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OPTIMIZATION OF THE PRODUCTION OF FIVE (05) ONION VARIETIES TESTED AT DIFFERENT DOSES OF ORGANIC AND MINERAL FERTILIZERS IN THE FAR NORTH CAMEROON.

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ABSTRACT

In the Sudano-Sahelian zone of Cameroon, the production of dry-season onion bulbs contributes substantially to improving the incomes of small producers in rural areas. However, improving the technical practice is one of the major challenges to boosting the yield of the onion crop through the identification of the best fertilizer according to the type of soil. Experiments were conducted at three sites (Godola, Mayo-kalio and Koza) tested 05 onion varieties at three doses of 13 fertilizers in a split-plot design. The data collected were analyzed using XLSTAT software. The determination of the best combinations of inputs for the best activities (treatments) was carried out using GAMS software. The results of the study showed on the Mayo-kalio site (clay-sandy textural classification), all yields have increased (increasing return to scale) following the three doses for the majority of fertilizers applied to the Safari variety, its highest potential yield in t/ha is 74.02t/ha with the dose of 700kg/ha of NPK of the FM3 formulation. Finally, on the Koza site (sandy-clay textural classification), the highest average yield (54.81t/ha) was obtained at a dose of 175kg/ha of FM9 (21-8-12-2MgO+2.7S+2.5CaO) applied to the landrace variety compared to other varieties tested. By comparing the three test sites, the marginal productivity relative to capital for the purchase of fuels and lubricants (1.431fcfa for the dose of 175kg/ha); the related cost for the purchase of seeds (6.764FCFA; 6.809 FCFA respectively at doses of 350 kg/ha and 700kg/ha of 12-14-19-3.5MgO-0.15B) are the most important resources in the production of onion bulbs on the Mayo-kalio site. The marginal productivity generated with the best combinations of production inputs was obtained with D1*y1*FM3 treatments; D2*y3*FM3 and D3*y4*FM3 which are the best activities on the Mayo-kalio site. Biochemical analyses and disease incidence of onion culture would be required.

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INTRODUCTION

Onion (*Allium cepa* L) cultivation covers an area more than 9 million hectares each year worldwide (FAO/OMS, 2017). Global production is around 93 to 104.53 million tons (FAOSTAT and CIRAD, 2021)). In Africa, the major onion-producing countries are Egypt (2,109,197t), Algeria (1,368,184t); Sudan (1,108,610t); Nigeria (985,400t); Morocco (813,707t) and South Africa

(651,070t). In the West and Central sub-regions of Africa, Cameroon recorded a national production of 338,634.66 t with more than 74.65% of this onion production located in the Far North Cameroon region (Agristat, 2022). In general, the volume of onion production not only contributes to economic growth but especially contributes to improving the incomes of a large number of rural households in some onion-producing countries such as Cameroon (Rameez *et al.,* 2014). The particular case of Cameroon's national production is between 10 and 19 billion franc of the French Community in Africa (CFA F)/year of its contribution to Cameroon's GDP (Jacqmin *et al.,* 2017). This economic value allows small rural producers in the Far North to make more of their income to meet their basic needs such as food, clothing, health care costs and education costs within farming households (Kamga *et al.,* 2016). Because of its crucial importance, this *liliaceae* (onion) would be a good lever for improving the incomes of small rural producers. However, its production is highly fluctuating and less efficient due to several production constraints such as poor cultural practices (Kamga *et al.,* 2016; Zougmoré *et al.,* 2009), loss of soil fertility (M'Biandoun and Olina Bassala, 2007), fertilizer doses and formulations are inadequate (Nchoutnji *et al.,* 2009; Akoa and Mabou, 2004) and poor irrigation technique (Chengappa *et al.,* 2012). All these constraints lead to the high rate of loss of bulbs in the field (Chengappa *et al.,* 2012), resulting in low onion yields ranging from 7.9 to 11 t/ha in Cameroon (kamga *et al.,* 2016; Agristat, 2022). However, it is important to note that high yields (32 t/ha to 35 t/ha) of onion bulbs are recorded in Niger (Archiani *et al.,* 2013). Yet these two sub-Saharan countries have almost similar pedoclimatic conditions. In Niger, the climate is Sahelo-Sudanese (temperature (12°C to 44°C/year); rainfall (150 to 800 mm) and the soil is sandy (Boubary *et al.,* 2012). In the Far North of Cameroon, the climate is Sudano-Sahelian (temperature (11°C to 45°C); rainfall (800-1000 mm/year)) and the textural classification is sandy-clay (Kamga *et al.,* 2016). In addition, the main varieties grown in the North Cameroon region and those found in some sub-Saharan countries are almost identical. The results of interviews with Abdou *et al*. (2014) in 06 different countries of West Africa showed that ecotype names vary only according to the language of the producer. The same ecotype may have different vernacular names from one site to another. His characterization of variety work conducted in these West African countries has shown that the main varieties of onion (*Violet de Galmi*, *Blanc de Galmi* and *Blanc de Soumara*) cultivated are native to Niger (Abdou *et al.,* 2015). In Cameroon, the main onion varieties found are constituted of "*Goudami*" which is the traditional variety, *violet de Galmi* resulting from the improvement of "*Goudami*" and "*Chagari*" (Bassole *et al.,* 2017). Despite these almost similar pedoclimatic and varietal characteristics, it is clear that yields continue to be recorded in the Far North compared to those of Niger, Mali and Burkina Faso. To compensate for this low onion yield in the Sudano-Sahelian zone of Cameroon, the preliminary results of M'Biandoun and Essang (2008) carried out on 03 soil types (clay (Lagdo and Kismatari); clay-sandy (Ouro mal hamadou) and sandy-clay (Tchontchi)) of the Northern region showed that the yields (70t/ha and 80t/ha) in onion bulbs of the *Goudami* variety are more efficient on clay-sandy and sandy-clay soils respectively with the formulation fertilizer 22-10-15 with irrigation with the peasant method. In addition, efforts made by Fleissner *et al*. (2015) and PADFA (2017) observed a substantial increase in yield among supervised producers that can reach 27 to 38 t/ha with the local *Goudami* "Landrace" whose average income increase was estimated at 60% for the onion producer benefiting from the project. In addition, great future opportunities for research would focus on the onion production system, which has long been less explored by researchers. Especially, this increase in population density leads to more intensive land use without adjustment of fertilization and irrigation of vegetable crops (Suwadu *et al.,* 2020). These imperfections related to how onion production inputs are used do not allow the improvement of bulb yield. Davinder *et al*. (2018) report that improving the productivity of onion production factors is the key to boosting onion yield. Thus, one of the ways of this increase in productivity is the application of organic manure which is sometimes supplemented with nutrients element from inorganic sources (mineral fertilizers) for crops to have a good balance in fertilization (Ngetich *et al*., 2014). But the application of these fertilizers must meet certain standards concerning the fertility status of the soil. Because companies formulate complex fertilizers without taking into account any composition of the nature of the soil. At least the non-availability of simple fertilizers to

formulate complex fertilizers that should meet the requirements of onion cultivation according to the state of the fertility of the soil to seek the maximum threshold of valorization of the fertilizer applied. It is in this sense that we initiated this work which seeks to optimize the production of the main onion varieties according to soil type under different organo-mineral fertilizers while generating marginal productivity by the method of linear programming (LP).

MATERIALS AND METHODS

Plant material

The plant material used consists of five onion varieties (Figure 1), i.e. three main onion varieties (*violet de Galmi*, *Chagari* and *Goudami certifiée*) (*Allium cepa* L.) most widely grown in the Far North region (Bassole *et al.,* 2017). A variety of local *Goudami* was used as a reference variety (control) and a variety of onion "*Safari*" was introduced from West Africa to see its adaptability at the level of the Sudano-Sahelian zone of Cameroon.

Figure 1. Range of photos of different onion seeds tested.

The experimental plot used is a complete factorial design (5*13*3) comprising three controlled factors.

The first factor consists of onion varieties (y1 = *Chagari*; y2 = *goudami locale*; y3 = *violet de Galmi*; y4 = *Safari*; y5 = *Goudami Certifiée*), the second factor consists of fertilizers (FM1: 22-10-15-5S-1B (Sodecoton); FM2: 21-9-11-5S-1.5MgO-0.15B2O3 (NPK+TE); FM3: 12-14-19-3.5MgO-0.15B; FM4: 13-13-21-3S-0.01Zn-0.01B; FM5: 23-10-5-2MgO+7.5S-0.3Zn; FM6: 14-23-14-6S-1B2O2 (OCP); FM7: 15.4-25.6 (Borated calcium nitrate); FM8: 20-10-10+6SO3; FM9: 21-8-12-2MgO+2.7S+2.5CaO; FM10: 20-10-01-2.5CaO; FO: fertilizer-free; FO1: Cow dung; FO2: sheep droppings) organic and mineral. While the third factor is intensification levels (D1 (175kg/ha NPK); D2 (350kg/ha NPK) and D3 (700kg/ha NPK)) organic and mineral fertilizers.

The combination of controlled factor modalities constituted the treatments. A total of 13*5*3 = 195 treatments F1, F2, F3* (y1m1; y1m2; y1m3; y1m4; .....; y1m10; y1O; y1O1; y1O2; y2m1; y2m2; .....; y2m10; y2O; y2O1; y2O1; y2O2; y3m1; y3m2; .....; y3m10; y3O; y3O1; y3O2; y4m1; y4m2; .....; y4m10; y4O; y4O1; y4O1; y4O2; y5m1; y5m10; y5O10; y5O1; y5O2) repeated four times were applied in the block set up. The experimental units measure 1m * 1m.

Conduct of the test

Two sites (Mayo-Kalio and Meskine) were chosen for the establishment of the nurseries. The implementation dates were 05/10/2021 and 06/10/2021 respectively. Transplanting took place 42 days after sowing, 44 days after sowing and 46 days after sowing respectively at the Godola, Koza and Mayo-kalio sites. The first fertilization was done at different doses (125kg (1/2N); 250kg (N) and 500kg (2N)) respectively at 25 days after transplanting (DAT) on each site. The second fertilization took place at 51 DAT at different doses (50kg (1/2N); 100kg (N) and 200kg (2N)) of nutrients applied at the same study sites. Three weeding was carried out at 36, 45 and 78 DAT respectively at each site. At the study sites, pest controls were made through the Pacha a broad-spectrum insecticide. The harvest was carried out when 100% of the non-flowering plants were laid down. It took place on 28/02/2022 (116 DAT), 16/03/2022 (134 DAT) and 07/04/2022 (107 DAT) respectively at the Godola, Koza and Mayo-kalio sites. The bulbs that constituted the samples intended for conservation finally to evaluate the rates of loss were stored in a shop fashionable by peasants at the level of Meskine. The piles of samples were layered differently at the store level, the storage period was from May to

September. At the end of September, the number of rotten bulbs was counted to evaluate the loss rates relative to each treatment tested.

Data analysis

Three (03) factors were controlled, and the different combinations of factor modalities resulted in 195 treatments corresponding to the different onion bulb production activities. 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 of onion bulb production. The production of each onion variety was done by applying different doses of fertilizers. By combining the fertilizers (13 modalities) with the varieties (05 modalities) of onion, then with the doses of these fertilizers, we obtain 195 problem activities of linear programming which are: (F1; F2; F3) * (y1; y2; y3; y4; y5) * (FM1; FM2; FM3; FM4; FM5; FM6; FM7; FM8; FM9; FM10; FO; FO1; FO2) for the Godola, Mayo-Kalio and Koza sites.

The net profit (∏j) is determined by:

$\sum_{1=i}^{n} PiBiXi - \sum_{1=i}^{n} Ci$ ……..(1)

For all i=1 to n; With Pi = selling price of a bag of 100 kg of bulbs in CFA F 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 F of production inputs invested in each activity of onion bulb production. In addition to other production expenses the expenses related to the costs of the store are estimated at 50,000 CFA F. The price of a bag of 100 kg of onion bulbs in the varieties (y2; y3; y4 and y5) is 35,000 CFA F, while the price of a 100 kg bag of bulbs of the y1 variety is 25,000 CFA F.

The function of the Z objective to be maximized for the Godola, Mayo-kalio and Koza sites is as follows:

$Maz\ Z = \sum_{j=1}^{5} \prod yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz$……..(2)

Where ∏j is the net gross (in CFA francs/ha) of the activity produced (exogenous variable/data for the year calculated from equation (1). The endogenous variables to be estimated are of the order j, i and z such that X_{yjfzmi} represents the areas (in ha) of onions to be produced according to each treatment applied where j, i and z respectively take the values of the corresponding intervals (j ∈ [1-5]; z ∈ [1-3]; i ∈ [1-13]).

Availability of soil (plot) for the Godola, Mayo-kalio and Koza sites: the cumulative sum of onion bulb production grown according to each variety and dose of fertilizers is less than or equal to the available space (C_{land}) that this activity can occupy.

$\sum_{j=1}^{5} Land, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{land}$ …….. (3)

Where $Land_{yjfzmi}$; ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] These variables correspond respectively to the amounts of capital used for the rental/plot value of one ha to produce onion bulbs for a chosen activity.

Capital availability for depreciation of materials and equipment for each site of Godola, Mayo-kalio and Koza: 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:

$\sum_{j=1}^{5} Acap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{amort}$ ……..(4)

Where $A_{cap,\ yjfzmi}$; ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] respectively, this corresponds to the amounts of useful capital of depreciation to produce one ha of a chosen activity. Availability of capital for the purchase of seeds of onion varieties at each site in Godola, Mayo-kalio and koza; this equation states that the summation of the capital shares per seed unit multiplied by the area of the activity must be less than or equal to the available capital (C_{sem}) for the purchase of seeds by a planter.

$\sum_{j=1}^{5} Scap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{sem}$…… (5)

Where $S_{cap,yjfzmi}$; ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] respectively, this corresponds to the amounts of capital useful for the purchase of seeds by a planter to produce on an area of one ha.

Capital availability for the purchase of fertilizers at each site in Godola, Mayo-kalio and Koza; the cumulative of the shares of capital per unit of each fertilizer multiplied by the area of the activity must be less than or equal to the available capital (C_{elf}) for the purchase of fertilizers by a planter results in:

$\sum_{j=1}^{5} Ecap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{elf}$ …… (6)

Where $E_{cap,yjfzmi;}$ ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] corresponds respectively to the amounts of capital needed for the purchase of fertilizers to produce one ha with a treatment. Availability of capital for the purchase of fuels and lubricants at each site in Godola, Mayo-kalio and Koza; this equation shows that the summation of the capital shares per unit of fuels and lubricants multiplied by the area of the activity must be less than or equal to the available capital (C_{carb}) for the purchase of fuels and irrigation lubricants by a planter:

$\sum_{j=1}^{5} CLcap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{carb}$…… (7)

Where $CL_{cap,\ yjfzmi;}$ ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] corresponds respectively to the amounts of capital needed to produce one ha of activity.

Capital availability for the purchase of pesticides and transport costs at each site in Godola, Mayo-kalio and Koza; this equation shows that the sum of the capital shares per unit of pesticides multiplied by the area of the activity must be less than or equal to the available capital (C_{pest}) for the purchase of pesticides and the cost of transport by a planter:

$\sum_{j=1}^{5} PTcap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{pest}$ …… (8)

Where $PT_{cap,\ yjfzmi;}$ ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] corresponds respectively to the amounts of capital used to purchase pesticides to produce one ha of the activity (applied treatment). Availability of work at the Godola, Mayo-kalio and Koza sites states that the summation of the labor intensity shares per man-day 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:

$\sum_{j=1}^{5} Lcap, yj\ X \sum_{i=1}^{13} mi \sum_{z=1}^{3} fz \leq C_{labor}$ …… (9)

Where $L_{cap,\ yjfzmi;}$ ∀ j, i, z ∈ [1-5]; [1-13]; [1-3] corresponds respectively to the quantities required man-days to produce one ha by a given treatment.

RESULTS AND DISCUSSION

Evaluation of the physical maximums of onion bulb production at the different experimental sites.

Tables 1, 2 and 3 show respectively the average yields in t/ha and the percentage loss rates of onion bulbs of the varieties tested at different doses at the Godola test site after storage.

Table 1. Physical maximum in t/ha of 05 onion varieties tested at a rate of 175 Kg/ha of fertilizers at the Godola site after 5 months of storage.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	30.88	24.61	18.38	36.93	24.63	30.75	18.38	40.03	30.88	10.20
FM2	7.50	29.63	9.29	36.12	3.04	50.39	9.29	37.94	3.04	13.32
FM3	5.86	36.39	18.36	30.54	24.61	40.58	18.36	44.24	5.86	7.93
FM4	27.07	27.81	14.57	32.00	27.07	37.13	27.07	32.63	20.82	14.39
FM5	11.25	31.99	23.75	34.54	30.00	33.52	11.25	37.76	30.00	14.32
FM6	13.56	34.77	13.56	35.48	19.81	41.25	13.56	36.97	26.06	25.03
FM7	29.00	20.04	16.50	26.53	10.25	35.61	10.25	32.15	10.25	8.39
FM8	21.79	32.80	19.90	27.39	26.15	41.04	7.40	33.95	7.40	36.98
FM9	18.24	28.18	5.74	32.06	11.99	45.61	11.99	36.39	18.24	26.70
FM10	30.04	33.54	17.54	35.52	11.29	41.37	17.54	37.19	11.29	20.42
FO1	6.33	25.34	12.58	28.43	6.33	42.53	12.58	30.97	18.83	16.53
FO2	10.23	29.01	10.23	32.61	16.48	36.86	16.48	33.24	10.23	24.33
FO0	31.19	22.78	12.44	22.14	12.44	36.16	24.94	32.50	24.94	15.15

TP: percentage loss rate

Table 2. Physical maximum of 05 onion varieties was tested at a dose of 350 kg/ha of fertilizers after 05 months of storage of the bulbs on the Godola site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	18.38	19.06	30.88	9.99	12.13	31.11	18.38	22.18	5.88	21.46
FM2	3.04	28.16	3.04	28.25	15.54	28.31	15.54	31.24	9.29	14.18
FM3	12.11	26.73	18.36	35.69	7.50	39.78	5.86	46.38	12.11	14.77

FM4	14.57	23.03	27.07	16.30	27.07	28.24	27.07	24.30	27.07	7.97
FM5	30.00	16.17	11.25	19.68	23.75	32.03	17.50	25.11	11.25	17.89
FM6	13.56	22.37	26.06	16.43	32.31	29.76	13.56	39.01	13.56	31.77
FM7	22.75	16.35	10.25	15.92	22.75	21.95	16.50	27.28	16.50	28.15
FM8	26.15	12.82	26.15	17.66	24.61	31.45	13.65	22.78	26.15	12.39
FM9	11.99	26.88	5.74	29.58	11.99	37.45	18.24	24.05	18.24	19.80
FM10	23.79	16.46	11.29	23.70	30.04	21.91	17.54	22.99	5.04	26.63
FO1	18.83	27.91	6.33	30.23	6.33	39.31	25.08	31.97	12.58	9.95
FO2	16.48	28.36	10.23	30.77	10.23	36.78	16.48	36.48	22.73	30.81
FO0	24.94	22.29	12.44	31.71	18.69	34.96	24.94	27.62	12.44	15.76

TP: percentage loss rate

Table 3. Physical maximum in t/ha of onion bulbs of 05 varieties tested at a dose of 700 kg/ha of fertilizers after 05 months of storage on the Godola site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	30.88	24.19	24.63	23.30	18.38	39.54	18.38	25.34	12.13	25.44
FM2	3.04	33.47	3.04	28.86	3.04	53.97	3.04	28.30	9.29	42.14
FM3	12.11	30.81	12.11	41.56	0.00	54.44	5.86	39.64	18.36	45.57
FM4	14.57	29.66	27.07	33.52	8.32	43.80	8.32	46.82	27.07	32.99
FM5	17.50	29.99	11.25	29.94	30.00	36.01	11.25	43.17	17.50	28.39
FM6	32.31	26.01	7.31	38.54	32.31	34.37	26.06	40.93	26.06	30.13
FM7	22.75	21.87	16.50	32.01	29.00	27.13	29.00	27.86	16.50	14.65
FM8	19.90	25.51	7.40	30.03	13.65	44.51	19.90	30.04	19.90	19.90
FM9	18.24	23.34	11.99	31.37	18.35	35.94	5.74	37.59	24.49	27.51
FM10	30.04	15.15	23.79	31.64	30.04	32.06	17.54	34.34	17.54	34.10
FO1	25.08	27.90	18.83	29.01	6.33	49.25	6.33	45.89	12.58	32.05
FO2	10.23	23.82	22.73	33.39	22.73	36.55	16.48	38.66	10.23	29.66
FO0	18.69	25.96	31.19	24.74	12.44	46.42	24.94	34.09	12.44	32.39

TP: percentage loss rate

After conservation of onion bulbs, it appears from table 1 (dose of 175 kg/ha NPK) that the best yields in t / ha were obtained with *violet de galmi* for formulations FM2, FM3, FM4, FM5, FM6, FM7, FM8, FM9, FM10, FO1, FO2 and FO0 compared to formulation FM1. This shows that *violet de galmi* has a good aptitude capacity at a dose of 175 kg/ha NPK. Moreover, at the 350 kg/ha NPK (Table 2) of the fertilizers, the same formulations saw their yields increase with *violet de galmi*. Except for FM10, FM6 and FM7 fertilizers, which recorded lower yields with the same variety (*violet de Galmi*). The highest yield (54.44t/ha) was always observed with the *Violet de Galmi* variety for the FM3 formulation (NPK 12-14-19-3.5MgO-0.15B), and the lowest yield (14.65t/ha) is obtained with *Goudami certifiée* for the FM7 formulation (NPK 15.4-25.6 (Borated calcium nitrate). From the dose of 175kg/ha to 700kg/ha of NPK, there is a decrease in yield with *violet de Galmi*, this decrease in yield is because these fertilizers have recorded the maximum loss rate (32.31% (NPK 14-23-14-6S-1B2O2) and 29% (Borated calcium nitrate). In addition, the level of assimilation by the cultivation of onion as a fertilizing element provided by the different formulations of fertilizers would explain its maximum nutritional need. Excess fertilizers could cause plant and soil toxicity. At a rate of 700 kg/ha of fertilizers, only the *Safari* variety

recorded a high yield of about 46.38t/ha with FM3 fertilizer (NPK 12-14-19-3.5MgO-0.15B). The maximum loss rate (32.31%) was always obtained with FM6 fertilizer (NPK 14-23-14-6S-1B2O2). On the clay-sandy soil of Godola, yields in t/ha vary little compared to the formulation and varieties tested after 05 months of bulb storage. These results also show that the rate of loss does not depend for the most part on the dose of the fertilizers applied but on the formulation in question. In sum, at an increasing dose of fertilizers, all varieties reached their physical maximums at a dose of 350kg/ha NPK. This explains the decreasing yield of scale beyond the 350kg/ha NPK dose of the fertilizers. Because of these results, it is also important to determine the physical maximums of these varieties on more clay soil (Mayo-kalio). Tables 4, 5 and 6 show the maximum yield in t/ha of 05 onion varieties tested at the different doses of fertilizers.

Table 4. Physical maximum in t/ha of 05 onion varieties tested in the 175 kg/ha NPK dose of fertilizers after 05 months of storage on the Mayo-kalio

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	40.00	28.57	7.50	42.63	26.25	41.58	14.15	53.33	35.25	34.03
FM2	20.00	46.66	11.59	50.22	3.75	38.44	3.75	46.11	5.40	43.79
FM3	11.25	66.21	8.75	51.72	5.35	34.61	4.55	56.64	6.25	51.54
FM4	34.23	42.42	7.50	53.44	25.00	27.58	28.64	47.96	21.25	43.12
FM5	41.25	37.15	16.25	35.35	25.00	29.34	13.22	57.64	27.50	47.11
FM6	41.25	31.98	8.75	51.40	13.21	44.16	13.30	58.29	18.75	57.72
FM7	55.91	18.55	2.50	42.88	33.50	35.84	6.25	54.48	6.25	60.09
FM8	12.92	36.29	17.84	36.96	25.00	35.60	3.75	58.93	8.75	53.95
FM9	29.59	31.86	3.75	46.94	12.50	41.80	10.00	55.54	17.84	64.46
FM10	60.00	22.64	2.50	53.75	6.25	42.13	10.19	62.97	8.75	53.84
FO1	21.25	43.28	11.25	40.60	8.75	47.91	2.50	59.98	12.92	63.42
FO2	33.75	24.74	4.59	43.10	18.25	29.84	2.50	55.17	4.59	39.34

TP: percentage loss rate

Table 5. Physical maximum of onion bulbs at the normal dose (D2 = 350Kg/ha NPK) of fertilizers after 05 months of storage on the Mayo-kalio site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	40.00	31.01	13.75	27.42	20.00	28.85	14.15	35.56	16.50	39.58
FM2	1.25	46.97	5.34	43.62	0.00	44.08	6.97	57.56	6.50	37.72
FM3	17.50	41.30	2.50	44.75	3.75	63.47	0.80	52.12	6.25	44.69
FM4	21.73	31.93	20.00	34.28	6.25	51.40	9.89	55.71	27.50	29.56
FM5	47.50	25.65	3.75	42.87	25.00	38.77	3.75	52.01	15.00	47.92
FM6	60.00	14.05	2.50	35.42	25.71	51.97	17.09	49.04	18.75	41.95
FM7	49.66	23.05	2.50	43.25	24.09	41.30	25.00	42.47	12.50	36.06
FM8	25.42	35.05	5.34	27.43	12.50	44.17	16.25	45.75	21.25	36.03
FM9	29.59	35.36	2.50	39.99	3.75	37.78	3.75	48.96	24.09	32.89
FM10	60.00	18.07	8.75	40.64	25.00	44.25	10.19	53.68	15.00	38.32
FO1	40.00	24.30	17.50	38.93	8.75	50.84	3.75	56.08	18.75	35.11

FO2	33.75	25.88	17.09	39.33	24.50	35.20	2.50	53.75	4.59	46.50
FO0	46.95	25.93	22.50	27.37	6.25	45.47	17.50	48.64	11.65	25.02

TP: percentage loss rate

Table 6. Physical maximum of onion bulbs at the double dose (700kg/ha) of fertilizers applied after 05 months of storage on the Mayo-kalio site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	27.50	26.30	20.00	17.74	13.75	37.35	14.15	43.57	10.25	37.64
FM2	1.25	30.48	5.34	31.11	8.75	34.50	2.50	49.56	6.25	35.47
FM3	17.50	36.16	8.75	40.55	6.50	25.08	0.80	74.02	2.50	51.34
FM4	21.73	40.82	20.00	23.54	25.00	47.42	28.64	48.61	27.50	36.46
FM5	60.00	18.41	3.75	37.00	18.75	42.84	2.50	67.99	8.75	51.29
FM6	41.25	27.04	21.25	43.00	25.71	37.58	4.59	67.31	11.65	53.88
FM7	49.66	14.39	3.75	32.13	17.84	35.83	12.50	49.93	12.50	29.58
FM8	31.67	29.02	24.09	24.31	33.50	24.95	10.00	41.76	27.50	24.59
FM9	23.34	33.30	3.75	31.06	12.50	27.76	16.25	53.15	17.84	28.01
FM10	53.75	16.87	3.75	45.82	25.00	40.50	10.19	44.02	12.50	34.06
FO1	33.75	27.00	5.00	47.26	8.75	39.27	15.00	62.64	6.67	52.02
FO2	40.00	29.39	4.59	46.99	12.00	49.21	19.47	50.47	17.09	30.31
FO0	53.20	22.26	3.75	36.78	12.50	44.19	17.50	57.20	6.50	40.21

TP: percentage loss rate

After 05 months of storage of onion bulbs at the Mayo-kalio site, variability in average onion bulb yield was observed at different doses of fertilizers applied to 05 onion varieties. At a rate of 175 kg/ha of these fertilizers, the highest yield (66.21t/ha) was obtained with the *Chagari* variety for an FM3 fertilizer formulation (NPK 12-14-19-3.5MgO-0.15B). At this dose of fertilizers (175kg/ha), the onion bulb loss rate is very high (60.00%) with the same *Chagari* variety for an FM10 formulation (NPK 20-10-10 + 2.5CaO). At a dose of 350 kg/ha of fertilizers, the *Violet de Galmi* variety recorded the highest yield value (63.47t/ha) with the FM3 formulation (NPK 12-14-19-3.5MgO-0.15B) compared to other varieties tested. While the smallest yield (14.05t/ha) was obtained with *Chagari* for a very high loss rate (60.00%) with the FM6 formulation (NPK 12-14-19-3.5 MgO-0.15B). At the double dose (700 Kg/ha) of fertilizers, most of the highest yields were obtained with the *Safari* variety regardless of the fertilizer applied. It can be seen that the yield of the scale of onion bulb production is increasing with the *Safari* variety for the majority of fertilizers applied. The highest physical maximum value can reach 74.02t/ha with the FM3 formulation (NPK 12-14-19-3.5MgO-0.15B), while the lowest value is 17.74t/ha with the control fertilizer (Sodecoton). This variability in bulb yield and loss is justified on the one hand by the nature of these fertilizers applied and also by the ability of some varieties to conserve better than others. Onion bulb yields are very varied on fertile soil with these fertilizing elements. To also see the suitability for the aptitude of these onion varieties tested, it would be important to evaluate them on poor soil under the contribution of these fertilizers. Tables 7; 8 and 9 present the physical maximums obtained after 5 months of conservation of onion bulbs of 05 varieties tested on the Koza site.

Table 7. Physical maximum bulbs of 05 onion varieties in the 175 kg/ha dose of fertilizers after 05 months of storage on the Koza site.

Fertilizers	TP	Chagari	TP	Goudami	TP	Violet de	TP (%)	Safari	TP	Goudami

	(%)	(y1)	(%)	locale (y2)	(%)	Galmi (y3)		(y4)	(%)	Certifiée (y5)
FM1	30	15.09	17.5	40.36	5	38.24	5	19.12	7.5	29.51
FM2	7.5	18.52	7.5	40.36	7.5	31.36	7.5	32.36	5	43.86
FM3	5	31.94	5	47.24	17.5	29.68	7.5	37.31	17.5	26.70
FM4	5	30.60	30	41.23	7.5	32.48	7.5	25.34	30	34.84
FM5	5	17.10	7.5	52.51	30	29.55	7.5	16.21	5	35.90
FM6	30	25.89	20	31.07	30	36.16	17.5	31.62	17.5	32.33
FM7	17.5	9.61	5	37.58	30	12.57	30	14.19	5	12.00
FM8	17.5	27.67	7.5	44.96	5	27.99	17.5	21.61	17.5	24.73
FM9	17.5	20.66	5	54.81	20	29.14	7.5	34.24	30	30.28
FM10	30	29.88	17.5	43.30	30	27.68	5	41.01	5	40.34
FO1	30	14.69	17.5	29.72	7.5	31.75	7.5	25.59	5	23.67
FO2	7.5	8.89	17.5	22.24	17.5	15.11	5	15.99	7.5	24.30
FO0	5	8.46	30	16.73	7.5	14.69	17.5	9.18	7.5	10.42

TP: percentage loss rate

Table 8. Physical maximum of bulbs of 05 onion varieties under the effect of the normal dose (350 kg/ha) of fertilizers after 05 months of storage on the Koza site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	50	9.60	37.5	21.60	25	32.42	25	27.46	12.5	23.17
FM2	12.5	38.82	12.5	39.63	12.5	35.08	12.5	25.90	25	27.35
FM3	25	14.75	0	33.12	0	16.90	12.5	16.86	37.5	17.51
FM4	25	13.69	50	14.36	12.5	33.98	12.5	22.02	50	11.11
FM5	25	12.05	12.5	38.45	50	7.54	12.5	8.58	25	19.56
FM6	50	9.50	25	23.05	50	20.86	37.5	23.83	37.5	19.33
FM7	37.5	12.14	25	21.32	50	13.63	50	9.48	25	10.14
FM8	37.5	34.77	12.5	34.93	25	21.44	37.5	12.85	37.5	16.66
FM9	37.5	20.23	25	28.25	37.5	15.39	12.5	21.47	50	11.88
FM10	50	8.66	37.5	23.94	50	16.73	25	21.19	25	17.42
FO1	50	4.23	37.5	23.09	12.5	15.17	12.5	14.72	25	18.32
FO2	12.5	3.47	37.5	15.55	37.5	14.26	25	10.36	12.5	10.72
FO0	25	2.97	50	12.44	12.5	19.96	37.5	8.63	12.5	10.72

TP: percentage loss rate

It can be seen from Tables 7, 8 and 9 that after 05 months of storage of onion bulbs at the Koza site, average yields and loss rates vary from one variety to another, from one dose to another and from one formulation to another depending on the fertilizer applied.

At half a dose (175 kg/ha) of fertilizers, the local *Goudami* variety has mostly recorded high yields of up to 54.81t/ha with the FM9 formulation. While the smallest yield (8.89t/ha) with the *Chagari* variety was recorded with cow dung because it could be that the fertilizers are not fully available to be assimilated by onions or perhaps its dose is still insufficient. On the other hand, with the dose of 350kg/ha of fertilizers, the highest yield is of the order of 39.63t/ha against 3.47t/ha respectively with FM2 and FO2 fertilizers for local *Goudami* and *Chagari*.

At the double dose (700 kg/ha) of the fertilizers, the organic fertilizer (FO1) recorded a high value (54.22t/ha) in average bulb yield always with the local *Goudami* variety. While the smallest value is of the order of 3.89t/ha always with the *Chagari* variety. The variability observed in the average yield of onion bulbs of the varieties tested with fertilizers at the different test sites was recorded.

Apart from the effects of variety, those of fertilizer formulations and especially the doses of fertilizers tested, other uncontrollable factors such as spatial and geographical distribution, soil and climatic conditions. All these factors could also influence the variation in onion bulb yield.

Table 9. Physical maximum of 05 onion varieties tested in the 700Kg/ha dose of fertilizers after 05 months of storage on the Koza site.

Fertilizers	TP (%)	Chagari (y1)	TP (%)	Goudami locale (y2)	TP (%)	Violet de Galmi (y3)	TP (%)	Safari (y4)	TP (%)	Goudami Certifiée (y5)
FM1	15	21.15	40	10.13	2.5	17.04	15	29.57	15	24.29
FM2	2.5	31.31	2.5	27.40	27.5	15.83	27.5	23.79	0	29.33
FM3	15	23.77	27.5	23.97	40	17.34	2.5	36.95	0	27.33
FM4	15	16.61	40	12.49	40	19.44	40	17.20	40	18.07
FM5	40	4.94	2.5	32.42	27.5	11.39	15	23.27	2.5	28.44
FM6	2.5	22.69	27.5	28.59	40	11.79	2.5	26.51	2.5	37.91
FM7	27.5	3.89	2.5	11.72	27.5	10.26	15	10.82	15	9.89
FM8	40	7.36	40	21.28	2.5	19.28	15	10.54	40	9.69
FM9	15	13.91	2.5	45.09	15	22.80	27.5	16.55	27.5	11.84
FM10	27.5	14.49	2.5	52.85	40	16.20	15	21.32	15	21.45
FO1	27.5	19.06	2.5	54.22	2.5	32.12	40	20.68	15	30.32
FO2	15	13.97	2.5	23.18	2.5	12.45	15	11.35	27.5	25.47
FO0	27.5	8.43	2.5	16.46	15	10.85	27.5	5.83	2.5	13.05

TP: percentage loss rate

Combined effects of the factors studied on 07 agro-morphological parameters of 05 onion varieties tested

Table 10 shows the combined effects of factors on certain agro-morphological parameters of 05 onion varieties. The outcome of Table 10 shows that the spatial and geographic distribution has a highly significant effect on all parameters assessed (TFLO, RTD, P10B, ΔVB, DC90JAR, H90JAR and NF90JAR), whereas the combined effect of site*variety*fertilizer type (A*B*C) does not affect these measured parameters. All factors (study site, variety, type of fertilizers and dose) have very significant effects on seeding rates, bulb yield and crown diameter. Furthermore, apart from the spatial and geographical distribution of the study site, the interaction between the other factors has no effect on the average number of leaves of varieties at physiological maturity.

Table 10. Combined effects of factors on some (07) agro-morphological parameters of onion.

Variation	measured parameters						
The principal effect of factors	TFLO	RDT	P10B	ΔVB	DC90JAR	H90JAR	NF90JAR
A: site	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
B: Varieties	0.0000***	0.0000***	0.0000***	0.0028**	0.0000***	0.0012**	0.1752
C: fertilizers element	0.0000***	0.0000***	0.3893	0.1404	0.0000***	0.0000***	0.3855
D: Dose	0.0000***	0.0000***	0.0006**	0.6901	0.0000***	0.2284	0.4000
Interactions of factors							

A*B	0.0000***	0.0000***	0.0002**	0.0002**	0.1089	0.7559	0.4818
A*C	0.9792	0.0000***	0.1114	0.0433*	0.0001**	0.0000***	0.8788
A*D	0.1207	0.0000***	0.0032**	0.7936	0.0001**	0.0455	0.7263
B*C	0.0011**	0.9088	0.1814	0.7048	0.5765	0.1562	0.4053
B*D	0.0000***	0.0123	0.0195	0.1377	0.0058**	0.9281	0.7931
C*D	0.0346	0.0010**	0.3106	0.0030**	0.0086**	0.0757	0.6597
A*B*C	0.9965	0.9988	0.1997	0.8468	0.5328	0.4396	0.9616
A*B*D	0.0046**	0.0043**	0.0000***	0.0627	0.0165	0.5622	0.7118
A*C*D	0.7214	0.7583	0.0665	0.0001**	0.8991	0.1939	0.6149
B*C*D	0.0004**	0.9715	0.1784	0.6168	0.9910	0.4348	0.8861
A*B*C*D	0.9998	0.9995	0.0421	0.6824	0.9642	0.1603	07713

Note: *** = significant at 1%; ** = significant at 5%; TFLO: percentage of blooms, RDT: yield, P10B: weight 10 bulbs, ΔVB: bulbar variation, DC90JAR: Diameter at the collar 90 days after transplanting, H90JAR: Height 90 days after transplanting, and NF90JAR: number of leaves 90 days after transplanting.

Because of these results, it can be seen that the site would be a determining factor in the production of onion bulbs. Among the components of the site, the soil is the primary element that contributes to the production of bulbs. Table 11 shows the relationships between soil constituents and response variables for this study. These results show that there is a positive correlation between soil clay structure and yields. While a negative correlation was recorded by the other two textural classes (Silty and Sandy) and the yield components. This positive correlation explains the suitability of clay soils for onion bulb production compared to loamy and sandy soils. This justifies the low yields recorded at the Koza site compared to the other study sites (Mayo-kalio and Godola). Moreover, among the major fertilizer like Nitrogen; Phosphorus and Potassium, only nitrogen showed a positive correlation with onion yield components. For an improvement in onion bulb yields, the addition of nitrogen would be a suitable element regardless of the type of soil used in its production. While the increase in potassium is favourable for sandy and loamy soils. In addition, potassium is more interesting in loamy soils. In addition, for a clay soil suitable for the production of onion bulbs, the inputs of residue elements (Mg2+, Ca2+ and Na+) would be a more important asset to increase the saturation of exchangeable bases with a strong contribution to the improvement of yields of onion bulbs with the best storage. At the end of the evaluation of the physical maximum yield of the bulbs under the effect of organo-mineral fertilizers, the yield is one of the most relevant agronomic parameters to be compared between the onion's varieties tested. Thus, the choice of varieties that give efficient results under the effect of the best fertilizers is one of the key steps in onion production. However, the evaluation of economic performance depends on onion bulb yield. Among the economic performance indicators, the analysis of production costs/benefits to determine the economic maximums per treatment is the first step.

Table 11. Autocorrelations of soil and yield parameters of different onion varieties tested at different doses of organo-mineral fertilizers

Variation	Clay	Sand	Silt	PHKcl	MO	CO	NTot	C/N	Ca2+	Mg2+	K+	Na+	Sbe	P	RD1	RD2	RD3	ΔBul	NJR	CAp	GLAp	VGAp	SAp	GCAp
Clay	1																							
Sand	-0.45	1																						
Silt	-0.95	0.4	1																					
PHKcl	0.29	0.28	-0.08	1																				
MO	0.46	0.5	-0.37	0.77	1																			
CO	0.25	0.61	-0.15	0.75	0.91	1																		
NTot	0.09	0.26	0.05	0.56	0.55	0.76	1																	
C/N	-0.52	-0.2	0.7	0.24	-0.34	-0.2	0.26	1																
Ca2+	0.22	-0.4	0.01	0.63	0.08	0.08	0.34	0.67	1															
Mg2+	0.37	-0.4	-0.17	0.69	0.21	0.17	0.36	0.53	0.97	1														
K+	-0.05	0.49	0.2	0.76	0.66	0.85	0.91	0.31	0.40	0.41	1													
Na+	0.27	0.13	-0.05	0.71	0.62	0.71	0.85	0.29	0.55	0.54	0.8	1												
Sbe	0.42	-0.8	-0.24	0.29	-0.2	-0.2	0.1	0.49	0.87	0.86	0.01	0.29	1											
P	-0.29	-0.3	0.5	0.36	-0.21	-0.1	0.28	0.95	0.82	0.71	0.33	0.39	0.66	1										
RD1Ap	1.00	-0.4	-0.95	0.29	0.46	0.25	0.09	-0.52	0.22	0.37	-0.1	0.27	0.42	-0.3	1									
RD2Ap	0.79	-0.8	-0.66	0.31	0.08	-0.0	0.09	0.03	0.67	0.75	-0.0	0.28	0.88	0.26	0.79	1								
RD3Ap	0.96	-0.5	-0.86	0.36	0.4	0.28	0.26	-0.33	0.38	0.51	0.09	0.38	0.57	-0.1	0.96	0.88	1							
ΔBul	-0.57	0.87	0.41	-0.23	0.13	0.22	-0.1	-0.33	-0.8	-0.8	0.05	-0.3	-0.97	-0.5	-0.57	-0.93	-0.69	1						
NJR	-0.84	0.82	0.75	-0.16	-0.08	0.09	-0.09	0.09	-0.5	-0.6	0.13	-0.2	-0.78	-0.2	-0.84	-0.94	-0.88	0.9	1					
CAp	0.92	-0.7	-0.83	0.31	0.23	0.09	0.08	-0.24	0.49	0.61	-0.0	0.25	0.71	0.00	0.92	0.96	0.96	-0.8	-0.9	1				
GLAp	0.80	0.00	-0.89	0.08	0.54	0.38	0.0	-0.90	-0.3	-0.2	-0.1	0.0	-0.17	-0.8	0.80	0.32	0.68	0.00	-0.4	0.57	1			
VGAp	0.33	-0.7	-0.14	0.37	-0.16	-0.2	0.14	0.58	0.91	0.91	0.1	0.3	0.98	0.75	0.33	0.82	0.49	-0.94	-0.7	0.63	-0.26	1		
SAp	0.92	-0.7	-0.83	0.31	0.23	0.09	0.08	-0.24	0.49	0.61	-0.0	0.25	0.71	0.00	0.92	0.96	0.96	-0.8	-0.9	1.0	0.57	0.63	1	
GCAp	1.00	-0.4	-0.95	0.29	0.46	0.25	0.09	-0.52	0.22	0.37	-0.1	0.27	0.42	-0.3	1.00	0.79	0.96	-0.57	-0.8	0.92	0.80	0.33	0.92	1

NB: *PHKcl: hydrogen potential of chlorydric acid; MO: organic matter; CO: carbon monoxide; NTot: Total nitrogen; C/N: nitrogen carbon ratio; Ca2+, Mg2+, K+ and Na+: calcium, magnesium, potassium and sodium ions; Sbe: Sum of exchangeable bases; P : available phosphorus; RD1Ap: yield at dose 1; RD2Ap: yield at dose 2; RD3Ap: yield at dose 3; ΔBul: bulb volume variation; NJR: Number of Days maturity after transplanting; CAp: yield of the Chagari variety; GLAp: yield of the Goudami locale variety; VGAp: yield of the Violet de Galmi variety; SAp: yield of the Safari variety; GCAp: yield of the Goudami certifiée variety. Ap : after storage of bulbs.*

Evaluation of the maximum economic production of bulbs of 05 onion varieties tested at different fertilizer rates.

Tables 12, 13 and 14 show the levels of profits obtained by applied treatments.

Table 12. Maximum economic in CFA F of treatments applied @ 175kg/ha of fertilizers after storage on the Godola site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-295691.97	184041.23	-129922.37	213423.63	-968152.77
FM2	-98125.17	148032.18	652122.92	126282.22	-846574.11
FM3	165335.65	-82104.85	252858.24	371189.55	-1069393.88
FM4	-174678.17	-20242.60	118124.66	-89859.18	-807185.63
FM5	-7185.77	81369.23	-26320.77	115564.23	-810080.77
FM6	98452.04	113830.45	277799.25	78621.86	-387049.63
FM7	-482012.77	-235662.77	61051.23	-105522.77	-1043795.77
FM8	32073.41	-197846.85	281554.80	-30089.03	103400.85
FM9	-159584.95	-17899.71	457414.15	60807.33	-314782.81
FM10	59880.54	125954.41	292945.45	97903.71	-560850.67
FO1	-238983.83	-128660.43	368906.62	-121587.05	-687436.72
F02	-91965.92	38698.74	142097.73	-30886.05	-375397.33
FO0	-281127.89	-320363.94	174046.95	-404.25	-682568.38

Table 13. Maximum economic in CFA francs at the normal dose (350kg/ha) of fertilizers applied to different onion varieties after storage on the Godola site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-399780.77	-448604.61	134008.35	-461740.37	-445926.17
FM2	-35650.90	-233193.00	704234.41	-350367.49	215275.29
FM3	-156228.95	260765.39	709139.23	89250.23	338419.48
FM4	-195050.59	-54090.80	290670.05	383316.99	-157773.78
FM5	-181910.77	-197010.77	-21140.77	237259.23	-341930.77
FM6	-351685.48	136355.94	-97291.94	137092.97	-282722.47
FM7	-499681.77	-107558.77	-369296.77	-368044.77	-884624.77
FM8	-346999.51	-179586.54	333055.61	-273975.77	-667276.71
FM9	-447704.47	-140038.93	-23767.57	14254.51	-377056.19
FM10	-764810.00	-118551.87	-168697.23	-105473.70	-103039.29
FO1	-196497.14	-165417.34	577543.57	415037.76	-126577.88
F02	-359504.91	9684.77	69411.95	125921.49	-222113.31
FO0	-153956.68	-216003.35	584532.92	62947.23	7091.79

Table 14. Maximum economic in CFA F at a dose of 700kg/ha of fertilizers applied to different onion varieties after 05 months of storage on the Godola site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-780129.97	-1155990.69	-377870.09	-763088.13	-780086.37
FM2	-430185.03	-439626.67	-504034.50	-414805.41	-1085348.10

FM3	-515354.65	-170369.53	-73409.11	162870.06	-1089833.25
FM4	-649216.00	-931813.39	-520967.39	-706489.71	-1347623.93
FM5	-923660.77	-796745.77	-369460.77	-673940.77	-950780.77
FM6	-696623.54	-947593.16	-480911.46	-139027.84	-416778.07
FM7	-902616.77	-932914.77	-758282.77	-573282.77	-526546.77
FM8	-1029653.31	-849193.54	-364637.33	-739306.12	-1142786.28
FM9	-495269.53	-400566.49	-152445.47	-716577.31	-874648.51
FM10	-890989.09	-614626.91	-753256.68	-737844.55	-580366.98
FO1	-316252.19	-236727.13	60020.83	-261777.41	-1130538.59
F02	-297979.43	-214909.38	-41375.56	-81269.22	-295913.54
FO0	-301036.33	62452.75	126088.43	-195562.85	-658021.57

On the Godola site, the maximum profit at dose 1 of the fertilizers was obtained with the FM2 formulation which is a value of 652122.92 CFA F (violet de Galmi). With this variety (violet de Galmi), other highest values (704234.41 CFA F and 709139.23 CFA F) were obtained respectively with FM2 and FM3 formulations at the normal dose (350kg/ha NPK). From the dose of 700 kg/ha, the high production costs generate negative values in profit to the different treatments on the Godola site.

Table 15. Maximum economic in CFA francs at a dose of 175kg/ha of the different fertilizers given after the conservation of onion bulbs on the Mayo-kalio site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-125354.96	424015.04	315215.04	757205.84	-2690.96
FM2	594745.04	723860.24	186195.04	464859.86	384118.64
FM3	1369805.04	777005.04	25769.04	879280.10	687255.04
FM4	421871.04	849175.04	-251894.96	535581.70	353630.04
FM5	210910.04	125720.04	-181394.96	922708.92	513425.04
FM6	-904.96	762480.04	406105.12	943425.90	932555.04
FM7	-529548.44	430405.04	82245.04	799630.04	1036255.04
FM8	183537.82	196907.76	75805.04	981360.04	793885.04
FM9	-483.46	589330.04	316955.04	838565.04	1207514.48
FM10	-364304.96	867005.04	335505.04	1140886.68	787755.04
FO1	490745.04	370310.04	595755.04	1050785.04	1200465.26
FO2	-250719.96	470143.26	-126944.96	858125.04	237089.22
FO0	-436554.04	666120.04	308505.04	585575.04	29549.04

Table 16. Maximum economic in CFA F at a dose of 350kg/ha of fertilizers applied to onion varieties after 05 months of storage of bulbs on the Mayo-kalio site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-114934.96	-272059.96	-281574.96	-41132.16	131665.04
FM2	516125.04	368958.16	320705.04	831935.22	50169.64
FM3	275485.04	400285.04	1082195.04	600397.32	315005.04
FM4	-92441.64	-11614.96	606630.04	750868.76	-283164.96
FM5	-343434.96	331975.04	101205.04	603045.04	451425.04
FM6	-817914.96	23555.04	618936.40	473773.94	201980.04

FM7	-440467.52	354225.04	209306.64	228105.04	-16144.96
FM8	46703.04	-271516.24	331305.04	366610.04	-10369.96
FM9	44719.90	216965.04	61630.04	481000.04	-149822.84
FM10	-636274.96	253395.04	331005.04	680182.52	77725.04
FO1	-328494.96	243455.04	652920.04	834900.04	7830.04
FO2	-265404.96	259580.08	27429.04	741575.04	463334.22
FO0	-143163.60	-99204.96	558255.04	657185.04	-275666.16

Table 17. Maximum economic in CFA F at dose 3 (700kg/ha) of fertilizers applied to onion varieties after 05 months of storage of bulbs on the Mayo-kalio site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-478664.96	-834374.96	-116299.96	104260.04	-120848.96
FM2	-325129.96	-313225.28	-244429.96	329954.60	-221593.96
FM3	-126104.96	36245.04	-649408.96	1280179.06	384955.04
FM4	74217.24	-630374.96	258405.04	277773.10	-196084.96
FM5	-822174.96	-91874.96	75230.04	1052975.04	397170.04
FM6	-498024.96	127085.04	-156459.68	1004734.68	479538.24
FM7	-968806.72	-272684.96	-191295.92	344605.04	-457144.96
FM8	-369893.32	-571559.68	-612462.96	31905.04	-642814.96
FM9	-226363.92	-329419.96	-527944.96	459415.04	-534161.20
FM10	-862614.96	281785.04	2505.04	115499.52	-271294.96
FO1	-340354.96	456685.04	70465.04	976965.04	564128.86
FO2	-244974.96	445860.54	467889.04	490356.42	-303946.00
FO0	-290076.64	277270.04	507005.04	999395.04	331705.04

Reading Tables 15, 16 and 17, it is noted that fertilizers of formulations FM2 and FM3 showed a level of positive profits with all varieties tested at doses of 175 kg/ha and 350 kg/ha of fertilizers applied. Up to the 700 kg/ha fertilizer dose, only Safari showed positive economic maximum values with all fertilizers applied except the FM1 formulation of 350 kg/ha. At the Koza site after the storage of bulbs of 05 onion varieties (tables 18, 19 and 20), profit levels are very variant, and they change from one fertilizer to another and from one variety to another. Most of these profit levels are negative and from dose 3 of the applied fertilizers, very few profit levels are positive. This shows very low-profit values in this locality (Koza) compared to other sites. In addition to the economic maximums evaluated, it is important to look at input management to identify the most important resources that would contribute significantly to the added value of onion bulb production.

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Table 18. Maximum economic in CFA francs at half the dose (175kg/ha) of fertilizers applied to onion varieties after storage of bulbs on the Koza site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-606897	390463.1	238923.1	-553637	-126277
FM2	-473337	386913.1	-39776.9	-27816.9	444383.1
FM3	56483.08	655343.1	-113737	163133.1	-249197
FM4	6403.07	418303.1	1493.07	-312147	79983.08
FM5	-533577	869593.1	-115697	-677337	122443.1

FM6	-187387	6733.07	143373.1	-65936.9	-25556.9
FM7	-829627	275883.1	-791197	-754517	-830137
FM8	-103757	574673.1	-171097	-454307	-317237
FM9	-391257	961323.1	-132137	44163.08	-102577
FM10	-17006.9	506193.1	-185207	320133.1	305153.1
FO1	-595637	-7736.92	6763.07	-267287	-332117
FO2	-827507	-306717	-658847	-651537	-307087
FO0	-784877	-467197	-615517	-863787	-802087

Table 19. Maximum economic in CFA F at a dose of 350kg/ha NPK of the treatments applied in the experiment after 05 months of conservation of onion bulbs on the Koza site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-914277	-447397	-81176.9	-307777	-467277
FM2	247523.1	266753.1	18073.08	-377077	-307277
FM3	-728977	-7596.92	-723077	-752627	-714577
FM4	-764577	-751197	-33026.9	-539127	-963877
FM5	-830277	212503.1	-1090477	-1076727	-625677
FM6	-942577	-413997	-568377	-477327	-645577
FM7	-819577	-465797	-840077	-1033877	-995477
FM8	92673.08	85803.08	-520677	-892077	-727827
FM9	-503077	-195297	-776327	-561177	-933077
FM10	-955377	-357147	-712377	-562077	-700677
FO1	-1073877	-332897	-716177	-762377	-606477
FO2	-1104477	-634397	-752827	-936777	-910327
FO0	-1004277	-638797	-404727	-885827	-790327

Table 20. Maximum economic in CFA francs per 700kg/ha of NPK (dose 3) of fertilizers applied to onion varieties after 05 months of storage of bulbs on the Koza site.

Varieties / Fertilizers elements	Chagari (y1)	Goudami locale (y2)	Violet de Galmi (y3)	Safari (y4)	Goudami Certifiée (y5)
FM1	-627157	-1081277	-871357	-398217	-597357
FM2	-234787	-404497	-933717	-643587	-409877
FM3	-564437	-569657	-901477	-144977	-517877
FM4	-836717	-1014717	-803477	-920997	-874437
FM5	-1303557	-217647	-1125487	-678157	-459447
FM6	-614547	-391637	-1130477	-569667	-101757
FM7	-1331637	-1031617	-1156727	-1162257	-1187657
FM8	-1178597	-635357	-782047	-1159477	-1181477
FM9	-944837	289353.1	-669197	-947007	-1123507
FM10	-900657	620793.1	-912077	-735357	-718257
FO1	-600667	792393.1	-158417	-644037	-246297
FO2	-804117	-449367	-945047	-1017177	-440307
FO0	-785807	-478077	-768897	-997917	-697257

Evaluation of the marginal productivity of the production inputs of the onion bulbs of the 05 varieties tested.

Table 21 shows the best combinations of factors according to three soil units of the comparative test sites.

It can be seen in this table that on sandy-clay soil (koza), the best combination of production inputs is the same regardless of the applied dose. But only the dose of 175Kg/ha of NPK has a better combination compared to other doses because it has a better optimal benefit (206,307,115 FCFA) compared to other applied doses. Moreover, on clay-sandy soil (Godola) with a high proportion of silt, the best combination of bulb production inputs is found at the dose of 350kg/ha of NPK of fertilizing elements for a marginal productivity of 4.432 CFA francs relative to the capital for the purchase of seeds. This could increase the optimal profit (101,052.34 FCFA) if an additional unit of capital in seed cost would have been added. In addition, on the clay-sandy soil (low silt proportion) of Mayo-kalio, the best combination of production inputs was obtained with the 175kg/ha dose of fertilizer because the best optimal profit is of the order of 283,471,445 CFA francs compared to other levels of optimal profits of applied doses. With this better combination of production inputs at a dose of 175kg/ha NPK fertilizer, only the cost related to the purchase of fuels and lubricants provided a marginal productivity of 1.431 CFA francs. Identification the best activities goes without saying with these best combinations of factors.

Table 21. Evaluation of the best combination in CFA F of onion bulb production inputs by site at different doses of fertilizers

Amount of fertilizers	D1 (175kg/ha de NPK)			D2 (350kg/ha de NPK)			D3 (700Kg/ha de NPK)		
Resources	Quantities needed	Quantities available	Marginal Productivities	Quantities needed	Quantities available	Marginal Productivities	Quantities needed	Quantities available	Marginal Productivities
Study site					Koza (sandy-clay)				
Acap	16788.74	23172.83		7511.26	23172.83		7511.26	23172.83	
Land	0.215	1.000		0.215	1.00		0.215	1.00	
Lcap	54.23	203.75		54.233	203.75		54.233	203.75	
Ecap	20280.40	2.2800E+5		39058.559	2.2800E+5		51505.79	2.2800E+5	
Scap	20027.19	91200.00		20027.169	91200.00		20027.169	91200.00	
CLcap	1.9810E+5	1.9810E+5	1.041	1.9810E+5	1.9810E+5	0.289	1.9810E+5	1.9810E+5	0.858
PTcap	18241.65	1.3035E+5		18241.635	1.3035E+5		18241.635	1.3035E+5	
Optimal profit		206307.115			57247.185			170053.475	
Study site					Godola (clay-sandy)				
Acap	16788.74	23172.83		11147.775	23172.83		9487.468	23172.83	
Land	1.00	1.00	4.658	19950.000	1.6000E+5		16978.723	1.6000E+5	
Lcap	54.23	203.75		36.001	203.75		30.639	203.750	
Ecap	20280.40	2.2800E+5		27930.000	2.2800E+5		47540.426	2.2800E+5	
Scap	20027.19	91200.00		22800.000	22800.00	4.432	22800.00	22800.00	0.866
CLcap	1.9810E+5	1.9810E+5		1.0962E+5	1.9810E+5		93289.688	1.9810E+5	
PTcap	18241.65	1.3035E+5		10687.500	1.3035E+5		9095.745	1.3035E+5	
Optimal profit		4.658			101052.34			19752.326	
Study site					Mayo-Kalio (clay-sandy)				
Acap	16189.144	23172.83		11147.775	23172.83		9487.468	23172.83	
Land	0.207	2.00		0.143	2.00		0.121	2.00	
Lcap	64.736	203.75		44.577	203.75		37.938	203.75	
Ecap	20280.406	2.2800E+5		27930.000	2.2800E+5		47540.426	2.2800E+5	
Scap	16555.433	22800.000		22800.000	22800.000	6.764	22800.00	22800.00	6.809
CLcap	1.9810E+5	1.9810E+5	1.431	1.3641E+5	1.9810E+5		1.1609E+5	1.9810E+5	
PTcap	13451.289	1.3035E+5		9262.500	1.3035E+5		7882.979	1.3035E+5	
Optimal profit		283471.445			154212.793			155255.758	

NB: Acap: Depreciation for materials and equipment; Land: Land capital; Lhj: Man-day for labour intensity; Ecap: Capital for the purchase of fertilizers; Scap: Capital for the purchase of seeds; CLcap: Capital for the purchase of fuels and lubricants; PTcap: Capital for transport and pesticides; Z (FCFA): Profit function (objective function).

3.5. Determination of the best treatments applied in onion bulb production at the different test sites

Table 22 shows the best activities par excellence on the Koza site with the best combination of factors.

Table 22. Determination of the best treatments (activities) at different doses of fertilizers on the sandy-clay soil of Koza.

Variation		Quantities needed					Marginal Productivities (reduced costs)				
Amount fertilizers	Activities	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-1.568E+6	-5.709E+5	-7.224E+5	-1.515E+6	-1.088E+6
	FM10						-9.783E+5	-4.551E+5	-1.147E+6	-6.412E+5	-6.562E+5
	FM2						-1.435E+6	-5.744E+5	-1.001E+6	-9.891E+5	-5.169E+5
	FM3						-9.048E+5	-3.060E+5	-1.075E+6	-7.982E+5	-1.211E+6
	FM4						-9.549E+5	-5.430E+5	-9.598E+5	-1.273E+6	-8.813E+5
	FM5						-1.495E+6	-9.173E+4	-1.077E+6	-1.639E+6	-8.389E+5
	FM6						-1.149E+6	-9.546E+5	-8.180E+5	-1.027E+6	-9.869E+5
D1	FM7						-1.791E+6	-6.854E+5	-1.753E+6	-1.716E+6	-1.791E+6
(175kg/h	FM8						-1.065E+6	-3.866E+5	-1.132E+6	-1.416E+6	-1.279E+6
a)	FM9		0.215				-1.353E+6	0	-1.093E+6	-9.172E+5	-1.064E+6
	FO0						-1.746E+6	-1.429E+6	-1.577E+6	-1.825E+6	-1.763E+6
	FO1						-1.557E+6	-9.691E+5	-9.546E+5	-1.229E+6	-1.293E+6
	FO2						-1.789E+6	-1.268E+6	-1.620E+6	-1.613E+6	-1.268E+6
	Activities	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-1.181E+6	-7.141E+5	-3.479E+5	-5.745E+5	-7.340E+5
	FM10						-1.222E+6	-6.239E+5	-9.791E+5	-8.288E+5	-9.674E+5
	FM2		0.215				-1.923E+4	0	-2.487E+5	-6.438E+5	-5.740E+5
	FM3						-9.957E+5	-2.743E+5	-9.898E+5	-1.019E+6	-9.813E+5
	FM4						-1.031E+6	-1.018E+6	-2.998E+5	-8.059E+5	-1.231E+6
	FM5						-1.097E+6	-5.425E+4	-1.357E+6	-1.343E+6	-8.924E+5
	FM6						-1.209E+6	-6.807E+5	-8.351E+5	-7.441E+5	-9.123E+5
D2	FM7						-1.086E+6	-7.325E+5	-1.107E+6	-1.301E+6	-1.262E+6
(350kg/h	FM8						-1.741E+5	-1.809E+5	-7.874E+5	-1.159E+6	-9.946E+5
a)	FM9						-7.698E+5	-4.620E+5	-1.043E+6	-8.279E+5	-1.200E+6
	FO0						-1.271E+6	-9.055E+5	-6.715E+5	-1.153E+6	-1.057E+6
	FO1						-1.341E+6	-5.996E+5	-9.829E+5	-1.029E+6	-8.732E+5
	FO2						-1.371E+6	-9.012E+5	-1.020E+6	-1.204E+6	-1.177E+6
	Activities	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-1.420E+6	-1.874E+6	-1.664E+6	-1.191E+6	-1.390E+6
	FM10						-1.693E+6	-1.716E+5	1.704E+6	-1.528E+6	-1.511E+6
	FM2						-1.027E+6	-1.197E+6	-1.726E+6	-1.436E+6	-1.202E+6
	FM3						-1.357E+6	-1.362E+6	-1.694E+6	-9.374E+5	-1.310E+6
	FM4						-1.629E+6	-1.807E+6	-1.596E+6	-1.713E+6	-1.667E+6
D3	FM5						-2.096E+6	-1.010E+6	-1.918E+6	-1.471E+6	-1.252E+6
(700kg/h	FM6						-1.407E+6	-1.184E+6	-1.923E+6	-1.362E+6	-8.942E+5
a)	FM7						-2.124E+6	-1.824E+6	-1.949E+6	-1.955E+6	-1.980E+6
	FM8						-1.971E+6	-1.428E+6	-1.574E+6	-1.952E+6	-1.974E+6
	FM9						-1.737E+6	-5.030E+5	-1.462E+6	-1.739E+6	-1.916E+6
	FO0						-1.578E+6	-1.270E+6	-1.561E+6	-1.790E+6	-1.490E+6
	FO1		0.215				-1.393E+6	0	-9.508E+5	-1.436E+6	-1.039E+6
	FO2						-1.597E+6	-1.242E+6	-1.737E+6	-1.810E+6	-1.233E+6

D1: dose of 175kg/ha NPK; D2: dose 350kg/ha NPK; D3: dose of 700kg/ha NPK; y1: *Chagari*; y2: *Goudami locale*; Y3: *violet de Galmi*; y4: *safari* and y5: *Goudami certifiée*.

Table 23 shows that at the Koza site with a sandy-clay texture, one of the optimal solutions can be deduced when the marginal productivities of the products are zero. Therefore, at different doses (175kg/ha; 350kg/ha and 700kg/ha) of fertilizers, the *Goudami locale* variety is an excellent activity of onion bulb production with FM9, FM2 and FO1 fertilizers respectively. In addition, Table 23 presents the best activities per excellence at different doses of fertilizers on the clay-sandy soil of Godola.

Table 23. Determination of the best treatments (activities) at different doses of fertilizers at the Godola experimental site (clay-sandy).

Variation		Quantities needed					Marginal Productivities (reduced costs)				
Amount fertilizers	Activities	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-9.478E+5	-4.681E+5	-7.820E+5	-4.387E+5	-1.620E+6
	FM10						-5.922E+5	-5.262E+5	-3.592E+5	-5.542E+5	-1.213E+6
	FM2			7.142 9E-6			-7.502E+5	-5.041E+5	0	-5.258E+5	-1.499E+6
	FM3						-4.868E+5	-7.342E+5	-3.993E+5	-2.809E+5	-1.722E+6
D1	FM4						-8.268E+5	-6.724E+5	-5.340E+5	-7.420E+5	-1.459E+6
(175kg/ha)	FM5						-6.593E+5	-5.708E+5	-6.784E+5	-5.366E+5	-1.462E+6
	FM6						-5.537E+5	-5.383E+5	-3.743E+5	-5.735E+5	-1.039E+6
	FM7						-1.134E+6	-8.878E+5	-5.911E+5	-7.576E+5	-1.696E+6
	FM8						-6.200E+5	-8.500E+5	-3.706E+5	-6.822E+5	-5.487E+5
	FM9						-8.117E+5	-6.700E+5	-1.947E+5	-5.913E+5	-9.669E+5
	FO0						-9.333E+5	-9.725E+5	-4.781E+5	-6.525E+5	-1.335E+6
	FO1						-8.911E+5	-7.808E+5	-2.832E+5	-7.737E+5	-1.340E+6
	FO2						-7.441E+5	-6.134E+5	-5.100E+5	-6.830E+5	-1.028E+6
	Activities	**y_1**	**y_2**	**y_3**	**y_4**	**y_5**	**y_1**	**y_2**	**y_3**	**y_4**	**y_5**
	FM1						-7.544E+5	-8.622E+5	-5.751E+5	-1.295E+6	-1.226E+6
	FM10						-1.119E+6	-5.322E+5	-8.778E+5	-9.387E+5	-8.831E+5
	FM2						-3.902E+5	-6.468E+5	-4904.820	-1.184E+6	-5.648E+5
	FM3			0.143			-5.108E+5	-1.528E+5	0	-7.440E+5	-4.416E+5
	FM4						-5.496E+5	-4.677E+5	-4.185E+5	-4.499E+5	-9.378E+5
D2	FM5						-5.365E+5	-6.106E+5	-7.303E+5	-5.960E+5	-1.122E+6
(350kg/ha)	FM6						-7.063E+5	-2.772E+5	-8.064E+5	-6.961E+5	-1.063E+6
	FM7						-8.543E+5	-5.212E+5	-1.078E+6	-1.201E+6	-1.665E+6
	FM8						-7.016E+5	-5.932E+5	-3.761E+5	-1.107E+6	-1.447E+6
	FM9						-8.023E+5	-5.536E+5	-7.329E+5	-8.190E+5	-1.157E+6
	FO0						-5.085E+5	-6.296E+5	-1.246E+5	-7.703E+5	-7.730E+5
	FO1						-5.511E+5	-5.790E+5	-1.316E+5	-4.182E+5	-9.066E+5
	FO2						-7.141E+5	-4.039E+5	-6.397E+5	-7.073E+5	-1.002E+6
	Activities	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-8.494E+5	-1.237E+6	-5.165E+5	-9.260E+5	-9.326E+5
	FM10						-9.603E+5	-6.955E+5	-8.919E+5	-9.007E+5	-7.328E+5
	FM2						-4.995E+5	-5.205E+5	-6.426E+5	-5.777E+5	-1.238E+6
	FM3			0.121			-5.847E+5	-2.512E+5	0	-2.120E+5	-1.242E+6
	FM4						-7.185E+5	-1.013E+6	-6.596E+5	-8.694E+5	-1.500E+6
D3	FM5						-9.930E+5	-8.776E+5	-5.081E+5	-8.368E+5	-1.103E+6
(700kg/ha)	FM6						-7.659E+5	-1.028E+6	-6.195E+5	-3.019E+5	-5.693E+5
	FM7						-9.719E+5	-1.014E+6	-8.969E+5	-7.362E+5	-6.790E+5
	FM8						-1.099E+6	-9.300E+5	-5.033E+5	-9.022E+5	-1.295E+6
	FM9						-5.646E+5	-4.814E+5	-2.911E+5	-8.794E+5	-1.027E+6
	FO0						-3.703E+5	-1.839E+4	-1.252E+4	-3.584E+5	-8.105E+5
	FO1						-3.856E+5	-3.176E+5	-7.859E+4	-4.246E+5	-1.283E+6

	FO2						-3.673E+5	-2.958E+5	-1.800E+5	-2.441E+5	-4.484E+5

D1: dose of 175kg/ha NPK; D2: dose 350kg/ha NPK; D3: dose of 700kg/ha NPK; y1: *Chagari*; y2: *Goudami locale*; y3: *violet de Galmi*; y4: *safari* and y5: *Goudami certifiée*.

The results of the analysis of the determination of the best activities (Table 23) of onion bulb production show that the best excellence activities vary from one dose to another and the types of fertilizers tested on onion varieties. At different fertilizer doses (175kg/ha, 350kg/ha and 7000kg/ha), the *violet de galmi* variety is an excellent activity with the application of FM2 and FM3 formulations respectively at different doses applied because their marginal productivity is zero. In addition, it would be more interesting to test on a more clay soil of Mayo-kalio to identify the best activities per excellence. The best treatments at different doses of fertilizers at the Mayo-kalio site are recorded in Table 24.

Table 24. Determination of best treatments (activities) at different nutrient doses on Mayo-Kalio clay-sandy soil.

Source de variation		Quantités nécessaires					Productivités Marginales (coûts réduits)				
Doses d'engrais	Activités	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-1.495E+6	-9.458E+5	-1.055E+6	-6.126E+5	-1.372E+6
	FM10						-1.734E+6	-5.028E+5	-1.034E+6	-2.289E+5	-5.820E+5
	FM2						-7.751E+5	-6.459E+5	-1.184E+6	-9.049E+5	-9.857E+5
	FM3	0.27					0	-5.928E+5	-1.344E+6	-4.905E+5	-6.825E+5
	FM4						-9.479E+5	-5.206E+5	-1.622E+6	-8.342E+5	-1.016E+6
D1	FM5						-1.159E+6	-1.244E+6	-1.551E+6	-4.471E+5	-8.564E+5
(175kg/ha)	FM6						-1.371E+6	-6.073E+5	-9.637E+5	-4.264E+5	-4.373E+5
	FM7						-1.899E+6	-9.394E+5	-1.288E+6	-5.702E+5	-3.336E+5
	FM8						-1.186E+6	-1.173E+6	-1.294E+6	-3.884E+5	-5.759E+5
	FM9						-1.370E+6	-7.805E+5	-1.053E+6	-5.312E+5	-1.623E+5
	FO0						-1.806E+6	-7.037E+5	-1.061E+6	-7.842E+5	-1.340E+6
	FO1						-8.791E+5	-0.999E+6	-7.740E+5	-3.190E+5	-1.693E+5
	FO2						-1.621E+6	-8.997E+5	-1.497E+6	-5.117E+5	-1.133E+6
	Activités	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-6.560E+5	-9.033E+5	-1.364E+6	-1.313E+6	-1.059E+6
	FM10						-1.177E+6	-3.778E+5	-7.512E+5	-5.914E+5	-1.113E+6
	FM2						-2.497E+4	-2.622E+5	-7.615E+5	-4.396E+5	-1.140E+6
	FM3			0.15			-2.656E+5	-2.309E+5	0	-6.712E+5	-8.754E+5
	FM4						-6.335E+5	-6.428E+5	-4.756E+5	-5.207E+5	-1.474E+6
D2	FM5						-8.845E+5	-2.992E+5	-9.810E+5	-6.685E+5	-7.390E+5
(350kg/ha)	FM6						-1.359E+6	-6.076E+5	-4.633E+5	-7.978E+5	-9.884E+5
	FM7						-9.816E+5	-2.770E+5	-8.729E+5	-1.043E+6	-1.207E+6
	FM8						-4.944E+5	-9.027E+5	-7.509E+5	-9.050E+5	-1.201E+6
	FM9						-4.964E+5	-4.142E+5	-1.021E+6	-7.906E+5	-1.340E+6
	FO0						-6.843E+5	-7.304E+5	-5.239E+5	-6.144E+5	-1.466E+6
	FO1						-8.696E+5	-3.877E+5	-4.293E+5	-4.367E+5	-1.183E+6
	FO2						-8.065E+5	-3.716E+5	-1.055E+6	-5.300E+5	-7.271E+5
	Activités	y_1	y_2	y_3	y_4	y_5	y_1	y_2	y_3	y_4	y_5
	FM1						-1.023E+6	-1.470E+6	-1.206E+6	-1.176E+6	-1.319E+6
	FM10						-1.407E+6	-3.537E+5	-1.087E+6	-1.165E+6	-1.470E+6
	FM2						-8.699E+5	-9.487E+5	-1.334E+6	-9.502E+5	-1.420E+6
	FM3				0.12		-6.709E+5	-5.992E+5	-1.739E+6	0	-8.135E+5

	FM4	-4.705E+5	-1.266E+6	-8.311E+5	-1.002E+6	-1.395E+6
D3	FM5	-1.367E+6	-7.273E+5	-1.014E+6	-2.272E+5	-8.013E+5
(700kg/ha)	FM6	-1.043E+6	-5.084E+5	-1.246E+6	-2.754E+5	-7.189E+5
	FM7	-1.514E+6	-9.081E+5	-1.281E+6	-9.356E+5	-1.656E+6
	FM8	-9.147E+5	-1.207E+6	-1.702E+6	-1.248E+6	-1.841E+6
	FM9	-7.711E+5	-9.649E+5	-1.617E+6	-8.208E+5	-1.733E+6
	FO0	-8.348E+5	-3.582E+5	-5.825E+5	-2.808E+5	-8.668E+5
	FO1	-8.851E+5	-1.788E+5	-1.019E+6	-3.032E+5	-6.343E+5
	FO2	-7.897E+5	-1.896E+5	-6.216E+5	-7.898E+5	-1.502E+6

D1: dose of 175kg/ha NPK; D2: dose 350kg/ha NPK; D3: dose of 700kg/ha NPK; y1: *Chagari; y2: Goudami locale; Y3: violet de Galmi; y4: safari and y5: Goudami Certifiée.*

The results of Table 24 show that at the Mayo-kalio site with a clay-sandy texture, one of the optimal solutions can be deduced when the marginal productivity of the products is zero. Therefore, at a dose of 175kg/ha of nutrients, *Chagari* is the best activity per excellence of onion bulb production with FM3 formulation fertilizer. Moreover, at a dose of 350kg/ha of fertilizing elements, *Violet de Galmi* is an activity per excellence in onion bulb production always with the FM3 formulation. While the dose of 700kg/ha of this same fertilizer formulation (FM3), it is the *Safari* that is an activity per excellence in onion bulb production.

DISCUSSION

Evaluation of the physical maximums of onion bulb production at the different test sites

The 05 onion varieties tested at different doses of mineral and organic fertilizers on three different soil types showed diversified yields. After 05 months of storage, these physical bulb maximums of these 05 onion varieties are very variable from one site to another; from one variety to another and finally from one dose to another of the fertilizers. Bulb loss after storage does not necessarily depend on soil texture and structure, as a high-rate value (60.00%) of loss was observed on very fertile soil (Mayo-kalio) and less fertile soil (Koza). The divergent results were reported by Bal *et al*. (2022) who found a lower onion bulb loss rate that is between 0.27-8.27 percent. This difference in the rate of loss of onion bulbs is justified on the one hand by the type of fertilizer used and especially the soil and climatic conditions of the environment, which would have played a very crucial role in the preservation of the bulbs. On the other hand, the rate of loss recorded during conservation usually depends on the storage design. In addition, the comparison of the average yield at harvest of the bulbs of the 05 varieties tested showed that there are significant differences ($p \geq 0.000$) between the treatments applied at each experimental site. This difference in bulb yield is due to the value that each fertilizing element according to the composition of each fertilizer formulation applied would also have contributed. This diversity of fertilizer formulations chosen is justified by the nutrients that make up the formulation. At first glance of the analyses, the more nitrogenous formulations make it possible to increase the yields of the bulbs at harvest but its bulbs are less preserved. While formulations that are more potassium give medium-sized and more calibrated bulbs that keep better production. Among the fertilizers tested, only the FM4 formulation (NPK 13-13-21-3S-0.01Zn-0.01B) has more potassium elements but has a poor ability to preserve onion bulbs. This lack of bulb preservation for this formulation, which is more potassium, could be attributed on the one hand to the high percentage of K_2O in the fertilizer combined with that of the soil that may have caused toxicity to the onion crop. Moreover, excess K_2O could also inhibit the action of another fertilizing element in the soil. On the other hand, the excess in Zn could negatively explain the growth and especially the quality of these products. In addition, the edaphic nature of the soils of different experimental sites would also be factors that strongly contributed to this variability in the yield of the onion bulbs obtained. This diversity of yield could be justified by the cultural background of the fertilizers applied on the plot and the different climatic conditions that exist between two consecutive crop years. The contradictory results with the peasant irrigation method obtained by M'Biandoun and Essang (2008) showed in the Northern region that the sandy-clay soil (80t/ha) of Tchontchi is more suitable for the production of the *Goudami* variety compared to clay soils (Lagdo and Kismatari) and clay-sandy soils (Ouro mal hamadou for 70t/ha) with the application of

Sodecoton fertilizer (22-10-15). Additional, contrary results obtained by Sakatai *et al*. (2021) on loamy soil with the same technical method practice (locker mode), for the same *Goudami locale* variety showed that the highest average yield in t/ha is 43.58 ± 0.21 t/ha. However, this high yield was obtained rather with the mixture of 21-8-12 (FM9) and 12-14-19 (FM3) following the proportion 2/3 and 1/3 respectively for an extremely high dose (2222 kg / ha). Similarly, the study carried out by Sakatai *et al*. (2019) in Gazawa in the dry season on clay-sandy soil showed satisfactory results in bulb yield with the *Chagari* variety (50.48 t/ha) compared to the *Goudami* variety (49.24kg/ha). This high value in average yield was observed in the ridge system for the mixture of DAP (18-46-00), potassium sulfate (00-00-50), NPK (20-10-10) and urea (46% N) respectively at a dose of 20 g / m; 15 g/m and 500 kg/ha. The yield size of the *Chagari* variety could be explained by the fact that the urea applied would have promoted the turgidity of the bulbs in water. Gupta *et al*. (2018) observed that the level of soil fertility is important in onion production. This is the case of Mayo-kalio soil, which has high proportions of organic matter (2.03), carbon monoxide (0.90), nitrogen (0.20) and especially clay (58.0) compared to other soil types tested. The onion needs substantial amounts of nutrients element for its growth. Therefore, to reach at least a level of 36 t/ha of onion bulb yield, onion cultivation needs an amount per ha of 124kg; 22.5kg and 135.5Kg respectively of N; P and K of major elements fertilizers (Yassen and Khalid, 2009). In addition, nitrogen is the constituent element of chlorophyll which rapidly develops the rate of increase proportional to the size of onion bulbs. However, its dose deficiency or overdose of fertilizers has been mentioned as an inevitability for the development of onion cropping (Ganie *et al.,* 2010). However, these authors revealed that the combined effects of variety and nitrogen are significant on leaf chlorophyll levels at different stages of onion crop growth. Similarly, increasing nitrogen doses leads to an increase in bulb yields of onion varieties, as the level of nitrogen doses increases, the more marketable bulb yields increase. The highest yield was recorded with a dose of 150 kg N/ha and 412 kg P/ha. Nitrogen applied showed a significant effect on marketable bulb yields. This significance for the increase in yield of marketable bulbs increases with nitrogen doses. This increase would be attributed to the high accumulation of chlorophyll quantities, which in turn accelerates photosynthesis and in turn the size and high weight of onion bulbs. The results showed that the onion varieties tested have considerable adsorption power concerning major fertilizing elements (N, P and K) available in the soil after harvest. Moreover, in Niger, the highest yield was 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 formulation 15-15-15 (Boukary *et al*., 2012). The intensity level into three (03) doses of the 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 (Habou *et al.,* 2015). These authors showed that after four months of bulb storage, NPK T2 (30-30-30) treatment recorded the lowest rate of loss (16%) compared to other treatments. This shows that the rate of loss does not necessarily depend on the nitrogen intensity applied but on other parameters. These findings are similar to those obtained in this study. The smallest values in loss rate recorded are of the order of 13.58% and 19.22% respectively with FM2 formulations: NPK 21-9-11-5S-1.5MgO-0.15B2O3 (NPK + TE), FM3 NPK 12-14-19-3.5MgO-0.15B. This difference in loss rates would be due to the quality of the storage design (aeration of the store), the technical practice (different formulations of fertilizer, technical irrigation ...) and especially the texture and structure of the soil. Thus, in the same idea with the soil conditions and especially the effect of the spatial and geographical distribution, the multi-local tests were carried out to see their effects on the yield averages of 05 varieties tested at the dose level of these fertilizers. It is with this in mind that this trial was implemented on three study sites with different soil textures and structures. The results showed on the sandy-clay soil of Godola that the 05 varieties (*Chagari*, *Goudami locale*, *Violet de Galmi*, *Safari* and *Goudami certifiée*) had the highest average yields of around 47.94 ± 4.51t/ha; 47.29 ± 3.56t/ha; 55.66 ± 3.16t/ha; 55.35 ± 2.06t/ha and 55.82 ± 1.83t/ha respectively with FM10 (D1), FM3 (D2), FM2 (D2), FM6 (D2), FM3 (D2) mineral fertilizers. In addition, on the same type of more clay soil of Mayo-kalio (clay-sandy), the average yields of onion bulbs of 05 varieties (*Chagari*, *Goudami locale*, *Violet de Galmi*, *Safari* and *Goudami certifiée*) are higher than those obtained at the Godola site. The highest values are around 74.60 ± 7.45t/ha; 57.77 ± 3.16t/ha; 69.96 ±

1.37t/ha; 74.61 ± 1.12t/ha and 78.46 ± 2.69t/ha with the following fertilizers (FM3 (D1), FM4 (D1), FM6 (D2), FM3 (D3) and FM9 (D1) respectively). On the other hand, on sandy-clay soil of Koza, the highest average yields are of the order of 44.36 ± 3.20t/ha; 58.90 ± 4.79 t/ha; 51.65 ± 2.74t/ha; 43.17 ± 2.48t/ha and 49.77 ± 2.58t/ha respectively with the varieties *Chagari*, *Goudami locale*, *Violet de Galmi*, *Safari* and *Goudami certifiée* under the application of FM2 (D2) formulations; FM4 (D1); FM6 (D1); FM10 (D1) and FM4 (D1). In other countries such as India where yields are low, Priyanka *et al*. (2017) obtained onion bulb yield that can reach a value of about 24.94 t/ha with the best dose of 125-75-125 kg of N-P2O5-K2O. These values obtained are almost similar to those of Nikhil and Jadhav (2016) whose yield values in t/ha are between 17 and 24t/ha. Chattopadhyay *et al*. (2013) also reported that onion bulb yields range from 15.04 to 26.33Kg/ha. While during the same season in the same context, Meher *et al*. (2016) showed that under the effect of sulfur, the yield in t/ha varies from 24t/ha to 35.5t/ha. Singh *et al*. (2018) observed that the potential gross yield of onion bulbs can be maximum up to 29.9 t/ha. In addition, the yield in tons per hectare of onion bulbs obtained by Prashanthi *et al*. (2021) is highly variable with average values between 26.20 and 52.80 t/ha. Instead, Aditika *et al*. (2017) showed that these yield values are very low and range from 4.24 to 8.3 t/ha for Agrifound White and L-652, respectively. The same findings of low yield were observed by Bal *et al*. (2022) but with high variability (5.4 to 35.75 t/ha) in bulb yield between applied treatments. The value of an onion bulb production treatment does not depend only on the largest quantity produced but largely depends on the cost of this resource that goes into production. It is therefore important to look at the quantities of inputs needed for more optimal production.

Best combination of onion bulb production inputs of the 05 varieties tested

The volume of onion bulb production depends on a number of the quantities of factors used to achieve a maximum level of yield that corresponds to one or more treatments applied. The best combinations of production inputs were obtained with the dose of 175 kg/ha NPK at the Koza and Mayo-kalio sites. But at the Godola site, the best combination is the dose of 350kg/ha of NPK. The values of these results compared to those obtained in a characterization study of 05 onion varieties in Gazawa by Sakatai *et al.* (2019) showed that the values of production inputs are practically less on 0.25 ha. Only the costs related to equipment and those of fuel and lubricants are enough higher than the costs obtained in the study conducted in Gazawa. The quantities required for inputs are respectively of the order of 203.75 man-day for all operations (clearing, ploughing, making lockers, transplanting, hoeing, treatment, guarding and harvesting) of onion bulb production; 35145.15 CFA F for the purchase capital of pesticides; 41347.238 CFA F for seed purchase capital; 28713.36 CFA F for the capital of the rental of the plot; 49524.80 CFA F for the purchase capital of fuels (gasoline and oil); 89126,268 CFA F for the purchase capital of fertilizers (fertilizers and DAP); 23172.83 CFA F for the depreciation of materials and equipment and 95200 CFA F for the capital of other expenses (packaging, transport, string) (Sakatai *et al.,* 2019). This variability in input value is due to the specific characteristics of the localities of production and to the variability of the prices of the resources used in production. More recently, studies by Sakatai *et al.* (2021) at the Meskine site have shown that the quantities of useful inputs/outputs vary from one resource to another. The degree of variability in the quantity of inputs/outputs of bulb production is due to the value of each factor during the crop year, which differs from year to year and from locality to locality.

Moreover, 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. The first input into production is seeds, most of which are imported. Because of its high cost, producers are more encouraged to produce their seeds (Currah 2002). Another, this price is not within their reach given the financial means they have (farmers). Additionally, in Tunisian oases, the value obtained in profit is 2,426,070 CFA F with the production of local onions (Chengappa *et al.,* 2012). This variability in profit is attributed on the one hand to the variability of prices (shortage of bulbs hence the price spike of products) of onion bulbs, and on the other hand to the quantity offered and demanded in consumer markets. For this best combination of the inputs of determined production, what is the treatment (activity) that combines it to obtain an optimal profit from the production of onion bulbs corresponding to each type of soil?

Best treatments (activities) for the production of onion bulbs of 05 varieties tested at the experimental sites

After storage of onion bulbs, all doses level of fertilizers recorded a marginal product productivity response according to the three soil types compared. The results of the analysis of the determination of the best activities of onion bulb production show that the best excellence activities vary from one soil type to another and the types of fertilizers tested on onion varieties. The *Safari* provided an optimal profit of about 155,255,758 CFA F compared to other onion varieties at a dose of 700 kg/ha (FM3). This shows that on rich soil (clay-sandy), it is preferable to produce on a maximum area of 0.25 ha with our local varieties (*Chagari* and *Goudami locale*) that adapt better to our locality (climatic conditions). While the same linear programming shows that it would be profitable to use respectively 21-9-11-5S-1.5MgO-0.15B2O3 (NPK+TE) and 12-14-19-3.5MgO-0.15B on *Violet de Galmi* and *Goudami locale* for the sale of bulbs after storage. Similar results were obtained by Sakatai *et al.* (2019) that it would be preferable to produce in ridge model system with the *Goudami locale* variety in the Gazawa area. However, it would be advantageous to always produce the same *Goudami locale* variety in the Meskine (loamy soil) locality in locker mode with the fertilizer mixture of the formulations 21-8-12-2MgO+2.7S+2.5CaO and 12-14-19-3.5MgO-0.15B (Sakatai *et al.,* 2021). In addition, the onion line irrigation system on the ridges is profitable in the North Cameroon region both in the rainy and dry seasons on the one hand and produces good quality of bulbs that are more preserved (M'biandoum and Essang, 2008). For these authors, the advantage of the ridge model system made with animal traction (mechanized beef production) makes it possible to reduce manual work times from 104 days to 10 days. This allows the effective reduction of the cost related to labour. But this value of production would only be profitable if the onion bulbs are sold after storage.

CONCLUSION

Onion production in the Sudano-Sahelian zone of Cameroon can improve the living conditions of smallholders. But this production is faced with many constraints responsible for the low yield of onion bulbs. Yet there are palliative measures to improve low yield. This has aroused a real interest in looking for other alternative solutions. One of the best solutions is the identification of the most suitable fertilizer formulations for bulb conservation and the most economically profitable for each type of soil frequently used in onion production.

The results of the tests showed that after the conservation of onion bulbs, variability in bulb yield was also recorded on two types of soil (clay-sandy and sandy-clay), but the clay-sandy soil (Mayo-kalio) presented at a dose of 700kg/ha of NPK efficient yields whose highest potential yield in t/ha is 74,02t/ha with 12-14-19-3.5MgO-0.15B. An evaluation of marginal factor productivity showed on the clay-sandy soil of Mayo-kalio that the best combination of production inputs was obtained with *Goudami locale* variety by applying the dose of 175kg/ha of NPK of the fertilizers because its best optimal profit is of the order of 283,471,445 CFA francs compared to other levels of optimal profits of the applied doses. With this better combination of production inputs at 175kg/ha, only the cost related to the purchase of fuels and lubricants provided marginal productivity of 1.431 CFA francs. For a better generalization of the results over the entire study, a fertilizer evaluation study on varieties must also extend to the entire Sudano-Sahelian zone.

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