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Tolerance and Susceptibility of Cowpea (*Vigna unguiculata* (L.) Walp.) Cultivars to Major Pathological and Entomological Pressures on Sub-Saharan Ferralsols

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Abstract: Cowpea is a grain legume, rich in proteins, carbohydrates, vitamins, and minerals. It enriches the soil through its biological nitrogen fixation capacity, thanks to rhizobia associated with its roots. Unfortunately, in sub-Saharan Africa, particularly in the Democratic Republic of Congo, within the territory of Tshilenge, the production of this crop faces biotic constraints. The most frequent diseases are anthracnose, cercosporiosis, and viral mosaic, as well as attacks by *Anoplocnemis curvipes* and *Ootheca mutabilis*. As a hypothesis for this study, we assume that certain cowpea cultivars would be tolerant while others would be susceptible to the major pathologies and pests in the Tshilenge region. The objective of this study is to identify the most tolerant and most susceptible cowpea cultivars to major pathological and pest pressures on sub-Saharan ferralsols in the Tshilenge region, Kasaï Oriental, through experimentation at different sowing dates. The results reveal that certain cultivars stand out for their remarkable tolerance, while others express increased susceptibility to major pathologies and pests. Cultivars C6 (index = 0), C1 (0.708), and C14 (0.744) are the most tolerant; their low index reflects high tolerance and stability against various pathogenic and entomological pressures. Conversely, cultivars C13 (2.95), C9 (2.97), and C8 (3.00) are highly susceptible; their high index reflects strong vulnerability to diseases, limiting their agronomic value under conditions of high pathogenic and entomological pressure.

Keywords: *Tolerance, Susceptibility, Cultivar, Cowpea, Pressure, Diseases, Pests, Ferralsol, Sub-Saharan.*

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I. INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is a grain legume and an important staple food for households in sub-Saharan Africa. The grain is rich in proteins (≥ 25%), carbohydrates, vitamins, and minerals (Omoigui et al., 2018). It is also a good soil fertilizer due to its biological nitrogen fixation capacity through rhizobia in its roots (Singh et al., 2007).

Despite its multiple benefits, cowpea production faces numerous constraints, including insect pests, diseases, parasitic weeds, low soil fertility, and intermittent drought (Abdoulaye et al., 2019; Singh & Tarawali, 1997). The combined effect of these constraints can lead to total crop loss if the crop is not properly managed (Singh et al., 2007). According to Ahmed et al. (2009), 80 to 100% of production is lost due to insect attacks. Biotic constraints are a determining factor in cowpea production. Among these, anthracnose, cercosporiosis, and viral mosaic, as well as insect pests such as aphids, thrips, and pod bugs, are the most frequently observed in the field (Mpiana et al., 2026; Omoigui et al., 2018; Dugje et al., 2009).

Understanding the tolerance and susceptibility of cowpea cultivars constitutes a preferred strategy for appropriate phytosanitary protection measures, selection, and dissemination of these cultivars adapted to local climatic conditions (Omoigui et al., 2018). Research on the tolerance

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and susceptibility of cowpea cultivars from Kasaï Oriental/DRC to diseases and pests remains absent, incomplete, and undocumented.

Considering the attacks of diseases and pests, it was hypothesized that some cowpea cultivars would be tolerant and others susceptible.

The objective of this study is to identify the most tolerant and most susceptible cowpea cultivars to pathologies: anthracnose, cercosporiosis, and viral mosaic, and to pests: *Anoplocnemis curvipes* and *Ootheca mutabilis* on sub-Saharan ferralsols in the Tshilenge region, Kasaï Oriental, through experimentation at different sowing dates.

The results of this study will provide a solid scientific basis for guiding varietal selection strategies and agronomic recommendations, favoring cultivars with a low tolerance index to improve production sustainability and reduce losses related to diseases and pest attacks.

II. METHODOLOGICAL APPROACH

➢ *Experimental Site*

The trial was conducted in the village of Bena Tshimanga, located in the territory of Tshilenge, Kasaï Oriental province, D.R. Congo (06°29'43.24 S, 023°34'11.30 E, 676 m altitude), which served as the experimental site (Figure 1).

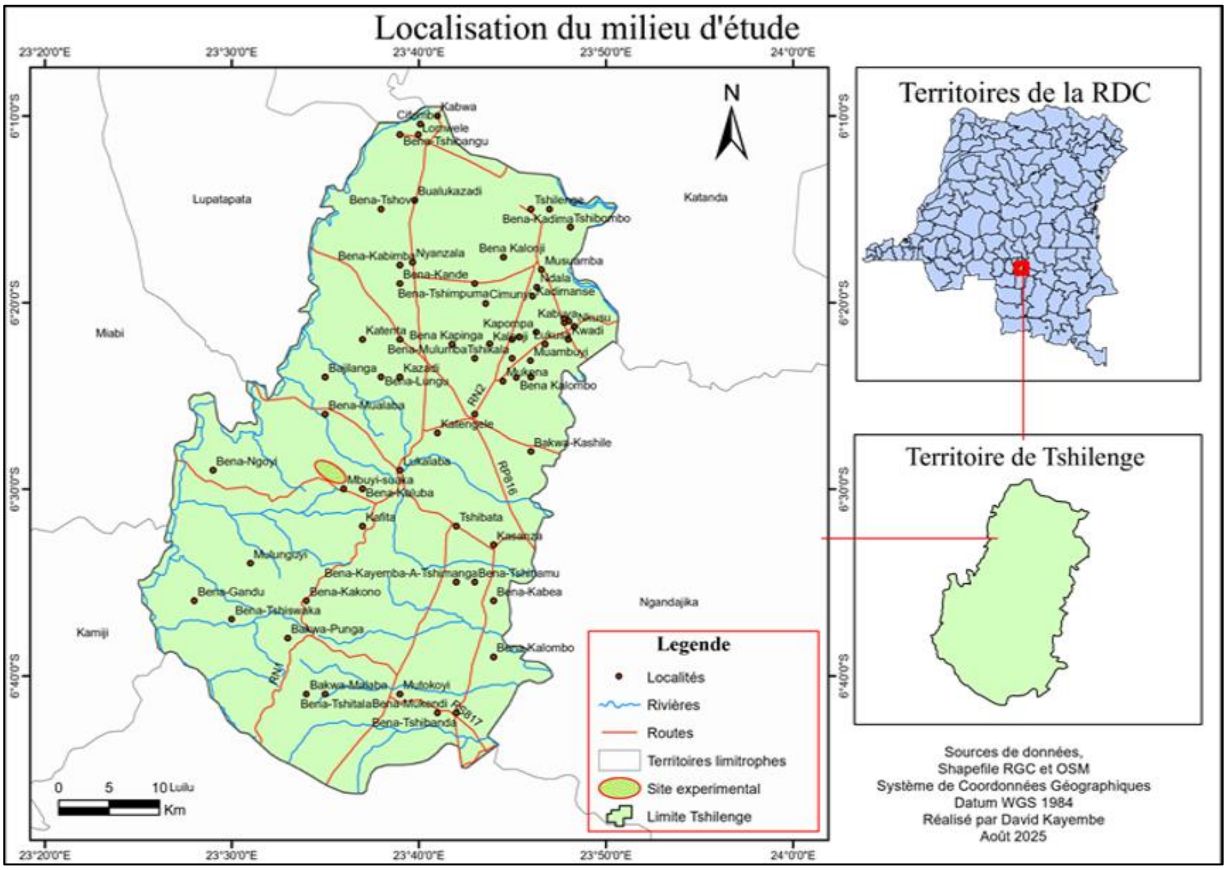

Fig 1 Location of Bena Tshimanga Village (Experimental Site) on the Administrative Map of the Tshilenge Territory, Kasaï Oriental, D.R. Congo.

➢ *Experimental Design*

The experimental design implemented was a split-plot design (Figure 2) with two factors: the main factor (1) consisted of fourteen cowpea cultivars commonly grown by farmers in Kasaï Oriental province and identified by their vernacular names: C1 = Kahelela, C2 = Kubikubi, C3 = Monji, C4 = Tshibute, C5 = Lufika, C6 = Nsebela, C7 = Zalanka, C8 = Kakumbe, C9 = Bena Cimungu, C10 = Mashala, C11 = Zonzoma, C12 = Kankunde, C13 = Bena Nsaka, and C14 = Kunde. The secondary factor (2) consisted of four sowing dates spaced in decades: D1 = first sowing date: 18/09/2024, D2 = second sowing date: 28/09/2024, D3 = third sowing date: 08/10/2024, D4 = fourth sowing date: 18/10/2024.

The experimental field measured 100.4 m in length and 28.5 m in width, for a total area of 2,861.4 m², divided into four replications. Replications were separated by a distance of 2 m. Main plots (main factor) were separated by 1.5 m, while the spacing between elementary sub-plots (secondary factor) was 0.30 m. Each elementary sub-plot had an area of 8 m², corresponding to dimensions of 1.60 m × 5 m. Each sub-plot had 4 rows per cultivar, sown at spacings of 0.60 m between rows and 0.30 m within the row, with 2 seeds per hole. Each row consisted of 10 holes, and each elementary plot had 80 plants.

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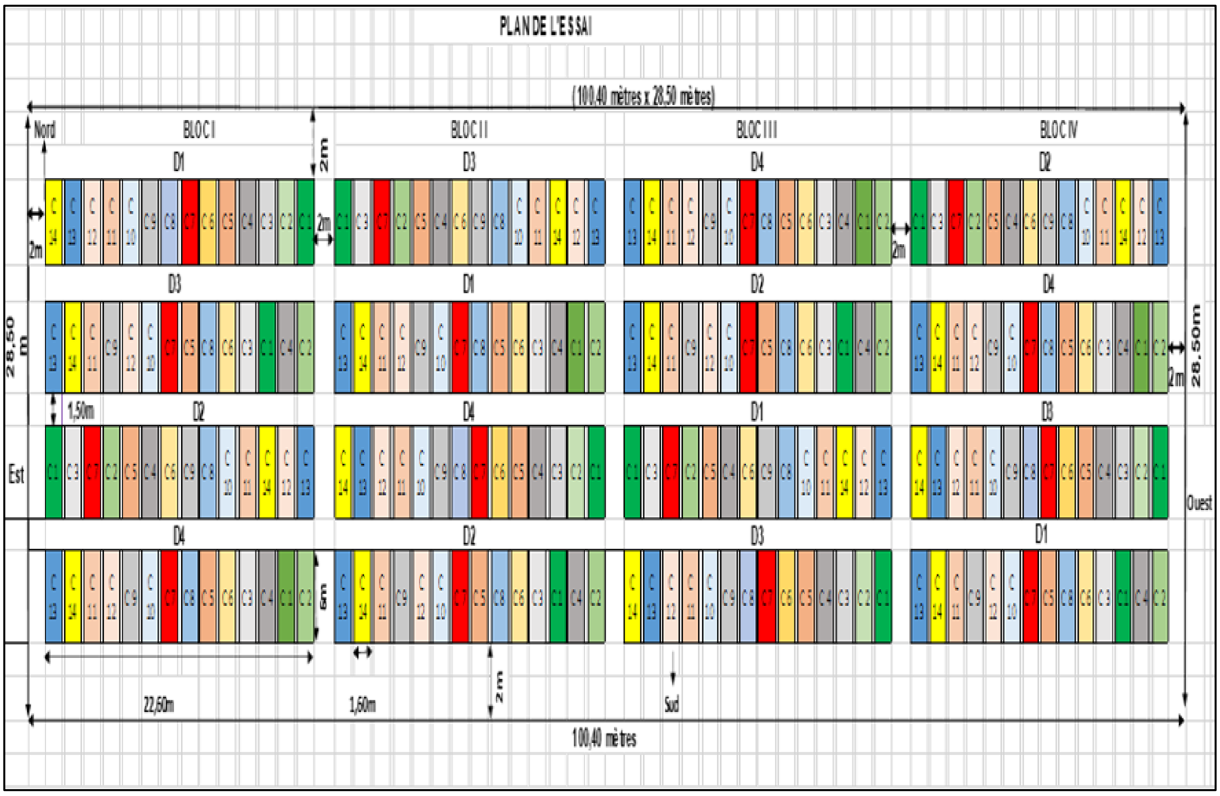

Fig 2 Diagram of the Split-Plot Experimental Design Including Cowpea Cultivars and Sowing Dates.

➢ *Data Collection and Analysis*

Data collection on diseases and pest attacks was observed 45 days after sowing, according to the corresponding sowing date and following the recommendations established by Gbaguidi (2015).

The data were subjected to analysis of variance (ANOVA). Tukey HSD and coefficients of variation (CV) were used to compare means and assess the stability of phytosanitary responses according to sowing dates. The overall cowpea tolerance index was also calculated to assess the susceptibility of each cowpea cultivar.

Correlation analysis between pathological and entomological variables was performed to identify differentiated associations between diseases and pests according to sowing dates. The calculated correlation coefficients allowed distinguishing positive, negative, or weak relationships between different attacks. Principal Component Analysis (PCA) was executed to assess the associative and differential pathological and entomological dynamics on cowpea cultivars.

III. RESULTS

The results of this study show that anthracnose, cercosporiosis, and viral mosaic were identified as major pathologies, while *Anoplocnemis curvipes* and *Ootheca mutabilis* constitute the major pests of cowpea cultivars.

➢ *Anthracnose Attack on Cowpea Cultivars*

Careful observation of Figure 2 reveals a significant interaction effect between sowing dates and cultivar potential on anthracnose incidence ($p < 0.05$). The means show that certain cultivars (C1, C2, C3, C6, C10, C11, and C14) exhibit very low and stable levels, reflecting marked resistance with little influence from the different sowing dates. These cultivars can be considered relatively tolerant, as their behavior remains constant regardless of the cropping calendar.

Conversely, several cultivars express increased and variable susceptibility according to dates. Cultivar C5 recorded stronger attacks at D1 and D3, reflecting particular vulnerability to early and intermediate sowings. C8 also showed high intensities at D1 and D3, confirming marked susceptibility during these periods. Cultivar C9 was distinguished by notable peaks at D3 and D4, indicating that late sowings accentuate its exposure to anthracnose. Similarly, C13 revealed high levels at sowings D3 and D4, reflecting a strong dependence of its susceptibility on the agricultural calendar.

This inter-cultivar and intra-date variability underlines that tolerance to anthracnose is both genotype-dependent and conditioned by sowing date. Resistant cultivars maintain remarkable stability, while susceptible cultivars express incidence peaks depending on the timing of crop establishment. These results confirm the importance of integrating cultivar × environment interactions into varietal selection strategies and agronomic planning to reduce epidemic risk and optimize production stability.

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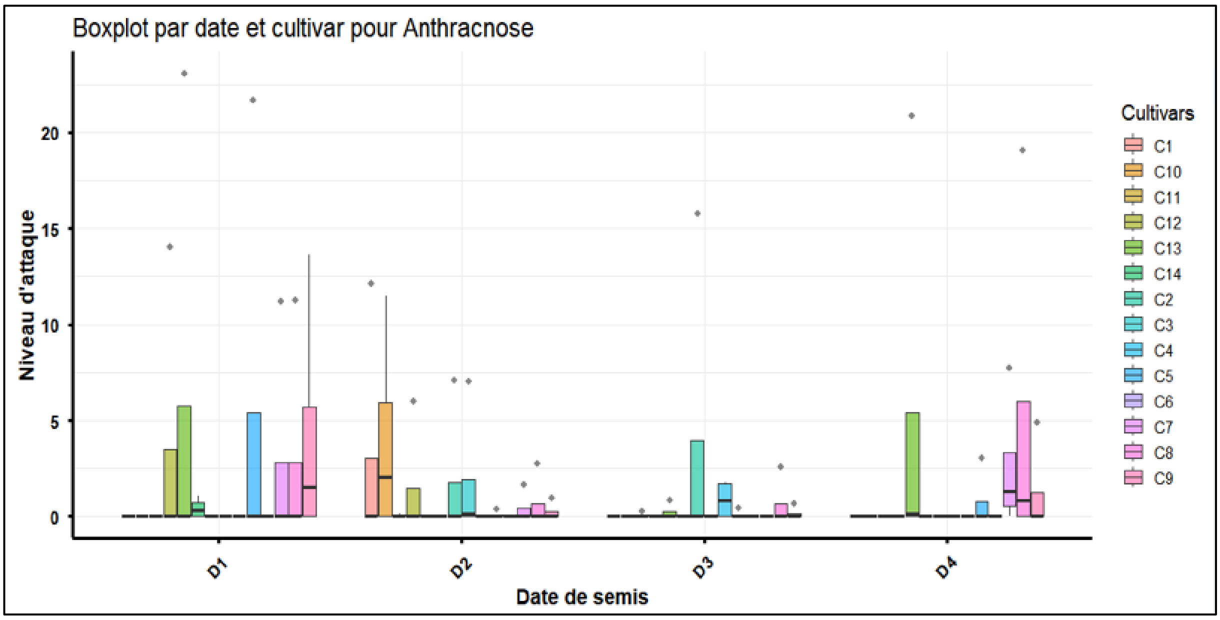

Fig 3 Anthracnose Attack on Cowpea Cultivars According to Sowing Dates

➢ *Cercosporiosis Attack on Cowpea Cultivars*

Examination of Figure 3 shows a significant interaction effect between sowing dates and cultivars on cercosporiosis incidence ($p < 0.05$). Cultivars C1, C2, C3, C6, C10, C11, and C14 exhibited low and relatively stable levels, reflecting marked resistance with little influence from the different sowing dates.

In contrast, several cultivars expressed increased susceptibility. Cultivar C5 recorded stronger attacks at sowings D1 and D3, reflecting particular vulnerability to early and intermediate sowings. C8 also showed high intensities at D1 and D3, confirming marked susceptibility during these periods. Cultivar C9 was distinguished by notable peaks at D3 and D4, indicating that late sowings accentuate its exposure to cercosporiosis. Similarly, C13 revealed high levels at sowings D3 and D4, reflecting a strong dependence of its susceptibility on the agricultural calendar.

This inter-cultivar and intra-date variability underlines that tolerance to cercosporiosis is both genotype-dependent and conditioned by sowing date. Resistant cultivars maintain remarkable stability, while susceptible cultivars express incidence peaks depending on the timing of crop establishment. These results confirm the importance of integrating genotype × environment interactions into varietal selection strategies and agronomic planning to reduce epidemic risk and optimize production stability.

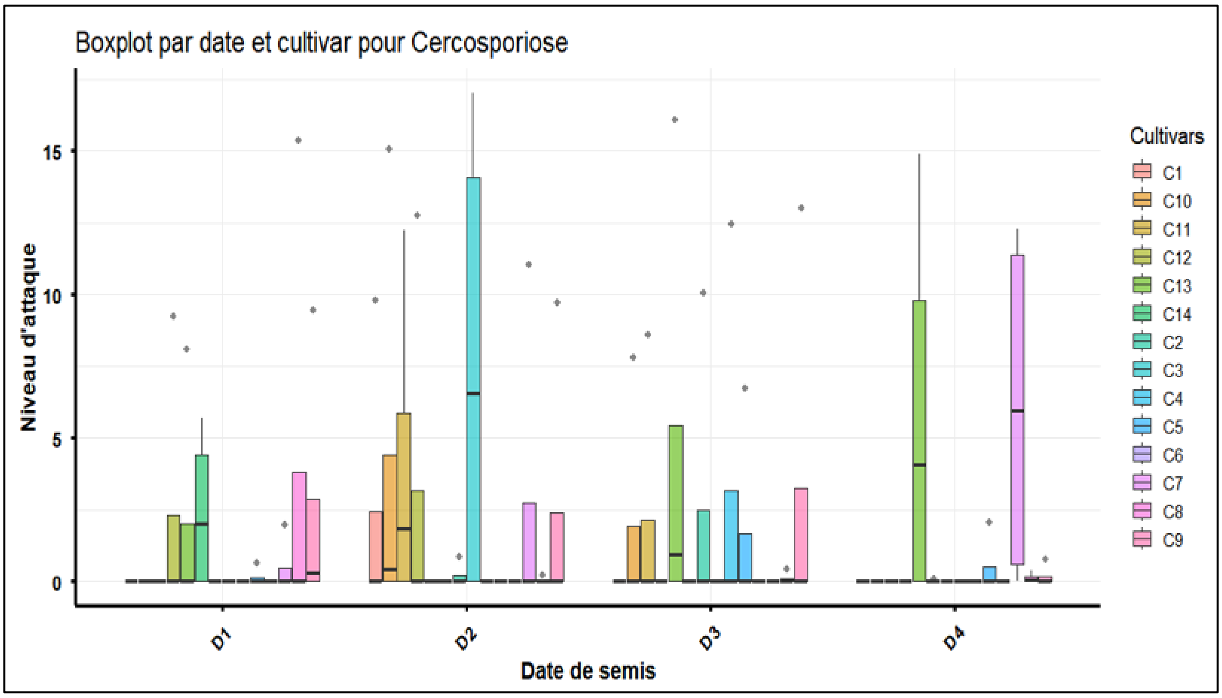

Fig 4 Cercosporiosis Attack on Cowpea Cultivars According to Sowing Dates

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➢ *Viral Mosaic Attack on Cowpea Cultivars*

Examination of Figure 4, dedicated to viral mosaic, reveals a significant interaction effect between sowing dates and cultivars on disease incidence ($p < 0.05$). Cultivars C1, C2, C3, C6, C10, C11, and C14 exhibited low and relatively stable levels, reflecting marked resistance with little influence from the different sowing dates. These genotypes appear tolerant, as their behavior remains constant regardless of the cropping calendar.

In contrast, several cultivars expressed increased susceptibility. Cultivar C4 recorded stronger attacks at sowings D2 and D3, reflecting particular vulnerability to intermediate sowings. C5 also showed high intensities at D1 and D3, confirming marked susceptibility to early and intermediate sowings. Cultivar C8 was distinguished by notable peaks at D2 and D3, indicating that these periods accentuate its exposure to viral mosaic. Similarly, C12 and C13 revealed high levels at sowings D3 and D4, reflecting a strong dependence of their susceptibility on late sowings. Finally, C9 presented a more marked intensity at D3, confirming particular vulnerability to this date.

This inter-cultivar and intra-date variability underlines that tolerance to viral mosaic is both genotype-dependent and conditioned by sowing date. Resistant cultivars maintain remarkable stability, while susceptible cultivars express incidence peaks depending on the timing of crop establishment. These results confirm the importance of integrating genotype × environment interactions into varietal selection strategies and agronomic planning to reduce epidemic risk and optimize production stability.

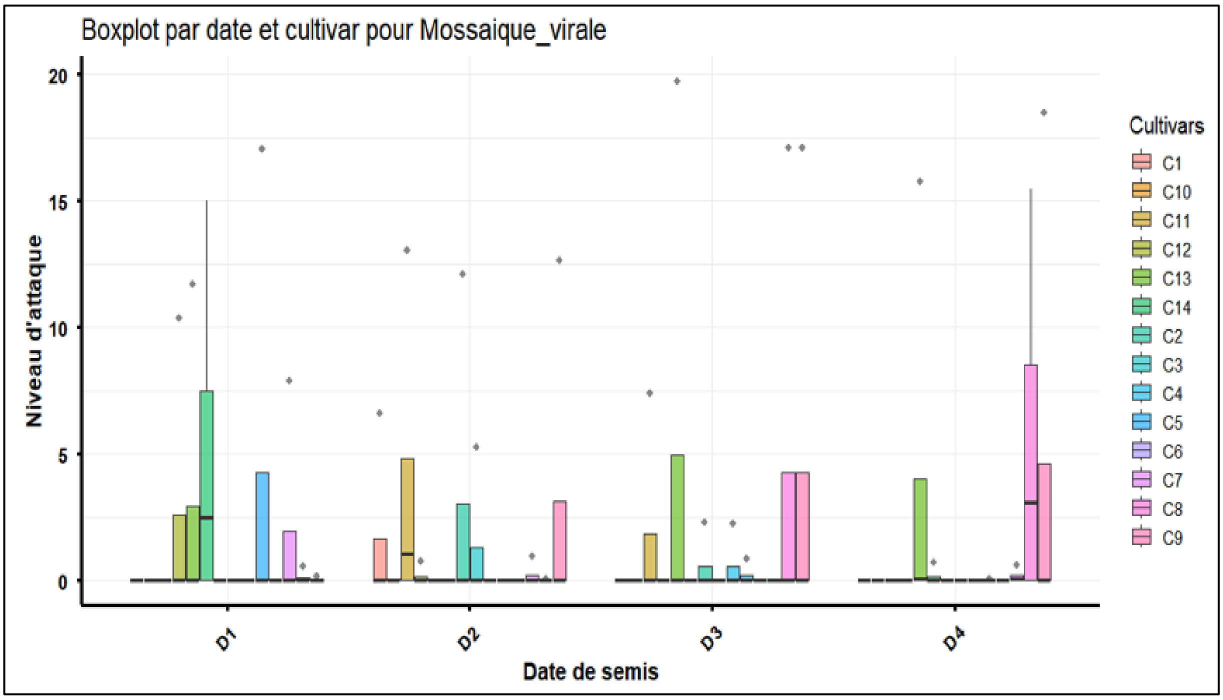

Fig 5 Viral Mosaic Attack on Cowpea Cultivars According to Sowing Dates

➢ *Anoplocnemis curvipes Attack on Cowpea Cultivars*

Examination of the results highlights a significant interaction between sowing dates and cultivars on the incidence of *Anoplocnemis curvipes* attacks ($p < 0.05$). The observed dynamics show that certain cultivars (C1, C2, C3, C6, C10, C11, and C14) are distinguished by low and relatively stable levels, reflecting marked resistance with little influence from the cropping calendar. These genotypes appear tolerant, as their behavior remains constant regardless of the sowing period.

Conversely, several cultivars expressed increased and variable susceptibility according to dates. Cultivar C4 recorded stronger attacks at sowings D2 and D3, reflecting particular vulnerability to intermediate sowings. C5 also showed high intensities at D1 and D3, confirming marked susceptibility to early and intermediate sowings. Cultivar C8 was distinguished by notable peaks at D2 and D3, indicating that these periods accentuate its exposure to the insect. Similarly, C12 and C13 revealed high levels at sowings D3 and D4, reflecting a strong dependence of their susceptibility on late sowings. Finally, C9 presented a more marked intensity at D3, confirming particular vulnerability to this date.

This inter-cultivar and intra-date variability underlines that tolerance to *Anoplocnemis curvipes* is both genotype-dependent and conditioned by sowing date. Resistant cultivars maintain remarkable stability, while susceptible cultivars express incidence peaks depending on the timing of crop establishment. These results confirm the importance of integrating genotype × environment interactions into varietal selection strategies and agronomic planning to reduce insect-related losses and optimize production stability.

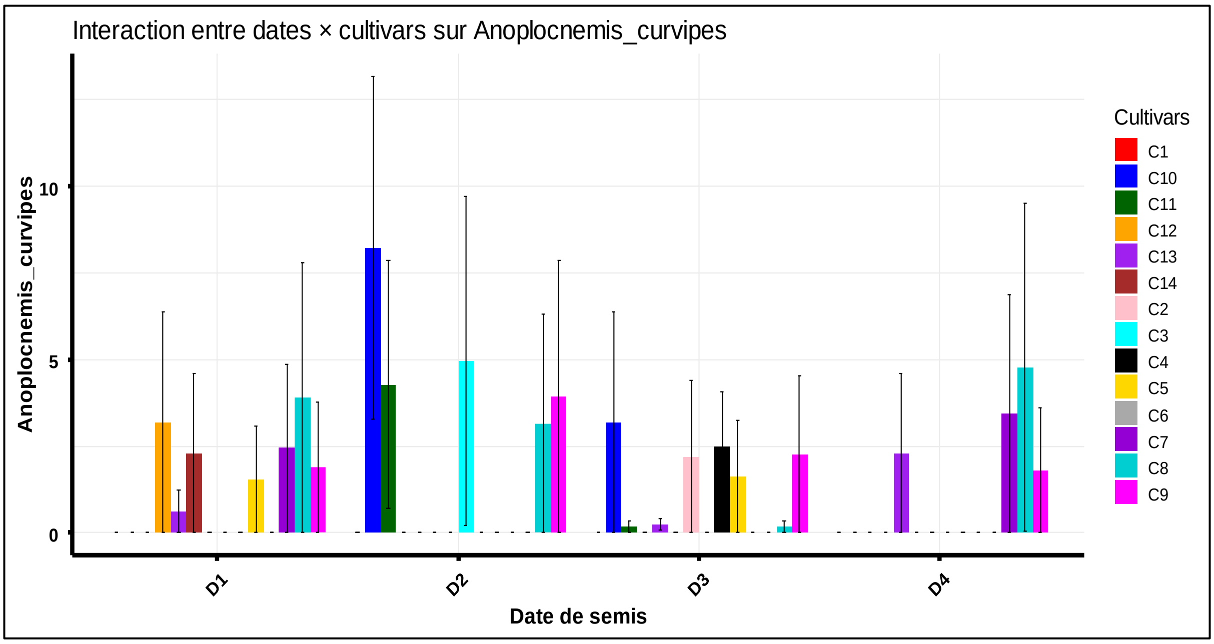

Fig 6 *Anoplocnemis curvipes* Attacks on Cowpea Cultivars According to Sowing Dates

➢ *Ootheca mutabilis Attack on Cowpea Cultivars*

Figure 5 illustrates the analysis of interactions between sowing dates and cultivars, highlighting significant variability in the incidence of *Ootheca mutabilis* attacks ($p < 0.05$). Certain cultivars (C1, C2, C3, C6, C10, C11, and C14) are distinguished by low and relatively stable levels, reflecting marked resistance with little influence from the cropping calendar. These genotypes appear tolerant, as their behavior remains constant regardless of the sowing period.

Conversely, several cultivars expressed increased and variable susceptibility according to dates. Cultivar C4 recorded stronger attacks at sowings D2 and D3, reflecting particular vulnerability to intermediate sowings. C5 also showed high intensities at D1 and D3, confirming marked susceptibility to early and intermediate sowings. Cultivar C8 was distinguished by notable peaks at D2 and D3, indicating that these periods accentuate its exposure to the insect. Similarly, C12 and C13 revealed high levels at sowings D3 and D4, reflecting a strong dependence of their susceptibility on late sowings. Finally, C9 presented a more marked intensity at D3, confirming particular vulnerability to this date.

This inter-cultivar and intra-date variability underlines that tolerance to *Ootheca mutabilis* is both genotype-dependent and conditioned by sowing date. Resistant cultivars maintain remarkable stability, while susceptible cultivars express incidence peaks depending on the timing of crop establishment. These results confirm the importance of integrating genotype × environment interactions into varietal selection strategies and agronomic planning to reduce insect-related losses and optimize production stability.

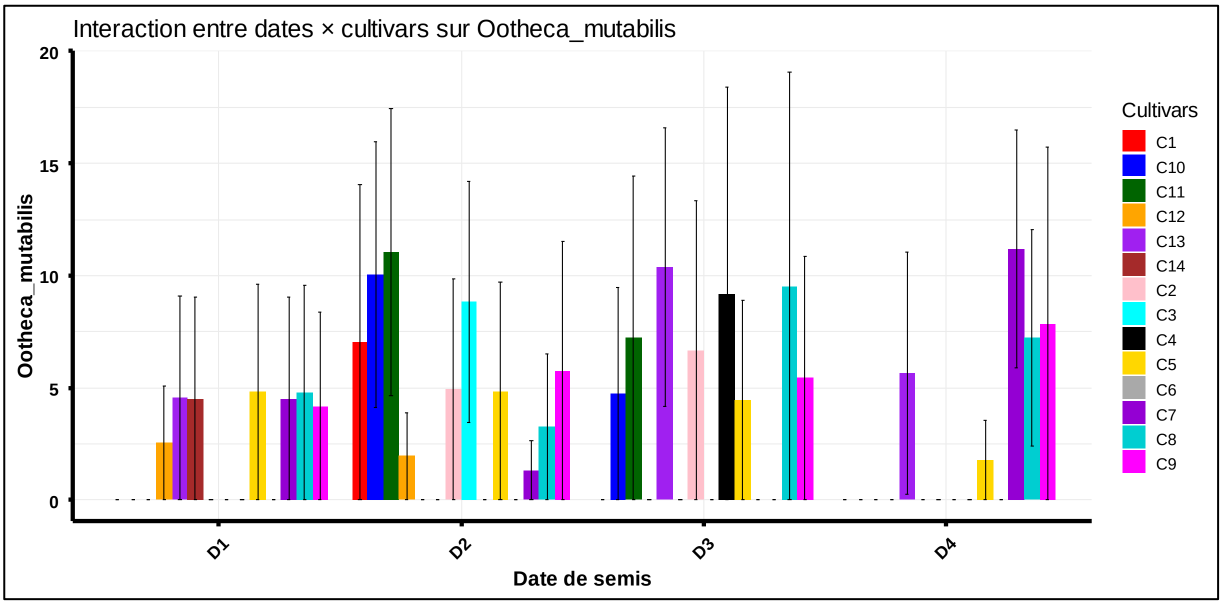

Fig 7 *Ootheca Mutabilis* Attacks on Cowpea Cultivars According to Sowing Dates

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> *Overall Tolerance Index of Local Accessions*

The calculation of the overall disease tolerance index in Table 1 highlights a clear hierarchy among cowpea cultivars.

Table 1 Classification of Cowpea Cultivars According to Overall Tolerance Index to Diseases and Pests

Local Accession	Overall Tolerance Index	Overall Tolerance Ranking
C6	0	1
C1	0.708	2
C14	0.744	3
C4	0.812	4
C12	1.05	5
C3	1.22	6
C2	1.29	7
C5	1.61	8
C11	1.73	9
C10	1.80	10
C7	2.02	11
C13	2.95	12
C9	2.97	13
C8	3.00	14

The results show that certain genotypes stand out for their remarkable resistance, while others express increased susceptibility.

- *Most Resistant Cultivars:*

C6 (index = 0), C1 (0.708), and C14 (0.744) occupy the top three positions in the ranking. Their low index reflects high tolerance and stability against various pathogenic and entomological pressures. These genotypes appear as preferred candidates for selection and dissemination.

- *Intermediate Cultivars:*

C4 (0.812), C12 (1.05), C3 (1.22), and C2 (1.29) exhibit moderate attack levels. They can be considered relatively tolerant, but their behavior remains more variable depending on diseases and sowing conditions.

- *Susceptible Cultivars:*

C5 (1.61), C11 (1.73), C10 (1.80), and C7 (2.02) show higher indices, reflecting increased susceptibility. Their use in production would require reinforced phytosanitary protection measures.

- *Highly Susceptible Cultivars:*

C13 (2.95), C9 (2.97), and C8 (3.00) occupy the last positions in the ranking. Their high index reflects strong vulnerability to diseases, limiting their agronomic value under conditions of high pathogenic pressure.

This ranking confirms that disease tolerance is genotype-dependent and that there is significant variability among cultivars. Genotypes C6, C1, and C14 stand out as the most tolerant, while C8, C9, and C13 appear as the most susceptible. These results provide a solid basis for guiding varietal selection strategies and agronomic recommendations, favoring cultivars with a low index to improve production sustainability and reduce disease-related losses.

> *Correlation Analysis between Pathological and Entomological Attacks on Local Cowpea Accessions*

Figure 8 presents the correlation analysis between pathological and entomological variables, revealing differentiated associations according to diseases and insects. The correlation coefficients indicated by colors allow distinguishing positive, negative, or weak relationships between the different attacks.

- *Strong Positive Correlations:*

Certain diseases tend to evolve together. For example, anthracnose and cercosporiosis show a positive association, suggesting that cultivars susceptible to one also tend to be susceptible to the other. This relationship likely reflects common vulnerability related to physiological factors or environmental conditions favoring both pathogens.

- *Moderate Correlations:*

Viral mosaic shows intermediate correlations with certain foliar diseases, indicating that its dynamics may be partially linked to the general susceptibility of the cultivar, but remains influenced by specific factors (vectors, transmission conditions).

- *Weak or Negative Correlations:*

Insect attacks (*Ootheca mutabilis* and *Anoplocnemis curvipes*) show weaker relationships with fungal diseases. This suggests that their incidence depends more on plant phenology and sowing conditions than on disease susceptibility. In some cases, a negative correlation appears, reflecting independence or even an inverse dynamic between entomological and pathogenic pressures. This correlogram highlights that cultivar tolerance is not uniform: some genotypes accumulate susceptibilities (positive correlations between diseases), while others present differentiated profiles (weak correlations with insects). These results confirm the importance of an integrated approach in varietal selection and phytosanitary management, considering both diseases and pests, as well as their potential interactions.

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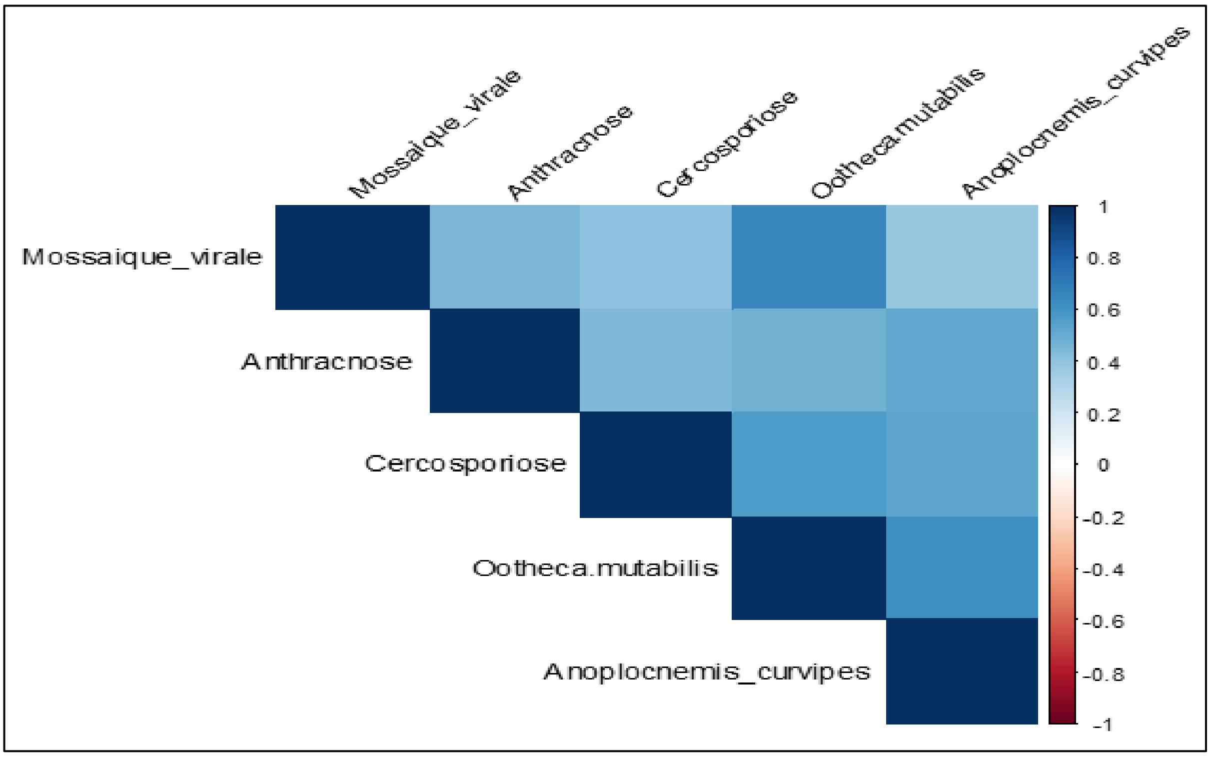

Fig 8 Correlation Analysis between Different Attacks on Local Cowpea Cultivars

➢ *Structuring of Tolerance and Susceptibility of Cowpea Cultivars Based on Pathological and Entomological Variables*

The PCA performed on the five variables (anthracnose, cercosporiosis, viral mosaic, *Ootheca mutabilis*, and *Anoplocnemis curvipes*) highlights two main axes explaining a significant portion of the variance: Dim1 (60.4%) and Dim2 (13.3%).

The contribution of fungal diseases, such as anthracnose and cercosporiosis, are strongly correlated with each other and project in the same direction on the Dim1 axis. This reflects a common dynamic: cultivars susceptible to anthracnose also tend to be susceptible to cercosporiosis. Regarding viral mosaic, the variable is in an intermediate position, partially correlated with foliar diseases but also expressing its own specificity. Its projection indicates that it contributes to cultivar differentiation, but to a lesser extent than anthracnose and cercosporiosis.

As for attacks by *Ootheca mutabilis* and *Anoplocnemis curvipes*, these two variables project in a distinct direction, reflecting a different dynamic from that of fungal diseases. Their contribution to Dim2 is more important, suggesting that the variability of insect attacks explains a complementary part of the differentiation between cultivars.

Thus, reading the correlations in this circle shows that: foliar diseases (anthracnose, cercosporiosis) form a homogeneous and strongly associated group, explaining the majority of the variance on Dim1. Viral mosaic occupies an intermediate position, reflecting shared but partially independent susceptibility. Insects (*Ootheca mutabilis* and *Anoplocnemis curvipes*) are clearly distinguished, explaining additional variability on Dim2 and confirming that entomological pressure follows a different logic from pathogenic pressure.

Thus, the PCA highlights two main axes of cultivar differentiation: (1) susceptibility to foliar diseases (Dim1), (2) entomological pressure (Dim2). These results confirm that the overall tolerance of cultivars must be evaluated in an integrated manner, considering both diseases and insects, as they contribute complementarily to the observed agronomic variability.

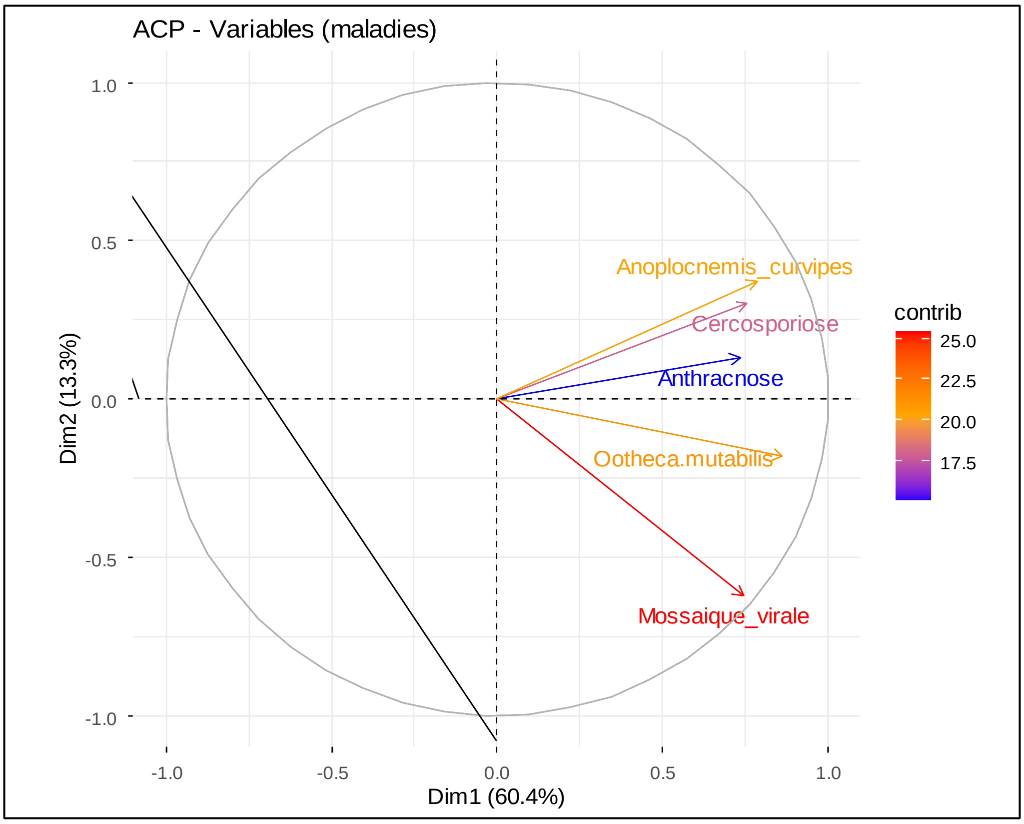

Fig 9 Contributions of Attack Effects between Diseases of Local Cowpea Cultivars

IV. DISCUSSIONS

Regarding the response of sowing dates on diseases and pests of the cowpea cultivars used in this study, the general trend observed in Figures 3, 4, 5, 6, and 7 highlights significantly important variability in the incidence of attacks by anthracnose, cercosporiosis, viral mosaic, *Anoplocnemis curvipes*, and *Ootheca mutabilis* between sowing dates and the infestation potential of cowpea cultivars ($p < 0.05$).

These results align with the conclusions of Gbaguidi (2015), who showed that cowpea cultivars exhibit significant vulnerability to diseases and pests, which could result from the expression of strong genotypic heterogeneity. Despite this genotypic heterogeneity, Sereme (1999) noted that production is nevertheless hindered by various constraints, including cryptogamic diseases, among which cercosporiosis is of particular concern.

According to Omoigui et al. (2018), cowpea cultivation faces numerous diseases caused by fungi, viruses, and bacteria, as well as plant parasites and insect pests that attack leaves, flowers, and pods. These attacks can lead to significant yield losses if no control measures are adopted.

Mpiana et al. (2026) observed that sowing cowpea as early as the first effective rains of the season generally allows the plant to escape the highest parasitic pressure. Furthermore, Omoigui et al. (2018) revealed that sowing cowpea too late exposes the crop to prolonged high humidity, which favors the development of cryptogamic diseases (rots, downy mildew, anthracnose) and insect attacks (such as *Maruca vitrata*) during critical phases of flowering and pod formation. These observations are also supported by Bila et al. (2025), according to whom the cowpea sowing period strongly influences the incidence of disease attacks, and consequently cowpea production.

Motis (2020) demonstrated that cowpea vulnerability to anthracnose depends on aggravating factors such as excess humidity and heavy rainfall, combined with late sowings, which increase the incidence of fungal diseases. These observations are reported by Akande et al. (2012), who examined cowpea seed yield and quality under the influence of sowing date.

Furthermore, early sowings (at the beginning or within the first weeks of the rainy season) are strongly recommended for cowpea. This allows the crop to avoid the end-of-cycle humidity peaks, which are the main factor favoring the appearance and development of cercosporiosis (Mpiana et al., 2026). Early sowing allows the cowpea crop to complete its vegetative and reproductive phases before the peak of very humid climatic conditions. Cercosporiosis attacks are then limited or arrive late, sparing the pods in formation (Akanza et al., 2020).

The results of this study are also reinforced by those of Chiang et al. (2017), demonstrating that cowpea is particularly susceptible to viral mosaic, which can cause losses of up to 100%. Kayode et al. (2020) add that aphids (*Aphis craccivora*), thrips, and pod borers (*Maruca vitrata*) are the main vectors responsible for the transmission of these diseases.

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V. CONCLUSION

At the conclusion of this study on the tolerance and susceptibility of cowpea cultivars to major pathological and entomological pressures on ferralsols in the Tshilenge region of sub-Saharan Africa, it should be noted that the results show that anthracnose, cercosporiosis, and viral mosaic are major pathologies, while *Ootheca mutabilis* and *Anoplocnemis curvipes* constitute major pests of these local cowpea cultivars in this region of Tshilenge.

Anthracnose and cercosporiosis show a positive association, suggesting that cultivars susceptible to one also tend to be susceptible to the other, while insect attacks by *Ootheca mutabilis* and *Anoplocnemis curvipes* show weaker relationships with fungal diseases. Cultivar tolerance is not uniform; some accumulate susceptibilities (positive correlations between diseases), while others present differentiated profiles (weak correlations with insects).

The results reveal that certain cultivars stand out for their remarkable tolerance, while others express increased susceptibility to major pathologies and pests. In summary, cultivars C6 (index = 0), C1 (0.708), and C14 (0.744) are the most tolerant; their low index reflects high tolerance and stability against various pathogenic and entomological pressures. These genotypes appear as preferred candidates for selection and dissemination. Conversely, cultivars C13 (2.95), C9 (2.97), and C8 (3.00) are highly susceptible; their high index reflects strong vulnerability to diseases, limiting their agronomic value under conditions of high pathogenic and entomological pressure. Their use in production would require reinforced phytosanitary protection measures.

These results confirm that the overall tolerance of cowpea cultivars must be evaluated in an integrated manner in varietal selection and phytosanitary management, considering both diseases and insects, as well as their potential interactions, as they contribute complementarily to the observed agronomic variability.

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