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Field Assessment of Morphometric and Agronomic Characteristics of Fifteen Groundnut (*Arachis hypogaea* L.) Varieties Under Agroecological Conditions of INERA Gimbi station, Democratic Republic of Congo

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Authors' contributions

This work was carried out in collaboration among all authors. Author GKM designed the study, coordinated all activities, compiled literature review, and wrote the first manuscript. Author AKM collected experiment data, and climatic parameters. Authors MLM and MMM carried out statistical analyzes and corrected the first manuscript. Authors JMK and AKM corrected the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate morphometric and agronomic traits of fifteen groundnut varieties from germplasm of the National Pulses Program of Institut National pour l'Etude et la Recherche Agronomiques.
Study Design: This study was conducted using a randomized complete block design (RCBD) with fifteen treatments repeated three times.
Place and duration of the study: The trial was conducted at Gimbi research station from March 9 to June 13, 2022.
Methodology: This study was conducted using fifteen varieties (treatments) replicated three times. Data collected concerned the percentage of seedlings that emerged, morphometric and agronomic parameters.
Results: Seeds emerged varied from 80.6 to 93.5%. Collar diameter varied from 8.7 to 10.1mm, and stem height from 40.5 to 55.1cm. Groundnut varieties flowered on 30 to 35 DAS, and pod maturity is reached on 90 to 98 DAS. Number of pods per plant varied from 10.2 to 16.6, and number of seeds per pod from 2.0 to 2.3. The weight of fresh pods per plot varied from 1,002.3 to 1,043.2g, and the weight of dry pods per plot from 742.3 to 858.7g. The 100-seed weight varied from 49.4 to 53.4g. Dry pods yield varied from 1,546.5 to 1,816.1kg/ha, and seeds yield from 1,376.8 to 1,642.4kg/ha. The principal component analysis figure explains reality with 55.32% information. The first axis explained explains 33.54% of the information, and the second axis explained explains 21.78% of the information. Ascending hierarchical classification grouped groundnut varieties into five classes.
Conclusion: This study shows high variability in the behaviour of groundnut varieties used. Collar diameter and plant height development are continuous from the second to the eighth WAS, then practically fade from the tenth WAS. Groundnut varieties flowered, and pods reached maturity at the same time. Yield is positively correlated with the weight of dry pods and the weight of seeds per plot. Hierarchical classification revealed five distinct classes of groundnut varieties.

Keywords: Groundnuts; morphometric; agronomic traits; germplasm; national pulses program; democratic republic of Congo.

1. INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an oilseed, leguminous plant belonging to the *Fabaceae* family [1]. It is of great nutritional and economic importance for thousands of people around the world. Originally from Central and South America, the peanut has spread across other regions of the world [2,3] where it is cultivated on nearly 25 million hectares [4]. With more than 300 varieties grown worldwide, peanuts are now grown in China, India, Indonesia, Africa, Japan, South America and the United States [2,5].

Groundnut is one of the most important crops in the world, not only because it is an important source of vegetable oil but also because it is a source of plant protein and healthy fats, vitamin A, vitamins B complex (thiamine, riboflavin and niacin), calcium, and iron [2,6]; according to Patee & Young [7] and Settaluri *et al.* [2], groundnut seeds contain approximately 22 to 30% crude protein. It is often grown on marginal soils with fewer inputs and generally intercropped with cereals in many developing countries [6]. According to USDA [8], China and India are the two largest peanut-producing countries in the world, with 41.6% and 12.5% of global production, respectively.

Once considered an unhealthy food due to its high-fat content [9], peanut is now considered a crop with greater potential to reduce hunger and malnutrition in countries of the third world [6]. Studies have demonstrated that dietary inclusion of groundnuts and tree nuts is associated with a reduction in heart disease [10,11], certain types of cancers [12], and better weight management [13]. According to Boa *et al*. [14], consuming peanuts twice a week can reduce the risk of death from heart disease by 24%. Jones *et al.* [11] point out that regular consumption of peanuts helps significantly reduce blood pressure in hypertensive people. In postmenopausal women, regular consumption of nuts and peanuts significantly reduces the risk of death from coronary heart disease [15]. This is how the perception of groundnuts has shifted from an energetic food to a beneficial food associated with benefits for improving health [2].

Groundnut is also grown in the Democratic Republic of Congo (DRC), particularly in the provinces of Bandundu (old configuration), Katanga, Eastern Province, Equateur, and Eastern Kasai and Western Kasai. However, groundnut production in the DRC remains marked by a sharp drop in production [16]. Indeed, statistics [17] indicate that groundnut production in the DRC is much lower than atof other countries such as China, India, the United States of America, Nigeria, Senegal, Argentina and Indonesia.

According to [18], in sub-Saharan Africa (SSA) in general, and the DRC in particular, peanut yields are generally low (964kg/ha), which is well below the potential yields of up to 3,500kg /ha reported elsewhere. In this region, this low peanut yield is due to various abiotic (drought and low soil fertility) and biotic constraints. Biotic constraints include pests such as aphids (*Aphis craccivora* Koch), the leaf miner (*Aproarema modicella* Deventer), thrips (*Thrips palmi* Karny, *Frankiniella schultzie* Trybom, *Scirtothrips dorsalis* Hood and *Caliothrips indicus*) and termites (*Isoptera* spp.), and diseases such as peanut rosette, cercosporioses and rust. Furthermore, in SSA, farmers grow unimproved varieties using inefficient technical routes (agronomic practices) and with limited access to extension services [19-23].

It is, therefore, essential to develop high-yielding peanut varieties that are resistant to abiotic and biotic constraints to increase productivity and harvest quality in order to meet the demands of farmers and value chains for food security and regional markets. According to [24], improving the genetic potential of peanuts for qualitative and quantitative traits is one of the main objectives of most peanut breeding programs. Over the past two decades, more than 100 improved high-yielding groundnut varieties have been developed, introduced and cultivated in SSA. Some of these released varieties are grown in several SSA countries. This is the case of the JL 24 variety, which is widely cultivated in Malawi, Mozambique, South Africa and the DRC due to its drought tolerance and early maturity [22].

With a view to diversifying varieties and broadening the genetic base of peanut germplasm in the DRC, several varieties of peanuts from various countries around the world were introduced to the INERA Legumes Branch/ Mvuazi. Some of these varieties have been evaluated or are being evaluated for their resistance to abiotic and biotic stresses and their agronomic performance, while other varieties have not yet been subject to any evaluation. It is in this context that the present study is located, which mainly aims to evaluate, in the agroecological conditions of INERA/Gimbi, the morphometric and agronomic characteristics of fifteen groundnut varieties derived from the germplasm of the Leguminous Antenna of INERA/Mvuazi. Specifically, this involves (1) evaluating the vegetative development of these groundnut varieties, (2) to analyze for each groundnut variety and the different production components; and (3) determining the types of correlations between vegetative and production parameters.

2. MATERIALS AND METHODS

2.1 Presentation of the Experimental Site

The present study was carried out at the research station of the National Institute for Agronomic Study and Research (INERA/Gimbi). The latter is located in the territory of SEKE-BANZA, in the province of Kongo Central. The geographical coordinates of the experimental site recorded using a Garmin GPS indicated 13°22' East longitude, 5°31' South latitude, and 339m altitude. Information from [25]indicate indicates that the characteristic climate of INERA/Gimbi is type Aw5 according to the Köppen classification. It is a humid tropical climate characterized by five months of dry season and seven months of rainy season. Generally, the dry season runs from the second half of May and ends in the first half of November. As for the rainy season, it goes from the second half of November and ends in the first half of May. The annual average rainfall is 1,185.24 mm. INERA/Gimbi soils are generally clayey to sandy-clayey, black and rich in humus. The temperature, relative humidity and precipitation conditions that prevailed during the experimental period are presented in Table 1.

2.2 Plant Material Used

FifteenIn the present study, fifteen varieties of peanut (*Arachis hypogaea* L.) constituted the plant material. These were selected such as,: A1408, A1423, CIALCA, HYQ(CES)14, ICGM 281, ICGM-SM-99530, ICGM-SM-99557, JL24, JL24-2, KIAKU, KIMPESE, LODI, NSANGU, NTOMBO, and SIVI, and. The JL24 variety served as control. Seeds of all groundnut varieties were obtained from the National Pulses Program of the Mvuazi Research Center. The main characteristics of the fifteen groundnut varieties are presented in Table 2.

2.3 Methods

2.3.1 Setting up the experiment

The trial was conducted from March 9 to June 13, 2022. The experimental land was fallow land on which plant species such as *Imperata cylindrica*, *Panicum maximum* and *Digitaria sanguinalis* were mainly encountered. The land was cleared manually with a machete, then ploughed and mechanically harrowed using a John Deere® tractor. The experimental field measured 38 m in length and 11 m in width, which corresponds to an area of 418 m^2. Each elementary plot measured 3m in length and 1.6 m in width, i.e. an area of 4.8 m^2. The distance between the two neighbouring plots was 80 cm.

Sowing was done manually at a depth of 3 cm with two seeds per pocket. The spacings used were 40 cm between the lines and 20 cm within the line. Each elementary plot had 5 sowing lines of 3 m length each, including three central lines making up the useful plot. Manual weeding using a hoe against weeds was the only cultural treatment applied during the experimental period. In total, three weedings were carried out. The first was carried out two weeks after sowing; the second was carried out two weeks after the first or four weeks after sowing. The third and final weeding was carried out three weeks after the

Table 1. Average temperature, relative humidity and precipitation that prevailed during the experimental period

Month	Temperature (°C)			Relative humidity (%)	Precipitation (mm)
	Maximum	Minimum	Average		
March	31.1	24.4	27.7	91.8	124.3
April	29.7	22.0	25.8	92.3	159.8
May	28.7	21.3	25.0	94.3	21.0
June	28.3	18.4	23.3	92	00

Table 2. The main characteristics of the fifteen groundnut varieties studied

Variety	Kind	Origin	Cycle (in days)	Integument color	Resistance to cercosporioses
A1408	Spanish	DRC (Bandundu)	94	Red	Very sensitive
A1423	Spanish	DRC (Bandundu)	94	Red	Resistant
CIALCA	Spanish	DRC (central Kongo)	93	Brownish pink	Resistant
HYQ(CES)14	Spanish	DRC (central Kongo)	93	Brownish pink	Resistant
ICGM281	Valencia	Bolivia	100-120	Red	Resistant
ICGM-SM-99530	Valencia	ICRISAT	90	Brownish pink	Very resistant
ICGM-SM-99557	Valencia	ICRISAT	94	Brownish pink	Very resistant
JL24 (control)	Spanish	DRC (central Kongo)	94	Brownish pink	Very resistant
JL24-2	Spanish	DRC (central Kongo)	94	Pink	Very resistant
KIAKU	Spanish	DRC (central Kongo)	93	Brownish pink	Resistant
KIMPESE	Spanish	DRC (central Kongo)	90	Pink	Tolerant
LODI	Spanish	DRC (central Kongo)	93	Pink	Resistant
NSANGU	Spanish	DRC (central Kongo)	90	Brownish pink	Resistant
NTOMBO	Spanish	DRC (central Kongo)	90	Brownish pink	Resistant
SIVI	Spanish	DRC (central Kongo)	90	Brownish pink	Resistant

second weeding. No phytosanitary treatment or fertilizer application had been carried out.

2.3.2 Experimental setup, observed parameters and statistical analysis of data

The trial was conducted using a randomized complete block design with three repetitions and fifteen treatments. These corresponded to the different varieties of groundnut studied. Each repetition included all groundnut varieties. During the experimental period, observations focused on morphometric and agronomic parameters. The morphometric parameters concerned the rate of seedlings emerged, the diameter at the collar and the height of the stem. The emergence rate was evaluated on the 10th day after sowing (DAS), and represented the percentage of seeds having emerged in relation to all the seeds sown. The diameter at the collar and the height of the stem were taken from the second week after sowing, every two weeks. The diameter at the collar was assessed using a digital calliper (Stainless brand Hardened, China), and the height was measured using a graduated slat of 60 cm long.

The agronomic parameters considered concerned: (1) the number of days for 50% of plants to flower (determined by counting the number of days between sowing and the day when at least 50% of the plants in the plot had flowered) ; (2) the number of days to maturity of the pods (assessed by the time in days between sowing and the moment when the pods reach maturity); (3) number of pods/plant; (4) number of seeds/pod; (5) the weight of fresh pods/plot (g); (6) weight of dry pods/plot (g); (7) dry pod yield (kg/ha); (8) the weight of 100 seeds (g); (9) seed weight/plot (g); and (10) seed yield (kg/ha). The weights of the pods and seeds and the yields were assessed using an OHAUS® brand precision balance (model SKX422, Naenikon, Switzerland).

For all parameters recorded, an analysis of variance (ANOVA) was carried out to compare the means between the different groundnut varieties. When a significant difference was revealed between varieties, the ANOVA was completed by the least significant difference test at the 5% probability threshold. Principal component analysis (PCA) and ascending hierarchical classification were carried out in order to group the selected parameters into categories likely to characterize groundnut varieties. The various tests and statistical analyses were carried out using Statistix (version 8.0) and R software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Percentage of seedlings emerged

Fig. 1 illustrates the percentage of seeds that emerged 10 DAS. Fig. 1 indicates overall that the percentage of seeds that emerged varied from 80.6 to 93.5%. The highest seed emergence rate (93.5%) was recorded on the JL24-2 variety, while the lowest emergence rate (80.6%) was noted on the LODI variety. The remaining thirteen groundnut varieties showed emergence rates ranging from 82.9 to 93.5%. At the 5% probability threshold, the analysis of variance revealed significant differences between the groundnut varieties studied ($LSD_{0.05}$ = 5.6).

3.1.2 Collar diameter and plant height

The results of collar diameter are illustrated in Fig. 2a, and those of plant height in Fig. 2b. In general, Fig. 2a indicates that the stem diameter of different groundnut varieties studied continuous growth until the 10th week after sowing (WAS), where it reaches its maximum, except for the ICGM281 variety, whose maximum stem diameter is reached at 8th WAS. At 12th WAS, the highest collar diameter (10.1 mm) was recorded on the ICGM281 variety, while the lowest collar diameter (8.7 mm) was noted on the A1408 variety. At the 5% probability threshold, the analysis of variance revealed significant differences between groundnut varieties at 4th, 8th, 10th and 12th WAS ($LSD_{0.05}$ = 0.2; 1.3; 0.6; and 0.6, respectively). Fig. 2b indicates that the stem growth is continuous for groundnut varieties, with the exception of the CIALCA, NSANGU, NTOMBO and SIVI varieties, in which the maximum height is almost reached from the 8th WAS. At the 12th WAS, the highest average stem height (55.1 cm) was recorded in the variety ICGM-SM-99557, while the lowest height (40.5 cm) was recorded in the variety JL24 (control). The analysis of variance revealed significant differences between groundnut varieties at the 5% probability threshold ($LSD_{0.05}$ = 0.4; 0.5; 4; 6.6; 6.9; and 7, respectively for 2nd, 4th, 6th, 8th, 10th and 12th WAS).

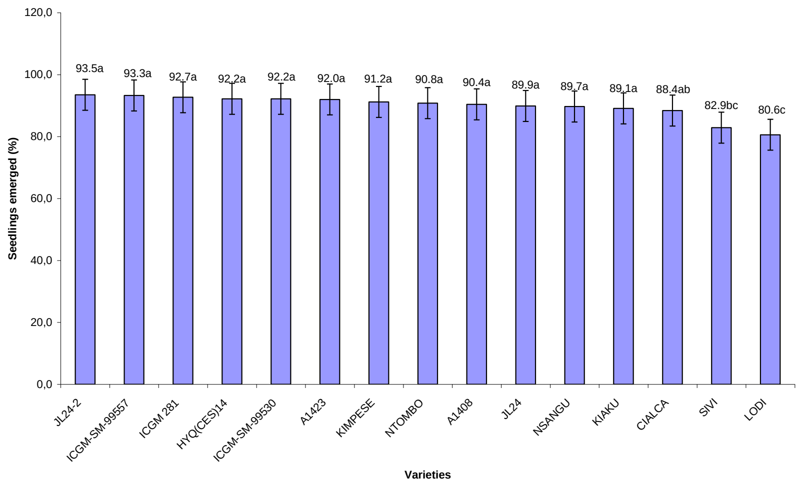

Fig. 1. Percentage of seedlings emerged 10 DAS

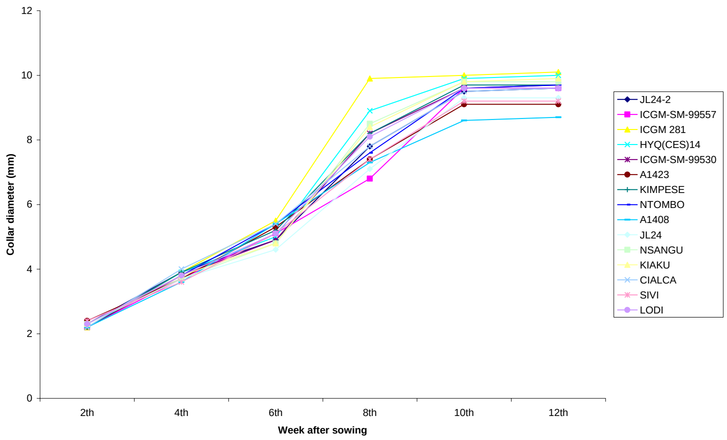

Fig. 2a. The collar diameter (mm) of fifteen groundnut varieties studied

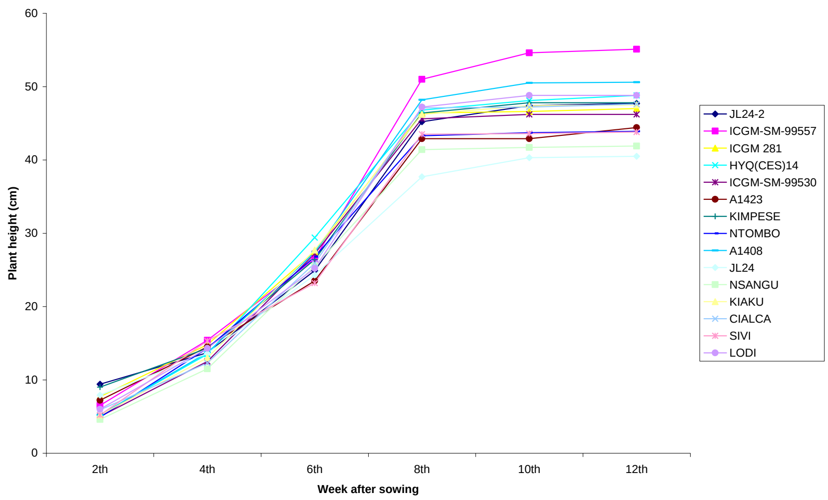

Fig. 2b. Plant height (cm) of fifteen groundnut varieties studied

3.1.3 Agronomic parameters

According to agronomic parameters recorded on the fifteen groundnut varieties, are presented in Table 3. The results of the number of days to flowering 50% and the time to maturity of the pods revealed no significant difference between all groundnut varieties (Table. 3). The criterion number of days to flowering 50% revealed that all groundnut varieties flower on average 30 to 35 DAS. The time (in days) which elapses between sowing and pod maturity revealed that pod maturity for groundnut varieties used is reached on average 90 to 98 DAS. The highest average number of pods per plant (16.6) was noted in the LODI variety, while the lowest number of pods per plant (10.2) was noted in the ICGM-SM-99530 variety. In varieties A1423, ICGM-SM-99530, ICGM-SM-99557 and JL24-2, the number of seeds per pod averaged 2.0, while it averaged 2.1 in ICGM281 and 2.3 in the remaining varieties. The highest weight of fresh pods per plot was recorded in the ICGM-SM-99530 variety (1,043.2 g), while the lowest weight of fresh pods per plot was obtained in the CIALCA variety (1,002.3 g). The NTOMBO variety had the highest weight of dry pods per plot (858.7 g), while the NSANGU variety had the lowest weight of dry pods per plot (742.3 g). The highest seed weight per plot (788.3 g) was obtained in the KIAKU variety, while the lowest seed weight per plot (660.9 g) was obtained in the NSANGU variety. The highest 100-seed weight was obtained in variety A1408 (53.4 g), while the lowest 100-seed weight was obtained in variety SIVI (49.4 g). The highest yields of dry pods and seeds (1,816.1 and 1,642.4 kg/ha, respectively) were obtained in the KIAKU variety, while the lowest yield values (1,546.5 and 1,376. 8 kg/ha, respectively) were obtained in the NSANGU variety.

3.1.4 Principal component analysis

The principal component analysis (Fig 3) illustrates the correlation circle resulting from the principal component analysis (PCA) made from the quantitative data. This figure explains reality with 55.32% information. The first axis explains 33.54% of the information. The variables which contribute the most to this axis and which are explained by it are the yield as well as its components after drying and hulling and the data relating to susceptibility to cercosporioses. The results indicate that the yield after hulling increases with the weight of dry pods and the weight of seeds after hulling. On the other hand, the severity of late cercosporiose disease reduces yield. The second axis explains 21.78% of the information. The variables which contribute the most to its formation and which are best

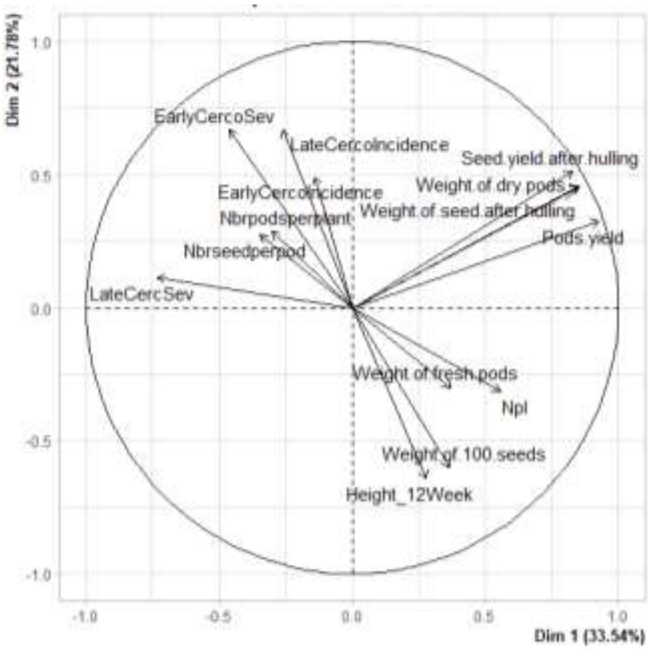

Fig. 3. Correlation circle from principal component analysis (PCA)

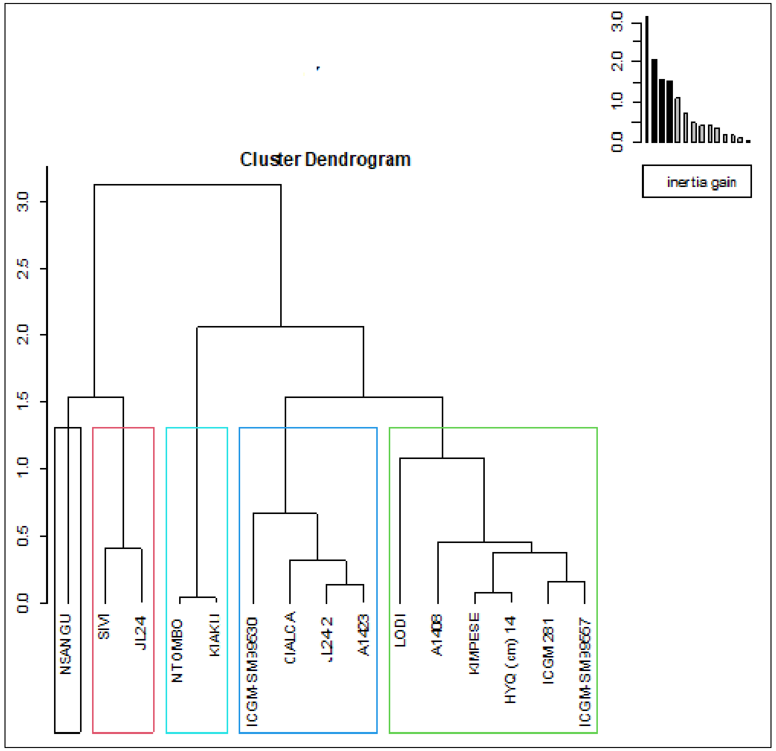

Fig. 4a. Dendrogram illustrating the hierarchical classification of fifteen groundnut varieties studied

Table 3. Agronomic parameters recorded on fifteen groundnut varieties studied

Varieties	NDF50%	NDPM	NPP	NSP	WFPP (g)	WDPP (g)	SWPP (g)	W100S (g)	DP Yield (kg/ha)	S Yield (kg/ha)
A1408	35^{a}	94^{a}	13.2^{abcd}	2.3^{a}	1,038.0^{ab}	818.4^{ab}	736.2^{ab}	53.4^{a}	1,704.9^{abc}	1,533.8^{ab}
A1423	35^{a}	94^{a}	13.3^{abcd}	2.0^{c}	1,028.5^{abc}	831.0^{ab}	748.8^{ab}	49.9^{g}	1,731.2^{abc}	1,558.7^{ab}
CIALCA	32^{a}	94^{a}	14.1^{abc}	2.3^{a}	1,002.3^{c}	799.3^{ab}	718.9^{ab}	51.2^{de}	1,665.3^{abc}	1,497.7^{ab}
HYQ(CES)14	32^{a}	93^{a}	12.2^{bcd}	2.3^{a}	1,027.8^{abc}	824.7^{ab}	740.2^{ab}	51.2^{de}	1,718.1^{abc}	1,542^{ab}
ICGM 281	32^{a}	98^{a}	11.0^{bcd}	2.1^{b}	1,029.2^{abc}	796.8^{ab}	710.1^{ab}	52.1^{bc}	1,659.9^{abc}	1,479.4^{ab}
ICGM-SM-99530	30^{a}	90^{a}	10.2^{d}	2.0^{c}	1,043.2^{a}	839.0^{a}	756.7^{a}	52.2^{b}	1,747.9^{ab}	1,576.4^{a}
ICGM-SM-99557	32^{a}	94^{a}	11.3^{bcd}	2.0^{c}	1,023.0^{abc}	796.4^{ab}	715.2^{ab}	52.1^{c}	1,659.2^{abc}	1,490.1^{ab}
JL 24	30^{a}	94^{a}	13.4^{abcd}	2.3^{a}	1,028.7^{abc}	815.4^{ab}	730^{ab}	51.2^{de}	1,698.7^{abc}	1,520.8^{ab}
JL 24-2	30^{a}	94^{a}	13.4^{abcd}	2.0^{c}	1,026.9^{abc}	807.5^{ab}	723.8^{ab}	51.1^{f}	1,688.6^{abc}	1,507.9^{ab}
KIAKU	32^{a}	92^{a}	10.4^{cd}	2.3^{a}	1,021.5^{abc}	871.7^{a}	788.3^{a}	51.2^{def}	1,816.1^{a}	1,642.4^{a}
KIMPESE	32^{a}	90^{a}	14.3^{ab}	2.3^{a}	1,032.7^{abc}	804.7^{ab}	723.5^{ab}	51.1^{ef}	1,676.5^{abc}	1,507.3^{ab}
LODI	32^{a}	93^{a}	16.6^{a}	2.3^{a}	1,033.9^{abc}	800.2^{ab}	717.4^{ab}	51.1^{f}	1,611.3^{bc}	1,494.7^{ab}
NSANGU	32^{a}	90^{a}	10.3^{cd}	2.3^{a}	1,015.7^{abc}	742.3^{b}	660.9^{b}	51.3^{d}	1,546.5^{c}	1,376.8^{b}
NTOMBO	32^{a}	90^{a}	13.6^{abcd}	2.3^{a}	1,016.1^{abc}	858.7^{a}	775.6^{a}	52.1^{c}	1,788.2^{ab}	1,615^{a}
SIVI	35^{a}	90^{a}	13.5^{abcd}	2.3^{a}	1,006.0^{bc}	802.2^{ab}	720.2^{ab}	49.4^{h}	1,613.7^{bc}	1,500.4^{ab}
$LSD_{0,05}$	NS	NS	3.7	0.07	35.1	90.1	88.8	0.1	190.9	185.1

NDF50%: number of days to flowering 50%; NDPM: number of days to pod maturity; NPP: number of pods per plant; NSP: number of seeds per pod; WFPP: weight of fresh pods per plot; WDPP: weight of dry pods per plot; SWPP: seed weight per plot; W100S: weight of 100 seeds; DP Yield: dry pods yield; S Yield: seed yield; NS: Not Significant

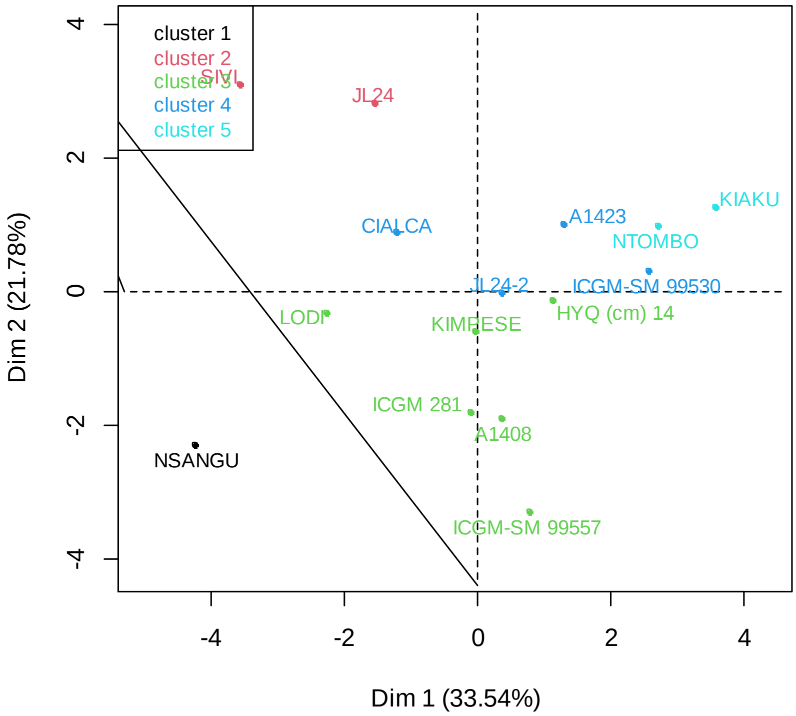

Fig. 4b. Factorial plane of the hierarchical classification of fifteen groundnut varieties studied

explained by it relate to growth, yield of fresh seeds and susceptibility to cercosporioses. Thus, the weight of fresh pods, the number of plants harvested, the weight of the pods and the plant height are positively correlated. It is also found that the high level of incidence and severity of cercosporioses negatively affects the growth parameters and yield of fresh pods.

3.1.5 Ascending hierarchical classification of fifteen groundnut varieties studied

The ascending hierarchical classification (dendrogram) of fifteen groundnut varieties studied is illustrated in Fig 4a, and its projection on a factorial plane is illustrated in Fig 4b. Figs 4a and 4b indicate that the fifteen groundnut varieties are grouped into five distinct classes. The determining variables for this classification are plant height, incidence and severity of cercosporioses (data not shown), weight of dry pods/plot, weight of seeds/plot, pod yield and seed yield. Thus, the first class includes the NSANGU variety; the second includes SIVI and JL24 varieties; the third class includes NTOMBO and KIAKU varieties; the fourth class includes A1423, CIALCA, JL24-2 and ICGM-SM-99530 varieties, and the fifth class includes A1408, HYQ(CES)14, ICGM281, ICGM-SM99557, KIMPESE and LODI varieties.

3.2 Discussion

In general, the results of this study revealed that all groundnut varieties behave differently from each other. Seeds emerged rate, collar diameter and plant height were significant differences between groundnut varieties studied. The emergence rate of groundnut seeds used varied on average from 80.6 to 93.5%, while the collar diameter varied from 8.7 to 10.1mm, and plant height from 40.5 to 55.1cm (Figs 1, 2 and 3). Overall, the present results are far superior to those obtained by Tshilenge-Lukanda [16] and Kalonji-Mbangila *et al.* [25]. Indeed, in a study carried out on the evaluation of some agronomic criteria of 4 groundnut varieties, Kalonji-Mbangila *et al.* [25] observed the highest seeds emerged rate (45.1%) on JL24-2 variety, while the lowest value (39.4%) was obtained on SIVI variety. Tshilenge-Lukanda's [16] results on groundnut seeds irradiation with gamma rays revealed in the controls (groundnut plants from non-irradiated seeds) that collar diameter and plant height varied respectively from 4.2 to 4.6 mm, and from 27.7 to 40.5 cm. The difference in these results with those of the present study can be explained by groundnut varieties used and by the location of experimental sites. Indeed, the present study was carried out on land resulting from a fallow period of more than four years, while Kalonji-Mbangila *et al.* [25] conducted their study on land where the previous crop was corn. In addition, the varieties used in the present study differ completely from those of Tshilenge-Lukanda [16] who conducted his experiment in Kinshasa region.

With the exception of the number of days to flowering 50% and the number of days to pod maturity, the analysis of the data in Table 3 revealed significant differences between the fifteen groundnut varieties for the other agronomic criteria considered. Overall, 50% of the plants had flowered between 30 and 35 DAS, and pod maturity was reached between 90 and 98 DAS. These results corroborate those of Tshilenge-Lukanda [16] and Tshilenge-Lukanda *et al.* [26] who observed that groundnut flowering varied from one variety to another and from one growing season to another. Indeed, working on three groundnut varieties over two growing seasons, Tshilenge-Lukanda *et al*. [26] noted that 50% of plants flowered on average between 30 and 35.5 DAS in 2012 and between 32 and 34.5 DAS in 2013.

In addition, analyzes made on other agronomic criteria retained revealed that they varied according to varieties. The recorded values indicate they varied from 10.2 to 16.6 pods per plot; 2.0 to 2.3 seeds per pod; 1,002.3 to 1,043.2 g fresh pods per plot; 742.3 to 871.7 g dry pods per plot; 660.9 to 788.3 g seeds per plot; 49.4 to 53.4 g of 100 seeds; 1,546.5 to 1,816.1 kg/ha dry pod yield, and from 1,376 to 1,642.4 kg/ha for seed yield. According to Tshilenge-Lukanda *et al.* [26], groundnut plants from JL12, JL24 and KIMPESE varieties grown from non-irradiated seeds gave on average 11.5 to 19.2 pods per plant, with a weight of 100 seeds varying from 49.3 to 50.9 g. These results are not so far from those of the present study with regard to the criteria cited. Seed yields obtained by Tshilenge-Lukanda *et al*. [26] varied from 2,002 to 2,337 kg/ha and were far higher than those of the present study, which varied from 1,376 to 1,642.4 kg/ha. However, yields recorded in the present study are encouraging. Indeed, in Sub-Saharan Africa (SSA), groundnut yield is often less than 964 kg/ha [18]. In addition, Abady *et al*. [27] noted that in SSA, groundnut yields above 1,000kg/ha are considered better. Monyo and Varshney [28], and Kebede *et al*. [29] emphasize that groundnut yields can reach 1,700 to 2,500 kg/ha if cultivation is carried out with elite or improved varieties.

4. CONCLUSION

This study shows high variability in the behaviour of the groundnut varieties used. In almost all varieties, collar diameter and plant height development are continuous from the second to the eighth WAS, then practically fade from the tenth WAS. All groundnut varieties flowered at almost the same time, and their pods reached maturity at the same time. The yields recorded, although slightly lower than the potential yields that could be obtained with improved varieties, were higher than those obtained on average in SSA regions. Principal component analysis revealed that the cercosporioses incidence and severity negatively affect growth parameters and yield. The latter is positively correlated with the weight of dry pods and the weight of seeds per plot. The weight of fresh pods per plot, the number of plants harvested, and the plant height are also positively correlated. The hierarchical classification made by combining data on plant height, cercosporioses incidence and severity, weight of dry pods per plot, weight of seeds per plot, and yield made it possible to group all groundnut varieties into five distinct classes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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