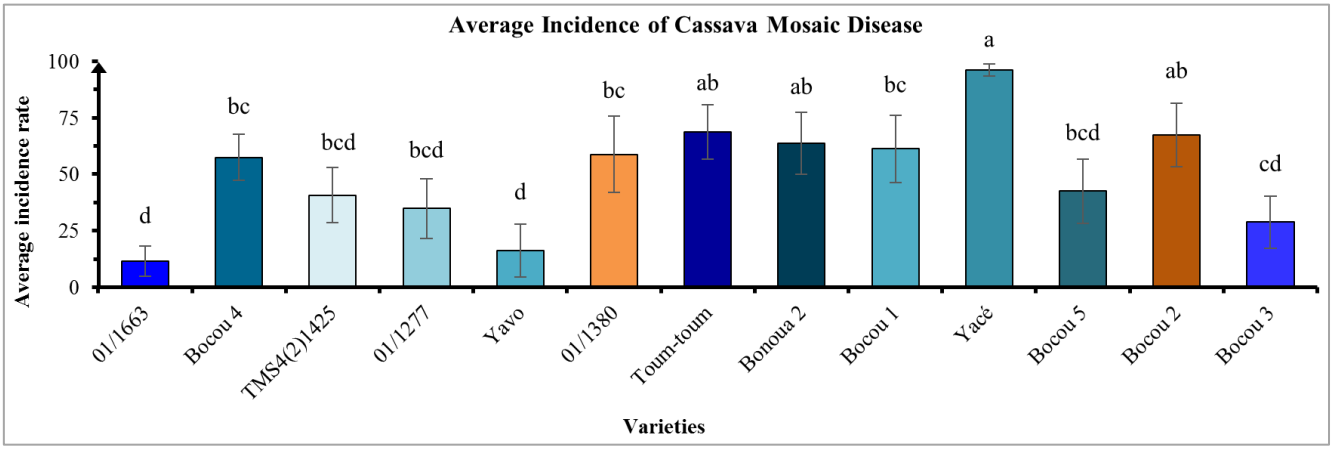

Figure 6. *Incidence of Cassava Mosaic Disease in the Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.1.2. Incidence of Bacterial Blight in Cassava

Figure 7 presents the average incidence of bacterial blight across the thirteen (13) cassava varieties. The incidence of bacterial blight showed no significant difference among the varieties. However, the average incidence rates were high, with over 50% of plants infected in each variety.

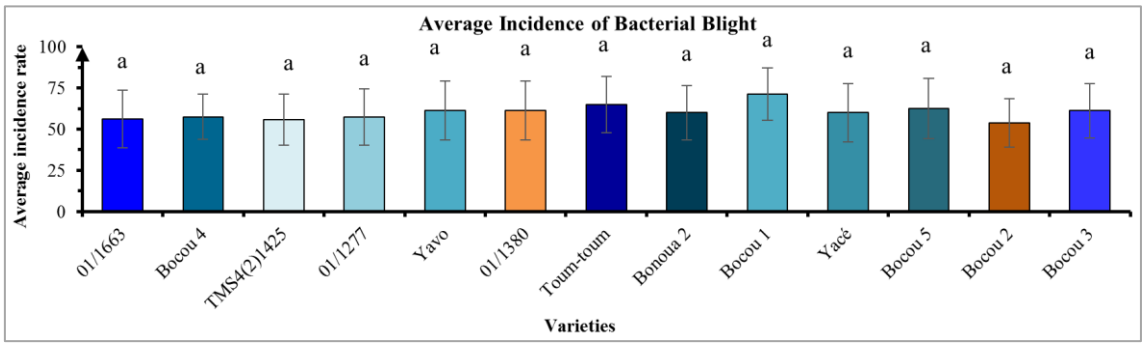

Figure 7. *Incidence of Bacterial Blight in Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.1.3. Incidence of Mite Attacks

The average incidence of mite attacks on the thirteen (13) cassava varieties is shown in figure 8. Similar to bacterial blight, there was no significant difference in mite incidence among the varieties. The incidence rates were high, with over 50% of plants attacked across all varieties.

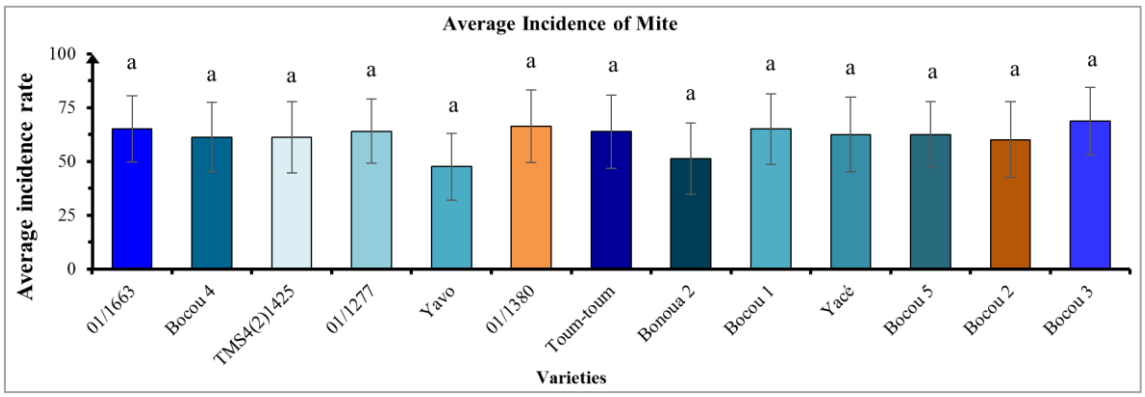

Figure 8. *Incidence of Mite Attacks on Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.1.4. Incidence of Mealybug Attacks

Figure 9 shows the average incidence of mealybug attacks across the thirteen (13) cassava varieties. The incidence of mealybugs was relatively low and did not show significant variation among the varieties, with rates below 35%.

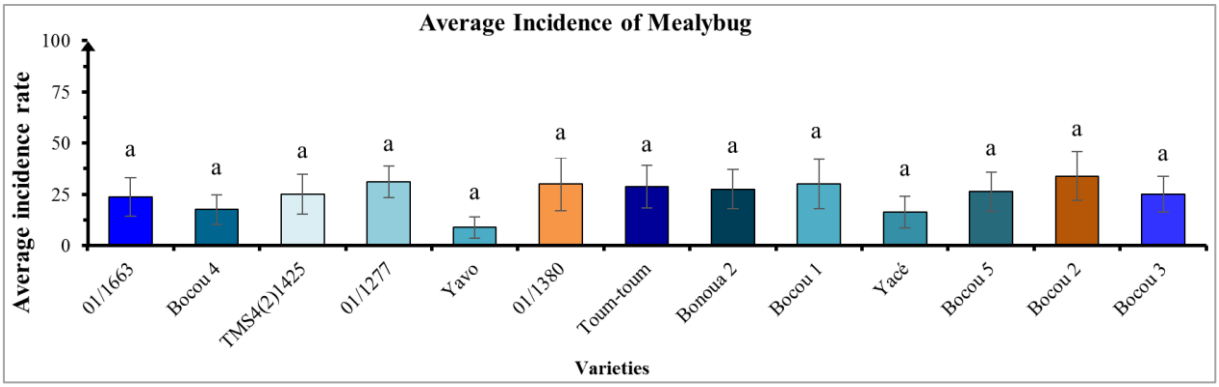

Figure 9. *Incidence of Mealybug Attacks on Cassava Varieties*.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.2. Evaluation of the Severity Index of Diseases and Pests

3.2.1. Severity Index of Cassava Mosaic Disease (CMD)

The average severity index for CMD varied significantly between the cassava varieties, ranging from a score of 1.30 to 2.81. It was highest in the Yac é variety, with a severity index of 2.81, followed by Bocou4 with 2.47. The lowest severity indices were observed in Yavo and 01/1663, with scores of 1.30 and 1.50, respectively, both statistically equal. The other varieties had CMD severity indices between 1.62 and 2.26 (Figure 10).

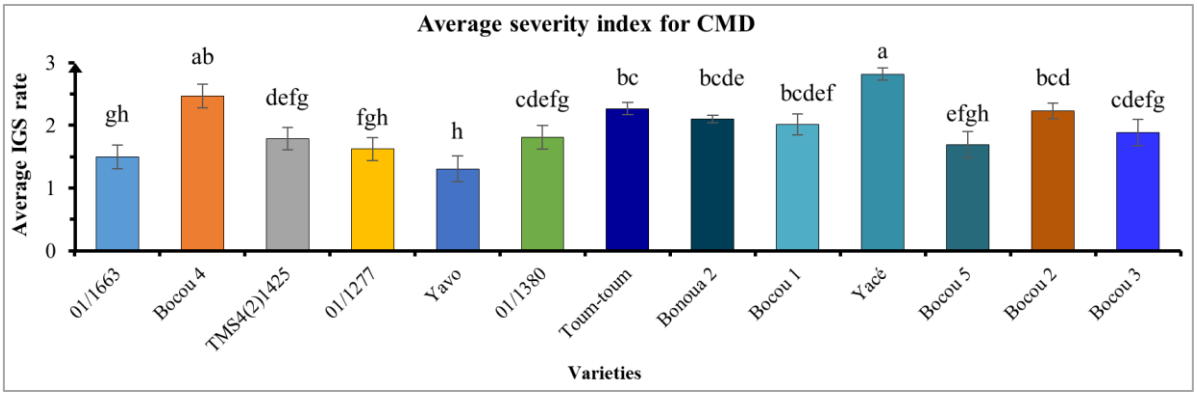

Figure 10. *Severity Index of Mosaic on the 13 Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.2.2. Severity Index of Bacterial Blight

The average severity index for bacterial blight, presented in figure 11, did not show any significant difference among the thirteen (13) cassava varieties.

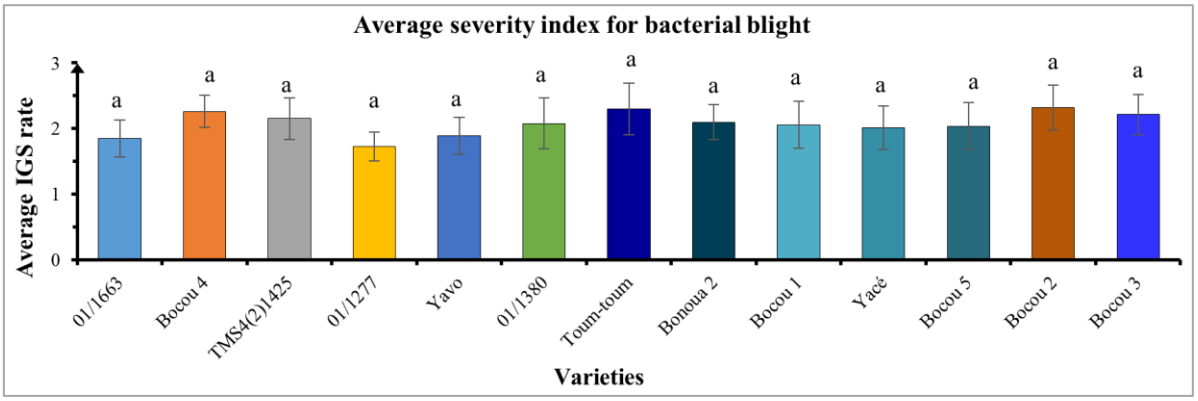

Figure 11. *Severity Index of bacterial blight on the 13 Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.2.3. Severity Index of Mealybug Attacks

The average severity index of mealybug attacks on the thirteen (13) cassava varieties did not show significant differences (Figure 12).

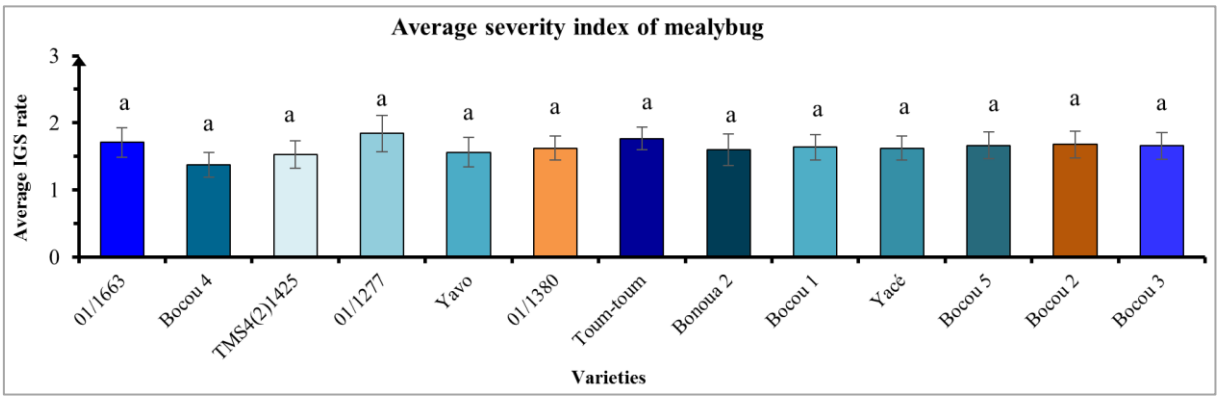

Figure 12. *Severity Index of Mealybug Attacks on the 13 Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

3.2.4. Severity Index of Mite Attacks

The average severity index of mite attacks on the thirteen (13) cassava varieties, presented in figure 13, did not show significant differences between the varieties.

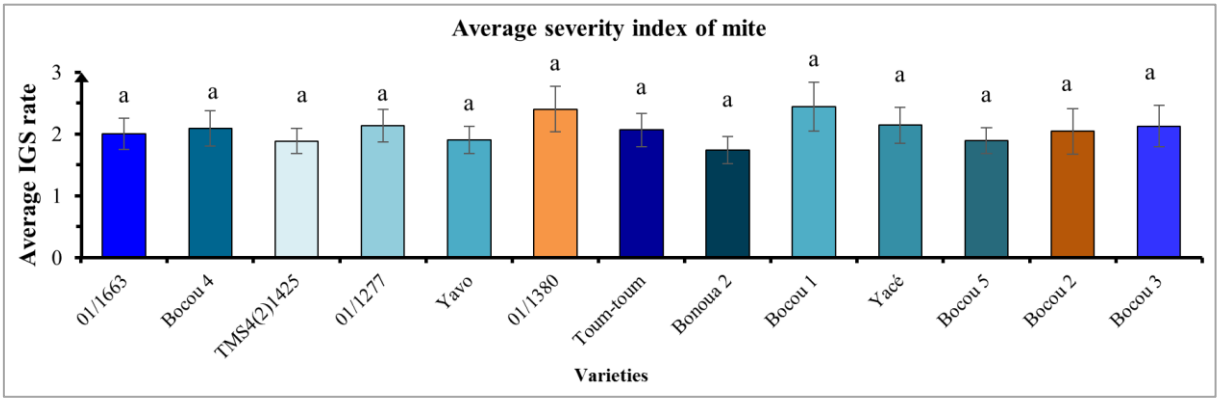

Figure 13. *Severity Index of Mite Attacks on the 13 Cassava Varieties.*

In the bar charts, bars marked with identical letters are not significantly different at the 5% significance level.

4. Discussion

This study highlighted which varieties exhibited apparent tolerance or resistance to cassava mosaic disease (CMD), bacterial blight, mites, and mealybugs. It was found that some varieties showed a degree of tolerance to these diseases and pests. Our results indicated that the presence of CMD symptoms was more pronounced in certain varieties, especially the Yacé variety, which exhibited a high incidence (96.25%) and severity (approximately 2.81), followed by Toum-toum (68.75%). This demonstrates their high sensitivity to CMD. These varieties are traditional and widely cultivated by farmers, particularly Yacé, known for its superior quality in producing attiéké and high dry matter content. It is also established that farmers' fields are predominantly planted with susceptible varieties. Traditional varieties are often more affected by CMD. Our findings are consistent with the characteristics of the Yacé variety described by other authors, who also noted its susceptibility to CMD [22]. Studies have shown that the incidence of CMD is high (around 60%) in most farmer fields (growing traditional varieties) in Côte d'Ivoire [21]. However, the low incidence observed in improved varieties such as 01/1663, Yavo, 01/1277, Bocou3, TMS4(2)1425, and Bocou5 may be explained by the fact that these varieties are designed to be resistant to diseases and pests, with a higher yield potential compared to traditional varieties.

Regarding the sensitivity of the thirteen varieties to bacterial blight, mites, and mealybugs, the results revealed that all varieties exhibited nearly the same level of sensitivity. However, the levels of sensitivity to bacterial blight and mites were high across all varieties, in contrast to the lower levels of

mealybug infestations. These findings suggest that these thirteen varieties are susceptible to bacterial blight and mites, with average incidence rates exceeding 50%, while they appear to tolerate mealybugs with incidence rates below 30%. This could be explained by the fact that neither the improved nor the traditional varieties possess resistance genes against bacterial blight and mites. Our results align with those of N'zué et al. (2004), who reported mixed levels of mite incidence in improved varieties and cultivars, indicating that breeding for mite-resistant varieties has been less effective. Similarly, Nankya (2018) suggested that the levels of sensitivity, tolerance, or resistance to diseases and pests differ according to the varieties being cultivated [17].

5. Conclusion

This study evaluated the performance of thirteen (13) promising cassava varieties against diseases (viruses and bacterial blight) and pests (mealybugs and mites). The findings showed that the Yacé variety was highly susceptible to CMD. All studied varieties also exhibited sensitivity to bacterial blight and mite attacks. However, they demonstrated a certain degree of tolerance to mealybug infestations. This study can serve as a resource for both cassava producers and researchers. It is recommended to perform a phytosanitary analysis and treat cuttings before planting to reduce disease and pest impact.

Abbreviations

ANOVA 1	One-way Analysis of Variance
CMD	Cassava Mosaic Disease
NCAR	National Center for Agronomic Research
IITA	International Institute of Tropical Agriculture (IITA)
FCRS	Food Crop Research Station
SSI	Symptom Severity Index

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Author Contributions

Brice Sidoine Essis: Conceptualization, Data curation, Formal Analysis, Methodology, Resources, Supervision, Validation, Writing – original draft

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Konan Brice Evrard Dibi: Conceptualization, Project administration, Formal Analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing

Boni N'Zué: Funding acquisition, Project administration, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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