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Optimal Evaluation of the Production of Five Main Varieties of Onion (*Allium Cepa.* L) Under Different Organo-Mineral Fertilizers in Cameroon

Derik Pierre Sakatai[1, 2, *], Wassouo Felix Alain[2], Yakouba Oumarou[2], Ndouvahad Lazare[2], Olina Bassala Jean Paul[1], Abdou Bouba Armand[2]

[1]Institute of Agricultural Research for Development, Agricultural Research Center, Maroua, Cameroon

[2]Department of Agriculture, Animal, Husbandry and Derived Products, National Advanced School of Engineering, University of Maroua, Maroua, Cameroun

Email address:

spierrederik@yahoo.com (D. P. Sakatai)

[*]Corresponding author

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Abstract: The low yield observed in the main varieties of onion grown in the Sudano-Sahelian zone of Cameroon is one of the major challenges to take up. The evaluation of the factors (land, capital and labor) of production would allow the optimization of the production of onion bulbs of 5 main varieties in the Sudano-Sahelian zone of Cameroon. The experimental used is a randomized completely block design with a split-plot arrangement. Each block of the plots repeated four times consisted of 13 and 05 modalities relating to the fertilizers and varieties. The results of the comparison of the average yields carried out with the XLSTAT software reveal that at the 5% level of significance, the average yield values in t/ha are significantly different between the treatments applied. The multi-variety analyses (DFA and HAC) revealed 03 distinct classes within 05 onion varieties tested. After storage, linear programming (GAMS software) shows that it would be more profitable to apply FM2: NPK+TE 21-9-11-5S-1.5MgO-0.15B_2O_3 and FM3: NPK 12-14-19-3.5MgO-0.15B respectively on *Violet* de *Galmi* and *landrace* (*Goudami local*) with a better combination of production inputs giving a surplus of a profit margin of 474810 FCFA compared to the direct sale of onion bulbs. For this optimal solution (986,040 CFA francs) after storage, only the capital relating to materials and equipment, and that of seed purchase would have provided marginal productivity "Shadow price" of the order of 28.625 CFA francs and 14.154 CFA francs respectively. To complete this study, it would be important to test the different doses of these fertilizers on the different varieties according to the textural and structural classification of the soil.

Keywords: Optimization, Linear Programming, Marginal Productivity, Onion, Sudano-Sahelian

1. Introduction

Onion cultivation occupies more than 9 million hectares each year worldwide [1]. Its world production is around 742.51 million tons [2]. This volume of production contributes both to GDP and to the improvement in incomes of many rural households in some producing countries [2]. In Africa, the onion contribution is of the order of 19 to 47 billion CFA francs for Niger [3], 35 billion CFA francs for Senegal [4], 4.38 billion to 24.87 billion for Burkina Faso [5]. In Cameroon precisely in the Far North, onion production is estimated at 120,000 tons/year, which represents nearly 60% of national production (200,000 tons/year), with a contribution to GDP that is between 10 and 19 billion CFA francs/year [6]. This economic value creates allows small rural producers in the Far North to meet their basic needs such as nutrition, clothing purchases, health care costs and school fees within agricultural households [7]. In view of the multiple importance that this family *liliacea* presents for Cameroon in general and for the population of the Far North region in particular, this speculation would be more of a good lever for improving the incomes of small rural producers if the yield were improved. Unfortunately, its production is very fluctuating and less efficient due to certain production constraints [8]. Insufficient information in relation to the nature and quantity of amendment and especially to the types of mineral fertilization is a hindrance to the improvement of low yield of onion bulbs which vary between 7.9 t/ha and 11 t/ha [7]. In addition, the lack of control of the technical practice production and the inefficiency of the management of the factors of production are also the causes of low onion yield in the Far North [9, 10, 7, 11]. On the other hand, in some West African countries there are high yields (32 t/ha to 35 t/ha in Niger [4]; 21.2 t/ha in Mali and 20 t/ha in Burkina Faso [12]. However, these sub-Saharan countries have edapho-climatic conditions almost similar to those of the Far North region of Cameroon. In Niger, for example, it had recorded average temperatures that vary between 12°C and 44°C per year [3]. The texture of the soil is predominantly sandy. Rainfall varies between 150 and 800 mm and the climate is Sahelo-Sudanese. While in the Far North, it has been recorded an average rainfall that oscillates from 800mm to 1000 mm /year, the texture of the soil is sandy-clay, temperatures vary between 11°C to 45°C and the climate is Sudano-Sahelian [7]. In addition, the main varieties ("*Goudami*"; *violet* de *Galmi* and "*Chagari*") grown in Cameroon [13] and those (*Goudami*, *violet* de *Galmi*, *blanc* de *Galmi* and *blanc* de *Soumarana*) found in some sub-Saharan countries in Africa are identical [14]. Despite these almost similar pedoclimatic and varietal characteristics, low yields are recorded in the Far North compared to those of Niger, Mali and Burkina Faso. In the Sudano-Sahelian zone of Cameroon, others noted that the yields of onion bulbs can reach 27 to 38 t/ha with the *Goudami local* "*Landraces*" in a peasant environment ([15, 16]). Recent studies of the characterization on 05 onion varieties conducted [11] in the locality of Gazawa in the inter-season also revealed high yields (50.48 t/ha and 49.24 t/ha) with these local varieties (*Chagari* and *Goudami* respectively). Despite these efforts to improve the production of onion bulbs, the problem of declining onion yield persists in peasant areas. Yet, one of the alternative solutions is the choice of the best fertilizers that give high bulb yields and more storage. It is in this perspective that this research work on the optimization of the production of the main onion varieties by the application of mineral and organic fertilizers in the Far North Cameroon area is inscribed. It is a question of testing 05 varieties of onion according to the fertilizer in order to identify the one (s) that will (have) to increase not only the bulb yield at harvest but also the most storage.

2. Material and Methods

2.1. Sites Characteristics

The study was conducted at the application farm of the Agricultural Research Center for Development (CRAD) of IRAD Maroua in Meskine. This locality is part of one of the large onion production zone in the Maroua 1st department of Diamaré, Far North Region Cameroon. It is a canton that lies between 10.5426 North latitude and 14.2504 East longitude. It is bounded to the East by Makabaye, to the West by Katouwal, to the North and South by the district of Gazawa. It is located at an altitude of 414 m. The annual rainfall is 1209 mm [17]. The climate is Sudano-Sahelian, characterized by a long dry season (November to June) and a short rainy season (July to October). The results of the soil analyses at LAB-FASA (University of Dschang) carried out in August 2021 showed that the textural classification of the soil of the test site is silt-sandy (20.457% clay; 53.071% silt and 26.471% sand). The vegetation is mostly grassy with the presence of some shrubs of *Feidherbia Albida*.

2.2. Plant Material Used in the Test

The vegetable material used consists of 5 different varieties of onion:

1. Two local varieties (*Goudami* and *Chagari*) that were used as control,
2. Two varieties introduced by the seed company *SEMAGRI* (*Violet de Galmi* and *Safari*),
3. A variety of *Goudami* that is certified by MINADER and produced by a seed producer in Tchontchi Garoua;

Each onion ecotype used constituted the modality of the variety factor of which y1 = *Chagari*; y2 = *Goudami Local*; y3 = *violet de Galmi*; y4 = *Safari* and y5 = *Goudami certifié*.

2.3. Experimental Design

The experimental used is a randomized complement block design with a split-plot arrangement compound two controlled factors. The first factor is the onion variety consisting of 05 modalities (y1; y2; y3; y4; y5). The second factor is organic and mineral fertilizer with 13 modalities (FM1: NPK 22-10-15-5S-1B; FM2: NPK+TE 21-9-11-5S-1.5MgO-0.15B_2O_3; FM3: NPK 12-14-19-3.5MgO-0.15B; FM4: NPK 13-13-21-3S-0.01Zn-0.01B; FM5: NPK 23-10-5-2MgO+7.5S-0.3Zn; FM6: NPK 14-23-14-6S-1B_2O_2; FM7: NPK 15.4-25.6 (Calcium Nitrate Borate); FM8: NPK 20-10-10+6SO_3; FM9: NPK 21-8-12-2MgO+2.7S+2.5CaO; FM10: NPK 11-11-22+5.5MgO; FM11(FO): control; FM12(FO1): Cowpat; FM13(FO2): sheep droppings). The combination of the modalities of the controlled factors gave a total of 65 treatments repeated four times. The experimental units measured 1.5m*1m with 1m of spacing between the blocks and 0.75m of the alternating ridges of the grooves separating the experimental units between them.

2.4. Conduct of the Study

The trial was conducted in the October 2020 to April 2021. Nurseries of different varieties of onion (*Goudami local*; *Violet* de *Galmi*; *Safari*; *Goudami* certifié) were installed on October 21, 2020 in a randomized completely design with three repetitions. The installation of the germinator required the incorporation of the Super Bastion (Systemic pesticide against nematodes, insects and mites) into the seedling beds. The seeds were measured and weighed (0.066kg) before being seeded in the plots with the same dimensions (1.20*1m). Irrigation of the germinator was done using an 11-liter watering can every day until the date of transplanting. Transplanting to the experimental field took place on November 27, 2020. At 20 days after transplanting (JAR), the first fertilization was done on the fly at a dose of 250 kg/ha for each mineral fertilizer and 20t/ha for organic fertilizers [18]. The second fertilization took place at 46 days after transplanting (JAR) at a dose of 100kg/ha and 10 t/ha respectively for mineral and organic fertilizer. Irrigation of onions was done at a frequency of once a week for the first month and 02 times a week from 75 JAR (beginning of bulb formation) until harvest. Weeding took place at 36, 45 and 78 JAR respectively. The harvest took place after 136 JAR (April 12, 2021).

2.5. Data Collection

Some agronomic data were collected using the descriptor of the DHS (homogeneity and stability distinction tests) and VAT (agronomic and technological value) protocols for the species of *Allium cepa* [19]. From 50 Date after planting (DAP), growth and development parameters were measured at a frequency of 14 days. In addition, the above-ground biomass, the number of bulbs formed, the number of days of the beginning of bulb formation, the number of days of commercial bulb ripening (75% of lying non-flowering plants) and the percentage of seed rise, all these parameters were also evaluated at different stages of the vegetative cycle. On two different dates (2 weeks after the start of bulb formation and the commercial maturation of the bulbs), using a dig filled with water, the bulb formed was removed and cut at the collar, then immersed in the dig, by the phenomenon of Archimedes' thrust, the difference that exists between the final and initial volume gives the volume bulb on a given date. This is also done at commercial maturation, the difference between the volume bulb measured at matured and that measured 2 weeks after the bulb formation start date gave the bulb growth rate per treatment. This made it possible to identify the best treatment that accelerates the speed of growth of onion bulbs in size. At harvest (136 DAP), yield components such as bulb diameter and height were measured using a Vernier scale. The weight of 10 bulbs and the weight of onion bulbs per experimental unit were evaluated. The evaluation of inputs and outputs of onion bulb production/processing were valued at the local market price at the time of operations.

2.6. Data Processing and Analysis

The raw data was entered using the Microsoft office EXCEEL 2013. The average yield values obtained were reduced in tons per hectare. The description of each variety from the most distinctive qualitative variables (color of the leaves, shape and color of the bulbs, uniformity of the shape and color of the bulbs, …) was carried out according to the descriptor key of the DHS and VAT protocol [19, 14].

Analyses of variance by the XLSTAT software made it possible to compare the different treatments for their average yield (t/ha) of the onion bulbs. Multivariate analyses (AFD and CAH) were used to highlight explanatory features of difference between varieties according to their common characteristics. Cost/benefit analyses by treatment were carried out. The evaluation of the quantities of production inputs of onion bulbs giving the best marginal productivity was carried out through Linear Programming (LP) and using GAMS 22.0 software. The following mathematical formulas were used for the optimization of all production inputs to estimate the best combination of inputs and one of the optimal profits from onion bulb production. The design of the optimization problem revolves around the following axes.

1) The production of each variety of onion was carried out by applying the different fertilizer. By combining the fertilizer (13 modalities) with the varieties (05 modalities) of onion, we obtain 65 activities of our linear programming problem which are: (y1; y2; y3; y4; y5) * (FM1; FM2; FM3; FM3; FM4; FM5; FM6; FM7; FM8; FM9; FM10; FM11(FO0); FM12(FO1); FM13(FO2)).
2) For any i=1 to n; With Pi = selling price of a bag of 100 kg of bulbs in CFA francs of each activity, Bi= yield of onion bulbs in Kg of each activity, Xi = area in ha occupied by each activity of onion bulb production and Ci = all total costs in CFA Francs of production inputs invested in each activity of onion bulb production.
3) The function of the objective Z to be maximized in this study is formulated as follows:
4) *Objective function* ($\prod_j$)

$$\sum_{1=i}^{n} PiBiXi \text{ - } \sum_{1=i}^{n} Ci \tag{1}$$

Implies that:

$$\text{Maz Z} = \sum_{j=1}^{5} \prod yj \sum_{i=1}^{13} Xfmi \tag{2}$$

is the net gross surplus (in CFAF/ha) of the activity produced (exogenous variable/data for the financial year calculated from equation (1). The production of onion bulbs of the different varieties tested was under major constraints of depreciation of materials and equipment, the cost related to the purchase of seeds, the cost related to the purchase of fertilizers, the cost for the purchase of fuel and lubricant, the cost related to the purchase of pesticides and transport costs, and finally, the labor cost of cropping operations. Thus, the function of the objective Z will be maximized under the constraints listed above according to the equations after:

Availability of land (plot): the cumulative sum of the production of onion bulbs grown according to each variety and fertilizer is less than or equal to the available space that can occupy an activity (C_{land}).

$$\sum_{j=1}^{5} Land, yj \sum_{i=1}^{13} Xfmi \leq \text{C}_{\text{land}} \tag{3}$$

Where $Land,_{yjfmi}$; for all j, i ε [1-5]; [1-13], these variables correspond respectively to the amounts of capital used on a hectare to produce onion bulbs by a chosen activity.

Capital availability for the depreciation of materials and equipment: the summation of the capital shares for each activity multiplied by the area of the activity must be less than or equal to the capital (C_{amort}) available for the depreciation of the planter's materials and equipment

$$\sum_{j=1}^{5} Acap, yj \sum_{i=1}^{13} Xfmi \leq \text{C}_{\text{amort}} \tag{4}$$

Where $Acap,_{yjfmi}$; for all j, i ε [1-5]; [1-13] respectively, this corresponds to the amounts of capital useful for depreciation to produce one ha of a chosen activity.

Availability of capital for the purchase of seeds of onion varieties; this equation stipulates that the summation of the capital shares per unit of each activity multiplied by the area of the activity must be less than or equal to the capital available (C_{sem}) for the purchase of seeds by a planter

$$\sum_{j=1}^{5} Scap,yj \sum_{i=1}^{13} Xfmi \leq C_{sem} \quad (5)$$

Where $Scap,_{yjfmi}$; for all j, i ε [1-5]; [1-13] respectively, this corresponds to the amounts of capital useful for the purchase of seeds by a planter.

Availability of capital for the purchase of the fertilizers: the accumulation of the capital shares per unit of each activity multiplied by the area of the activity must be less than or equal to the capital available (C_{elf}) for the purchase of fertilizers by a planter:

$$\sum_{j=1}^{5} Ecap,yj \sum_{i=1}^{13} Xfmi \leq C_{elf} \quad (6)$$

Where $Ecap,_{yjfmi}$; for all j ε [1-5] and i ε[1-13] correspond respectively to the amounts of capital needed for the purchase of fertilizers to produce a ha with a treatment.

Availability of capital for the purchase of fuels and lubricants; this equation states that the summation of the capital shares per unit of each activity multiplied by the area of the activity must be less than or equal to the capital available (C_{carb}) for the purchase of irrigation fuels and lubricants by a planter:

$$\sum_{j=1}^{5} CLcap,yj \sum_{i=1}^{13} Xfmi \leq C_{carb} \quad (7)$$

Where $CLcap,_{yjfmi}$; for all j ε [1-5] and i ε [1-13] correspond respectively to the amounts of capital needed to produce one ha of the activity.

Capital availability for the purchase of pesticides and transportation costs; this equation states that the sum of the capital shares per unit of each activity multiplied by the area of the activity must be less than or equal to the capital available (C_{pest}) for the purchase of pesticides by a planter:

$$\sum_{j=1}^{5} PTcap,yj \sum_{i=1}^{13} Xfmi \leq C_{pest} \quad (8)$$

Where $PTcap,_{yjfmi}$; for all j ε [1-5] and i ε[1-13] correspond respectively to the amounts of capital used to purchase pesticides to produce one ha of the activity (applied treatment).

Availability for work; this equation states that the summation of the labor intensity shares in man per day per unit of each activity multiplied by the area occupied by treatment must be less than or equal to the quantities of man days available (C_{labor}) by a planter:

$$\sum_{j=1}^{5} Lcap,yj \sum_{i=1}^{13} Xfmi \leq C_{labor} \quad (9)$$

Where $Lcap,_{yjfmi}$; for all j ε [1-5] and i ε [1-13] correspond respectively to the quantities of man days needed to produce a ha by a given treatment.

Note: The endogenous variables to be estimated are: *Xy1fm1; Xy1fm2; Xy1fm3; Xy1fm4;.......; Xy1fm10; Xy1fm11; Xy1fm12; Xy1fm13; Xy2fm1; Xy2fm2;.......; Xy2fm10; Xy2fm11; Xy2fm12; Xy2fm13; Xy3fm1; Xy3fm2;.......; Xy3fm10; Xy3fm11; Xy3fm12; Xy3fm13; Xy4fm1; Xy4fm2;.......; Xy4fm10; Xy4fm11; Xy4fm12; Xy4fm13; Xy5fm1; Xy5fm2;.......;Xy5fm10; Xy5fm11; Xy5fm12; Xy5fm13* representing the areas (in ha) of onions to be produced according to each treatment applied. Where $Land_{yjfmi}$; $A_{cap, yjfmi}$; $S_{cap,yjfmi}$; $E_{cap,yjfmi}$; $CL_{cap,yjfmi}$; $PT_{cap,yjfmi}$; $L_{cap,yjfmi}$; all *j, i* ϵ [1-5]; [1-13].

3. Results

3.1. Characterization of Different Onion Varieties/Ecotypes

3.1.1. Description of Different Onion Varieties/Ecotypes According to Qualitative Characteristics

The table 1 presents the variability of qualitative traits observed in 05 onion varieties studied.

Table 1 shows that only the position of the maximum diameter and the color of onion bulb epidermis of the scales are similar for the five onion varieties tested. From the point of view of certain morphological parameters taken into account, the *Goudami local* variety showed intermediate characteristics between the four onion varieties tested. On the other hand, the *Safari* variety seems a little homogeneous and well calibrated compared to other onion varieties. Variations in leaf color were also observed within the onion varieties tested. These colors range from light green (*Chagari* and *safari*) to dark green (*violet* de *Galmi* and *Goudami certifie*) through the color green (*Goudami local*). In view of these analyses, certain resemblance traits are related to each other onion variety/ecotype on the basis of these qualitative parameters considered. Therefore, there are 05 groups that correspond to 05 different onion varieties from the global point of view (Table 1). The consideration of quantitative parameters could also be decided on this differentiation between onion varieties/ecotypes (individuals tested). Discriminating factor analysis (DFA) has made it possible to standardize the controlled factors in order to better group the varieties tested in class. Figure 1 shows the diagram of the discriminating factor analysis to categorize the onion varieties tested according to the observations of these quantitative parameters taken into account.

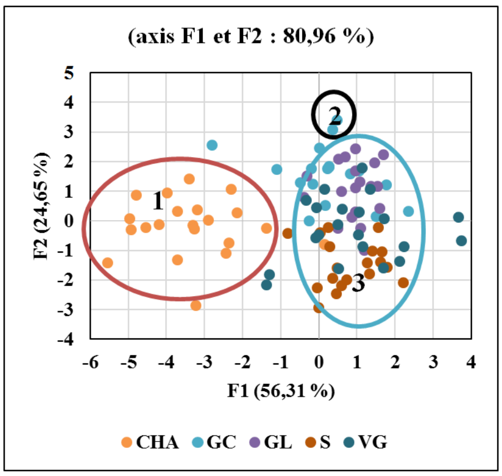

Figure 1. *Standardization of tested onion varieties. Note: y1 = Chagari (CHA); y2 = Goudami Local (GL); y3 = Violet de violet (VG); y4 = Safari (S); y5 = Goudami Certifié (GC).*

Table 1. *Qualitative morphological characteristics of 05 onion varieties.*

Parameters/ varieties	*Chagari*	*Goudami local*	*Violet* de *Galmi*	*Safari*	*Goudami Certifie*
Leaves color	light green	green	dark green	light green	dark green
Number of leaves	great	average	average	small	average
Length of leaves	short	average	average	average	average
Bulb separation	weak	weak	weak	weak	absent
Size of bulb	short	average	great	average	great
Height of bulb	short	average	great	average	high
Diameter of bulb	average	average	great	great	Great
Report H/D bulb	short	average	great	average	Great
Position of maximal diameter	in the middle	in the middle	in the middle	in the middle	in the middle
Collar thickness	large	cramped	cramped	cramped	cramped
General form of bulb	ovoid	ovoid	ovoid	ovoid	flattened
Top form of bulb	rounded	pointed/depressed	slightly pointed/flattened	slightly pointed	flattened
Dawn form of bulb	flattened	flattened	slightly conical/flattened	slightly conical	slightly conical/ pointed
Adherence of scale bulb	weak	weak	average	weak	weak
Thickness of dry scale bulb	average	average/mince	average	mince	mince
Color of basic scale	rose	brown/white	grey	grey	grey/brown
Color of the epidermis of the scales	reddish	reddish	reddish	reddish	reddish

AFD responsibility for the quantitative parameters measured made it possible to group the onion varieties into 03 groups. Following the axis of standardization, the distribution of onion varieties are explained to 56.31% by axis 1 (F1). While axis 2 (F2) explains this variability at 24.65%. Therefore, the set of two axis explains to 80.96% of variability of individuals (varieties) according to their common characteristics. The three classes constituted would make it possible to highlight and categorize homogeneous groups of morphotypes by hierarchical ascending classification (HAC).

3.1.2. Hierarchical Ascending Classification of Tested Onion Varieties

Figure 2 shows the dendrogram obtained from the hierarchical ascending classification (HAC) by the Unweighted Pair-Group Method with Arithmetic Mean (UPGAM). This method makes it possible to classify individuals who have a sufficient degree of similarity in the same group.

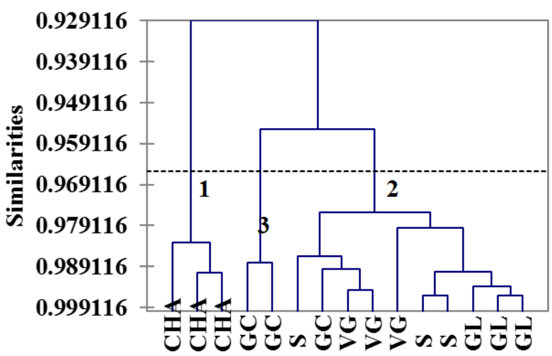

Figure 2. *Dendrogram of the hierarchy of different onion varieties tested.*

Note: y1 = *Chagari* (CHA); y2 = *Goudami Local* (GL); y3 = *Violet* de *Galmi* (VG); y4 = *Safari* (S); y5 = *Goudami Certifié* (GC).

The outcome of this dendrogram shows that the onion varieties tested are categorized into 03 distinct classes, each with its own characteristics. The observation of this dendrogram shows that the 03 classes constituted are composed of: class 1 composed essentially of *Chagari*; Class 3 consists of *Goudami Certifié* and Class 2 is a mixture of *Goudami Local* (GL); *Violet* de *Galmi* (VG); *Safari* (S) and *Goudami certifié* (GC). This differentiation observed within these different classes describes the different characteristics of the individuals of the groups studied. This intra and inter-group nuance of the individuals studied is reflected in the relative proportion of the degree of similarity. This degree of intra and inter-variety resemblance is shown in table 2.

Table 2. *Degree of similarities between onion varieties.*

Source of variation	degree (%) of similarities
Within varieties	42,51
Between varieties	57,49
Total	100

It appears from this table 2 that the onion varieties tested have a similarity in quantitative character measured at 42.51%. This similarity observed within the groups (classes 1 and 3) of onion varieties would certainly be justified by the genomic characteristics associated with this variety. The similarity within class 1 and consisting essentially of *Chagari* is justified by its seasonality of the culture and especially its color (pink) bulbs different from other bulbs. While for class 3, this degree of similarity would certainly be justified by its homogeneous character linked to the purification of heterotypes of individuals during its seed production. Moreover, the similarity between the individuals of class 2 is due to the fact that there have certainly been exchanges of seeds on the one hand and on the other hand the process of pollination (bees) between the different varieties set up in a neighboring radius of space. In addition, the peasant massal selection which is based on the perceptible characteristics of seed bulb. At the end of the characterization of different onion varieties studied from the point of view of their agronomic parameters, yield is one of the most relevant parameters compared between the onions varieties tested.

3.2. Yield Assessment (t/ha) at Harvest/After Storage of Different Onion Varieties

Table 3 shows the comparison of average yields in t/ha at harvest of different onion varieties tested with organic and mineral fertilizers. The results reveal a significant difference at the 5% level for some varieties with a fixed organic and mineral fertilizer. In addition, significant differences were also recorded in fertilizer for one onion variety used. Moreover, the best average yields in t/ha were also obtained with FM8: NPK 20-10-10+6SO_3 for three varieties of onion (*Goudami local*, *Safari* and *Goudami Certifie*). Compared to the variety (*Goudami local*), the best average yields in t/ha were obtained with the *Violet* de *Galmi* variety (FM5: NPK 23-10-5-2MgO+7,5S-0,3Zn and FM2: NPK+TE 21-9-11-5S-1,5MgO-0,15B_2O_3) and the *Goudami certifie* variety (FM8: NPK 20-10-10+6SO_3). These high yield values of the *Violet* de *Galmi* variety are explained by the improved nature of the genome related to this variety. For a better gain in average income, onion bulbs must be stored. This conservation requires the best choices of the variety and the fertilizer element. Table 4 shows the results of the average yields in t/ha of bulbs kept after 05 months in the store. These results showed that there are significant effects of fertilizers and varieties on the average yield of onion bulbs. Compared to FM1 (NPK: 22-10-15-5S-1B) fertilizer, the best average yield values in t/ha were obtained with FM2, FM3, FM4, FM5 and FM6 fertilizers respectively with the *Goudami local*, *violet* de *galmi* and *Goudami certifie* varieties. The outcome of table 4 shows that for a given onion variety, the highest loss rate (59.17%) was recorded by the *Chagari* variety while the lowest loss rate (11.19%) was observed with the *Goudami local* variety. Moreover, for a fertilizer given the variability (13.58% and 34.62%) extreme loss rate was recorded respectively by fertilizers FM3 (NPK 12-14-19-3.5MgO-0.15B) and FM6 (NPK 14-23-14-6S-1B_2O_2). The highest loss rate recorded with the *Chagari* variety is due to its non-storage bulb.

Therefore, this variety is intended for direct sale which justifies a strong seed rise observed and not allowing the drying of the collar of onion bulbs at the time of harvest. For a better choice of the fertilizer, the evaluation of the costs/benefits of production is necessary.

3.3. Cost/Benefit Analysis of Onion Bulb Production by Applied Treatment

The association of the selling prices of a 100kg bag of bulbs with the yield makes it possible to evaluate the income per treatment. The average revenue value per treatment applied after storage is shown in Table 5.

Table 3. *Yield of onion bulbs of different varieties by nutrients applied in t/ha at 136 JAR.*

Fertilizers / varieties	*Chagari* (y_1)	*Goudami local* (y_2)	*Violet* de *Galmi* (y_3)	*Safari* (y_4)	*Goudami certifie* (y_5)	Sig (P)
FM1	22,68 ± 11,52 abA	35,20 ± 6,70 abA	38,38 ± 3,81 abA	32,60 ± 7,60 abA	37,40 ± 14,49 abA	0,334
FM10	21,38 ± 9,81 abA	30,80 ± 14,38 abA	34,03 ± 6,75 abA	21,88 ± 11,60 aA	22,60 ± 1,01aA	0,418
FM2	16,40 ± 10,01 abA	36,10 ± 9,40 abAB	49,53 ± 15,98 bB	23,43 ± 11,54 abA	39,68 ± 11,73 abAB	0,044
FM3	22,78 ± 4,24 abA	42,98 ± 6,54 abB	40,18 ± 7,60 abB	23,18 ± 3,80 abA	42,01 ± 7,17 abB	0,003
FM4	20,68 ± 2,01 abA	41,03 ± 11,17 abB	40,88 ± 17,40 abB	29,65 ± 6,35 abAB	30,01 ± 1,94 abAB	0,030
FM5	28,73 ± 4,01bA	30,20 ± 3,17 abA	48,18 ± 3,57 abB	28,78 ± 8,92 abA	31,50 ± 13,70 abA	0,027
FM6	27,08 ± 4,39 abA	38,65 ± 6,98 abA	39,20 ± 16,30 abA	32,80 ± 9,07 abA	42,30 ± 16,84 abA	0,525
FM7	24,10 ± 8,12 abA	39,43 ± 11,77 abA	37,93 ± 13,72 abA	30,43 ± 12,85 abA	30,73 ± 3,33 abA	0,443
FM8	19,40 ± 9,04 abA	43,20 ± 7,72 bAB	32,93 ± 14,70 abAB	40,00 ± 7,31 bAB	46,40 ± 24,92 bB	0,023
FM9	26,90 ± 4,43 abAB	27,18 ± 4,09 aAB	37,30 ± 6,97 abB	18,10 ± 10,60 aA	37,38 ± 3,34 abB	0,022
FO0	15,13 ± 3,47aA	37,48 ± 10,27 abB	36,40 ± 8,27 abB	30,68 ± 2,29 abAB	31,98 ± 14,15 abB	0,050
FO1	24,03 ± 5,68 abA	33,48 ± 2,83 abA	36,63 ± 6,35 abA	24,47 ± 10,78 abA	33,60 ± 8,84 abA	0,197
FO2	16,00 ± 3,30 abA	31,80 ± 5,10 abAB	27,50 ± 5,60 aAB	31,98 ± 7,58 abAB	42,13 ± 21,05 abB	0,023
Sig (P)	0,032	0,043	0,040	0,037	0,031	

NB: the lowercase letters compare the average yield of onion bulbs of the different fertilizers for a given onion variety. While the capital letters compare the yields of the different varieties of onion to a fertilizer element used. Values that bear the same letters are statistically (Turkey Test) homogeneous at the 5% significance level.

Table 4. *Average yield of onion bulbs in t/ha after storage (5 months).*

Varieties	*Chagari* (y_1)		*Goudami local* (y_2)		*Violet* de *Galmi* (y_3)		*Safari* (y_4)		*Goudami Certifie* (y_5)		Total loss
Fertilizers	Yield	Loss (%)	Yield	Loss (%)	Yield	Loss (%)	Yield	Loss (%)	Yield	Loss (%)	Mean Loss (%)
FM1	11,34	50,00	31,68	10,00	24,95	35,00	25,00	23,30	22,25	40,50	31,76
FM10	2,14	90,00	30,80	0,00	27,22	20,00	18,51	15,38	16,95	25,00	30,08
FM2	14,76	10,00	29,54	18,18	49,53	0,00	18,41	21,43	32,42	18,30	13,58
FM3	15,95	30,00	42,98	0,00	25,31	37,00	21,07	9,09	33,61	20,00	19,22
FM4	12,73	38,46	36,93	10,00	32,70	20,00	21,56	27,27	22,51	25,00	24,15
FM5	2,87	90,00	25,67	15,00	38,54	20,00	28,78	0,00	23,63	25,00	30,00
FM6	2,71	90,00	28,99	25,00	30,80	21,42	27,33	16,67	33,84	20,00	34,62
FM7	4,38	81,82	39,43	0,00	31,03	18,18	24,34	20,00	24,58	20,00	28,00
FM8	12,93	33,33	35,35	18,18	26,34	20,00	34,00	15,00	34,80	25,00	22,30
FM9	15,69	41,67	27,18	0,00	29,84	20,00	15,39	15,00	30,58	18,18	18,97
FO0	7,57	50,00	30,92	17,50	27,30	25,00	30,68	0,00	29,32	8,33	20,17
FO1	6,01	75,00	27,90	16,67	25,09	31,50	24,47	0,00	28,00	16,67	27,97
FO2	1,78	88,89	27,03	15,00	22,00	20,00	26,38	17,50	33,49	20,50	32,38
Sig (P)		59,17		11,19		22,16		13,90		21,73	

***Table 5.** Evaluation of revenues in CFA Francs of treatments applied after storage (05 months after storage).*

Fertilizers	*Chagari* (Y_1)	*Goudami local* (Y_2)	*Violet* de *galmi* (Y_3)	*Safari* (Y_4)	*Goudami Certifie* (Y_5)
FM1	1134000	4752000	3742050	3750630	3337950
FM10	213800	4620000	4083600	2777076,92	2542500
FM2	1476000	4430454,55	7429500	2761392,86	4862784
FM3	1594600	6447000	3797010	3160909,09	5041200
FM4	1272615,38	5539050	4905600	3234545,45	3376125
FM5	287300	3850500	5781600	4317000	3543750
FM6	270800	4348125	4620504	4100000	5076000
FM7	438181,818	5914500	4655045,45	3651600	3687600
FM8	1293333,33	5301818,18	3951600	5100000	5220000
FM9	1569166,67	4077000	4476000	2307750	4587545,45
FO0	756500	4638150	4095000	4602000	4397250
FO1	600750	4185000	3763732,5	3670500	4200000
FO2	177777,778	4054500	3300000	3957525	5024002,5

Notes: charge related to the cost of the store: 50,000 FCFA, Price of a 100 kg bag of bulbs of varieties y2; y3; y4 and y5 = 15,000 FCFA, while the price of a 100 kg bag of bulbs of the y1 variety = 10,000 FCFA.

The results of this table show that by storing the onion bulbs, the *Chagari* variety recorded the lowest income value (177777.778 Fcfa) compared to the *Violet* de *Galmi* variety which recorded the highest value (7429500 Fcfa). These income values correspond respectively to organic fertilizer (cow dung) and NPK fertilizer of FM3 formulation: NPK 12-14-19-3.5MgO-0.15B. In addition, with the *Goudami local* variety, a small variability in income was recorded within different nutrients applied. From the income obtained, the profits after storage are recorded in table 6. Profit after storage has shown that production with the *Chagari* variety in the dry season is still not beneficial because most profit levels are negative. These results of post-storage cost-benefit analyses showed that some formulations (FM2: NPK+TE 21-9-11-5S-1.5MgO-0.15B_2O_3; FM3: NPK 12-14-19-3.5MgO-0.15B and FM9: NPK 21-8-12-2MgO+2.7S+2.5CaO) showed positive benefit levels with all onion varieties tested. Only fertilizer formulations FM2: NPK+TE 21-9-11-5S-1.5MgO-0.15B_2O_3 (NPK+TE) and FM3: NPK 12-14-19-3.5MgO-0.15B provided significant gross margins (4991450 Fcfa and 5935270 Fcfa respectively with the *Violet* de *Galmi* and *Goudami local* varieties) compared to other fertilizers. The outcome of these results would make it possible to have a step in the choice of the best fertilizer according to the onion varieties tested. However, the evaluation of better combinations of inputs/outputs according to treatments would give one of the optimal solutions in profit (table 6).

***Table 6.** Valuation of profits (FCFA) after storage of treatments applied to the production of onion bulbs.*

Fertilizers	*Chagari* (y_1)	*Goudami local* (y_2)	*Violet* de *Galmi* (y_3)	*Safari* (y_4)	*Goudami Certifie* (y_5)
FM1	-269 730	3 334 950	2 258 320	2 238 900	1 838 220
FM10	-1 270 430	3 122 450	2 519 370	1 184 847	962 270
FM2	61 770	3 002 905	5 935 270	1 239 163	3 352 554
FM3	152 370	4 991 450	2 274 780	1 610 679	3 502 970
FM4	-190 615	4 062 500	3 362 370	1 663 315	1 816 895
FM5	-1 116 430	2 433 450	4 297 870	2 805 270	2 044 020
FM6	-1 136 430	2 927 575	3 133 274	2 584 770	3 572 770
FM7	-1 004 048	4 458 950	3 132 815	2 101 370	2 149 370
FM8	-106 897	3 888 268	2 471 370	3 591 770	3 723 770
FM9	158 437	2 652 950	2 985 270	789 020	3 080 815
FO0	-517 730	3 350 600	2 740 770	3 219 770	3 027 020
FO1	-807 480	2 763 450	2 275 503	2 154 270	2 695 770
FO2	-1 196 952	2 666 450	1 845 270	2 474 795	3 553 273

3.4. Evaluation of the Best Combination of Onion Bulb Production Inputs

Table 7 summarizes the results of the combination of necessary and available resources and marginal productivity for the production of onion bulbs for a chosen treatment.

The results of table 7 show that after storage on an area of 0.181ha, linear programming recommends for better bulb production the following amounts: 23172.830 FCFA; 35,729 FCFA; 27867.223 Fcfa; 22800.000 Fcfa; 52045.349 Fcfa; 3975.686 CFA francs respectively for the capital of materials and equipment, for the workforce of cultivation operations, for fertilizers, for the capital of purchase of seeds, for the capital of purchase of fuels and lubricants and for the capital of purchase of pesticides and transport. In addition, for this better combination, only capital relating to materials and equipment, and that of seed purchases, would provide marginal productivity of the order of 28.625 CFA francs and 14.154 CFA francs respectively. The optimal solution of the sale of the bulbs after storage would have given a surplus of a margin of 474810 FCFA compared to the direct sale of the onion bulbs. To this end, this better combination of inputs makes it possible to identify the most optimal activity (processing) in profitability.

Table 7. *Evaluation of inputs of onion bulb production for applied treatment.*

Resources	Periods	LEVEL	UPPER	*«Shadow price»*
Acap	Before storage	19113.202	23172.830	/
	After storage	23172.830	23172.830	28.625
Land	Before storage	0.244	2.000	/
	After storage	0.181	2.000	/
Lhj	Before storage	48.305	203.750	/
	After storage	35.729	203.750	/
Ecap	Before storage	30784.398	2.2800E+5	/
	After storage	27867.223	2.2800E+5	/
Scap	Before storage	22800.000	22800.000	22.422
	After storage	22800.000	22800.000	14.154
CLcap	Before storage	70364.338	1.9810E+5	/
	After storage	52045.349	1.9810E+5	/
PTcap	Before storage	5375.054	1.3035E+5	/
	After storage	3975.686	1.3035E+5	/
Optimal Solution (CfaF)	Before storage	5.1123E+5	+INF	/
	After storage	9.8604E+5	+INF	/

3.5. Determination of Best Treatment Applied in the Production of Onion Bulbs

The identification of the best treatment can be found in table 8. At harvest, one of the optimal solutions can be deduced when the reduced cost (marginal productivity) of the product is zero (0). So, for an onion grower who wants to choose the best fertilizer formulation with the best variety that would provide optimal profit with the best combination of production input. The FM8: NPK 20-10-10+6SO_3 formulation applied to *Goudami local* is an activity (treatment) per excellence when onion bulbs are sold directly after harvest. On the other hand, after storage, the best activities (treatments) having one (986,040 Fcfa) of the optimal solutions consist of the fertilizers of the FM2: NPK+TE 21-9-11-5S-1.5MgO-0.15B_2O_3 and FM3: NPK 12-14-19-3.5MgO-0.15B formulations applied respectively to the *Violet* de *Galmi* and the *Goudami local* varieties.

Table 8. *Determination of the best treatments (activities) for the production of onion bulbs.*

ACTIVITIES	Periods	LEVEL					Marginal Productivity (reduced cost)				
		y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
FM1	Before storage	/	/	/	/	/	-2.240E+6	-6.435E+5	-1.951E+6	-3.069E+6	-2.404E+6
	After storage	/	/	/	/	/	-5.073E+6	-1.656E+6	-3.677E+6	-4.093E+6	-4.324E+6
FM10	Before storage	/	/	/	/	/	-2.373E+6	-1.076E+6	-1.980E+6	-4.007E+6	-3.669E+6
	After storage	/	/	/	/	/	-4.210E+6	-1.869E+6	-3.416E+6	-5.147E+6	-5.199E+6
FM2	Before storage	/	/	/	/	/	-2.502E+6	-5.820E+5	-1.069E+6	-3.813E+6	-2.232E+6
	After storage	/	0.089	/	/	/	-4.741E+6	-1.989E+6	0	-5.092E+6	-2.809E+6
FM3	Before storage	/	/	/	/	/	-2.275E+6	-5.960E+4	-1.845E+6	-3.861E+6	-2.074E+6
	After storage	/	0.092	/	/	/	-4.651E+6	0	-3.660E+6	-4.721E+6	-2.659E+6
FM4	Before storage	/	/	/	/	/	-2.380E+6	-2.366E+5	-1.810E+6	-3.365E+6	-3.055E+6
	After storage	/	/	/	/	/	-4.994E+6	-9.289E+5	-2.573E+6	-4.668E+6	-4.345E+6
FM5	Before storage	/	/	/	/	/	-1.998E+6	-1.043E+6	-1.167E+6	-3.375E+6	-2.876E+6
	After storage	/	/	/	/	/	-5.919E+6	-2.558E+6	-1.637E+6	-3.526E+6	-4.118E+6
FM6	Before storage	/	/	/	/	/	-2.068E+6	-3.710E+5	-1.889E+6	-3.057E+6	-2.016E+6
	After storage	/	/	/	/	/	-5.939E+6	-2.064E+6	-2.802E+6	-3.747E+6	-2.589E+6
FM7	Before storage	/	/	/	/	/	-2.222E+6	-3.436E+5	-2.025E+6	-3.281E+6	-2.976E+6
	After storage	/	/	/	/	/	-5.807E+6	-5.325E+5	-2.802E+6	-4.230E+6	-4.012E+6
FM8	Before storage	/	0.244	/	/	/	-2.368E+6	0	-2.383E+6	-2.474E+6	-1.681E+6
	After storage	/	/	/	/	/	-4.910E+6	-1.103E+6	-3.464E+6	-2.740E+6	-2.438E+6
FM9	Before storage	/	/	/	/	/	-2.079E+6	-1.292E+6	-2.044E+6	-4.236E+6	-2.413E+6
	After storage	/	/	/	/	/	-4.644E+6	-2.338E+6	-2.950E+6	-5.543E+6	-3.081E+6
FO0 (FM11)	Before storage	/	/	/	/	/	-2.413E+6	-3.316E+5	-2.095E+6	-3.093E+6	-2.708E+6
	After storage	/	/	/	/	/	-5.321E+6	-1.641E+6	-3.195E+6	-3.112E+6	-3.135E+6
FO1 (FM12)	Before storage	/	/	/	/	/	-2.191E+6	-7.856E+5	-2.095E+6	-3.724E+6	-2.713E+6
	After storage	/	/	/	/	/	-5.610E+6	-2.228E+6	-3.660E+6	-4.177E+6	-3.466E+6
FO2 (FM13)	Before storage	/	/	/	/	/	-2.479E+6	-8.865E+5	-2.792E+6	-3.090E+6	-1.997E+6
	After storage	/	/	/	/	/	-6.000E+6	-2.325E+6	-4.090E+6	-3.857E+6	-2.608E+6

4. Discussion

4.1. Characterization of Different Varieties/Ecotypes of Onions Tested

The 05 onion varieties tested had different qualitative characteristics. This phenotypic variation observed within the onion varieties tested, is certainly due to the influence of the climatic conditions of the environment on the one hand and genomic aspects related to each variety / ecotype of onion studied on the other hand. Similar qualitative trait analysis results obtained in Niger showed from 16 characterized ecotypes, 05 different groups of individuals [14]. In addition, the multiple component analysis made by these same authors on qualitative characteristics showed that the first axis explains 92.44% of the total variability while axis 2 accumulates only 7.56% of the total diversity. These results corroborate with those obtained on the 21 onion ecotypes of Niger. Greater variability was also observed within groups than that between groups, which explains the presence of ecotypes of different colors and different regions in the same group [3]. Apart from the erect port observed, on all the ecotypes of Niger studied, some relevant qualitative characteristics presented differences in their breasts. Going in the same direction, the characterization by multiple component analysis (MCA) from physiological maturation parameters carried out showed the different character of the *chagari* variety from the other varieties tested. And also obtaining three (03) different classes from 05 varieties studied. For them, the differentiation of onion ecotypes is due to the area of origin of the seeds, the seasonality characteristics (dry season and rainy season) of onion production and the edapho-climatic conditions of the locality [11]. The characteristics of the similarities and distinctions observed in the 05 varieties of onions tested are due to seed exchanges and especially the process of pollination (bees) between the different varieties set up in a neighboring radius of space. Under the conditions of Niger, the results obtained from this study reported that the variability of sorghum ecotypes is related to botanical aspects and especially to the cartographic distribution of seeds from the different collection sites [20]. This also shows that the diversity that exists between onion ecotypes is a function of localities in Niger [14]. Their analyses showed that there is significant genetic variability (86%) within onion ecotypes due to gene flows from the spread of the improved *Violet de Galmi* variety near plots occupied by local ecotypes. The main normalization from the quantitative parameters of 05 different onion varieties tested at the experimental Meskine site showed based on the discriminating factor analysis that 03 groups of individuals were formed around two axes. The degree of strong correlation of Class 1 for certain yield and phenological parameters (bulb diameter; bulb height; Weight of 10 bulbs; yields; number of days commercial maturation; number of seed rises and average rate of bulb loss after storage) was observed while classes 2 and 3 are related and are moderately correlated with certain growth parameters (leaf number 50 days after transplanting; sheet number 64 days after transplanting; sheet number 80 days after transplanting; neck diameter 64 days after transplanting; neck diameter 80 days after transplanting and size 91 days after transplanting). The formed classes reflect the genetic diversity of the constituted groups, which shows according to the Wilks Lambda Test a high significance ($P<0.0001$) of the constituted groups. Similar results from the discriminating factor analysis carried out on 21 local onion ecotypes, showed that group 2 approaches group 3 by yield (21.82 t/ha on average, for group 2 and 21.98 t/ha for group 3) but also to group 1 by cycle (149 days for group 1 and 152 days on average for group 2) [3]. The Discriminating Factor Analysis (DFM) obtained from study on all nine quantitative variables, showed the same results through the Wilks' Lambda test, and that it reveals a significant difference between the 3 groups based on all the variables considered [14].

Hierarchical ascending classification (HAC) based on Euclidean distance actually showed that the 05 onion varieties tested at Meskine grouped into 03 distinct classes with different and significant degrees of intra- and inter-group similarities. The 03 classes were also obtained by Boukary et al. (2012) [3] on 21 local onion ecotypes from Niger. For them, the groups constituted are on the basis of quantitative agro-morphological and physiological characteristics, the first of which was noticed at 71% of local varieties and/or ecotypes, while the second and third corresponded to 19%; 10% respectively. In addition, molecular analysis of variation between local onion ecotypes (16 local varieties) from Niger using simple sequence repeat markers (SSRs) showed greater (90%) diversity within the population than between population diversity (10%) [14]). To this end, the agro-morphological characterization of 05 onion varieties is a step on the choice of the most productive varieties, but the evaluation of economic performance depending on the bulb yield would be the most essential step for the choice of a variety.

4.2. Cost-Benefit Analysis of Bulb Production of Different Onion Varieties

In relation to the evaluation of yields in t/ha, the comparison of average values in yields (t/ha) bulbs per fertilizer applied to varieties using the Turkey test showed significant differences at the 5% level, but only FM6, FM7 and FM10 fertilizers applied to the 05 varieties showed this difference at the 5% level significance.

This difference in bulb yield is certainly due to the contribution of each fertilizer element that makes up each fertilizer formulation applied. And on the other hand to the genomic nature of each variety tested. At an equal dose (350kg/ha) of mineral fertilizers, the highest yields (49.53 ± 15.98t/ha; 48.18 ± 3.57t/ha) were obtained respectively with FM2 and FM5 formulations for the *Violet de Galmi* variety. But after storage, the *Goudami local* variety keeps better with FM3 fertilizer (42.98 t/ha). In addition, with the FM8 formulation (20-10-10+6SO_3), the yield values (43.20±7.72;

46.40±24.92) in t/ha obtained respectively by the *Goudami* local and *Goudami certifie* varieties are almost identical to the results obtained with the same cultivation practice (locker mode), for the same *Goudami local* variety whose highest average yield in t/ha is 43.58 ± 0.21 t/ha. The high yield was obtained rather with the mixture of 21-8-12 and 12-14-19 following the proportion 2/3 and 1/3 respectively for a dose of 2222 kg / ha [21]. The results of the average yields in t/ha obtained in the dry season are low with the *Chagari* variety regardless of the fertilizer used. These low yields in t/ha are explained by the fact that the *Chagari* variety is intended for the rainy season. It may be that the *Chagari* variety cannot truly express its agronomic potential in the dry-season. While the study carried out in Gazawa in the inter-season has showed satisfactory results in bulb yield of up to 50.48 t/ha with the *Chagari* variety compared to the *Goudami* variety (49.24kg/ha) [11]. This high value in average yield was observed in the "*billon*" system for the mixture of DAP (18-46-00), potassium sulphate (00-00-50), NPK (20-10-10) and urea (46 % N) respectively at the dose of 20 g/m; 15 g/m and 500 kg/ha. The yield size of the latter is explained by the fact that the applied urea favored the swelling of the bulbs in water. In addition, in Niger, the highest yield is observed in the *Guidan Magagi* ecotype with 34.22 t/ha and the lowest in the *Rose de Diffa* ecotype (17.75 t/ha) with the NPK 15-15-15 formulation [3]. Later in 2015, still in Niger, 03 inputs of mixture of NPK (15-15-15) and urea (46-0-0) made it possible to obtain bulb yields of the order of 17, 22, 28, 27, and 34 tons of bulbs respectively for T2: 30-30-30; T3: 60-30-30; T4: 90-30-30 and T5: 120-30-30. [22]. These authors showed that after five months of bulb storage, fertilizer compound T2 (30-30-30) treatment recorded the smallest (16%) loss rate compared to other treatments. This result shows that the loss rate does not necessarily depend on the nitrogen intensity applied. Overall, the same findings were made in this study. The smallest values in recorded loss rate are of the order of 13.58% and 19.22% respectively in FM2: NPK 21-9-11-5S-1.5MgO-0.15B_2O_3 (NPK+TE), FM3 NPK 12-14-19-3.5MgO-0.15B formulations. This difference in loss rate is certainly due to the different conditions of the storage design, the different technical practice (different formulations of fertilizer, technical practice) and especially to the texture and structure of the soil.

Logically with the comparison of the average bulb yield values, the price association showed that at harvest, the highest profits (2,518,170 CFA francs; 2,420,670 CFA francs) were recorded with the same formulations and varieties. The same results (5,935,270 CFA francs; 4,991,450 CFA francs) were also observed after storage. On the other hand, results obtained from cost-benefit analysis of bulb production by treatment showed that the *Goudami local* variety has a better profit (1582411 CFA Francs /ha) compared to the *Goudami certifie* variety. And that with the same variety, the studies carried out on the mode of development have shown that the locker system has provided the best profit (1775377 CFA Francs /ha) compared to other systems (board and ridge) [11]. In addition, with the *Violet de Galmi* variety, a capital gain (marginal profit) of 3,417,100 CFA francs was observed after the storage of the sale of the bulbs compared to the sale at harvest for the same FM2 (21-9-11-5S-1.5MgO-0.15B_2O_3 (NPK+TE)) formulation. This implies that the marginal benefit obtained after storage for FM2 is 02 times greater than those obtained at harvest with the control formulations (FM1: NPK 22-10-15-5S-1B (Sodecoton) and FM8: NPK 20-10-10+6SO_3). Divergent results obtained with the innovative treatment (ray irrigation with onion on ridge) showed that the benefit value is higher compared to the control treatment (flooded lockers), which increases the benefit from 432,925 CFA francs to 1,708,325 CFA francs respectively for the two treatments (innovative and control) (M'biandoum and Essang, 2008). Similar results obtained with the same mode of development ("*billon*" system) in the Gazawa production zone (Far-North) showed that the profit is maximum (1078821 CFA francs) with the *Chagari* variety [11]. This variability in profit is certainly due to the effects of the type of development and the period of sale of the bulbs on the one hand, and on the other hand to the soil conditions and the genomic aspect of the varieties tested in question for the present study. In addition, in the Sudano-Sahelian and Sudano-Guinean zones of Cameroon the profit margin per ha was estimated at 2502000 CFA francs [23]. For better decision-making on the choice of a better profitable treatment, the rational management of inputs makes it possible to have an added value of the production of onion bulbs for each variety tested.

4.3. Evaluation of the Necessary Quantities of Inputs from Onion Production

The satisfactory results of linear programming giving one of the optimal profits with the locker mode made it possible to determine the best combination of resources useful for harvesting and after storage. These results showed that on 0.25 ha, the values of production inputs are practically less than those obtained in a study conducted in Gazawa [11]. Only the costs related to equipment for materials and fuels and lubricants are quite higher than the latter (Gazawa study). The correspondences relating to inputs are respectively: 203.75 man/day for all operations (clearing, ploughing, making of lockers, transplanting, hoeing, treatment, guarding and harvesting) of the production of onion bulbs, 35145.15 CFA francs for the purchase capital of pesticides, 41347.238 CFA francs for the capital of purchase of seeds, 28713.36 CFA francs for the capital of the rental of the plot, 49524.80 CFA francs for the purchase capital of fuels (gasoline and oil), 89126.268 CFA francs for the purchase capital of fertilizer elements (fertilizers and DAP), 23172.83 CFA francs for the depreciation of materials and equipment, and 95200 CFA francs for capital of other expenses (packaging, transport, string) [11]. This variability in input values is due to the specific characteristics of the localities of production. Recent studies conducted on the same site have shown that the quantities of useful inputs/outputs differ from one resource to another [21]. This difference in the quantity of inputs/outputs of bulb production is due to the value of each factor during the crop year varying from one year to another. In addition, the nature (types of fertilizers and variety) of the controlled factors of production would have a significant influence on the variability of production inputs/outputs. Speaking of imported seeds, its high cost encourages producers to produce their own seeds [24]. Because this price is not within their reach in view of the low levels that the peasants lead. Speaking of this study, the best combination in locker mode with the same *Goudami* local variety on an area of 0.25ha is the order of 5700 CFA Francs; 57000 CFA Francs; 23913 CFA Francs; 4425 CFA Francs; 3700.75 CFA Francs; 1236.25 CFA Francs; 5793.25 CFA Francs and 2846.75 CFA Francs respectively for the cost of purchasing seeds; the cost of purchasing fertilizers; the cost of purchasing fuel; the cost of purchasing pesticides; the cost of packing and transporting the bags; the cost of the total labor force; the depreciation of equipment and materials and finally the cost allocated to the profitable of the plot [21]. An additional unit of CFA francs from the seed would add to the optimal profit a marginal "shadow price" productivity of 22.43 CFA francs, so the seed is a scarce resource in the production of onion bulbs in Meskine. While in Gazawa, labor and other costs have constituted scarce resources whose marginal "shadow price" productivity is 6733.507 FCFA and 27.419 FCFA respectively. On the other hand, the capital resource linked to the depreciation of equipment and materials provided marginal productivity of around 21.75 CFA francs. Moreover, after storage, the rarest inputs consist of the cost related to the depreciation of equipment and materials and the cost related to the purchase of seeds because their "Shadow price" correspond to 14.154 CFA francs and 28.625 CFA francs respectively. After storage, a better combination of inputs less than that obtained from the direct sale of the bulbs was obtained for a shortfall that could generate 474,810 CFA francs of optimal profit compared to the sale at harvest of the bulbs. In Tunisian oasians, the value obtained in profit is 2426070 cfa Francs with the production of local onions [25]. This variability in profit is attributed on the one hand to the variability of prices (shortage of bulbs hence the soaring prices) of onion bulbs, on the other hand to the quantity offered and demanded on the consumer markets. For this better combination of production inputs, it would be wise to identify the best treatments (activities) for good production.

4.4. Determination of Best Treatment Applied in the Production of Onion Bulbs

The best variety that combines with the most efficient fertilizer is evaluated by the output value indicating zero reduced cost (marginal productivity of the product). At harvest, one of the optimal solutions was deduced when the reduced cost relative to the activity (processing) y2*FM8 is zero (0). While after the storage of the bulbs, one of the optimal solutions is obtained when the y2*FM3 and y3*FM2 treatments have provided zero marginal productivity. Therefore, the production of onion bulbs is very profitable with the application of 20-10-10-6SO_3 on the *Goudami local* for direct sale. While the same linear programming shows that it would be profitable to use respectively the 21-9-11-5S-1.5MgO-0.15B_2O_3 (NPK+TE) and the 12-14-19-3.5MgO-0.15B on the *Violet de Galmi* and the *Goudami local* for the sale of the bulbs after storage. Similar results were obtained [11]. Their results reported that it would be better to produce in billon mode with the *Goudami local* variety in the Gazawa area. In addition, it would be advantageous to always produce with the same *Goudami local* variety in the locality of Meskine in locker mode with a mixture of 21-8-12-2MgO+2.7S+2.5CaO and 12-14-19-3.5MgO-0.15B of fertilizer [21]. In addition, the line irrigation system with onions on ridges is profitable in the North Cameroon region both in the rainy season and in the dry season on the one hand, and that it produces a good quality of bulbs more storage on the other hand [9]. For them, the advantage of the “billon” system made with animal traction makes it possible to reduce manual work times from 104 days to 10 days. This allows the effective reduction of the cost related to labor. But this value of production would only be profitable if the onion bulbs are sold after storage.

5. Conclusion

In order to improve onion bulb production in Cameroon, the choice of the best fertilizer(s) that combines with high-performance varieties is a palliative way to improve yield. The study evaluating the factors of production of 05 varieties of onion under different organic and mineral fertilizers was conducted at the IRAD experimental farming in Meskine. At the end of this study, the 05 varieties had different agro morphological characteristics. The categorization of this 05 varieties of onion presented three distinct classes. Among these 05 varieties, *Violet de Galmi* and *Goudami Certifie* showed high yields in t/ha at harvest with NPK 21-9-11-5S-1.5MgO-0,15B_2O_3 (NPK+TE) and NPK 20-10-10-6SO_3 fertilizers respectively. While *Violet de Galmi* and *Goudami local* are economically the most profitable after bulb storage respectively NPK 21-9-11-5S-1.5MgO-0.15B_2O_3 (NPK+TE) and NPK 12-14-19-3.5MgO-0.15B fertilizers. To complete this study, it would be judicious to conduct further experiments on the different soil units of onion production using the same formulations with different doses.

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