Agromorphological characterization of three (3) hybrid carrot varieties (*Daucus carota*), cultivated in the commune of Korhogo, in northern Côte d'Ivoire

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Abstract— *The carrot (Daucus carota) is a biennial plant whose pivoting root plays a major role in feeding populations worldwide. Few studies have been carried out on the characterization of the agromorphological diversity of this species. Varieties were collected, in order to assess their agromorphological performances under the ecological conditions of Korhogo. The Amazonia, Pamela+, Bahia and Madona varieties were evaluated. The Amazonia variety, which is the most cultivated in the Korhogo region, was used as a control. The study was carried out using a completely randomized Fisher block system, comprising 4 treatments and 4 repetitions. The blocks were separated by a distance of 80 cm. In the same block, the elementary plots were spaced 50 cm apart. Each elementary plot consists of 6 seeding lines, spaced 25 cm, and comprising 72 plants. The measurements concerned some vegetative and agronomic characteristics. The results obtained showed that the Pamela+ variety, with a yield of 25 t/ha, was the most productive. It is also distinguished from other varieties by the length of the roots and the high number of leaves produced. The Bahia and Madona varieties showed similar characteristics and less efficient than those of the control (Amazonia). On the basis of the characteristics evaluated, the Pamela+ variety was the most efficient and adapted to the agroecological conditions of the Korhogo region. However, the evaluation of certain characteristics will confirm the results of this study.*

Keywords— *Daucus carota, varieties, agromorphological characterization, Korhogo, Côte d'Ivoire.*

I. INTRODUCTION

Agriculture is Côte d'Ivoire's main economic activity. It represents the mainstay of the Ivorian economy in that it occupies about 66 % of the working population and generates 2 % of the State's export earnings. A great diversity of crops is practiced and vegetables occupy a prominent place, notably the carrot. The carrot sector has been identified as a strategic market and priority sector by the rulers because of its large implantation in the agrarian systems of Cote d'Ivoire.

The carrot is a biennial herbaceous plant of the family *Apiaceae*, native to the Mediterranean basin of Asia and Europe. It is mainly grown for its fleshy, edible rotating root, rich in carotene, vitamins and mineral salts. It is consumed as a vegetable (**Lecomte, 2013**). It is part of the top three of the three most purchased vegetables by households, just behind the potato and tomato. Consumption is estimated at 10 kg per person per year (**Parent and Sourdin, 2013**). Its annual world production is now estimated at more than 35.5 million tonnes (Mt). The largest producers are China, Russia and the United States, with production of 17 Mt, 1.6 Mt and 1.3 Mt respectively (**FAO, 2014**).

Very popular for its therapeutic and nutritional properties, its culture has grown not only in the temperate zones of Asia and Europe, but also in some tropical regions of Africa, including Côte d'Ivoire, and, particularly, In the north of the country. Since the 20th century, the carrot is a relatively well-established culture in the north of Côte d'Ivoire, and, thanks to its ease of cultivation and high productivity, it accompanies socio-economic diversification, Urbanization and the development of trade in vegetables.

Intended for consumption in fresh or cooked, the carrot is an important source of minerals, vitamins, proteins and sugar in the human diet. Carrot consumption contributes to a healthy and balanced diet (**Shankara *et al.*, 2005**). The carrot is one of the most widespread cultures around the world, and particularly in Côte d'Ivoire. It is therefore an

important cash crop for smallholder farmers and resellers. However, according to FAO production estimates and compared to the situation of other market gardening crops, the Ivorian carrot sector appears to be experiencing a declining production (**FAO, 2014**).

This lower dynamism can be explained, among other things, by the plurality of valued vegetables, the low productivity of the cultivated varieties, a production sector requiring a wide range of inputs and degradation of pedoclimatic conditions. The major constraints, reducing productivity, are undoubtedly the degradation of climate and soils (**Piéri, 1989, Sedogo 1993, Bacyé, 1993**) and conservation problems that have direct impacts on national production.

Soil degradation from slash-and-burn agriculture, depletion of soil minerals are serious threats to agricultural productivity and identified as important causes of declining yields in core-based cropping systems (**Henao and Baanante, 2006**). One of the major constraints is linked to climatic conditions, which are currently characterized by a decrease in rainfall and an increase in water deficit, often exceeding the critical threshold.

However, under these marginal crop conditions, the carrot is almost always one of the most widely grown vegetable crops in all savannah areas, especially in the Korhogo region, which is the country's main production area.

The need to improve crop yields and productivity on existing agricultural land becomes an overarching and obvious goal. Only the selection of more productive varieties opens up perspectives in this direction. The Amazonia variety, characterized by low productivity and short root, is the most cultivated in the Korhogo region.

In this regional and national context, Côte d'Ivoire aims to increase its carrot production in order to fill the long periods of scarcity and reduce large imports. Agricultural research must accompany this ambitious sector development program, by providing producers with plant material adapted to the evolving production environment (increase in water deficit, decrease in soil fertility, land problems).

Global consumption of carrots has become very important, and for a number of years consumers have complained about the standardization of this product and the loss of taste of the carrot (**Pitrat and Foury, 2003**). Current research is therefore oriented towards characterization of other varieties in order to improve the production and organoleptic properties of the carrot.

These commercial and food requirements have led to the selection of other hybrids, the aim of which is to have more homogeneous, earlier, more pathogen-resistant, higher yielding and good quality (**Pitrat and Foury, 2003**).

The present work is in line with the search for new individuals with interesting characteristics. It aims at comparing the agromorphological performances of three varieties of carrots compared to an old variety, commonly cultivated in the region. The objective of this research is to identify the variety of carrot that has the best agronomic potential for its popularization. Thus, the following hypotheses have been issued: (i) one of the new varieties possesses the best agronomic potential; (ii) the old variety is no longer suitable for growing conditions.

II. MATERIAL AND METHODS

Study environment

The study was carried out in the commune of Korhogo, located in northern Côte d'Ivoire, whose geographical coordinates are 9° 26' longitude north and 5° 38' west latitude. The climate of the Sudanese zone is characterized by an alternation of two seasons. A great dry season, from October to May, precedes the rainy season, marked by two rainfall peaks, one in June and the other in September. The zone is also characterized by average temperatures varying between 24 and 33° C and a monthly average humidity of 20 %. The annual rainfall is between 1100 and 1600 mm and the duration of sunshine is 2600 hours per year.

The soil is of the tropical ferruginous type, formed on granite, the more or less intense leaching of which reduces its fertility. The relief is generally flat and scattered in places of inselbergs (**Koffie and Yéo, 2016**).

Material

Plant material

The plant material is composed of four (4) hybrid carrot varieties (*Daucus carota sub. sp., Sativus*), all of which are kuroda-like. These varieties are known by their vernacular names. The Amazonia variety is the most cultivated in the region. It was used as a control in the present study because of these well-known agronomic characteristics. After 90 to 95 days of cultivation, the rotating roots can reach 16 to 18 cm in length (**Technisem, 2017**). On the other hand, the Bahia, Madona and Pamela+ varieties were chosen for the test because of their strong appreciation by the populations and their new introduction into the region.

METHODS

The trial was carried out using a fully randomized Fisher block system, consisting of 4 treatments and 4 repetitions. The study consisted of 16 elementary plots. Each sub-plot was made up of 72 plants, planted on 6 lines according to the 25 cm x 8 cm (25 cm between two lines and 8 cm between two plants of the same line) spacing and covering an area of 2 m2. Elementary plots and blocks were separated by a distance of 50 cm and 80 cm respectively. The entire plot consisted of 1152 plants, covering a total area of 60 cm^2.

Conduct of the test

The study was conducted from December to March. Two (2) kilograms of completely decomposed chicken droppings were delivered per unit plot as a bottom fertilizer two weeks prior to sowing the core. Sowing was carried out, followed by mulching of the plots to maintain sufficient soil moisture after the watering operations.

Thinning was carried out in the 3 to 5 leaf stages, is 22 to 35 days after emergence (JAL), respectively. They aim to maintain the spacing of 8 cm between the plants on the same line. Weeding's were regularly carried out to remove weeds and ensure good aeration of the soil.

A first mineral fertilization was carried out at 46 days after sowing (JAS), with mineral fertilizer NPK of formula 12-11-18 + 2.7MgO + 8S + B + Fe + Zn + Mn, 50 g by elementary plot. A second intake of mineral fertilizer, of formula 15.4N + 25.6CaO + 0.3B, was carried out 3 weeks after the first addition, at a rate of 30 g per elementary plot. Preventive treatments against insects were carried out, once a week, from the 8-leaf stage (66 JAS), with Cypercal, at the rate of 1 l / ha. This dose is equivalent to a mixture of 6.6 ml of the product at 2.5 l of water per unit plot. The harvest started from the 90th JAS, that is to say 3 months and one week after sowing.

Measured parameters

Various parameters were measured on the 4 varieties studied in our study.

The plants height was determined by measuring the longest sheet using a tape measure.

The leaves number per plant was obtained by counting all the leaves contained in the crown.

The dry matter content of the leaves was estimated by weighing all the sheets contained in the crown after drying in the oven at 180° C.

The roots length was obtained by measuring the length of all the rooting roots, using tape measure.

The diameters of the different zones of the root (base, center and apex) were determined by measuring these different sections using a tape measure.

The weight of the rotating roots was obtained by weighing all the roots.

The yield or carrot tonnage (CT) was calculated using the following formula:

$$CT = PMC * D$$

With CT = carrot tonnage (kg/ha); PMC = average carrot weight (kg/plant) and D = planting density (plant/ha).

Statistical processing

The data, collected and recorded using the Excel spreadsheet, were analyzed for variance using XLSTAT software version 7.5. The Student Newman Keuls test (SNK), at the 5 % threshold, was used in case of a significant difference between the averages. Correlations followed by a Principal Component Analysis (PCA) were also conducted to determine the best varieties.

III.   RESULTS

Length of carrot roots

Figure 1 shows the results obtained after measuring the length of all the roots of the different varieties studied. The analysis of the variance shows that there is a significant difference between the averages obtained. The Newman Keuls test allowed the formation of two homogeneous groups. The Pamela+ variety, with an average length of 13.4 cm, is the first group. This variety has produced the longest roots. The second group consisted of the Madona, Bahia and Amazonia varieties. These varieties yielded the shortest roots, with mean values of 11.3, 11.0 and 10 cm in length. Compared to the witness (Amazonia), only the Pamela + variety produced longer roots.
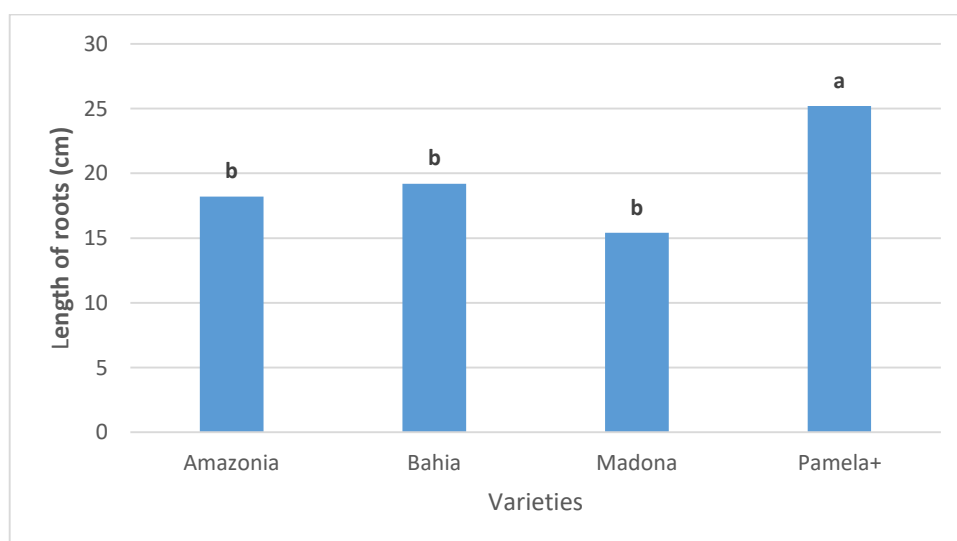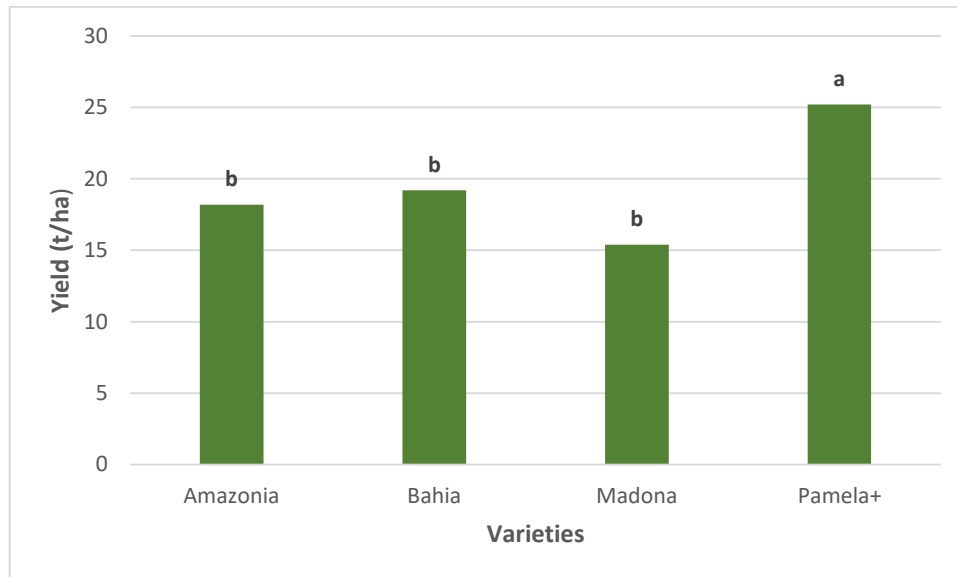

The histogram bars with the same letters are not significantly different
Fig.1: Evolution of the length of the carrot roots according to the varieties

Carrot yield

In the analysis of figure 2, which presents the results of the yields of the different varieties, the analysis of the variance revealed significant differences between the averages obtained. Two (2) homogeneous groups were constituted according to the Newman Keuls test. The first group consists of the Pamela+ variety, with an average of 25.2 t/ha. This variety produced the highest yield, compared to the control (Amazonia) and the other varieties tested, namely Madona and Bahia. The second lowest yield group was Bahia (19.2 t/ha), Madona (15.4 t/ha) and Amazonia (18.2 t/ha). The Bahia and Madona varieties produced the same yields as the Amazonia control.

The histogram bars with the same letters are not significantly different
Fig.2: Evolution of the core yield according to the different varieties

Growth parameters of different varieties of carrot

The mean values obtained on the number of leaves per plant, the height of the plants and the dry matter content of the leaves are given in Table 1. The results in Table 1 show that the number of leaves emitted per plant Varied between 8.6 leaves (Bahia) and 10 leaves (Pamela+) depending on the varieties studied. The analysis of the variance revealed that the Pamela+, Amazonia and Madonia varieties gave a higher number of leaves per plant than the Bahia variety. This variety (Bahia) produced fewer leaves than the control (Amazonia).

The average height of the carrot plants varied from 33.6 cm (Madona) to 39.5 cm (Amazonia) depending on the varieties studied. The analysis of the variance (Table 1) reveals that there are significant differences between the averages obtained with the different varieties. The Madona variety, with 33.6 cm, gave a significantly lower mean height and significantly different from the other varieties (Amazonia, Bahia and Pamela+) with higher heights.

The dry matter content of the leaves, shown in Table 1, varied from 77.7 % (Madona) to 80 % (Amazonia) depending on the varieties compared. The analysis of the variance reveals that there are no significant differences between the averages obtained with the different varieties. It is clear from the above that all the varieties studied gave statistically equal averages of dry matter content.

Diameter of the different sections of the carrot roots

Figure 2 shows the diameter averages of the different sections (base, center and apex) on the roots of all the varieties studied. From the analysis of this figure, it appears that the diameter averages have been decreasing from the base to the top of the roots, passing through the center.

At the basal level, the Amazonia control, with 26.79 mm, yielded larger diameter averages than all the varieties tested. Generally, for this section, the Madona variety produces roots with the smallest diameters, with an average of 23.48 mm.

As regards the diameter at the center, the decrease in the mean from the base was less marked in the Pamela + variety. The mean diameter was higher in this variety (Pamela+), with mean values of 23.40 mm. The average recorded with the Madona variety is always the lowest.

For the averages obtained at the top of the roots, the analysis of figure 2 shows that the Pamela+ variety recorded the highest diameter values compared to the other varieties. On the other hand, the Bahia, Madona and Amazonia varieties produced roots of similar diameters. The decrease in diameters from the base to the top was significantly more marked in the Amazonia control compared to the varieties tested.

Table.1: Summary of the growth parameters of the different varieties of carrots

Varieties	Leaves number	Plants height (cm)	Dry matter content of the leaves (%)
Amazonia	**9,64 ab**	**39,55 a**	**80,05 a**
Bahia	**8,61 b**	**37,31 a**	**79,25 a**
Madona	**8,96 ab**	**33,68 b**	**77,74 a**
Pamela+	**10, 00 a**	**36,89 a**	**78,84 a**

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
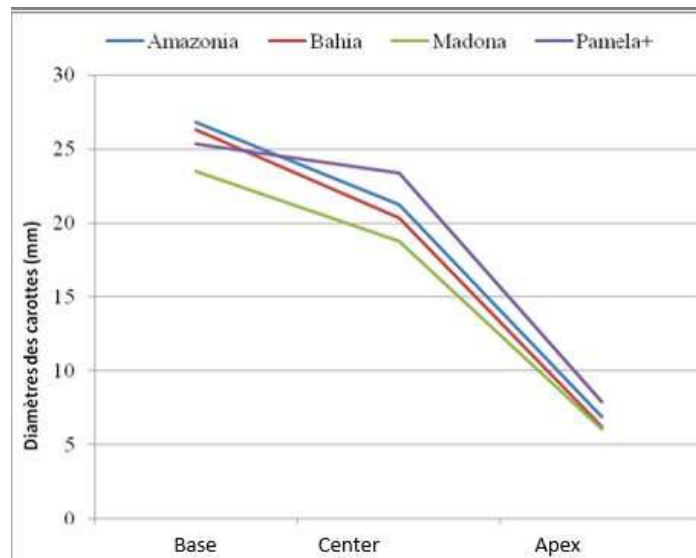

Fig.3: Evolution of the carrot diameter according to the different sections

Study of correlations

The correlations between the different parameters for the four varieties were studied. Table 2 presents the matrix of correlations between these parameters. The analysis of this table reveals the existence of positive and significant correlations between the parameters for the varieties studied. These correlations are as follows:
- the dry matter content of the leaves and the height of the plants ($R^2 = 0.994$);
- the diameter at the base of the carrots and the height of the plants ($R^2 = 0.965$);
- the diameter at the base of the cores and the dry matter content of the leaves ($R^2 = 0.975$);
- the diameter at the top of the cores and that of their center ($R^2 = 0.968$);
- yield and diameter at the center of the cores ($R^2 = 0.955$).

Correlations between the parameters studied in the different varieties

Explaining nearly 94.07 % of the variability expressed, the first two axes of the principal component analysis were taken into account (Table 3 and Figure 3). On axis F1, which absorbed the greatest percentage of variability

(58.28 %), it is the diameter variables at the center and at the top, the yield and the number of leaves emitted that contribute to the formation of this axis. These parameters were positively correlated to the F1 axis. The second axis, which absorbs nearly 35.78 % of the variability, is defined on the positive side by the length of the core and the negative side by the dry matter content of the leaves (Table 3). The diameter at the base and the height of the plants were correlated positively with the axis F1 and negatively with the axis F2.

According to the Biplot plan (Figure 3), each of the four varieties studied is represented in a quarter of a plane, drawn by the first two axes. The plan quarters representing the Madona and Bahia varieties do not have any studied parameters. The Pamela+ variety and some parameters, namely root length, diameter at the center and top of the root, yield and number of leaves per plant belong to the same quarter of the Biplot. Figure 3 shows the proximity between the Pamela+ variety and these parameters. As for the Amazonia variety, it is in the plan quarter containing the parameters as plant height, dry matter content and diameter at the base of the carrot roots.

*Table.2: Correlations between the parameters studied*

Parameters studied	Leaves number	Plants height	Dry matter	Roots length	Diameter base	Diameter centre	Diameter apex	Yield
Leaves number	1							
Plants height	0,372	1						
Dry matter	0,275	**0,994**	1					
Roots length	0,482	-0,352	-0,439	1				
Diameter of base	0,169	**0,965**	**0,975**	-0,365	1			
Diameter of center	0,806	0,534	0,446	0,600	0,469	1		
Diameter of apex	0,915	0,406	0,306	0,664	0,288	**0,968**	1	
Yield	0,657	0,336	0,251	0,757	0,329	**0,955**	0,904	1

In bold, significant values (off diagonal) at the alpha threshold = 0.05 (bilateral test)

Table.3: Coordinates of the parameters along the axes F1 and F2

Parameters studied	F1	F2
Leaves number	0,804	0,297
Plants height	0,701	-0,712
Dry matter	0,624	-0,782
Roots length	0,410	0,886
Diameter of base	0,623	-0,753
Diameter of center	0,975	0,206
Diameter of apex	0,928	0,350
Yield	0,875	0,374

Ø: diameter; TMS: dry matter content of leaves
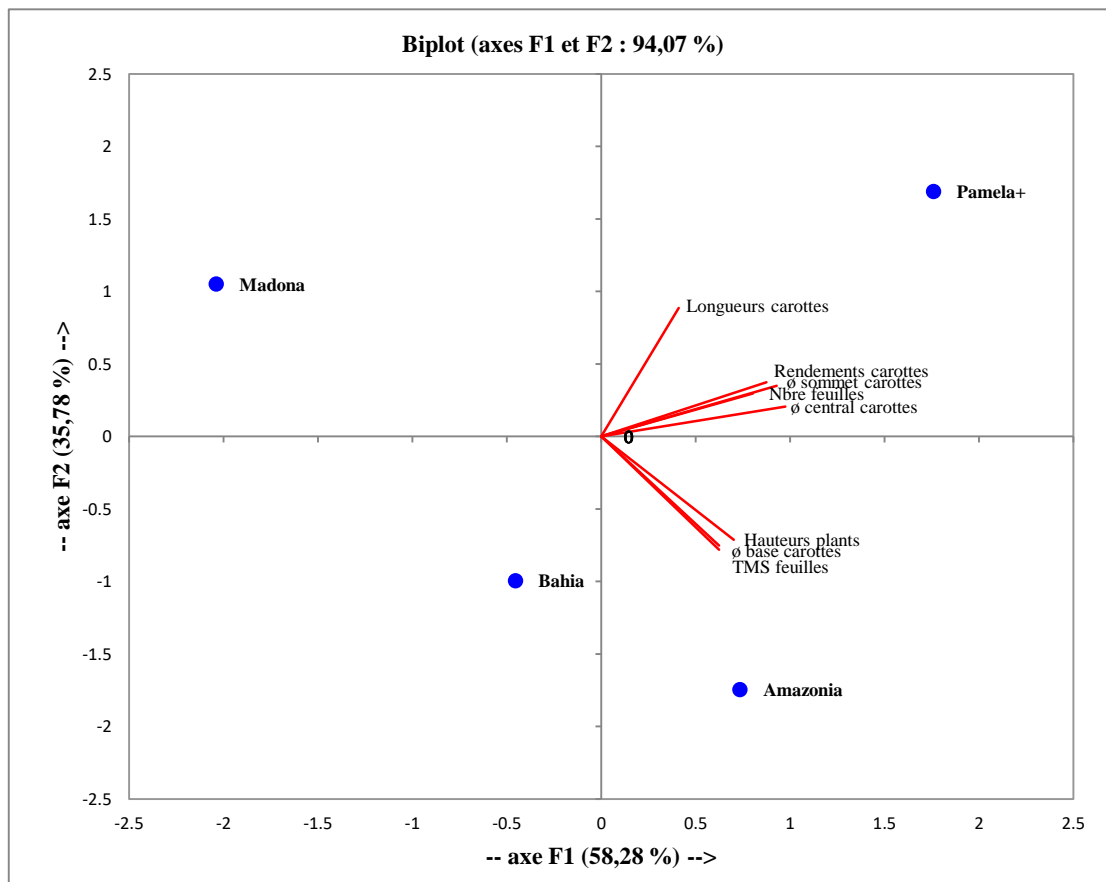
Longueur carottes (Roots length); Rendement carottes (Yield); Nombre de feuilles (Leaves number); Hauteur des plants (Plants height); TMS feuilles (Dry matter); Ø base (Diameter of base); Ø central (Diameter of center); Ø sommet (Diameter of apex)

Fig.4: Distribution of the studied parameters according to the different varieties

IV.   DISCUSSION

Knowledge of genetic variability is essential in breeding. The identification of genetic variability for certain morphological characteristics is the first necessary step in the description of genetic resources (**Radhouane, 2004**).

Analysis of the agromorphological diversity of the local varieties of carrots grown in Côte d'Ivoire revealed significant differences between the characteristics analyzed, indicating a strong phenotypic heterogeneity between the four varieties. This morphological diversity was structured into 3 groups that differed in plant height, root length, number of leaves, base, center and top diameters, dry matter and yield. The first group consists of the Madona and Bahia varieties, which have no better agronomic characteristics. The second group is Amazonia, whose best agronomic potential is plant height, diameter at the base and dry matter content. The Pamela+ variety, which is the third group, has the best agronomic characteristics: root length, number of leaves, diameter at the center and at the top and yield. This Pamela+ variety presented an agronomic performance that the other varieties studied.

For the morphological and agronomic characteristics studied, the Pamela+ variety proved to be the most efficient. Thus, this performance results from the production of a high number of sheets and productivity. This structure of the morphological diversity of these varieties shows that in carrots, morphological differentiation is often based on agronomic traits (**Sanou, 1996; Hidayat *et al.,* 2008**). The yield performance of a variety is therefore related to vegetative characteristics. These results, which reflect a more efficient photosynthetic activity at the level of the Pamela + variety, are in agreement with the work of many authors (**Laure, 1993, Péron, 2006, Lebas, 2012**). According to **Lebas (2012)**, leaves are the seat of photosynthesis in plants, a mechanism allowing the synthesis of fructose and glucose. At the level of the carrot, the roots correspond to the site of photosynthetic reserves. This assertion corroborates our results, which allowed us to establish a relationship between vegetative trait and yield in the Pamela+ variety. For **Laure (1993) and Peron (2006)**, the development of carrot foliage ensures the migration of photosynthesis products to the pivotal root. This would explain high leaf production and yield of carrot roots in the Pamela+ variety. At the core level, selection was also made on the foliage (**Gry, 1993**). The development of the mechanical cultivation of the carrot has given rise to new demands. Harvesting the carrot is done by pulling on the foliage and not on the root.

Phenotypic selection based on perceptible characteristics (phenological, vegetative, yield) could explain the contribution of these variables to the structuring of variability. According to **Louette (1994)**, vegetative traits (leaves number, roots length, plants height) and agronomic (yield) appear to be the main criteria used by farmers to identify many varieties. In the carrot, according to **Parent and Sourdin (2013)**, the objective is to increase the commercial yield that is the quantity of marketable carrots, after sorting and sizing. This is why homogeneity is paramount. This characteristic is also found in the Pamela+ variety. Indeed, this variety has roots whose diameters of the different sections (base, center and apex) decrease less in comparison with the others. The current standard of preference is the cylindrical shape that is pushed because it occupies less space on the ground and is well placed in crates, bags, trays or stalls. The Pamela+ variety is the one that conforms to these characteristics. Unlike the latter, the excessively cylindrical cores make it possible to optimize the filling of the soil and the packaging. They have the disadvantage of being more sensitive to breakage during handling (**Parent and Sourdin, 2013**).

For the vegetative and agronomic characteristics studied, the Pamela+ variety shows the best performances. On this basis, it therefore seems the best to be recommended for popularization instead of the Amazonia variety, formerly the most cultivated in the region of Korhogo.

However, for **Gry (1993)**, the choice of a variety of carrot, intended for popularization, must depend on several criteria. For the finalization of a choice and the popularization of another variety, in replacement of the Amazonia variety, certain morphological, behavioral, biochemical and pathological characteristics must be taken into account and studied. Thus, the main characteristics that must be sought are summarized as follows:

- storage capacity or conservation possibilities in the field;
- resistance to certain diseases or fungi;
- adaptation to a wide range of climate and soil type;
- the precocity of the variety;
- the ability to quickly color and its resistance to the rise of the seed;
- the organoleptic quality of the variety to be sought.

The results of these studies will allow the identification of the best varieties of carrot adapted to the region and for extension to growers.

V.   CONCLUSION

Preliminary results on the diversity and agromorphological structuring of the carrot grown in the Korhogo region clearly show that the varieties analyzed show a variation for all the characters used, particularly those related to phenology, architecture And yields. This observed genetic variability between varieties is an asset for selection work. The study revealed the formation of three groups of varieties. The different characteristics of these three groups have been described. The group formed by the Bahia and Madona varieties exhibits less efficient agromorphological characteristics. As for the Amazonia variety, the control, it

shows performances, in a few vegetative characters, in particular, the height of the plants and the dry matter content. Pamela+ is the variety with the highest variability. This variety showed much better agromorphological characteristics. It has therefore given the best vegetative characters, in particular, the leaves number and the roots length and productivity. On the basis of the characteristics studied, the Pamela+ variety appears to be the best and to be recommended for extension in the Korhogo region. However, this agromorphological characterization should be supplemented by further, in particular biochemical and agronomic studies. Thus, the use of other varieties and an appropriate technical route will increase the production of carrots.

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