

# Morphological Characterization and Seed-Bulb Multiplication of Three Onion (*Allium cepa* L.) Varieties in Northern Côte d'Ivoire

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## Abstract

Onion (*Allium cepa* L.) is a strategic crop in Côte d'Ivoire. However, production remains insufficient to meet the growing local demand. This study was conducted to characterize and multiply seed bulbs of three onion varieties (SAFARI, ARES, and NAFIS), with the aim of improving national production, and was carried out in parallel with a complementary study on onion botanical seed production. Two experiments were carried out: the first focused on the characterization of base bulbs, while the second involved planting these bulbs for multiplication and agro-morphological evaluation. The data were collected in two stages. Prior to planting, bulb weight, length, and width were measured. Following bulb planting, germination rate, establishment success rate, yield in terms of number of bulbs per plant, and bulb weight were determined. The results revealed high morphological variability, particularly in bulb weight, which ranged from 5.84 to 68.31 g. The ARES variety was distinguished by heavier and wider bulbs. After planting, the average germination rate reached 83%, while the establishment success rate was 68%. SAFARI exhibited the highest germination rate (92%) but a lower success rate (53%). In contrast, ARES achieved the highest yield, with an average of three bulbs per multiplied seed-bulb. Positive correlations were observed between bulb weight and width, as well as between these traits and yield. These findings highlight the potential for multiplying seed bulbs prior to true seed production, particularly when varietal choice is well adapted to local conditions. ARES appears to be the most promising

variety for optimizing yields, whereas SAFARI, despite its vigorous germination, could benefit from genetic improvement to enhance its productivity.

## Keywords

*Allium cepa*, Morphological Characterization, Bulb-Seed Production, Korhogo

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## 1. Introduction

Onion, scientifically known as *Allium cepa* L., is of major importance in the global agricultural landscape. Native to Central Asia, it has been cultivated for thousands of years [1]. It is a widely grown vegetable crop worldwide for its edible bulbs and distinctive flavor [2]. Among the most cultivated vegetables globally, onion ranks second after tomato. Global onion production in 2022 was estimated at 106.7 million tons [3].

In Africa, onion plays a vital role in agriculture, being an essential ingredient in the cuisine of many countries. It is widely used in the preparation of various dishes and is also recognized for its therapeutic properties [2]. The leading onion-producing countries include Egypt, with an annual production of 3,312,469.77 tons, followed by Algeria (1,710,595 tons), Nigeria (1,378,493.83 tons), and Morocco (855,331 tons) [4].

In West Africa, onion consumption accounts for between 10% and 25% of total vegetable consumption according to [5]. The average annual onion production in this region is estimated at approximately 1.1 million tons, representing less than 2% of global production.

In Côte d'Ivoire, onion imports have increased significantly, in contrast to historically low national production levels [6]. From an economic perspective, onion imports—estimated at about 100,000 tons—represent a financial loss of nearly 30 billion CFA francs to meet domestic demand [7]. Côte d'Ivoire therefore remains highly dependent on external markets [8]. To achieve self-sufficiency, it is crucial to conduct studies aimed at increasing onion production. Improving onion production in Côte d'Ivoire largely depends on the development and/or selection of new varieties adapted to local agro-climatic conditions [9]. In this context, the morphological characterization of *Allium cepa* bulbs is of paramount importance. Bulb morphological traits such as size, shape, color, and disease resistance play a decisive role in seed quality and, consequently, in crop yield. A thorough understanding of these traits enables the selection of varieties best suited to the region, thereby optimizing local seed production.

At the same time, the multiplication of seed-bulb represents a major challenge for the sustainability of onion production [10] and should be addressed in complementarity with botanical seed production systems. The study of multiplication methods, whether natural or artificial, is essential to ensure a continuous supply

of high-quality seeds without reliance on costly imports. Mastery of multiplication techniques allows for the efficient propagation of seed-bulbs, thereby promoting seed self-sufficiency and reducing vulnerability to fluctuations in international markets [10]. This study is fully aligned with this objective. Overall, it aims to characterize different onion bulb varieties based on their morphological traits and to develop adapted and efficient multiplication methods. More specifically, the study seeks to analyze and describe in detail the bulb morphology of three onion varieties and to experiment with seed-bulb multiplication. Seed bulbs indeed constitute the basic planting material for true seed production.

## **2. Materials and Methods**

### **2.1. Study Site**

The experiment was conducted in the vegetable garden of the botanical garden of Peleforo GON COULIBALY University (UPGC), located in Korhogo, northern Côte d'Ivoire. The area lies at 9° 27'28" North latitude and 5° 37'46" West longitude, at an altitude of 360 m above sea level. The climate is tropical Sudanian–Guinean, characterized by two main seasons: a rainy season from May to October and a dry season from November to April [11]. The mean annual temperature is approximately 27°C, and average annual rainfall is about 1200 mm.

### **2.2. Plant Material**

The plant material consisted of three onion varieties: ARES, SAFARI, and NAFIS. The ARES and SAFARI varieties were selected for their good agronomic performance [12]. The NAFIS variety was introduced from Kenya in order to evaluate its agronomic performance under the ecological conditions of Côte d'Ivoire.

### **2.3. Methods**

#### **2.3.1. Experimental Design and Setup**

Within the framework of this study, two distinct experiments were conducted. The first aimed to obtain seed bulbs from three onion varieties and to describe them based on their morphological characteristics. The second experiment focused on the multiplication of these seed bulbs. For both experiments, the experimental design was a randomized complete block design (RCBD) following Fisher's model, which is recognized for its effectiveness in controlling environmental variability. Each variety was established in three replicates, with experimental units randomly distributed within each block to ensure equitable allocation and to minimize biases related to soil heterogeneity. The blocks were arranged to reduce, as much as possible, the effects of field variability.

#### **Transplanting of seedlings for seed bulb production**

The experiment was conducted on raised beds measuring 100 cm in length, 100 cm in width, and 20 cm in height, arranged with a spacing of 0.75 m between beds. The beds were thoroughly irrigated on the day of transplanting to ensure optimal soil moisture prior to seedling establishment. Seedlings aged 40 days in the nursery

were transplanted onto each bed at a spacing of 10 cm between rows and 15 cm between plants, resulting in a total of 70 plants per bed, arranged in 7 rows of 10 plants each. Transplanting was carried out manually, ensuring that each seedling was placed at an appropriate depth to promote good establishment. Careful watering, particularly during transplanting, was applied to facilitate root development. Planting conditions were regularly monitored to ensure proper onion growth.

#### **Planting and multiplication of bulbs**

This experiment was also conducted on raised beds measuring 100 cm × 100 cm × 20 cm, with a spacing of 0.75 m between beds. The beds were thoroughly irrigated on the day of planting to ensure adequate soil moisture before bulb planting. After one week of storing the bulbs from the first experiment, bulbs obtained from the harvest were planted on each bed at a spacing of 20 cm between rows and 20 cm between bulbs, resulting in 25 bulbs per bed arranged in 5 rows of 5 bulbs, corresponding to 75 bulbs per variety. Planting was performed manually, ensuring that each bulb was buried at an appropriate depth to achieve optimal germination.

#### **Fertilization and crop management**

To ensure optimal onion growth, several fertilization and crop management practices were implemented. An application of 2 kg of compost per bed, applied three days before transplanting, enriched the soil with organic matter and essential nutrients for onion development. Regular weeding was carried out to prevent competition from weeds, which could otherwise limit access to light, water, and nutrients. Hoeing was performed to loosen the soil, improve root development, and reduce weed growth. Finally, regular irrigation ensured consistent soil moisture, which is essential for proper root development and bulb growth. These practices created favorable conditions for onion cultivation.

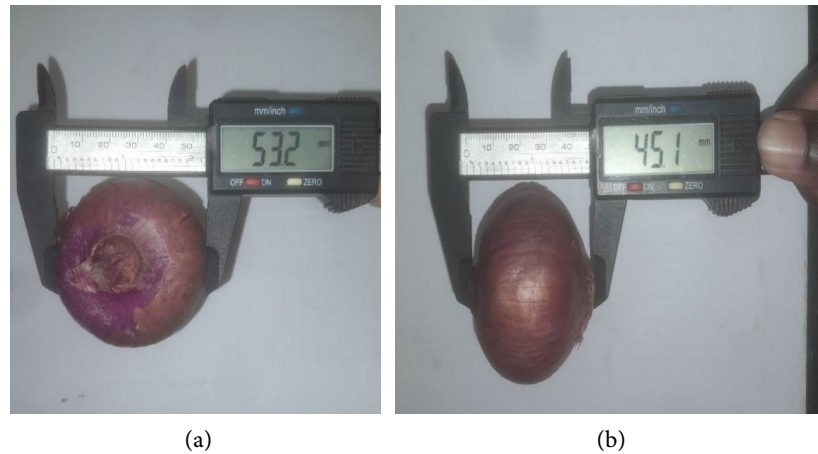
### **2.3.2. Sampling and Data Collection**

#### **• Data collection on base seed bulbs**

Data were collected from a sample of 25 bulbs per bed, corresponding to 75 bulbs per variety and a total of 225 bulbs for the three varieties. For each bed and each variety, bulb length, width, and weight were measured (**Figure 1** and **Figure 2**).



**Figure 1.** Measurement of onion bulb weight.



**Figure 2.** Measurement of onion bulb dimensions.

- **Seed bulb multiplication**

After planting, germination duration was determined by monitoring the seed bulbs from planting until the emergence of the first seedlings. Daily observations were carried out to record the day of first emergence. The germination rate was calculated for the 25 bulbs per bed and per onion variety. For each bed, the number of germinated bulbs was counted and divided by the total number of bulbs planted, allowing the determination of the germination percentage for each variety.

$$\text{Germination rate} = \frac{\text{Number of germinated bulbs}}{\text{Number of bulbs planted}} \times 100$$

Regarding the establishment success rate, the number of bulbs that successfully multiplied was recorded and divided by the total number of bulbs planted, enabling the calculation of the success percentage for each variety at specific dates.

$$\text{Success rate} = \frac{\text{Number of successfully established bulbs}}{\text{Number of bulbs planted}} \times 100$$

The number of bulbs obtained from each planted bulb was recorded at harvest. The newly formed bulbs were counted individually, and the total number of bulbs produced was noted. The total weight of bulbs produced after multiplication was measured using a precision balance.

- **Statistical data analysis**

Descriptive analysis was conducted to obtain coefficients of variation (CV), which were used to assess the variability of the different measured traits. The coefficient of variation was considered high when it exceeded 30% [13]. Analysis of variance (ANOVA) was performed to test for the existence of differences among varieties with respect to the measured variables. When significant differences were detected, Tukey's post hoc test was used to classify the different groups. Pearson's correlation coefficient (*r*) was used to measure the strength of the linear relationship between variables and to assess the degree of association between pairs of variables.

A simple linear regression was performed to predict yield expressed as the number of bulbs (Yield, Nb) as a function of bulb weight (Mb) prior to multiplication, according to the model:

$$(Y = aX + b),$$

where (*Y*) is the yield in number of bulbs, (*a*) is the regression coefficient, (*X*) is the bulb weight before multiplication, and (*b*) is the constant.

All statistical analyses were carried out using XLSTAT software, version 2019.

### 3. Results and Discussion

#### 3.1. Results

##### 3.1.1. Morphological Characteristics of Onion Seed Bulbs before Multiplication

**Table 1** shows substantial variability in the measured traits. Bulb weight (Mb) ranged from 5.84 to 68.31 g, with a mean of 24.14 g and a relatively high coefficient of variation (CV = 42.1%). Bulb length (Lb) exhibited more moderate variability, with a CV of 17%, a mean value of 43.38 mm, and values ranging from 25 mm to 69.8 mm. Similarly, bulb width (lb) showed comparable dispersion (CV = 17%), with a mean of 35.13 mm and values between 20 mm and 54.7 mm.

**Table 1.** Mean  $\pm$  standard deviation, minimum, maximum, and coefficient of variation (CV) of seed bulb traits.

Measured traits	Min.	Max.	Mean $\pm$ Standard deviation	CV (%)
<b>Mb (g)</b>	5.84	68.31	24.14 $\pm$ 10.17	42.1
<b>Lb (mm)</b>	25	69.8	43.38 $\pm$ 7.36	17
<b>lb (mm)</b>	20	54.7	35.13 $\pm$ 5.97	17

**Table 2.** Mean ( $\pm$ standard deviation), minimum, maximum, and coefficient of variation (CV) of traits analyzed by variety.

Measured traits	Min.	Max.	CV (%)	Mean $\pm$ Standard deviation	F	P-value
Mb (g)   ARES	13.64	68.31	34	29.32 $\pm$ 9.84 <sup>a</sup>		
Mb (g)   NAFIS	5.84	41.2	54	17.93 $\pm$ 9.77 <sup>b</sup>	35.933	<0.0001
Mb (g)   SAFARI	10.3	41.93	35	18.85 $\pm$ 6.57 <sup>b</sup>		
Lb (mm)   ARES	32.3	69.8	15	45.83 $\pm$ 6.65 <sup>a</sup>		
Lb (mm)   NAFIS	31.7	58.1	19	45.24 $\pm$ 8.53 <sup>a</sup>	17.889	<0.0001
Lb (mm)   SAFARI	25	58.7	16	39.74 $\pm$ 6.50 <sup>b</sup>		
lb (mm)   ARES	28.8	54.7	14	38.21 $\pm$ 5.28 <sup>a</sup>		
lb (mm)   NAFIS	20.2	41.7	20	29.77 $\pm$ 5.99 <sup>b</sup>	39.521	<0.0001
lb (mm)   SAFARI	25.8	47.3	14	32.40 $\pm$ 4.44 <sup>b</sup>		

Mb: Bulb weight; Lb: Bulb length; lb: Bulb width.

The results presented in **Table 2** indicate significant variability in the quantitative

traits analyzed among the varieties. For bulb weight (Mb), ARES showed the highest mean (29.32 g) with relatively low variability (CV = 34%). NAFIS exhibited a lower mean (17.93 g) but a high coefficient of variation (CV = 54%). Regarding bulb length (Lb), ARES and NAFIS had similar mean values (45.83 mm and 45.24 mm, respectively). SAFARI was distinguished by a significantly lower mean bulb length compared with ARES and NAFIS (39.74 mm). Bulb width (lb) followed a similar trend, with ARES showing the highest mean value (38.21 mm) and NAFIS the lowest (29.77 mm).

### 3.1.2. Agro-Morphological Characteristics of Seed Bulbs in the Field and after Multiplication

#### Variability of measured traits

**Table 3** presents the overall results for germination duration, germination rate, and establishment success for all seed bulbs of the onion varieties. Germination duration ranged from 6 to 49 days, with a mean of 23.02 days and a CV of 45.1%. The average germination rate was relatively high (83%) with low variability (CV = 11%). The establishment success rate was 68% with a CV of 28%, with extreme values ranging from 32% to 100%.

**Table 3.** Mean ( $\pm$ standard deviation), minimum, maximum, and coefficient of variation (CV) of germination duration, germination rate, and establishment success.

Parameters	Min.	Max.	Mean $\pm$ Standard deviation	CV (%)
Dg (j)	6	49	23.02 $\pm$ 10.38	45.1
%Ger	72%	96%	83% $\pm$ 0.09	11
%Réu	32%	100%	68% $\pm$ 0.19	28

**Table 4.** Mean ( $\pm$ standard deviation), minimum, maximum, and coefficient of variation (CV) of germination duration, germination rate, and establishment success by variety.

Parameters/Onion varieties	Min.	Max.	CV (%)	Mean $\pm$ Standard deviation	F	P-value
Dg (j)   ARES	8	39	38	22.31 $\pm$ 8.52 <sup>a</sup>		
Dg (j)   NAFIS	11	35	38	25.92 $\pm$ 9.88 <sup>a</sup>	0.641	0.528
Dg (j)   SAFARI	6	49	53	23.30 $\pm$ 12.32 <sup>a</sup>		
%Ger   ARES	80%	92%	7	85% $\pm$ 0.06 <sup>a</sup>		
%Ger   NAFIS	72%	72%	0	72% $\pm$ 0.00 <sup>b</sup>	16.431	0.002
%Ger   SAFARI	88%	96%	4	92% $\pm$ 0.04 <sup>a</sup>		
%Réu   ARES	56%	100%	27	77% $\pm$ 0.020 <sup>a</sup>		
%Réu   NAFIS	72%	72%	0	72% $\pm$ 0.00 <sup>a</sup>	1.594	0.269
%Réu   SAFARI	32%	76%	41	53% $\pm$ 0.22 <sup>a</sup>		

**Table 4** shows that germination duration (Dg) of the three varieties ranged between 22.31 and 25.92 days, with SAFARI exhibiting the highest variability for this trait (CV = 53%). Significant differences were observed among onion varieties for

germination and establishment success rates. The ARES variety showed a relatively high germination rate (average 85%) with low variability (CV = 7%), while its success rate was less uniform (CV = 27%). In contrast, the NAFIS variety displayed remarkable stability for both parameters, with constant germination and success rates of 72%. The SAFARI variety showed an excellent mean germination rate (92%) with low variability (CV = 4%), but its success rate was both the lowest (average 53%) and the most variable (CV = 41%).

#### Morphological characterization of onion seed bulbs during and after multiplication

**Table 5** presents the overall results for yield in number of bulbs and bulb weight after multiplication (Mbam). The yield in number of bulbs (Rend (Nb)) was 2.23 bulbs per plant, with high dispersion (CV = 52.8%), ranging from 1 to 5. Bulb weight after multiplication (Mbam) showed the highest variability (CV = 71.7%), with a mean of 31.76 g and values ranging from 2.55 g to 126.63 g.

**Table 5.** Mean ( $\pm$ standard deviation), minimum, maximum, and coefficient of variation (CV) after multiplication.

Parameters	Min.	Max.	CV (%)	Mean $\pm$ Standard deviation
Rend (Nb)	1	5	52.8	2.23 $\pm$ 1.18
Mbam (g)	2.55	126.63	71.7	31.76 $\pm$ 22.78

**Table 6** shows the yield in number and weight of bulbs for the different varieties. Regarding the yield in number of bulbs (Rend (Nb)), ARES had the highest mean with 2.48 bulbs per plant, followed by SAFARI (2.03) and NAFIS (1.46), the latter also showing high variability (CV = 53%).

**Table 6.** Mean ( $\pm$ standard deviation), minimum, maximum, and coefficient of variation (CV) after multiplication by variety.

Measured traits	Min.	Max.	CV (%)	Mean $\pm$ Standard deviation	F	P-value
Rend (Nb)   ARES	1	5	52	2.48 $\pm$ 1.28 <sup>a</sup>		
Rend (Nb)   NAFIS	1	3	53	1.46 $\pm$ 0.78 <sup>b</sup>	5.633	0.004
Rend (Nb)   SAFARI	1	4	47	2.03 $\pm$ 0.95 <sup>ab</sup>		
Mbam (g)   ARES	4.74	126.63	65	36.27 $\pm$ 23.64 <sup>a</sup>		
Mbam (g)   NAFIS	11.59	84.96	66	37.24 $\pm$ 24.55 <sup>a</sup>	5.565	0.004
Mbam (g)   SAFARI	2.55	66.76	79	21.53 $\pm$ 16.94 <sup>b</sup>		

For total bulb weight, NAFIS recorded a mean of 37.24 g, slightly higher than ARES (36.27 g), indicating that these two varieties produced bulbs of relatively similar size. In contrast, SAFARI had a lower mean weight of 21.53 g. NAFIS and ARES showed low variability, while SAFARI exhibited high variability with a CV of 79%.

Variance analysis indicated significant differences among varieties for most of the traits studied, except for germination duration (Dg), where no significant difference was observed ( $P = 0.528$ ). For bulb weight (Mb), ARES had the highest value (29.324 g), significantly higher than NAFIS (17.926 g) and SAFARI (18.846 g). Regarding bulb length (Lb), ARES (45.830 mm) and NAFIS (45.244 mm) were significantly higher than SAFARI (39.736 mm).

Bulb width (lb) followed a similar trend, with ARES (38.208 mm) statistically superior to NAFIS (29.772 mm) and SAFARI (32.397 mm). The yield in number of bulbs (Rend (Nb)) for ARES (2.48 bulbs) was significantly higher than NAFIS (1.46 bulbs), while SAFARI (2.03 bulbs) had an intermediate value. For bulb weight after multiplication (Mbam), no significant differences were observed between varieties, despite variability in means ranging from 21.53 g (SAFARI) to 37.24 g (NAFIS).

These results indicate that the varieties differ in several important traits related to growth and bulb production, highlighting substantial diversity in how the varieties develop and produce bulbs.

### 3.1.3. Relationships among the Traits Studied in Onion Varieties

Correlation analysis revealed several significant relationships among the different variables studied. **Table 7** shows that bulb weight (Mb) was highly positively correlated with bulb width (lb) ( $r = 0.972$ ) and yield in number of bulbs (Rend (Nb)) ( $r = 0.8045$ ), while it was weakly correlated with bulb length (Lb) ( $r = 0.512$ ). In contrast, its correlation with germination duration (Dg) was negative ( $r = -0.790$ ).

**Table 7.** Correlation matrix among onion traits.

Variables	Mb (g)	Lb (mm)	lb (mm)	Dg (j)	Mbam (g)	%Ger	%Réu	Rend (Nb)
Mb (g)	<b>1</b>							
Lb (mm)	0.512	<b>1</b>						
lb (mm)	<b>0.972</b>	0.297	<b>1</b>					
Dg (j)	-0.790	0.121	-0.912	<b>1</b>				
Mbam (g)	0.393	<b>0.991</b>	0.167	0.253	<b>1</b>			
%Ger	0.214	-0.729	0.437	-0.768	-0.814	<b>1</b>		
%Réu	0.607	<b>0.993</b>	0.404	0.007	<b>0.969</b>	-0.646	<b>1</b>	
Rend (Nb)	<b>0.8045</b>	-0.026	<b>0.947</b>	-0.995	-0.160	<b>0.703</b>	0.088	<b>1</b>

Mb: Bulb weight; Lb: Bulb length; lb: Bulb width; Dg: Germination duration; Rend (Nb): Yield in number of bulbs; Mbam: Bulb weight after multiplication.

Bulb length (Lb) was strongly associated with bulb weight after multiplication (Mbam) ( $r = 0.991$ ) and establishment success rate (%Réu) ( $r = 0.993$ ), but negatively correlated with germination rate (%Ger) ( $r = -0.729$ ). Similarly, bulb width showed a strong positive correlation with bulb weight ( $r = 0.972$ ) and Rend (Nb) ( $r = 0.947$ ), and a strong negative correlation with Dg ( $r = -0.912$ ).

Germination duration (Dg) exhibited negative correlations with several variables, including Mb ( $r = -0.790$ ), lb ( $r = -0.912$ ), %Ger ( $r = -0.768$ ), and Rend (Nb) ( $r = -0.995$ ). Bulb weight after multiplication (Mbam) was positively correlated with Lb ( $r = 0.991$ ) and %Reu ( $r = 0.969$ ), but negatively with %Ger ( $r = -0.814$ ). Finally, yield in number of bulbs (Rend(Nb)) was positively correlated with Mb ( $r = 0.8045$ ), lb ( $r = 0.947$ ), and %Ger ( $r = 0.703$ ), but negatively correlated with Dg ( $r = -0.995$ ).

### 3.1.4. Linear Regression of Yield in Number of Bulbs as a Function of Base Bulb Weight

**Table 8** shows that the model is overall significant, with an F-statistic of 18.50 and a p-value less than 0.0001, indicating that bulb weight has a significant effect on the variable studied. The regression coefficient for bulb weight is 0.0395 ( $p < 0.0001$ ), demonstrating a statistically significant influence.

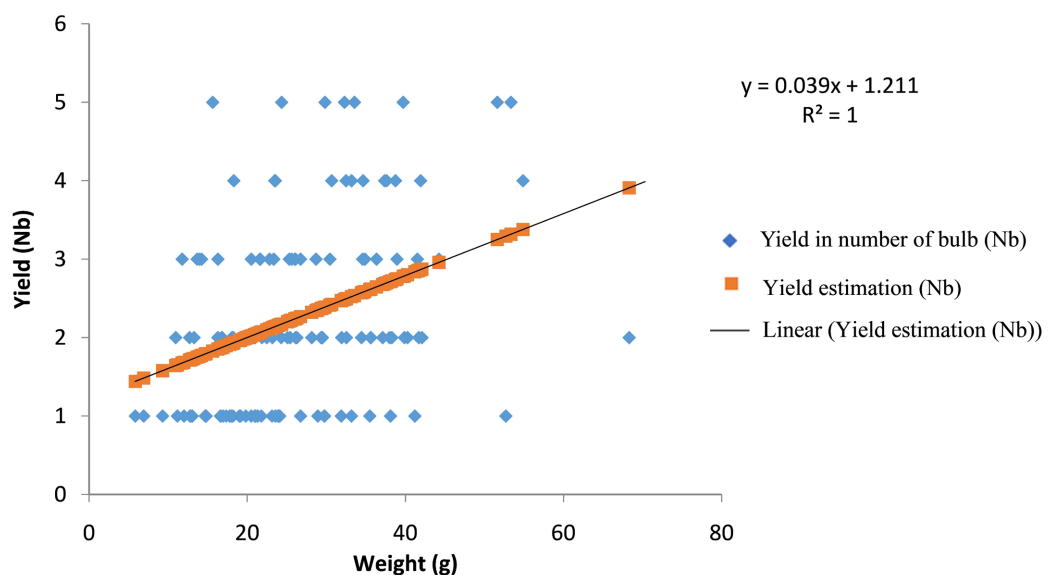
**Table 8.** Linear regression test of yield in number of bulbs as a function of base bulb weight.

	Valeur	Standard error	T-statistic	Probability	F	P-value
Constant	1.21108	0.26011072	4.65601725	<0.0001	18.503	<0.0001
Weight b (g)	0.03947925	0.00917809	4.30146919	<0.0001		

**Figure 3** illustrates the correspondence between predicted and observed values, represented by orange and blue points, respectively. The black linear line indicates the estimated trend of yield as a function of bulb weight. The resulting regression equation is:

$$\text{Yield (Nb)} = 0.0395 \times \text{Mb} + 1.2111$$

where each coefficient represents the impact of bulb weight on the yield in number of bulbs.



**Figure 3.** Linear regression line of yield in number of bulbs as a function of base bulb weight.

## 4. Discussion

The results obtained indicate that the three bulb varieties studied ARES, NAFIS, and SAFARI exhibited different behaviors for bulb morphological traits at various stages of development, from sowing to harvest. Before seed multiplication, ARES bulbs were on average heavier than those of NAFIS and SAFARI. This difference can be explained by a higher capacity to accumulate nutrient reserves during formation, which is essential for ensuring a good start after sowing [14]. These reserves provide the plant with the energy required for the early growth stages, especially in the absence of photosynthesis at the very beginning. In contrast, SAFARI produced the smallest and lightest bulbs, possibly due to slower development or a lower capacity to store useful biomass in the bulb [15].

Germination duration, the number of days a bulb takes to start sprouting, does not appear to be related to its size or final weight. This confirms [16], who noted that rapid germination is not always an advantage. A bulb that sprouts quickly does not necessarily multiply efficiently; other factors, such as internal bulb quality or root development capacity, are more critical.

Regarding seed bulb germination, SAFARI exhibited a high germination rate. However, this variety also showed high variability in establishment success. Many SAFARI seedlings failed to develop into new bulbs, indicating that while the variety starts well, it struggles to maintain growth. It appears more sensitive to external conditions such as moisture, temperature, or soil structure, making its performance unstable and less reliable [15]. In contrast, ARES and NAFIS demonstrated both good germination rates and good establishment success, suggesting better physiological resilience and ability to cope with environmental fluctuations [14].

The results indicate that heavier bulbs generally produce a greater number of new bulbs. This may be explained by a higher capacity to activate cell division and tissue multiplication, leading to the formation of new organs [17]. A larger bulb acts as a more powerful engine, with more energy, more active tissue, and thus greater potential to produce multiple secondary bulbs. These findings are consistent with [18], who showed that using heavier base seed bulbs significantly enhances productivity, especially in soilless cultivation. This confirms that initial bulb quality is a key determinant of yield, sometimes even more than soil conditions.

After seed bulb multiplication, ARES and NAFIS continued to produce heavier bulbs than SAFARI. This suggests that they are more efficient in capturing and utilizing soil resources (water, minerals) and converting them into biomass. In SAFARI, the bulbs remained smaller, possibly due to less effective root development or a lower metabolic efficiency for nutrient conversion [16]. Considerable variability was also observed among individuals of this variety, suggesting strong environmental influence: some plants multiplied well, while others did not, affecting uniformity in bulb number yield [17]. These results align with [19], who found that some onion bulb varieties show highly variable performance depending on

soil texture and irrigation regime. The marked sensitivity of SAFARI may therefore be comparable to varieties less adapted to unstable cultivation conditions, highlighting the importance of selecting varieties suited to local conditions.

Data analysis showed that the wider a bulb, the heavier it is, which is logical since a wider bulb has more volume for development and storage of biomass. This relationship is particularly evident because width appears to better reflect bulb filling [15]. Bulb length also plays a role but is not as reliable an indicator of weight; a bulb can be long without being dense, while a wide bulb is more likely to have well-formed tissue.

Finally, regression analysis helped clarify the relationship between initial bulb weight and the number of bulbs produced. The regression model highlighted a clear positive relationship: an increase in initial weight is generally associated with higher yield in number of bulbs. This confirms that the quality of bulbs used as seed is fundamental to successful cultivation. This observation is consistent with [19], who showed that using heavier seeds can significantly improve productivity in agricultural systems, including soilless cultivation. Therefore, this analysis reinforces the idea that initial bulb weight is an essential selection criterion in vegetative multiplication programs, as it reliably predicts final yield potential.

## 5. Conclusion

This study aimed to evaluate the performance of three bulb varieties—ARES, NAFIS, and SAFARI—used as base seeds, to analyze their agronomic performance and potential for vegetative multiplication. The results highlighted marked differences among varieties, both in initial bulb characteristics and in germination, growth, and final yield. ARES stood out for its heavier bulbs, uniform germination, and good yield, demonstrating excellent stability. NAFIS also exhibited balanced performance, while SAFARI, although showing good germination, displayed greater variability and lower adaptation to environmental conditions.

Correlation analysis helped clarify the developmental mechanisms of bulbs and identify key criteria for effective selection, notably emphasizing the importance of initial bulb weight in forming new bulbs. Moreover, regression analysis confirmed that the weight of the bulb used as seed is a predictive factor for yield in number of bulbs. This means that the heavier a bulb is at the start, the greater its potential to produce a large number of new bulbs.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- [1] Michel, P. and Claude, F. (2003) Histoires de légumes. Des origines à l'orée du XXI<sup>e</sup> siècle. INRA, 410 p.
- [2] Molas, C. (2009) Intoxications des carnivores domestiques dues aux denrées alimentaires consommées par l'homme. Thèse de Doctorat, Faculté de Médecine de Créteil, 142 p.
- [3] FAO (2023) Production de légumes, légumineuses et racines comestibles. FAOSTAT. Organisation des Nations Unies pour l'Alimentation et l'Agriculture. <https://www.fao.org/faostat/en/#data/QC>
- [4] AtlasBig (2023) Pays par production d'oignons. <https://www.atlasbig.com/fr-ch/pays-par-production-doignons>
- [5] Dupaigne, B., Baris, P. and Liagre, L. (2006) Etude sur la compétitivité des filières agricoles dans l'espace UEMOA. IRAM, 296 p.
- [6] Dosso, M., Nandjui, J. and Avadí, A. (2019) Understanding the Ivorian Market Vegetables Production: Is the Agroecological Transition the Right Strategy? *Agricultural Systems*, **218**, Article 103971. <http://doi.org/10.1016/j.agsy.2024.103971>
- [7] Bi, D. (2015) La culture d'oignon en Côte d'Ivoire reste encore timide (Interprofession). <https://news.abidjan.net/articles/550120/la-culture-doignon-en-cote-divoire-reste-encore-timide-interprofession>
- [8] Rongead and Chigata (2014) Redynamiser les productions, l'accès au marché et le conseil agricole pour les filières vivrières et commerciales du nord de la Côte d'Ivoire. [https://reca-niger.org/IMG/pdf/Diagnostic\\_de\\_la\\_Filiere\\_Oignon\\_en\\_cote\\_d\\_Ivoire\\_RONGEA\\_D\\_2014.pdf](https://reca-niger.org/IMG/pdf/Diagnostic_de_la_Filiere_Oignon_en_cote_d_Ivoire_RONGEA_D_2014.pdf)
- [9] FAO (2022) Crops and Livestock Products. <https://www.fao.org/faostat/en/#data/QC>
- [10] Delbosc, G. (1983) Les semences certifiées. Système de multiplication et contrôle. *Oléagineux*, **38**, 119-129. <https://agritrop.cirad.fr/453757/1/Id453757.pdf>
- [11] Boko-Koiadia, A.N.N., Cisse, G., Koné, B. and Séry, D. (2016) Variabilité climatique et changements dans l'environnement à Korhogo en Côte d'Ivoire: Mythes ou réalité? *European Scientific Journal*, **12**, 158-176. <https://doi.org/10.19044/esj.2016.v12n5p158>
- [12] Koffi, B., Yao, M. and Diomandé, O. (2019) Analyse de la performance des variétés d'oignon ARES et SAFARI en conditions semis-arides. *Journal des Sciences Agronomiques*, **28**, 123-137.
- [13] Gomez, K.A. and Gomez, A.A. (1984) Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley & Sons, 17. [https://www.academia.edu/2456341/statistical\\_Procedures\\_for\\_Agricultural\\_Research](https://www.academia.edu/2456341/statistical_Procedures_for_Agricultural_Research)
- [14] Lamichhane, J.R., Debaeke, P., Steinberg, C., You, M.P., Barbetti, M.J. and Aubertot, J. (2018) Abiotic and Biotic Factors Affecting Crop Seed Germination and Seedling Emergence: A Conceptual Framework. *Plant and Soil*, **432**, 1-28. <https://doi.org/10.1007/s11104-018-3780-9>
- [15] Kale, R.B., Khandagale, K., Ramadas, S., Gavhane, A.D., Gedam, P. and Mahajan, V.

- (2024) Unravelling Physiological Disorders in Onion and Garlic: Critical Assessment and Bibliometric Visualization. *Frontiers in Plant Science*, **15**, Article 1500917. <https://doi.org/10.3389/fpls.2024.1500917>
- [16] Moradi-Shakoorian, Z., Delshad, M., Diaz-Perez, J.C., Askari-Sarcheshmeh, M., Nambeesan, S. and Mamedi, A. (2023) Onion (*Allium cepa* L.) Seed Germination Affected by Temperature and Water Potential: Hydrothermal Time Model. *Journal of Applied Research on Medicinal and Aromatic Plants*, **35**, Article 100495. <https://doi.org/10.1016/j.jarmap.2023.100495>
- [17] Taiz, L., Zeiger, E., Møller, I.M. and Murphy A. (2015) *Plant Physiology and Development*. Sixth Edition, Sinauer Associates, 210-250. [https://sirsyedcollege.ac.in/crm/public/uploads/download\\_image/H8aTDrHeKuTo-gISO7SE1r80gjP2dmU.pdf](https://sirsyedcollege.ac.in/crm/public/uploads/download_image/H8aTDrHeKuTo-gISO7SE1r80gjP2dmU.pdf)
- [18] Edelstein, M., Peretz, J. and Kamenetsky, R. (2012) Effect of Seed-Bulb Weight on Growth and Yield of Onion (*Allium cepa* L.) under Different Cultivation Systems. *Scientia Horticulturae*, **136**, 17-22. <https://doi.org/10.1016/j.scienta.2012.01.024>
- [19] Beye, N.F., Sètonджи Vodounnou, F.N., Kane, A., Tiréra, H., Diop, R., Ndao, S., *et al.* (2024) Effect of Cultivation Practices on the Quality of Onion Bulbs (*Allium cepa* L.) Produced at Two Sites in Northern Senegal: Evaluation of Morphological and Physicochemical Parameters. *Journal of Agriculture and Food Research*, **15**, 101022. <https://doi.org/10.1016/j.jafr.2024.101022>