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SELECTION OF HIGH-YIELDING CASHEW TREE (*Anacardium occidentale* L.) GENOTYPES BASED ON THEIR SUSCEPTIBILITY TO ANTHRACNOSE AND METHODS OF CONTROL IN CÔTE D'IVOIRE

Soro NA[1,2]*, Soro S[3], Kouman AMN[1,2], Konan KA[1], Abo K[4] and D Koné[1,2]

Nahangnon Arsène Soro

*Corresponding author emails: na.arsenesoro@gmail.com / nsoro@rsif-paset.org
ORCID ID: https://orcid.org/0000-0003-4303-7391

[1]UPR Physiologie et Pathologie Végétale, Université Félix HOUPHOUËT-BOIGNY (UFHB), UFR Biosciences, 01 BP V34 Abidjan 01, Côte d'Ivoire

[2]WASCAL / Africa Centre of Excellence in Climate Change, Biodiversity and Sustainable Agriculture, Pôle Scientifique et d'Innovation de l'Université Félix HOUPHOUËT-BOIGNY, Bingerville, 22 BP 582 Abidjan 22, Côte d'Ivoire

[3]Laboratoire d'Amélioration de la Production Agricole, UFR Agroforesterie, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire

[4]Laboratoire de Phytopathologie et de Biologie Végétale, Département de Formation et de Recherche Agriculture et Ressources Animales, Institut National Polytechnique Félix Houphouët-Boigny (INP-HB), BP 1313 Yamoussoukro, Côte d'Ivoire

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ABSTRACT

A varietal selection of three high-yielding cashew tree genotypes (A24, A27, A30) was carried out in Côte d'Ivoire without taking into account disease resistance requirements, particularly anthracnose. Anthracnose, a fungal disease, is one of the main diseases and is widely distributed in the country's cashew orchards. It can cause cashew nut yield losses exceeding 50%. This study aimed to screen the genotypes A24, A27, and A30 for their susceptibility to natural anthracnose infection in the field and to identify the control methods used to control the crop's diseases. To do this, assessments were carried out over two consecutive years in nurseries, wood parks, and plantations. In each site, the assessments were carried out on ten grafted plants selected randomly for each genotype. The anthracnose symptoms observed were characterized. Then, this disease's infection level was determined through the incidence and severity index. During the assessments, the control methods used were identified by interviewing each nurseryman and farmer. Visual observation revealed the presence of anthracnose in various forms on the leaves and floral panicles of the three genotypes. This disease was noticed on the leaves of young grafted plants in the nursery. It was also found on old plants in the wood parks and in plantations. In general, genotype A24 was more affected by the disease than genotypes A27 and A30. In nursery, the average incidence ranged from 52.83% to 62.13%, while the severity index ranged from 8.75% to 11.72%. However, in wood parks and plantations, the disease was slightly higher, with minimums of 10% and 60% respectively for incidence and severity index. In addition, the study revealed that plot weeding, pruning cashew trees, and the use of synthetic chemical products are the control methods adopted against cashew tree diseases in Côte d'Ivoire. The synthetic chemicals most frequently used are mancozeb (28%), copper oxide (28%), chlorothalonil associated with carbendazim (24%), or maneb (17%). To the knowledge, this is the first study of susceptibility to anthracnose of high-yielding cashew genotypes disseminated in Côte d'Ivoire which explored the whole cashew production zone of the country.

Key words: genotypes, cashew, screening, susceptibility, anthracnose, nursery, wood park, plantation, control

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INTRODUCTION

Since 2015, Côte d'Ivoire is still the world's leading cashew nut producer. Cashew nuts, the main raw material for cashew cultivation, are Côte d'Ivoire's 2nd largest export after cocoa [1]. The national production of raw nuts, estimated at 700,000 tons in 2015, has risen to around one million tons in 2022 [1, 2]. This production represents around a quarter of the world's raw nut production. Most of the increase in national production is linked to the expansion of cultivated areas. Indeed, the orchard in Côte d'Ivoire is characterized by its low average yield, estimated at 547 kg of nuts/ha in 2018, compared with a yield of 1 or even 2 t/ha in some countries [3]. This low yield per hectare is due to several factors, including failure to follow the technical itinerary, which is characterized by high cashew plantation densities and poor field maintenance [3]. In addition, this low yield can be explained by the high parasite pressure, characterized by the presence of many diseases and insect pests observed on “non-selected” cashew genotypes [4–7]. These “non-selected” genotypes are the plant material most frequently found in the country's cashew orchards and are characterized by low productivity. To provide farmers with selected planting material, research undertaken through the Cashew Varietal Improvement Project has resulted in the retention of three genotypes for dissemination to farmers from among eight High Yielding Trees identified. Since 2014, these three high-yielding genotypes (A24, A27, A30) have been disseminated to farmers as grafted plants by nurserymen set up and accredited by the cashew nut sector in Côte d'Ivoire [3]. So, farmers were not involved in the selection, and they are using all three genotypes as first-generation planting material. In addition, during the genotype selection process, the basic criteria defined were yield (kg of nuts/tree/year), kernel rate and nut shape, clustered maturity, production earliness, and tree architecture [8]. The authors did not consider the requirement of resistance of these genotypes to identified pests and diseases. Consequently, these genotypes could be subject to diseases, particularly anthracnose which is the most important and widely distributed fungal disease in cashew orchards in Côte d’Ivoire [9, 10]. On “non-selected” genotypes in plantations, anthracnose occurs on leaves, flower panicles, nuts, and cashew apples, leading to cashew nut yield losses ranging from 54 to 73% [6, 11]. This disease has also been described on cashew trees in several countries around the world, particularly in Africa, such as Burkina Faso [12], Benin [13], Cameroon [14], and Ghana [15].

The present study focused on screening the three high-yielding cashew genotypes disseminated based on their susceptibility to anthracnose in the field throughout the cashew nut production zone in Côte d'Ivoire. The aim was to describe anthracnose symptoms, to determine and compare the level of infection of the

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disease on the three clones in nurseries, wood parks, and plantations, and to identify the control methods adopted against diseases on these cashew genotypes.

MATERIALS AND METHODS

Materials

The plant material used in this study was composed of clones from the three high-yielding cashew genotypes disseminated in Côte d'Ivoire (A24, A27, and A30). These clones are planted in the wood park where the buds are used to graft the plants in the nursery. Once the grafted plants are strong and have mature and dark-green leaves, they are distributed to farmers for planting.

Methods

Assessment of anthracnose on high-yielding cashew genotypes in nurseries

This study consisted of conducting sanitary surveys in 23 nurseries accredited by Conseil du Coton et de l'Anacarde (CCA), the organization in charge of regulating and monitoring the activities of the country's cotton and cashew sectors. The list of nurserimen was provided by this organisation. Figure 1 shows the site visited in this study.

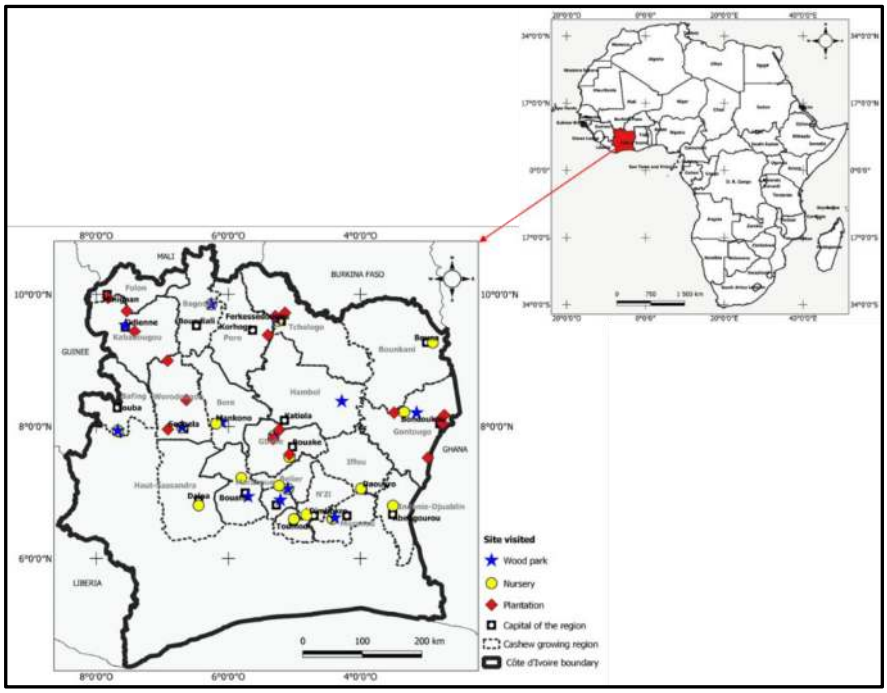

Figure 1: Map of Côte d'Ivoire showing the sites visited in this study

In nursery, the sanitary surveys were carried out over two years, during the 2021 - 2022 and 2022 - 2023 seasons, in 2022 and 2023 to be precise. In each nursery, a total of 30 grafted plants were assessed, with ten plants for each high-yielding genotype. The plants were selected randomly by following the two diagonals of the

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blocks formed with each genotype and ensuring that the plant had at least five leaves. Assessments were made by observing the first five mature leaves of the grafted plants, starting from the apex.
When the nurseryman had a wood park, ten cashew trees per genotype were surveyed in his wood park. In this case, the assessment was carried out using the method of 1 m^2 quadrats placed at foliage as described by Soro *et al.* [10].

The anthracnose symptoms observed were described and the level of infection was determined. The ratio between the number of diseased tissue and the total number observed of this tissue was used to determine the incidence. Disease severity was assessed on leaves using a 0 to 9 rating scale based on the percentage of leaves area affected: 0 = 0%, 1 = 1 to 5%, 3 = 6 to 10%, 5 = 11 to 25%, 7 = 26 to 50% and 9 = > 50% [16 modified]. This severity was expressed using the severity index equation [17]:

$$Is = \frac{\Sigma(xi.\,ni)}{N.Z} \times 100$$

Is: Disease severity index; **xi**: Disease severity i on the leaf; **ni**: Number of leaves with severity i; **N**: Total number of leaves observed and **Z**: Highest score on the scale, i.e. 9

Assessment of anthracnose in plantations on disseminated high-yielding cashew genotypes

The study of anthracnose on high-yielding genotypes in plantations was carried out in 20 orchards located in seven regions of the country (Figure 1). Surveys in plantations were carried out in 2022. In each plantation, one hectare was delimited and ten cashew trees/ha were surveyed at random by genotype, giving a total of 30 trees in the orchard. On each tree, the assessment method in 1 m^2 quadrats placed at foliage was adopted as before [10]. The incidence and severity index of anthracnose on the affected organs of cashew trees were determined as previously described.

Inventory of methods used to control diseases on the three disseminated high-yielding cashew genotypes

An inventory of the methods used to control cashew tree diseases was carried out during the sanitary surveys of accredited nurseries and in plantations. Once the plants had been visually assessed, an interview was conducted with the nurseryman or the farmer to identify the control methods used. The commercial name was noted for the chemical products used, as well as the active ingredient(s) if the container was present. If not, searching for the active ingredient was done using the web.

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Data analysis

The parameters measured in the field (Incidence and severity index) were analyzed statistically using R software version 4.1.2. Firstly, these parameters were transformed to $arcsin\sqrt{(\frac{parameter}{100})}$ for normality and homogeneity of variance then subjected to an analysis of variance with a significance level of 5%. In case of a significant difference, the Student-Newman-Keuls Post Hoc Test was used to compare the three genotypes. The R package ggplot2 was used to build the box plots [18]. The box plots show the median, upper and lower quartiles, and the outlying data are shown as dots

RESULTS AND DISCUSSION

Anthracnose symptoms on high-yielding cashew genotypes disseminated in Côte d'Ivoire

For the 23 accredited nurseries visited, anthracnose was observed on both old and young leaves of cashew genotypes. This disease appeared as necrotic spots showing as dotted lines (Figure 2).

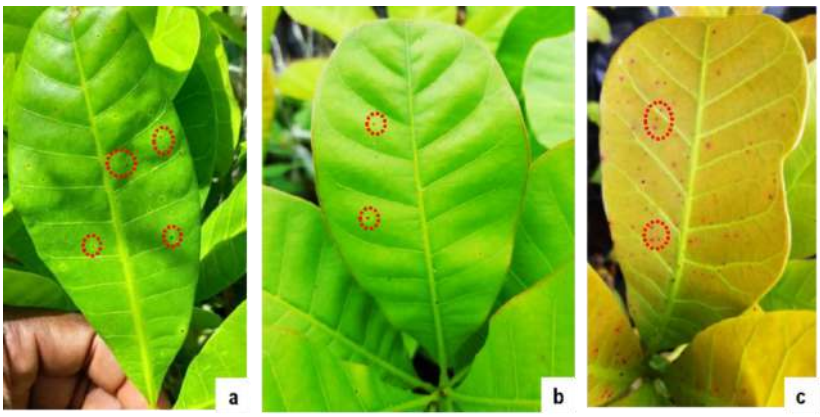

Figure 2: Anthracnose symptoms on the leaves of cashew genotypes in nurseries; a and **b**: Old leaves; **c**: Young leaves

However, in their wood parks installed and in plantations, anthracnose symptoms on clones of these disseminated genotypes were diverse and present on leaves and flower panicles. Besides the dotted form, the disease was observed on the leaves as grey or brown patches covering the veins. On the flower panicles, black spots were generally found at the intersections of the pedicels or at the end where the flowers are precisely located (Figure 3).

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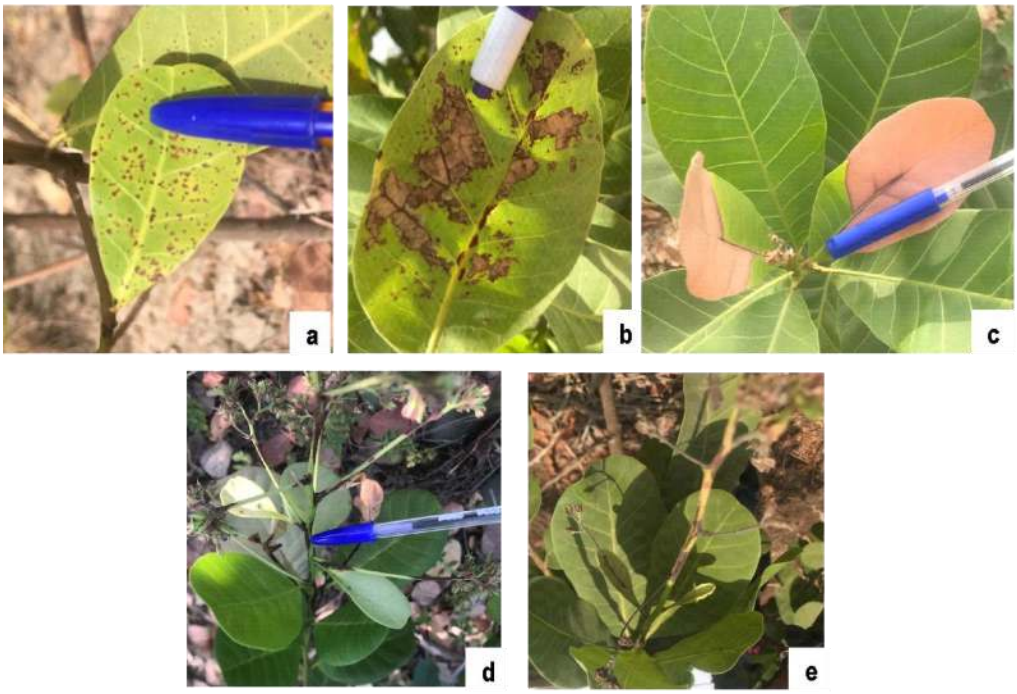

Figure 3: Anthracnose symptoms on leaves and flowers of cashew genotypes in wood parks and plantations
a: Necrotic spots showing as dotted lines
b, **c**: Grey or brown patches covering the veins
d, **e**: Black spots located on the flower panicle *(initial and advanced stages*)

As the bugs used for grafting seedlings in nurseries come from wood parks, infection in nurseries could be the result of infection from wood parks. This is because anthracnose is a latent fungal disease. Consequently, plant tissues can be infected by conidia of *Colletotrichum* species without the plant showing any visible symptoms of disease. Once conditions become favourable for conidia germination, the disease manifests itself on the tissues [19]. Also, the proximity of nurseries to wood parks in some sites could lead to inter-site transfer of fungus conidia. The wind, raindrops, work tools, and living organisms can facilitate this transfer of conidia from one site to another. The symptoms observed in this study are similar to those observed in plantations on the "non-selected" cashew genotypes in Burkina Faso [12], in Côte d'Ivoire [6, 10] and Ghana [15]. Severe occurrences of anthracnose on flower panicles can result in the desiccation of these tissues with a direct impact on cashew nut yields. Cashew nut yield losses due to anthracnose can exceed 50% [11].

Level of anthracnose infection on the high-yielding cashew genotypes

Anthracnose infection in nurseries differed from one site to another. The average incidence ranged from 52.83% to 62.13%, while the severity index ranged from

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8.75% to 11.72%. The statistical analysis using the Student-Newman-Keuls test revealed no significant difference between the genotypes for these two parameters (Table 1). However, from one year to the next statistical analysis revealed a highly significant difference (p-value = 8.344e-10 and 3.933e-06, respectively for incidence and severity index). This could be explained by the fact that in nurseries, disease control methods can change from one year to the next. Variations of environmental factors on the same site from one year to the next could also be an explanation.

In wood parks, statistical analysis revealed also a highly significant difference between the genotypes for these 2 parameters. Genotype A24 was the most affected with an average incidence of 75.74% in the two years of the study, and the average severity index was 18.95% (Table 2). However, a comparative analysis of the level of anthracnose infection revealed no significant difference from one year to the next (p-value = 0.5837 and 0.8597, respectively for incidence and severity index). This could be explained by the fact that, in wood parks, after the grafting season, nurserymen prune the clones to encourage regrowth and make healthier the trees. This practice remains the same every year for all nurseries.

Surveys in plantations revealed the presence of anthracnose at variable rates on leaves and flower panicles (Table 3). Leaves were the most affected by this disease, with an average incidence ranging from 60.59% to 80.07%. Statistical analysis revealed a highly significant difference between the three cashew genotypes for the disease incidence on leaves. Genotype A27 was the most affected with a maximum incidence value of 80.07%. However, on the flower panicles, the average incidence was low, with values ranging from 3.42% to 7.73%. Also, the anthracnose severity index was determined for leaves only. It was between 10.79% and 15.82%. For this parameter, the Student-Newman-Keuls test revealed no significant difference between the genotypes with a p-value = 0.2228 (Table 3).

General susceptibility of high-yielding cashew genotypes to anthracnose disease

The investigation of the general susceptibility of genotypes to anthracnose focused only on the level of disease infection on leaves, which are tissues more affected by this disease. It revealed that the leaves of genotype A24 were more affected by anthracnose than those of genotypes A27 and A30. This could be linked to the genetic heritage of these genotypes. Anthracnose on genotype A24 had an overall severity index of 14.46%. However, on genotypes A27 and A30, the disease was less severe with 10.26% and 11.19%, respectively. This difference was significant (p-value=0.01314) (Figure 4).

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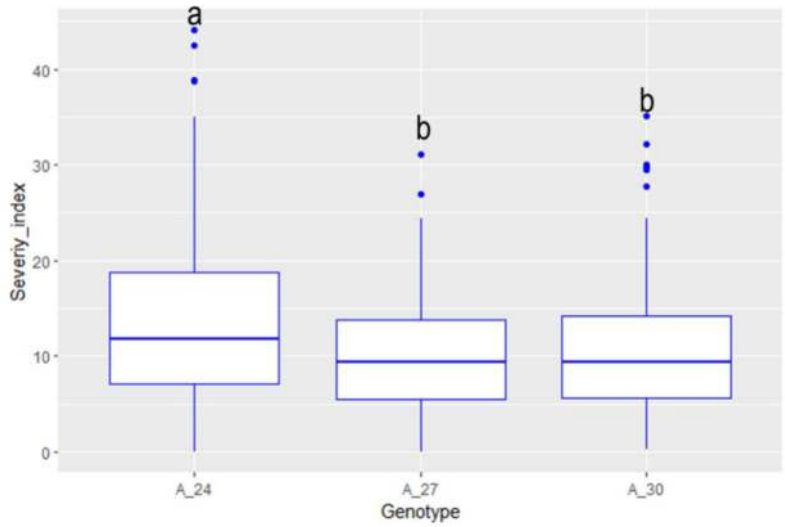

Figure 4: Overall severity index of anthracnose on leaves of cashew genotypes

For the rate of cashew leaves affected by anthracnose (incidence), statistical analysis indicated a non-significant difference between genotypes, although genotype A24 seemed to be the most affected (Figure 5).

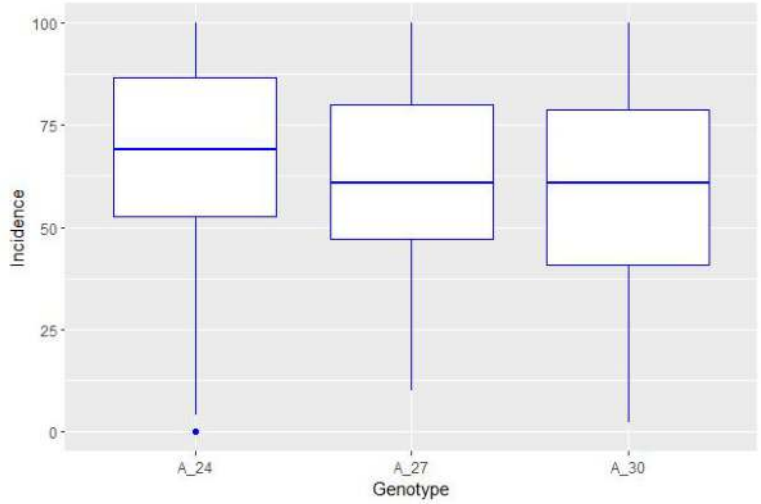

Figure 5: Overall incidence of anthracnose on leaves of cashew genotypes

Methods applied to control diseases affecting high-yielding cashew genotypes

The surveys revealed that nurserymen and farmers use both indirect and direct methods to control diseases on these cashew genotypes. Indirect control methods involve regular weeding of nurseries, wood parks, and plantations. Weeds in cashew orchards are potential hosts for fungi [20]. So, removing them also helps to control diseases.

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Direct methods include mechanical and chemical control. Mechanical control involves pruning severely affected leaves from grafted plants in nurseries. In wood parks, the technique consists of pruning the plants after the grafting season, to promote less-attacked regrowth. Chemical control is based on the spraying of synthetic chemical products. The synthetic chemicals most frequently used are mancozeb (28%), copper oxide (28%), chlorothalonil associated with carbendazim (24%), or maneb (17%). Nurserymen rarely use products based on carbendazim associated with mancozeb (3%) (Figure 6). A previous study revealed the use of synthetic chemicals to control cashew diseases in Côte d'Ivoire [21]. Among these products, the active ingredients most frequently used were mancozeb, chlorothalonil, and carbendazim [22, 23].

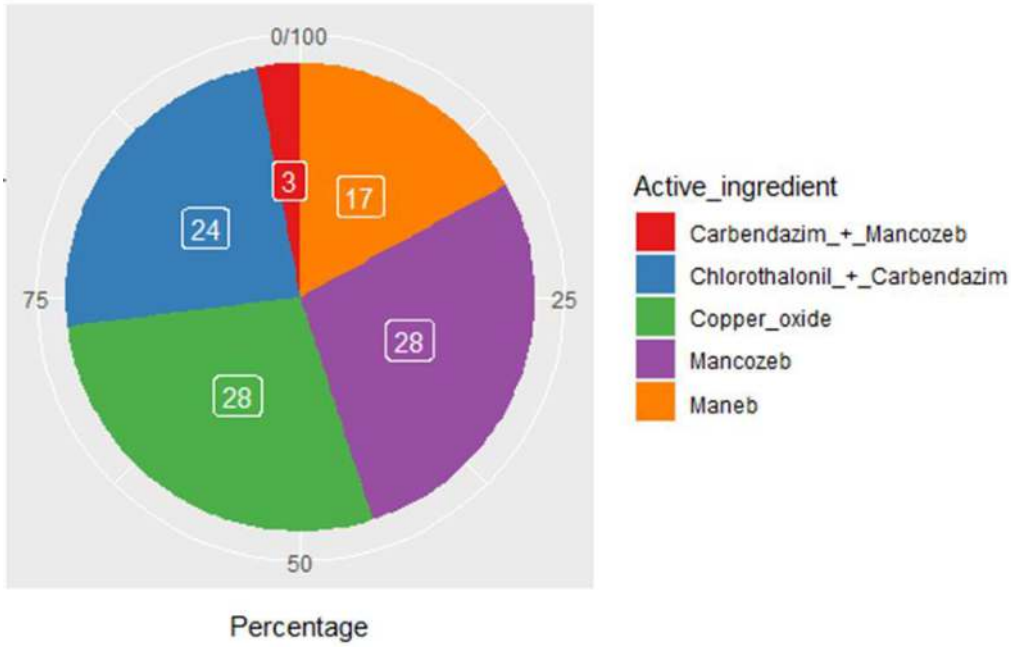

Figure 6: Active ingredients in synthetic chemical products used to control cashew diseases

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The study revealed the presence of anthracnose in diverse forms on the leaves and flower panicles of the three high-yielding cashew genotypes disseminated in Côte d'Ivoire. This disease affects young grafted plants in nurseries and has also been reported in wood parks and cashew plantations. Genotype A24 was generally more affected by anthracnose than the other two genotypes (A27 and A30). To the knowledge, this is the first study of susceptibility to anthracnose of high-yielding cashew genotypes disseminated in Côte d'Ivoire which explored the whole cashew production zone of the country. Given the losses that this disease can cause, this research provides information on the methods adopted to control its impact. The

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methods are weeding plots, pruning cashew trees, and using synthetic chemical products. We recommend that disease resistance, particularly to anthracnose, be incorporated into the cashew varietal selection process in Côte d'Ivoire, before any genotype be disseminated to farmers. More studies need to be done to accurately determine the agents responsible for cashew anthracnose in Côte d'Ivoire. There is also a need for further research on more effective and sustainable control methods, such as biological products.

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Table 1: Averages of incidence and severity index of anthracnose on leaves in nurseries

Genotype	Incidence (%)	Severity index (%)
A24	62.13 ± 1.90	11.72 ± 0.64
A27	54.79 ± 1.74	9.61 ± 0.51
A30	52.83 ± 1.82	8.75 ± 0.54
p-value	0.3044	0.349

Table 2: Averages of incidence and severity index of anthracnose on leaves in wood parks

Genotype	Incidence (%)	Severity index (%)
A24	75.74 ± 1.69 [a]	18.95 ± 1.04 [a]
A27	60.83 ± 1.88 [b]	10.51 ± 0.58 [b]
A30	63.56 ± 1.83 [b]	11.18 ± 0.60 [b]
p-value	0.005141	0.0002643

Table 3: Averages of incidence and severity index of anthracnose on tissues in plantations

Genotype	Incidence on flowers (%)	Incidence on leaves (%)	Severity index on leaves (%)
A24	7.73 ± 2.30	60.95 ± 3.39 [b]	12.96 ± 1.50
A27	3.93 ± 1.89	80.07 ± 4.08 [a]	10.79 ± 1.39
A30	3.43 ± 1.89	60.59 ± 4.08 [b]	15.82 ± 1.77
p-value	0.1711	0.04806	0.2228

The averages of incidence and severity index, with the same letters, are not significantly different according to the Student-Newman-Keuls *post hoc* test with a significance level of 5%.

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