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Genetic Characterization of the Kada-Goudami Lineage for the Improvement of Onion (*Allium cepa* L.) Cultivation in the Sudano-Sahelian Zone of Cameroon

Gabriel Moutsavara[a*], Philippe Kosma[b], Jean Baptiste Noubissié Tchiagam[c]

[a,b]*University of Maroua, National Advanced School of Engineering of Maroua, Department of Agriculture, Livestock and Related Products, P.O. Box 46 Maroua, Cameroon*

[c]*University of Ngaoundéré, Faculty of Sciences, Department of Biological Sciences, P.O. Box 454 Ngaoundéré, Cameroon*

[a]*Email: godjeved@gmail.com*, [b]*Email: philippekosma@yahoo.fr*, [c]*Email: jbnoubissitch@yahoo.fr*

Summary

The objective of this study is to analyze the possibilities of growing the Kada-Goudami lineage for improved onion production in the Sudano-Sahelian zone of Cameroon. From multi-location trials conducted during the 2019 to 2020 rainy and dry seasons at the Nguetchewe, Palar and Pitoa sites. Yield and phenology characteristics were evaluated to select the Kada-Goudami lineage as a "rescue seed, catch-up cultivar or alternative crop". The popularized varieties (El Kara, Goudami and Violet de Galmi) served as controls. Vegetative development, phenology and yield components of the different genotypes were evaluated and compared in a randomized complete block design in each site during the two seasons. Extended heritability values and expected gains from selection were determined. Variance analyses show the significant differences between the genotypes tested. The mean value of heritability of the studied traits is overall high ($h^2 \geq 0.84$) and the expected gains from selection are relatively appreciable. This shows the possibility of effective selection and genetic improvement. The Kada-Goudami lineage appears to be better adapted to the dry season in our growing area, but it can also be used as a cool season crop (October-January).

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* Corresponding author.

This study shows that the Kada-Goudami lineage is promising for improving onion production in the Sudano-Sahelian environment of Cameroon.

Key words: *Allium cepa* L.; Kada-Goudami; heritability; improvement; Sudano-Sahelian zone; Cameroon.

Résumé : L'objectif de cette étude est d'analyser les possibilités de culture de la lignée Kada-Goudami pour une amélioration de la production de l'oignon en zone soudano-sahélienne du Cameroun. A partir des essais multilocaux conduits au cours de la saison pluvieuse et sèche en 2019 et 2020, sur les sites de Nguetchewe, Palar et Pitoa. Les caractéristiques du rendement et de la phénologie ont été évaluées en vue de sélectionner la lignée Kada-Goudami comme « semence secours ou cultivar de rattrapage voire culture alternative ». Les variétés vulgarisées (El Kara, Goudami et le Violet de Galmi) ont servi des témoins. Le développement végétatif, la phénologie et les composantes du rendement des différents génotypes ont été évalués et comparés dans un dispositif en blocs complets randomisés dans chaque site pendant les deux saisons. Les valeurs d'héritabilité au sens large et les gains attendus de la sélection ont été déterminées. Les analyses de variance montrent les différences significatives entre les génotypes testés. La valeur moyenne de l'héritabilité des caractères étudiés est globalement élevée ($h^2 \geq 0,84$**)** et les gains attendus de sélection sont relativement appréciables. Ce qui montre la possibilité d'une sélection efficace et d'amélioration génétique. La lignée Kada-Goudami semble mieux adaptée en saison sèche dans notre zone de culture mais on peut aussi l'utiliser comme culture de saison fraiche (Octobre-Janvier). Cette étude montre que la lignée Kada-Goudami est prometteuse pour améliorer la production de l'oignon en milieu soudano-sahélienne du Cameroun.

Mots clefs: *Allium cepa* L. ; Kada-Goudami ; héritabilité ; amélioration ; zone soudano-sahélienne ; Cameroun.

1. Introduction

Native from south-western central Asia and grown as a vegetable for its bulbs and leaves, onions are a crop found throughout the world [1], it is cultivated on an area of 3.35 million hectares with a production of 742.51 million tons due to its adaptation to all seasons of the year [2]. To the conditions present in different latitudes, to climatic variations and to different cropping systems, onion varieties have undergone hereditary modifications and have been adapted over the centuries to different environments [3]. Its introduction into Sub-saharian, and more specifically into Cameroon, was made by Muslim traders in a system of border exchanges in the 19th century [4]. This crop with several benefits both in terms of health, socio-cultural and economic, is thus used for specific purposes [5]. Indeed, onions are used as seasoning in different types of dishes, eaten raw to calm hunger and alleviate colds or flu. In medicine, onions are involved in reducing the risk of cardiovascular diseases. Thanks to its medicinal value, its simple and varied modes of consumption, as well as its moderate price, the onion is the most consumed root vegetable in the world [6]. Today, the advent of the COVID-19 pandemic has amplified the choice of this crop for its therapeutic virtue [7]. In Cameroon, onion cultivation is the first speculation that generates a particular development because its contribution to the GDP is 40% and employs 70% of the active population [8;9]. It is also a way out of the crises that threaten and become more serious [10]. It is a key to the Cameroonian economy, at least in its food and foreign exchange self-sufficiency [9]. In Cameroon, particularly in the Far North and North production basins, onion and garlic cultivation occupy a prominent place among market garden crops. Production of this crop increased by about 70% between 2011 and 2017 due to the expansion of cultivation areas and the modernization of cultivation techniques [11]. Its productivity in 2018 is 12 to 18 t/ha on 83% of land used for onion cultivation [11]. However, arable land under the influence of climate change and cropping systems in the Sudano-Sahelian zone of Cameroon is progressively being modified and degraded, resulting in variation in production according to variety, season and environment. Climate change is a major factor in genotypic variation and microclimate, a factor in varietal adaptation, are a constraint to onion productivity. For this reason, a system of seeking new land for the dissemination of cultivars from one environment by moving cultivation areas to another under the effect of global warming [12], stable genotypes, is adopted by farmers. This variation and periodic maladjustment of cultivars in their environment and the method by which farmers preserve and manage phylogenetic resources remains a great challenge in the research field [5]. Plant genetic resource management is not limited to collecting cultivars of cultivated native species and wild relatives. But it also addresses existing modifications within cultivars at their sites of establishment. In short, it includes the study of environmental, gene flow interactions, as well as the knowledge and know-how of farmer populations who are actors in the selection and dissemination of locally cultivated plants [13] cited by [5]. On the other hand, climatic fluctuations [14] further lead to cultivar variations in less favorable regions with low ecological potentials for agricultural production. Moreover, at the time of sowing in a nursery and of transplanting in culture, the quantity of seeds always comes to miss. The seed of the Goudami variety, which is widely distributed in this area, is often insufficient to cover the demand. Thus, farmers resort to seeds from the first year of the crop cycle. These seeds are considered as a means of limiting early sales and catching up. The insufficiency of varieties distributed in quantity is a recurring difficulty for farmers, thus limiting the intensification of production. As far as we know about onion cultivars in Cameroon, specifically in the onion production basins, no evaluation has been made of the Kada-Goudami lineage. The Kada-Goudami lineage is used as a fish food source and occasionally as a cultivar. Field trials should be conducted in order to valorize the cultivation of the Kada-Goudami lineage, considered as an alternative or catch-up crop following insufficiency or lack. Specifically, the aim is to characterize the Kada-Goudami lineage being improved in the production basins through an evaluation of the heritability effect of quantitative characteristics and seasonality. Since the vigor of a genotype is very variable according to the pedoclimatic conditions in which it is implanted and the cultivation technique to which it is subjected [15].

2. Material and methods

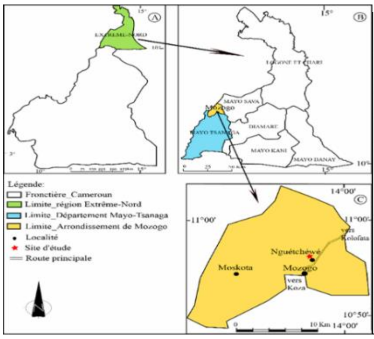
2.1. Choice and location of the study area

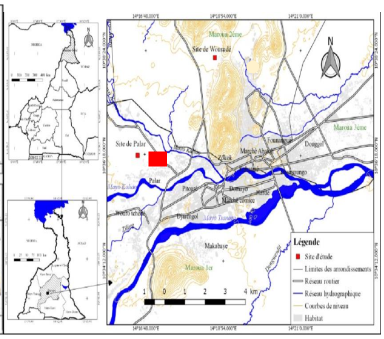
The Far North region (Garoua, Maroua, and Ngaoundere) is an excellence area in Cameroon [16]. The intensive production basins that are in the Far North and North regions and provide 85% of the onion in Cameroon [10]. The experiment was conducted at three sites, representing the predominant onion growing area of the national production, characterized by different microclimates and relief:

- The Department of Mayo-Tsanaga: the locality of Nguetchewe, in the Mozogo Council (Figure 1), with geographic coordinates: 10° 57'58" North; 13° 54' 24" East and an altitude of 508 m, with variable annual rainfall of 800 to 900 mm, a Sudano-Sahelian climate, and the Mont Mandara zone [17].

- The Department of Diamaré: The locality of Palar, in Maroua 1er council (Figure 2), which lies between the 10th and 13th of Latitude North and the 13th and 15th of Longitude East. The Diamaré plain has an average annual temperature of 39° [17]

- The Department of Benue: the locality of Pitoa (Figure 3), chief town of the Pitoa Arrondissement, has the following geographical coordinates: 9º23'.00.0" Latitude North and 13º32'00.0" Longitude East and an altitude of 295m. The average monthly temperature evolving from 26°C in August to 40°C in March (extreme temperatures: 17°C to 40°C). The soils are sedimentary (highly eroded) and alluvial types (the Benue Valley) [17].





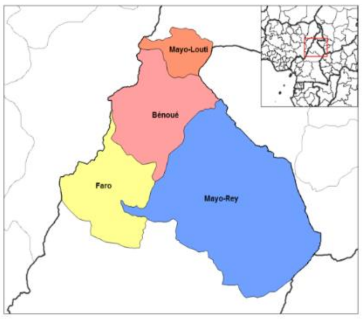


Figure 1: Map of the Nguetchewe study area, 2016. **Figure 2**: Map of the Palar study area, 2014). **Figure 3:** Map of the Pitoa study area 2014.

2.2. Materials

2.2.1. vegetal material

The plant material used consists of four onion genotypes. The cultivar El Kara was purchased in Kano, Nigeria. Violet de Galmi, a variety from France, was purchased from a Semagri approved store in Maroua. The local Goudami and the Kada-Goudami lineage were collected from onion producers in Nguetchewe. The Kada Goudami is derived from the seminal multiplication of Goudami plants obtained from seeds and is locally called "Goudami fake".

Tableau1: characteristics of the seeds of 04 genotypes given by the farmers

Genotypes	Provenance	Local name	Type of seed	Production season	Crop cycle
1	Nguetchewe	Goudami	Original	dry	2 years, short
2	Nguetchewe	Kada-Goudami	Fake Goudami	Dry and Fresh	1 year and short
3	France	Violet Galmi	Enhanced	Dry	1year, short
4	Nigeria	El kara	Certified	Rainy	1 year, short

1= Goudami; 2= Kada-Goudami lineage; 3= Violet of Galmi; 4= El Kara.

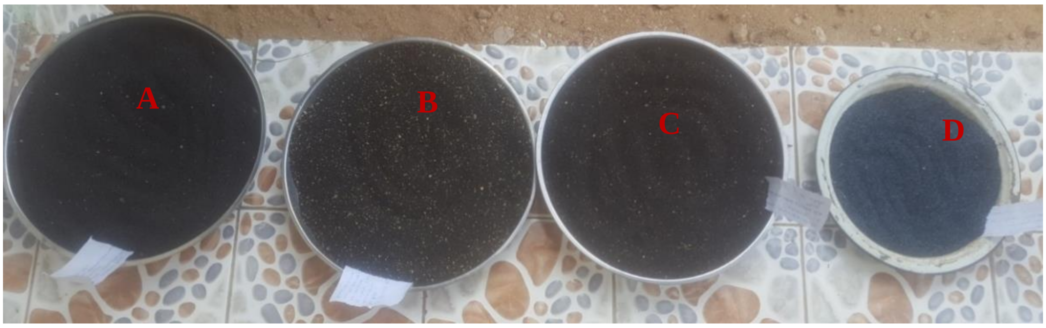


Figure 4: Seeds of 04 onions genotypes: A= Goudami; B= El Kara; C= Kada-Goudami; D = Violet de Galmi. (Picture, 2020).

2.2.2. Culture material used

From the nursery phase to the harvest, some specific tools for vegetable cultivation were used. The land was plowed with a pair of oxen pulling the plow. Large and small hoes were used for planking, weeding, watering and harvesting. The beds were sized using 100m of string. During the nursery phase, irrigation was carried out using a watering can that was filled with water. And during the phase of cultivation in open field, the motor pump ensured the irrigation until the harvest.

2.2.3. Measurement tools for the studied parameters

The raw data was collected using the following tools: The ruler, tape measure, electronic precision balance and calipers etc.

2.3. Methods

2.3.1. Experimental device

- ***In nursery***

The experimental design is a Fisher block with 4 treatments (cultivars) and 3 randomized replications. Each block is a composition of bins. Each bin is 1 m long and 0.75 m wide, in which seeds were spread in a nursery. The distribution of cultivars in the plots was done in a random manner. The spreading in a nursery of 130g of seeds of each cultivar was done on August 10, 2019/2020 for the cultivars El kara and Kada-Goudami and on October 15, 2019/2020 for the cultivars Violet de Galmi, Goudami and Kada-Goudami which is under test. The chemical fertilizer NPK formula 20-10-10 (20% N, 10% P_2O_5 and 10% K_2O), was used in three times for plant growth in a nursery and in the field.

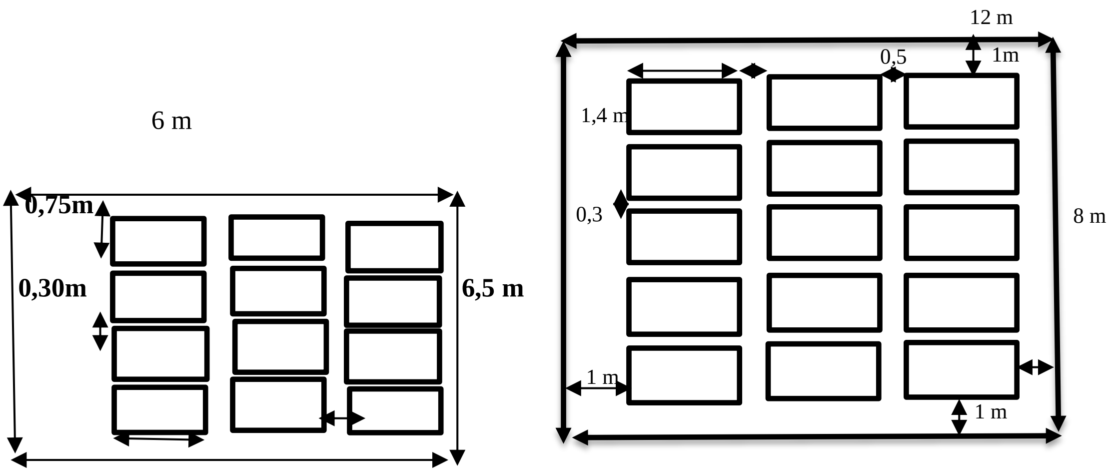


Figure 5

- ***In the fields***

The experimental set-up in the field is also a Fisher block with 4 treatments, subdivided into 02 plots for the rainy season trial and 03 plots for the dry season trial. Each plot has an area of 30 m^2. Transplants were transplanted into the 2.8 m² (1.4/2m) lockers on September 18, 2019/2020 for the rainy season cultivars and December 22, 2019/2020 for the off-season cultivars Adjacent plots were separated by a 0.5 m corridor serving as a water way during watering. Consecutive compartments are distanced by 30 cm bunds. This approach is that of the technical sheets developed by the Burkinabes [18] and Nigeriens [5].

- ***Conduct of the trial***

The trials were conducted at the Nguetchewe, Palar and Pitoa sites in two crop years of varietal production and on alluvial, sandy clay and sandy loam soils [17]. Three control cultivars including one rainy season, two dry season and the Kada-Goudami lineage of unknown season were nursed. Total emergence after sowing was observed around August 20 and October 22, 2019/2020. Field transplanting was done on September 18 and December 26, 2019/2020. Healthy, thick transplants between 15-20 cm in height were selected and transplanted into the trays. The spacing between the rows of the pots and between pots of the same row were respectively about 15 cm and 10 cm. This means a maximum density of about 280 transplants per locker for a number of about 8400 transplants per site.

- ***Crop maintenance***

Nursery bed cover straws were removed and the remnants discarded from the germinated plants. Watering was done in two ways: manually with the watering can during the first two weeks from the two to four leaf stage. Mechanically, using the motor pump: from the four-leaf stage, transplanting until the maturity of the bulbs in the field. Exceptionally, during the rainy season, the watering of the nurseries was done only manually. In rainy season, 50 g/m² of NPK mineral fertilizer (20-10-10) was applied around the second week after emergence in sowing and around the 4th week. In dry season, 100 g/m² of NPK mineral fertilizer (20-10-10) was applied in 04 applications from the two-leaf stage to transplanting. Weeding was done manually on a daily basis: in the nursery and in the field, it was done manually. In the field, weeding was carried out with small hoes of smaller size than the one between the clusters and was done once a month.

- ***Data collection***

From emergence in the nursery to harvest, observations and measurements were made on the indicator traits of the yield components and the phenomenon of bolting which is the main discriminating trait. On an electronic precision scale, the weights of the bulbs and the seeds were weighed. The size of the plants was determined with a 1m graduated ruler. The plants with flowering stems and those without (sterile plants) were counted and chosen as focal criteria for selection.

2.3.1. Germination rate

The used equation is that of [19]: Germination rate in seeding = (number of germinated seeds x 100)/number of seeds applied.

2.3.2. Transplanting

Transplantation = number of desired plants x 100 / germination percentage [19].

2.3.3. Performance

The performance focused on the qualitative and quantitative productivity traits.

2.3.4. Heritability and expected gain from selection

Heritability and expected gain from selection were determined by applying the method of [20] and [21], respectively.

- $h^2 = (\sigma^2I-\sigma^2i)/\sigma^2I$. Where, σ^2I= inter-variate variance and σ^2i = intra-variate variance
- $G = K \times (\sigma^2p)^{1/2} \times h^2$. With, G = gain selection; K= differential Standardized selection or differential selection in units of standard deviation, the value of which depends on the percentage of selection (K = 1.76 for a selection intensity of 10%); σ^2p = Phenotypic variance in the initial population; h^2 = Heritability in the broad sense.

2.3.5. Evaluation of genetic correlations

The used equation is the Pearson Bravais:

$$r(X_1, X_2) = \frac{\sum_{i=1}^{n}(x_{1i}-\overline{x_1})(x_{2i}-\overline{x_2})}{\sqrt{\sum_{i=1}^{n}(x_{1i}-\overline{x_1})^2}\sqrt{\sum_{i=1}^{n}(x_{2i}-\overline{x_2})^2}}$$

The significance of the value of r ($-1 < r < 1$) is assessed from the theoretical value read from the statistical table according to the corresponding degree of freedom [22].

2.3.6. Data analysis

MS EXCEL and XLSTAT 2014.5.02 were used for the data analysis. When a significant difference was observed between cultivars for a studied trait, the ANOVA was completed by the Fisher grouping of means test [23].

3. Results and discussion

3.1. Rainy season trial

3.1.1. Agromorphological analysis

- ***Sprouting***

Table 2 shows the suitability of germinated seeds in the nursery. From this table, it appears that no significant difference exists between environments (P-Value = 0.06 > 0.05). But a significant difference was noted within cultivars (P = 0.003). The cultivar El Kara (56.47±0.24%) germinated more than the lineage Kada-Goudami (12.86±0.55%) in all sites. This difference would be related to the effects of the season which influences negatively on the Kada-Goudami lineage by the excess of water causing tegumentary dormancy and salinization on the seeds. These observations have been highlighted by [24]. The humidity would have affected the viability of the harvested seeds during conservation. This finding was made by [25]. This result obtained does not corroborate that of [25] and those set by the European directives for the marketing of onion seed, whose threshold is 65%. The low germination in nurseries could come from seeds that have not reached full maturity as a result of pests. The same observation was made by [24], when they noted heavy attacks of viruses (*Allium virus* 1) that significantly reduce the crop by producing very small and poorly fed seeds at the end of the vegetation period.

- ***Transplanting (Table 2)***

The majority of Kada-Goudami seedlings were destroyed by excessive rainwater. Transplanting was poor in each site. The difference observed between cultivars would still be related to the season. The same result was obtained in 2016, during our experimental trials conducted in some localities of Mayo-Tsanaga, Benue and Vina, where the Goudami kada and its Goudami parents did not succeed in transplanting. The non-resistance of the Kada-Goudami lineage is thought to be due to its genotypic constitution, whose genes do not tolerate the aggressiveness and acidity of rainwater. This remark was emphasized by [25], who mentioned that the onion fears excessive acidity, the onion does not support the salinity of the soil.

Harvest Index (Table 2)

After a few days of transplanting, transplants of the Kada-Goudami lineage were progressively killed by rainwater. No transplants of the Kada-Goudami lineage were harvested (0%). While the control cultivar was harvested by 54.88%. This means that Kada-Goudami is not a rainy season crop. The agromorphological characteristics studied and compared, attest that all onion cultivars have a specific defined periodicity, a limited adaptability in time. Our results are in agreement with those [25], when he established the technical recommendation sheet for onion production of different varieties.

Table 2: Sprouting, transplantation and harvest index

Site	Cultivar	Germ (%)	Transplants (%)	harvest index (%)
N	1	$68{,}40\pm0{,}37^{b}$	$47{,}23\pm1{,}23^{a}$	$67{,}71\pm2{,}48^{c}$
P	1	$48{,}80\pm0{,}19^{a}$	$64{,}92\pm1{,}47^{b}$	$42{,}74\pm1{,}6^{a}$
I	1	$52{,}20\pm0{,}16^{a}$	$47{,}23\pm1{,}10^{a}$	$54{,}19\pm2^{b}$
Mg		**$56{,}47\pm0{,}24^{ab}$**	**$53{,}12\pm1{,}26^{ab}$**	**$54{,}88\pm2{,}06^{abc}$**
N	2	$14{,}60\pm0{,}77^{a}$	$1{,}21\pm0{,}01^{a}$	$0{,}00\pm0{,}00^{a}$
P	2	$13{,}79\pm0{,}61^{a}$	$1{,}39\pm0{,}06^{a}$	$0{,}00\pm0{,}00^{a}$
I	2	$10{,}28\pm0{,}56^{a}$	$1{,}79\pm0{,}04^{a}$	$0{,}00\pm0{,}00^{a}$
Mg		**$12{,}89\pm0{,}64^{a}$**	**$1{,}46\pm0{,}03^{a}$**	**$0{,}00\pm0{,}00^{a}$**

N = Nguetchewe; P = Palar; I= Pitoa; 1= El Kara; 2= Kada-Goudami lineage; Germ = sprouting; Mg=mean genotype in environnement. Means followed by the same letter are not significantly different at the 5% threshold.

3.2. Dry season trial

3.2.1. Agromorphological analyses

- ***sprouting (Table 3)***

Table 3 showed the expression of sprouted seeds. From this table, it appears that no significant difference exists between cultivars and their sites (P-Value = 0.26 > 0.05). But a significant difference was noted between cultivars (P = 0.0038). The cultivars Goudami (71.16±4.90%) and Violet de Galmi (80±1.98%) have a higher germination rate than the Kada-Goudami lineage (47.26±3.62%). This difference would be due to the production system of the seeds from which they are derived. Seeds from mother bulbs with a 2-year cycle have good germination capacity and high viability compared to seeds from the first year of cultivation. The same remark was made by [25]. The time to full maturity of the flowers giving the kada-Goudami lineage was shortened by harvesting. Insecticides and pesticides used during treatment against pests and diseases have occasionally limited the presence of pollinating insects, the consequences of which would have resulted in fertilized flowers with low germination power. This analysis is consistent with those of [25]. Seeds of the Kada-Goudami lineage would have undergone inbreeding depression as heterogeneity in culture was observed. For resulting from reproduction by allogamy, there is this possibility of maintaining a level of genetic heterogeneity that could promote its adaptability to the hazards of the environment [5].

Table 3: Sprouting, transplantation and harvest index

Sites	Cultivars	Germ (%)	Transplants (%)	harvest index (%)
N	1	76,13±1,93^{b}	32,30±0,42^{a}	45, 35±0,63^{a}
P	1	72,86±2,02^{b}	32,30±0,44^{a}	67,50±0,6^{c}
I	1	64,48±2,28^{a}	32,30±0,50^{a}	54,64±1,67^{b}
Mg		**71,16±4,90**^{ab}	**32,32±0,45**^{a}	**55,83±3,53**^{abc}
N	2	49,73±3,53^{a}	32,30±0,64^{a}	67,85±1,41^{b}
P	2	49,92±3,54^{a}	32,30±0,64	89,64±1,41^{c}
I	2	42 ,13±3,46^{a}	32,30±0,76^{a}	36,42±0,89^{a}
Mg		**47,26±3,62**^{a}	**32,30±0,68**^{a}	**52,61±1,2**^{abc}
N	3	82,70 ±0,63^{b}	32,30±0,46^{a}	92,14±2,48^{b}
P	3	85,96 ±0,52^{b}	32,30±0,46^{a}	97,38±3,38^{b}
I	3	71,34±0,85^{a}	32,30±0,67^{a}	67,66±2,27^{a}
Mg		**80,00 ± 2,00**^{ab}	**32,30±0,53**^{a}	**85,72±0,58**^{a}

N = Nguetchewe; P = Palar; I= Pitoa; 1= El Kara; 2= Kada-Goudami lineage age; 3= violet of Galmi, Germ = sprouting; Mg=mean genotype in environment. Means followed by the same letter are not significantly different at the 5% threshold.

- ***Transplants and harvest index (%) (Table 3)***

Variance Analysis of transplanting rates and harvest index of 32% and 52% respectively between the control cultivars and the Kada-Goudami lineage prints out or shows no difference. The Kada-Goudami lineage appears to be a dry season crop in terms of its adaptability and resistance to seasonal effects. Although no difference was observed, there was a reduction in average yield. Onion diseases such as root rot (*Pyrenochaeta terrestris*), downy mildew (*Peronospora destructor*) and *Fusarium* (*Fusarium sp*), were the most represented and caused the death of some plants in cultivation. These results were revealed by [26] and [27].

- ***Flowering (Table 4)***

Variance Analysis shows that variability exists within collections with significant differences recorded (P-Value= 0.00 < 0.05). In contrast, there were no significant differences between cultivars and environments. The existence of flowers in culture could be from the impacts of environment and genotype. The cultivar Kada-Goudami and its parents Goudami revealed a high rate of flowering plants, respectively 30.82±0.49% and 12.73±0.50%. The bolting is doubled in the kada-Goudami lineage when the floral scape is emitted. The induction of flowers would be due to temperature and cultural practices. This corroborates the result of [28], who found that the capacity to produce flowers is variable according to cultivar, environment and time. It is mainly induced by low temperatures during growth. Cultivation practices have an effect on early flowering, e.g. fertilizer application can contribute to flower induction. This finding was made by [29], who showed that in

Nigeria, bolting could be increased by excess nitrogen or phosphorus fertilizers. Seasonality depends on the cultivar whose expression is a function of its genotypic constitution. The varietal effect on flower induction is well demonstrated by [30], who reported that under the same pedoclimatic conditions, the number of flowers is higher on Violet de Galmi than on Blanc de Galmi. Galmi violet expressed a very low flowering rate (5.59±0.48%) compared to the cultivars Goudami and its lineage age. It is much more observed at the end of February and March when watering is repeated two to three times a week. This result is revealed by [28], who pointed out that a difference in bolting rate exists depending on the donor and the mode of peasant seed production. He states that seeds from plants in the first year of the crop cycle have a high aptitude for early bolting. This result was obtained by [29], having noted and obtained a percentage of the plants having manifested the floral stem: 99,17 ± 1,44% against 60,00 ± 9,10% in 2007 and 94,92 ± 5,13% against 29,35 ± 4,40% in 2009, respectively for the annual and biennial seeds of violet of Galmi.

- ***Bulb weight (g) (Table 4)***

Table 3 illustrates the performance of agro-morphological traits. Between the control cultivars and the Kada-Goudami lineage, no significant differences within cultivars (P = 0.56 < 5%) and between cultivars and sites (P = 0.72 >5%). This result does not corroborate those of [30], in his experiment, when he agreed that the impact of cultivar on bulb yield levels was very highly significant (P < 0.01). He observed a significant difference of 6.5 t/ha at the 5% threshold and 8.6 t/ha at the 1% threshold between cultivar yield levels. The non-existence of differences between cultivars could mean that the cultivation period and adaptability of the Kada-Goudami lineage tested. These results are related to those of [25], which showed that genotypes with an average yield are better adapted to the cultivation period.

- ***Plant size (Cm) (Table 4)***

High height plants were recorded in the Kada-Goudami lineage (49.52±1.04 cm) compared to the control cultivars which had an average height of 46.17±1.18 cm. The analysis with Fisher's test shows that a significant difference was noted between the cultivars in the implantation sites (P-Value=0.00). However, there was no significant difference between cultivars and sites (P-Value=0.56 < 5%). The variability observed within cultivars would be related to the nature of the genes characterizing the variety. For example, Kada-Goudami showed flower stalks that were emitted from the first two weeks of transplanting. The distribution of fertilizers and irrigation would be unevenly distributed at the level of the plants, the work was conducted on clay, sandy and silty soils that have an influence on productivity. These results are consistent with those of [29]. The size of the plant is an indicator character of varietal productivity.

- ***Number of leaves (Table 4)***

For the character number of leaves, there was no significant difference within cultivars (P=0.18>5% of the same site but a significant difference between cultivars from one site to another. The kada-Goudami lineage with its parents expressed an identical number (15±0.81) compared to Galmi violet (14±0.81). Our results coincide with those of [5], when he finds that all onion cultivars grown in Niger have a number between about 12 and 23 leaves. In this study, the identification of the cultivation period of the Kada-Goudami lineage would be similar to that of its Goudami relatives.

Table 4: Agro-morphological parameters studied

Sites	Cultivars	PHF (%)	PS (%)	PB (kg)	TP (Cm)	NF
N	1	16,18±0,5[b]	83,81±0,34[b]	494,71±0,66[b]	40,8±0,96[a]	15±0,89[a]
P	1	6,34±0,45[a]	94,18±0,73[b]	421.62±0,67[a]	53,44±0,83[b]	13±0,63[a]
I	1	15,68±0,56[b]	60,78±0,51[a]	490,12±0,52[a]	44,28±0,92[a]	17±0,63[a]
Mg		**12,73±0,50**	**79,59±0,52**	**492,41±2,29**	**46,17±1,18**	**15±0,81**
N	2	36,31±0,47[b]	18,94±0,33[a]	563.50±0,79[b]	45,52±0,6	15 ±0,41[a]
P	2	30,67±0,28[b]	77,29±0,6[c]	799,38±1,09[c]	55,00±1,09	14±0,89[a]
I	2	25,48±0,72[a]	54,91±1,01[b]	282,07±0,82[a]	48,04±0,95	16±0,89[a]
Mg		**30,82±0,49**	**50,38±0,66**	**548,31±2,34**	**49,52±1,04**	**15±0,81**
N	3	7,85±0,5[a]	77,16±0,8[a]	350,90±0,87[b]	41,02±0,82	13±0,89[a]
P	3	3,40±0,33[a]	98,95±0,73[b]	557,98±0,67[c]	57,6±0,61	13±0,89[a]
I	3	5,57±0,6[a]	94,44±0,59[b]	301,79±0,66[a]	41,72±0,89	16±0,63[a]
Mg		**5,59±0,48[a]**	**90,18±0,70**	**403,56±1,77**	**46,78±0,82**	**14±0,81**

N = Nguetchewe; P = Palar; I= Pitoa; 1= Goudami; 2= Kada-Goudami lineage; 3= Violet of Galmi; Mg=mean of the genotype in the environment; PS= Sterile plants; PB= Weight of the bulbs; TP=Size of the sterile plants; NF= Number of leaves; PHF= plants having a floral stem.

Means followed by the same letter are not significantly different at the 5% threshold.

3.2.2. Genetic analysis

1. Heritability and expected gain from selection of yield components

- ***Flowering plants, Sterile plants, Bulb weight, Plant size, Leaf number (Table 6)***

Broad-sense heritability values are significant [0,5;0,99] in all environments except for the plant size trait (h^2=0, 45) in the Palar site in 2019. The broad sense heritability rate is very high (h^2= 0.99), confirming the preponderance of genetic variability. However, environmental impacts are more notable on plant size in 2019 at Palar. The selection of the Kada-Goudami lineage is therefore effective. This finding was made by [31], in their work on tomato variety selection. The high values of heritability in the broad sense suggest that the variations observed for these physical characteristics are mainly genetic in origin and the influence of the environment is weak [32].

2. Expected gain from selection (Table 6)

From the heritability values and considering a selection rate of 10%, an expected selection gains of 8,78% can be expected to increase commercially sterile plants. Furthermore, a reduction gains of 30,42% can also be expected in flowering plants to limit bolting in cultivation compared to the average of genotypes with a normal distribution [21]. This rate shows that the selection for genetic improvement of sterile plants cannot be continuous until the stability of the character that its parents Goudami. This result would allow an investigation of the screening of the Kada –Goudami lineage for genetic improvement. This implies that the genetic base should be broadened by a genotype-environment interaction study.

3. Genetic correlation (Table 5)

All positive correlation values observed between the tested traits are those between plant size, sterile plants, bulb weight, number of leaves and plants without floral scape. These correlations are non-significant (r < 0, 6). Thus, there is facilitation of genetic improvement of positively correlated traits. Indeed, [33] stated that if a trait has a strong genetic correlation with yield in environments and that trait has higher heritability than yield, it would be more efficient to select lineage for that specific trait. There is this possibility of obtaining the early-cycle, high-yielding Kada-Goudami cultivar that produces the large bulbs so sought after by producers and consumers. On the other hand, the non-significant negative correlations indicate that the cultivars studied occupy different positions and therefor [34] have a different genetic constitution.

Table 5: Correlation matrix of the studied traits

Variables	PHF (%)	PS (%)	PB (g)	TP (Cm)	NF
PHF (%)	1				
PS (%)	-0,19^{ns}	1			
PB (kg)	-0,04^{ns}	-0,09^{ns}	1		
TP (Cm)	-0,224^{ns}	0,25^{ns}	0,52*	1	
NF	0,41^{ns}	-0,37^{ns}	-0,29^{ns}	-0,45^{ns}	1

PS=Sterile plants; PB=Bulb weight; TP=Sterile plant size; NF=Number of leaves; PHF=Plants with flowering stem;

ns=not significant. *=significant.

Table 6: Summary of heritability and expected gains from selection of 05 studied traits of 04 onion genotypes.

CARACTERES ETUDIES	**GENOTYPES**	**NGUETCHEWE**		**PALAR**		**PITOA**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**
	1	28,8±3,56^{b}	25±1,58^{b}	31,2±1,3^{b}	23,4±3,04^{c}	26,2±3,19^{b}	20,4±2,3^{b}
	2	36,8±2,94^{c}	65,2±2,94^{c}	37,2±2,86^{bc}	60,2±4,32^{d}	34,2±4,26^{c}	27,2±3,11^{c}
Flowering stem (%)	3	13,2±1,92^{a}	10,8±1,09^{a}	12,8±2,16^{a}	5,4±1,14^{a}	18,4±2,7^{a}	10,6±2,07^{a}
	4	34,8±3,56^{c}	24,8±1,78^{b}	28,6±3,2^{b}	20,6±3,04^{b}	30,8±3,96^{b}	19±2,54^{b}
	Mg	**28,4±2,99**	**31,45±1,8**	**27,45±2,3**	**27,4±2,88**	**27,4±3,52**	**19,3±2,50**

			4	**8**			
	h²	**0,91**	**0,99**	**0,94**	**0,98**	**0,72**	**0,86**
	G(%)	**18,58**	**26,88**	**19,50**	**30,42**	**12,18**	**20,51**
Sterile plants (%)	1	158±3,39^{c}	113±2,23^{b}	153,8±4,81^{c}	106,8±3,03^{c}	155,8±3,76^{d}	78,4±2,07^{a}
	2	134±2,73^{b}	135,6±2,96^{c}	125,8±3,7^{b}	142,8±4,14^{b}	123,8±4,54^{b}	153,4±4,77^{c}
	3	176,8±3,42^{d}	176,8±3,42^{d}	153,4±3,2^{c}	153,8±3,42^{d}	148,4±3,91^{c}	168,4±2,4^{d}
	4	109±2,23^{a}	99,4±3,5^{a}	108,2±1,48^{a}	97,8±3,7^{a}	107,8±3,11^{a}	110,2±2,28^{b}
	Mg	**144,45±2,94**	**131,2±3,02**	**135,3±3,29**	**125,3±3,57**	**133,95±3,83**	**127,6±2,88**
	h²	**0,98**	**0,99**	**0,97**	**0,98**	**0,96**	**0 ,99**
	G(%)	**6,54**	**7,74**	**5,99**	**7,19**	**5,99**	**8,78**
Bulb weight(g)	1	139,98±2,62^{c}	95,32±3,65^{a}	142,88±3,86^{b}	78,36±3,4^{a}	118,02±1,93^{b}	112,6±3,24^{c}
	2	134,78±3,8^{c}	98,86±2,44^{a}	141,28±3,2^{b}	106,16±3,39^{d}	114,62±4,26^{a}	92,18±1,73^{b}
	3	101,52±3,28^{a}	92,14±3,32^{a}	136,74±1,93^{a}	97,38±4,28^{b}	110,98±2,39^{a}	67,66±3,99^{a}
	4	142,1±4,14^{b}	120±3,34^{b}	130,02±3,6^{a}	110±3,8^{c}	125,98± 3,23^{c}	90,98±2,9^{b}
	Mg	**129,59±3,46**	**101,58±3,18**	**137,73±3,14**	**97,97±3,71**	**117,4±2,95**	**90,85±2,96**
	h²	**0,96**	**0,93**	**0,68**	**0,92**	**0,76**	**0,97**
	G(%)	**5,71**	**5,74**	**2,10**	**6,27**	**2,91**	**8,07**
Plant size (cm)	1	60,44±3,7^{c}	44,6±3,84^{a}	62,22±2,9^{b}	52,8±2,68^{a}	55,58±3,31^{a}	41±2,44^{a}
	2	55,04±2,85^{b}	48,02±2,43^{a}	58,42±2,53^{a}	52,2±3,96^{a}	54,18±2,47^{a}	51,28±2,75^{b}
	3	42,6±2,6^{a}	52,6±2,3^{b}	55,2±1,19^{a}	53±2,91^{a}	48,8±3,27^{a}	42,2±1,3^{a}
	4	67±3,24^{d}	61,8±2,86^{d}	57,74±1,51^{a}	65,7±3,7^{b}	62,8±4,08^{b}	57,4±3,64^{b}
	Mg	**56,27±3,09**	**51,75±2,85**	**58,39±2,03**	**55,92±3,31**	**55,34±3,28**	**47,97±2,53**
	h²	**0,90**	**0,84**	**0 ,45**	**0,73**	**0,66**	**0,88**
	G(%)	**9,14**	**7,86**	**2,31**	**5,91**	**5,09**	**9,03**
Number of leaves	1	19,4±1,3^{b}	16,4±1,14^{a}	17±1,39^{a}	14,6±1,14^{a}	17±1,64^{a}	16,6±1,81^{a}
	2	16,4±2,3^{a}	16,4±2,4^{b}	16,6±1,96^{a}	14,4±1,67^{a}	16,8±0,86^{a}	14±1,58^{a}
	3	15,4±1,07^{a}	14,8±2,16^{a}	13,2±1,48^{a}	14,4±1,14^{a}	13,4±0,3^{a}	15,4±1,07^{a}
	4	21±1,34^{b}	22,4±2,3^{b}	19,2±1,58^{a}	19±1,58^{a}	15±0,4 ^{a}	11,6±1,14^{a}
	Mg	**18,05±1,50**	**17,5±2,00**	**16,5±1,60**	**15,6±1,38**	**15,55±0,8**	**14,4±1,4**
	h²	**0,63**	**0,62**	**0,57**	**0,61**	**0,67**	**0,55**
	G(%)	**9,95**	**11,44**	**9,64**	**10,48**	**9,99**	**9,93**

1= Goudami; 2= Kada-Goudami lineage; 3= Galmi's violet; h²= heritability; Mg= Mean of genotype in environment; G (%) = Expected gain from selection

4. Conclusion

The Kada-Goudami lineage, collected by massal selection in the first year of cultivation of Goudami, was conducted in the Sudano-Sahelian zone of Cameroon. The trial focused on the identification of genetic and crop year production characteristics for selection for improvement. The interest was to characterize Kada-Goudami for use as a "rescue seed, catch-up crop or alternative crop". From the analysis of the defined traits and in comparison, to the controls, it appears that Kada-Goudami reflects similar characteristics to its parents. The high heritability and the expected gains from selection evaluated confirm the effectiveness of the selection of this lineage for improvement and dissemination. Kada-Goudami, selected as a cultivar, is more adaptable in the dry season, but to a lesser extent, it can be used as an intermediate crop (cool season). To ensure this selection and to make a wide dissemination, it would be better to evaluate the genotype-environment interactions over a long period of time in order to determine with more confidence the performance of this lineage, since significant variations within the same cultivar are not limited to cultivars, since the adaptability of a genotype is influenced by climatic hazards.

5. Recommendation

In light of all these observations, it is suggested that control of irrigation techniques that take into account soil type, season or microclimate would be a way to reduce floral induction. The Kada-Goudami lineage is a dry season or cool season cultivar. For wide release, it would be necessary to include a genotype-environment interaction analysis to assess its stability and adaptability in environments.

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