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Agromorphological Variability of Five Onion (*Allium cepa* L.) Varieties in Korhogo, Northern Côte d'Ivoire

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Abstract Onion production is low in Côte d'Ivoire. The country is therefore dependent on producer countries in the sub-region. One of the solutions would be to select adapted varieties to the growing conditions of the production areas. It is for this purpose that this study was conducted. This study aims to determine the agronomic and morphological characteristics of five varieties of onion in order to select the best ones. The experiment was carried out in a block with three replications. Data's used was vegetative characteristics and bulb yield components. Multivariate analysis were performed on the collected data. The results revealed three agromorphological groups. The first group, composed of the varieties BATI and KARIBOU, is characterised by a high seed germination rate (85.65%), heavier bulbs (40.19 g), large size (bulb diameter=4.26 cm), a greater number of thick (0.14 cm) scales (6 scales) and a high bulb yield (4.02 kg/m^2). The second (Group 2) consisting of the varieties CARA and DAMANI recorded the highest plant height (42.19 cm), longer leaves (40.19 cm) and longer bulbs (4 cm). The third (Group 3) consisting of the variety SAFARI gave intermediate morphological characteristics to the two previous groups. Based to the measured characteristics, the varieties BATI and KARIBOU with interesting agronomic characteristics are to be recommended to farmers in Korhogo to make onion cultivation profitable.

Keywords: *selection, onion, agromorphological performance, Côte d'Ivoire*

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1. Introduction

Onions (*Allium cepa L.*) are grown all over the world, especially in hot regions. In the list of the world's most grown vegetables, onions are ranked second, afetr tomatoes. Global production has increased from 82,850,000 tonnes per year in 2012 to 99,90.10^6 tonnes per year in 2019 [1]. The main producing countries are China with 24,600,000 tonnes per year, India with 22,308,990 tonnes per year and the United States of America (USA) with 3,277,460 tonnes per year [1].

In Africa, onions are used both for their gustatory qualities and for their pharmacological properties [2]. According to [3], total onion production in Africa, estimated at 5.3 million tonnes, has almost tripled in the last three decades. The main producing countries are Egypt with 2,024,881 tonnes per year, Algeria with 1,183,268 tonnes per year, Morocco with 855,764 tonnes per year and Nigeria with 618,000 tonnes per year [3].

In West Africa, onions are commonly consumed and account for 10-25% of vegetable consumption [4]. Average annual onion production in West Africa, estimated at about 1.1 million tonnes, represents less than 2% of world production. The largest producer in the West African region is Nigeria. It is also the largest net importer because of its large population, which consumes the local annual production [5].

The growth of onion imports is particularly strong in Côte d'Ivoire compared to a national production that has remained very low until now. In 2018, with an estimated annual production of between 5,000 and 8,000 tonnes, Côte d'Ivoire remains one of the smallest onion-producing countries in West Africa despite significant production potential in both savannah and forest areas [6]. Economically, Côte d'Ivoire imports more than 100,000 tonnes of onions each year, which corresponds to 30,000,000,000 F CFA, which represents a shortfall for the country's domestic needs [7].

Côte d'Ivoire's dependence on the external market is a handicap. Indeed, in the event of the appearance of cultural constraints (diseases, pests, climatic factors, etc.) in importing countries, Côte d'Ivoire would find itself out of supply

with onions on its various markets [6]. To remedy this situation, studies are needed to increase onion production by identifying adapted varieties for the production areas. It is in this context that this study was conducted. It evaluates the diversity of five onion varieties in order to make available to farmers those with good agromorphological aptitudes.

2. Materials and Methods

2.1. Experimetal Site

The experiment was conducted at the experimental site of the Peleforo GON COULIBALY University (UPGC) in Korhogo, northern Côte d'Ivoire (Figure 1). The altitude in relation to sea level is 360 m. The site is characterised by a tropical Sudanese-Guinean climate, marked by two main seasons. A rainy one that extends from May to October and a dry season from November to April [8]. The average annual temperature is 27°C and the average rainfall is about 1200 mm/year.

2.2. Plant Material

Five onion varieties were studied (Table 1, Figure 2). These are the varieties named DAMANI, CARA, SAFARI, KARIBOU and BATI bought on the local market.

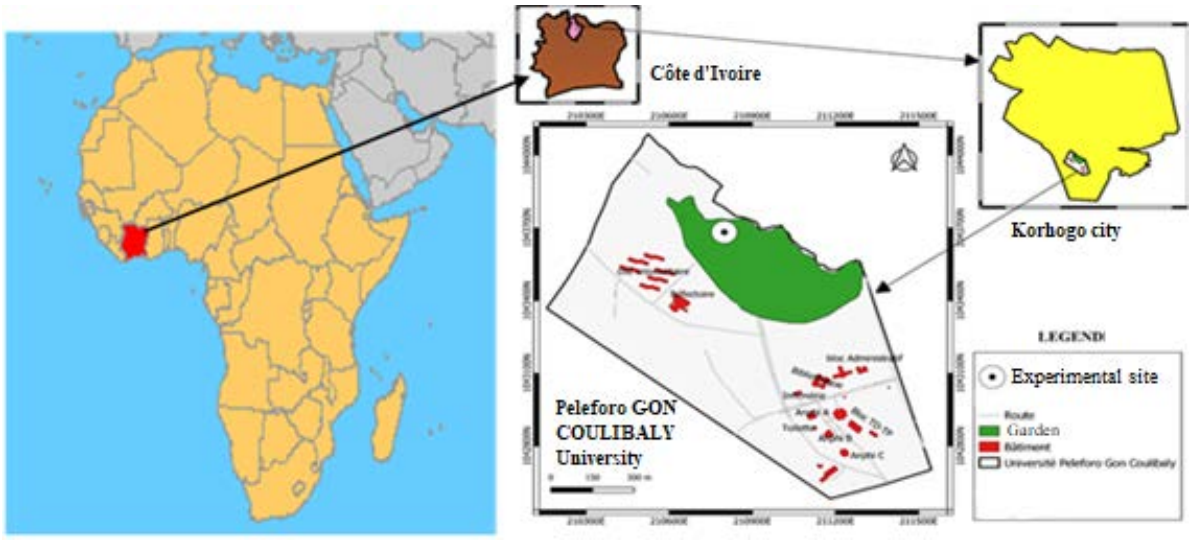

Figure 1. Map showing Côte d'Ivoire, the town of Korhogo, the University and the study site

Table 1. Some characteristics of the five onion varieties studied in Korhogo

Commercial name of the variety studied	Some agromorphological characteristics reported on the label	
	Purity rate	Germination rate
DAMANI	99 %	80 %
CARA	99 %	80 %
SAFARI	99 %	80 %
KARIBOU	99 %	80 %
BATI	99 %	80 %

Figure 2. Different bulbs assessed in the five onion varieties

2.3. Methods

2.3.1. Sowing and Maintenance of Plants

2.3.1.1. Sowing onion seeds in the nursery

The nursery was conducted in well plate with industrial substrate as recommended by [9]. Each onion variety was sown in two plates. Three seeds were sown in each hole. In sum, 10 plates were used for the five onion varieties (Figure 3 and Figure 4). A total of 432 seeds of each variety were sown and each seedling plate contained 216 seedling holes. Watering was done in the morning and evening using a sprayer. The seedlings were transplanted to the field after 40 days in nursery.

Figure 3. Well plate with industrial substrate

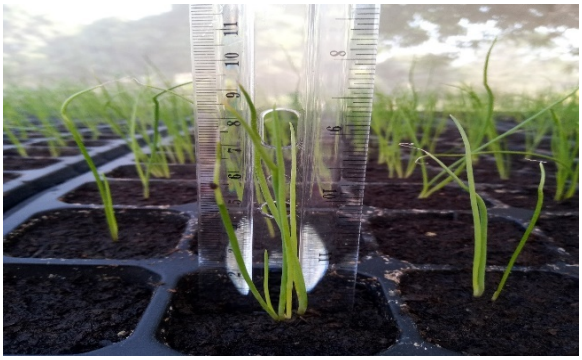

Figure 4. Onion seedlings days 20 after sowing

2.3.1.2. Experimental design and conduct of the field trial

The trial was conducted in a three-repeat design (Figure 5. The elementary plots were made up, according to measurements, of square planks or furrows of dimensions 100 cm x 100 cm x 15 cm (L x W x H) or 1 m^2 and 15 cm high. On the day of transplanting, the beds were watered to facilitate the operation. On each seedlings trays 100 plants were transplanted and seed in 10 lines. Each line was seed with 10 plants at 10 cm intervals. Three days before transplanting, each bed received one (01) kilogram of compost. To prevent attacks by fungi and certain insect pests, the beds were treated with pesticide to eliminate soil parasites. Maintenance consisted of regular weeding of the planting beds to avoid competition between the young plants and weeds. The plants were watered every day with 15 litres of water per bed until bulb formation.

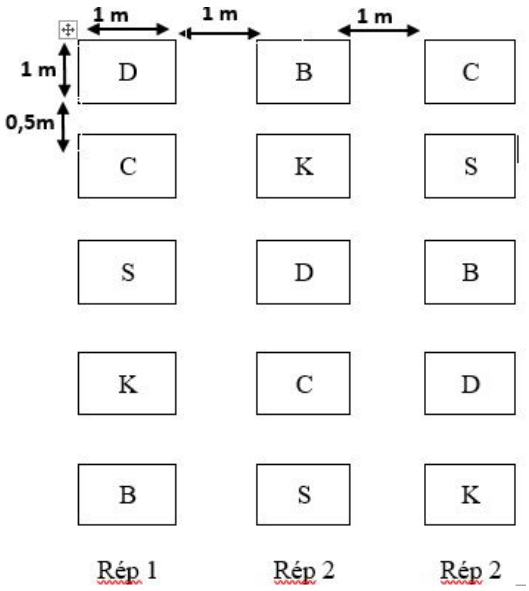

Figure 5. Experimental design of the five onion varieties at UPGC (NB: D = DAMANI; C = CARA; S = SAFARI; K = KARIBOU; B = BATI; Rep = Repeat)

2.3.3. Sampling and Data Collection

Data were collected in the nursery and in the field. In the nursery only the germination rate per variety was determined. In the field, 10 plants was randomly sampled per bed, which correspond to 30 plants for each onion variety. In sum, 150 onion plants were sampled for the five varieties.

The agromorphological variables used are listed in the Allium descriptor proposed by IPGRI (2001). Table 2 presents the descriptors used and the measurement methods.

Figure 6. Measurement of leaf dimensions in onion varieties

Figure 7. Measurement of bulb weight of onion

Figure 8. Measurement of bulb dimensions of onion varieties

Figure 9. Evaluation of the number of scales on onion bulbs in the onion varieties tested

Table 2. Descriptors and collection methods for agromorphological variables of the five onion varieties

Quantitative morphological characteristics (SI unit)	Code	Measurement method
Germination Rate (%)	GR	It was first determined per hole for each variety (Number of germinated seeds/3), the final value is the average for the 144 holes for the two cells of each variety. $GR(\%) = \frac{\text{Number of germinated seeds}}{\text{Total of germinated seeds}} x100$
Height of the plant (cm)	HP	The measurement is made from the crown to the top of the longest leaf. The measurement is taken at 60 days after transplanting (DAT).
Number of leaves per plant	NF	All leaves including terminal buds are counted 60 DAT
Maximum leaf length (cm)	LMF	The measurement is made with a tape measure on the longest sheet at 60 DAT (Figure 6).
Maximum leaf diameter (cm)	DMF	The measurement is made with a tape measure on the longest sheet at 60 DAT .
Bulb weight (g)	PB	Measured with an electronic balance of precision 0.01 g. The average weight was calculated from the data of 30 bulbs per variety (Figure7).
Bulb length (cm)	LB	Measured with a caliper. The average length was calculated from the data of 30 bulbs per variety (Figure 8).
Bulb diameter (cm)	DB	Measured with a caliper (Figure 8).
Number of scales on each bulb	NEB	All scales are counted on the mature bulb. The average number of scales was calculated from the data of 30 bulbs per variety (Figure 9).
Thickness of the scales of each bulb (cm)	EEB	The thickness of the thickest scale of the mature bulb was measured with a caliper. The average scale thickness was calculated from the data of 30 bulbs per variety (Figure 9).
Bulb yield (kg/m^2)	REND	Yield is the mass of bulb harvested per bed. For each variety the average yield is obtained by averaging the three replications.

2.3.5. Data Analysis

2.3.5.1 Analysis of quantitative data

Descriptive statistics (means, standard deviations.) and analysis of variance (ANOVA) were performed for each descriptor. For the data collected in the nursery, a one-sample T-test with a threshold of 5% was performed to compare the germination rate obtained in our trial with those indicated on the seed package. For each descriptor, the Newman and Keuls post ANOVA test was performed to make comparisons between the mean values of each variety at the 5% threshold.

The links between the different variables were assessed using the Pearson correlation coefficient. A Hierarchical Ascending Classification (HAC) was performed to structure the onion varieties studied. It was done on the basis of Euclidean distances and using the Unweighted Pair-Group Method Using Arithmetic Average (UPGMA) as a rule for linking distances between groups. An variance analysis between the classes obtained from the AHC was carried out to identify the descriptors that discriminate the populations studied. The analyses were performed using SPSS software version 22.00 and Statistica version 7.0.

3. Results and Discussion

3.1. Results

3.1.1. Germination Rates of the Five Onion Varieties in the Nursery

The seeds of the varieties studied germinated three to four days after sowing and reached their maximum germination rate between 13 and 16 days after sowing (Figure 10). The varieties CARA, SAFARI showed statistically lower germination rates (66.20 %) than those reported on their labels (80 %) (Table 3). The varieties BATI and DAMANI had statistically identical germination rates (78.95 % and 81.71 %) to the rates reported on the packages. The variety KARIBOU gave a germination rate of 89.58 % statistically higher than that mentioned on the label (80 %).

3.1.2. Link between Growth Vegetative Characteristics and Leaf Size in the Five Onion Varieties Tested

The germination rate differed significantly between the onions varieties studied. The variety KARIBOU got the best germination rate (89.55%) followed by DAMANI and

BATI which hat germination rates ranging from 78.95% to 81.71%. The varieties SAFARI and CARA had lowest germination rates in seedling plate (66.20%) (Table 4).

With the exception of the number of leaves per plant, all other variables did not significantly differentiate the onion varieties studied.

All the varieties studied expressed statistically identical height growth ranging from 37.80 cm to 42.23 cm. The maximum leaf length was similar among all onion varieties and ranged from 36.00 cm to 40.23 cm. In all onion varieties, the maximum leaf diameter ranged from 0.97 cm to 1.23 cm (Table 4). the leaves number of per plant of varieties BATI, DAMANI, KARIBOU and SAFARI showed highest values (5 to 6 leaves). The variety CARA expressed a lower average value of number of leaves per plant (5 leaves).

3.1.3. Bulb Morphology and Yield of the Five Onion Varieties Tested

Bulb length significantly (F= 22.42; p<0.001) differentiated onion varieties (Table 5) and classified them into two groups. The first group consisted of the variety CARA with the longest bulbs (4.28 cm). A second group consisting of BATI, DAMANI, KARIBOU and SAFARI which had shorter bulbs (3.23 and 3.5 cm). The diameter of the bulbs makes it possible to form three different groups of varieties. A first group consisting of the variety KARIBOU presented bulbs with the largest diameters (4.34 cm). A second group consisting of the varieties CARA and SAFARI had the smallest bulbs (3.83 cm to 3.92 cm). The third group contains the varieties BATI and DAMANI which have bulbs with an intermediate diameter (4.18 cm to 4.34 cm) between the first two groups. For the variable number of scales per bulb, two groups could be distinguished. The first group, BATI, DAMANI and SAFARI, had highest number of scales (6 scales) and the second group, CARA and KARIBOU, had a lower number of scales (5 scales).The variable thickness of the scales of each bulb made it possible to differentiate two groups. One group is composed of the varieties BATI, KARIBOU, SAFARI and DAMANI, which had thinner scales (0.12 cm to 0.15 cm). The second one composed of the CARA variety with thicker scales (0.2 cm). The weight of the bulbs did not allow differentiation between varieties. It varies from 35g to 40g. The bulb yield did not also distinguished onion varieties. It varied from 3.5 to 4 kg/m^2.

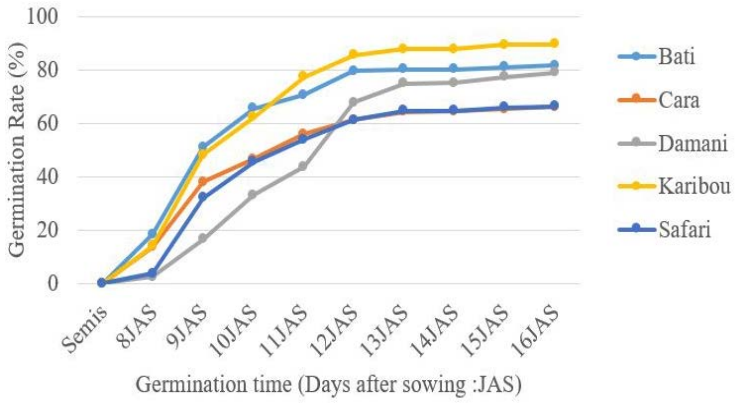

Figure 10. Evolution of germination rate of the five onion varieties in trays from sowing to 16ème after sowing

Table 3. Comparative analysis of observed and predicted germination rates of the five onion varieties

Varieties	Observed germination rate (%)	Expected germination rate (%)	t	p-value
BATI	81.71 ± 21.88 a	80 a	0.94	0.35
CARA	66.20 ± 28.15 b	80 a	-5.88	<0.001
DAMANI	78.95 ± 27.24 a	80 a	-0.47	0.64
KARIBOU	89.58 ± 19.09 a	80 b	6.02	<0.001
SAFARI	66.20 ± 32.74 b	80 a	-5.06	<0.001

NB: Values with the same letter are not significantly different at the 5% threshold (Newman Keuls test), t: t-test statistic; p: probability value associated with the t-test.

Table 4. Mean values (± standard deviation) of vegetative characteristics of the five onion varieties evaluated in Korhogo

Varieties	GR (%)	HP (cm)	NFP	LMF(cm)	DMF (cm)
Bati	81.71 ± 21.89 b	37.8 ± 9.33 a	5.70 ± 1.24 ab	36.00 ± 9.47 a	1.23 ± 0.72 a
Cara	66.2 ± 28.15 a	42.23 ± 8.70 a	5.10 ± 1.40 a	40.23 ± 8.70 a	0.99 ± 0.31 a
Damani	78.95 ± 27.24 b	42.15 ± 5.55 a	6.23 ± 1.45 b	40.15 ± 5.55 a	1.17 ± 0.26 a
Karibou	89.58 19.10 a	38.13 ± 6.13 a	6.33 ± 1.79 b	36.20 ± 6.10 a	0.97 ± 0.30 a
Safari	66.2 ± 32.74 c	39.93 ± 7.00 a	6.17 ± 1.88 b	38.03 ± 7.09 a	1.11 ± 0.27 a
F	27.72	2.4	3.2	2.22	2.29
Pvalue	0.00	0.053	0.015	0.07	0.063

NB: Means indexed by the same letter are not significantly different at the 5% threshold (Newman Keuls test). F: ANOVA test statistic; p: probability value associated with the ANOVA test. GR= Germination rate, HP= Plant height; NFP= Number of leaves per plant; LMF= Maximum leaf length; DMF= Maximum leaf diameter.

Table 5. Mean values (± standard deviation) of production characteristics of the five onion varieties evaluated

Varieties	PB (g)	LB (cm)	DB (cm)	NEB	EEB (cm)	R (Kg/m^2)
Bati	40.63 ± 14.67 a	3.51 ± 0.42 a	4.18 ± 0.61 ab	6.53 ± 0.68 c	0.15 ± 0.06 a	4.06 ± 1.47 a
Cara	37.03 ± 13.79 a	4.28 ± 0.69 b	3.84 ± 0.62 a	4.90 ± 0.92 a	0.20 ± 0.10 b	3.70 ± 1.38 a
Damani	37.73 ± 9.83 a	3.50 ± 0.32 a	4.16 ± 0.41 ab	6.23 ± 1.01 c	0.13 ± 0.06 a	3.77 ± 0.98 a
Karibou	39.75 ± 11.95 a	3.23 ± 0.35 a	4.34 ± 0.55 b	5.70 ± 0.92 b	0.13 ± 0.06 a	3.97 ± 1.20 a
Safari	32.16 ± 10.10 a	3.44 ± 0.43 a	3.92 ± 0.49 a	6.50 ± 1.28 c	0.12 ± 0.06 a	3.22 ± 1.01 a
F	2.19	22.42	4.33	14.72	7.03	2.19
Pvalue	0.073	0.001	0.002	0.001	0.001	0.073

NB: Means indexed by the same letter are not significantly different at the 5% threshold (Newman Keuls test). F: ANOVA test statistic; p: probability value associated with the ANOVA test. PB= Bulb weight; LB= Bulb length; DB= Bulb diameter; NEB= Number of scales on each bulb; EEB= Thickness of scales on each bulb; R=Yield

Table 6. Pearson correlation matrix (r) between measured variables

	GR	HP	NFP	LMF	DMF	PB	LB	DB	NEB	EEB	REND
TG	1	-0,15	0,15	-0,15	0,01	0,19	-0,41	0,32	0,11	-0,14	0,19
HP		1	**0,51****	**0,99****	**0,52****	0,32	0,35	0,26	0,07	0,04	0,32
NFP			1	**0,51****	0,37	0,23	0,04	0,24	0,26	-0,11	0,23
LMF				1	**0,52****	0,31	0,35	0,26	0,07	0,04	0,34
DMF					1	0,20	0,04	0,21	0,27	0,01	0,20
PB						1	**0,45****	**0,92****	0,35	0,24	**0,99****
LB							1	0,16	-0,10	0,38	**0,45****
DB								1	0,42	0,11	**0,92****
NEB									1	-0,17	0,35
EEB										1	0,24
REND											1

**. The correlation is significant at the 0.01 level
GR= Germination rate; HP= Plant height; NFP= Number of leaves per plant; LMF= Maximum leaf length; DMF= Maximum leaf diameter; PB= Bulb weight; LB= Bulb length; DB= Bulb diameter; NEB= Number of scales on each bulb; EEB= Scale thickness on each bulb; REND= Yield.

3.1.4. Links between Quantitative Descriptors Measured in Onion Varieties

The Pearson correlation matrix presents the different relationships between the measured variables (Table 6). Plant height is positively linked to the number, length and of leaves diameter with correlation coefficient values of 0,510.99 and 0.52 respectively.

The leaf length of is positively correlated with the number of leaves (r = 0.51) and the diameter (r = 0.52). The weight of the bulb depends on its length (r = 0.45) and diameter (r = 0.92). Yield is positively linked to bulb characteristics with correlation coefficients ranging from 0.45 to 0.99.

3.1.5. Agromorphological Structuring of the Five Onion Varieties

The Hierarchical Ascending Classification (HAC) revealed three groups (Figure 11). The simultaneous analysis of Figure 11 and Table 7 shows that:

- Group 1 consists of the varieties BATI and KARIBOU, which have high germination rate (85.65%), heaviest bulbs (40.19 g), larger sizes (DB=4.26 cm), greater number of thick (0.14 cm) scales (6 scales) and a high yield (4.02 kg/m^2)

- Group 2 consists of the varieties CARA and DAMANI which have the largest plants (42.19 cm high), with large leaves (40.19 cm), long bulbs (3.89 cm), thick scales (0.17 cm) and high bulb yield (3.74 kg/m^2)

- Group 3 includes the variety SAFARI, which has vegetative and production characteristics intermediate to groups 1 and 2 (Table 7).

3.1.6. Variability of Quality Characteristics in the Five Onion Varieties

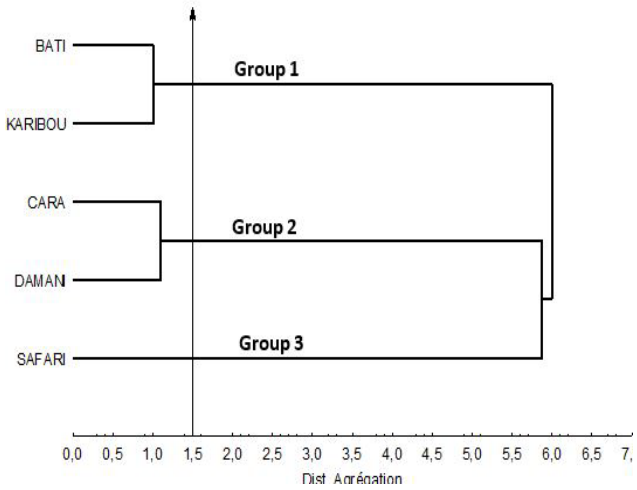

Figure 11. Dendrogram (UPGMA) of onion varieties studied

Table 7. Agromorphological characteristics of the three onion groups

Traits	Group 1	Group 2	Group 3	F	p-value
TG (%)	85.65 ± 3.97 a	72.58 ± 6.43 b	66.20 ± 0.00 c	199.16	**<0.001**
HP (cm)	37.97 ± 7.83 b	42.19 ± 7.23a	39.93 ± 7 ab	4.85	**0.009**
NFP	6.02 ± 1.56 a	5.67 ± 1.53 a	6.17 ± 1.88 a	1.19	0.306
LMF (cm)	36.1 ± 7.90 b	40.19 ± 7.23 a	38.03 ± 7.09 ab	4.5	**0.013**
DMF (cm)	1.10 ± 0.57 a	1.08 ± 0.30 a	1.11 ± 0.27 a	0.053	0.948
PB (g)	40.19 ± 13.28 a	37.38 ± 11.88 ab	32.16 ± 10.10 b	4.37	**0.014**
LB (cm)	3.37 ± 0.41 b	3.89 ± 0.66 a	3.44 ± 0.43 b	15.97	**<0.001**
DB (cm)	4.26 ± 0.58 a	4.00 ± 0.55 b	3.92 ± 0.49 b	5.13	**0.007**
NEB	6.12 ± 0.90 a	5.57 ± 1.17 b	6.50 ± 1.28 a	8.12	**<0.001**
EEB (cm)	0.14 ± 0.06 a	0.17 ± 0.09 a	0.12 ± 0.05 b	5.56	**0.005**
REND (Kg/m^2)	4.02 ± 1.33 a	3.74 ± 1.19 a	3.22 ± 1.01 b	4.37	**0.014**

NB: Means indexed by the same letter are not significantly different at the 5% threshold (Newman Keuls test). TG= Germination rate; HP= Plant height; NFP= Number of leaves per plant; LMF= Maximum leaf length; DMF= Maximum leaf diameter; PB= Bulb weight; LB= Bulb length; DB= Bulb diameter; NEB= Number of scales on each bulb; EEB= Thickness of scales on each bulb; REND= Yield.

3.2. Discussion

This study revealed that germination rate varies with variety. Since the germination trial was conducted under the same conditions, the genotype effect could explain the variability in germination rates observed in onion. Also, the germination substrate would have an influence on the germination of onion seeds since the germination rates observed in some varieties were statistically different from those reported on the labels. In order to optimise onion seed germination, the search for a variety-specific germination substrate would be an avenue to explore. According to [11] the seed may appear healthy but not germinate because it has not been fertilised or has entered a dormant state due to internal factors. In addition, [12] reveled that the presence of fungus on the sown seed causes they rotting.

The results of the elemental statistics for the agromorphological descriptors showed variability for the characters number of leaves per plant, bulb length, bulb diameter, bulb scale thickness and number of bulb scales. This result could be explained by environmental factors, such as day length, humidity and temperature. Indeed, the expression of morphological traits is influenced by both genes and the environment. These environmental factors could lead to variable effects on vegetative development and onion production depending on the variety. These results are in line with those of [13] and [14] obtained on different onion varieties.

Significant correlations were observed between plant height and leaf dimensions and between vegetative traits and those expressing bulb production. This could be explained by photosynthesis which takes place mainly in the leaves of the plant. The onion does not have a true leaf. Increasing the size of the leaves to carry out photosynthesis in order to meet these organic needs also promotes the growth in height of the plant and bulb production. Indeed, the varieties with high bulb yields are those with high height growth, with a high number of large leaves and larger bulbs. These results are in agreement with those of [15].

The structuring of diversity observed in the onion varieties studied through Hierarchical Ascending Classification (HAC) constitutes a tool for assessing the relative contribution of the different characters to the total diversity and for evaluating the degree of similarity between the different genotypes studied [16]. On the basis of the eleven quantitative variables studied, the five onion varieties were separated into three morphological groups by Hierarchical Ascending Classification (HAC).

4. Conclusion

The aims of the study was to evaluate the agromorphological potential of five onion varieties. The results shown that, on the basis of the descriptors used, a high morphological variation was observed in the onion varieties. Significant correlations were also observed between the different quantitative variables. Such correlations will help to identify important variables that can be used for varietal improvement. From the quantitative traits three morphological groups were formed, group 1 of which is composed of the varieties BATI and KARIBOU, group 2 witch contains the varieties DAMANI and SAFARI and group 3 fomed only with the variety CARA. On the basis of quantitative characteristics, the BATI and KARIBOU varieties have interesting agronomic characteristics and should be recommended to farmers in Korhogo in order to make onion cultivation profitable. Indeed, these varieties have a high seed germination rate (85.65%), heavier bulbs (40.19 g), large sizes (bulb diameter = 4.26 cm), a greater number of scales (6 scales) thick of 0.14 cm and a high bulb yield (4.02 kg/m^2).

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Statement of Competing Interests

The authors declare that they have no competing interests.

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