

Optimization of Okra [*Abelmoschus esculentus* (L.)] Production through Improved Technical Itineraries in Korhogo (Northern Côte d'Ivoire): Evaluation of some Agrophysiological Parameters

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Received:- 03 July 2026/ Revised:- 06 August 2026/ Accepted:- 03 September 2026/ Published: 05-10-2026

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Abstract— Okra (*Abelmoschus esculentus*) is cultivated throughout northern Côte d'Ivoire. However, it is threatened by poor soil quality, which reduces production. Our overall objective was to provide producers with technical itineraries to contribute to increased okra productivity. Therefore, planting beds consisting of flat ground (TP), ridges without polyethylene film cover (BSP), and ridges with polyethylene film cover (BAP) were prepared at densities of 20,000 and 80,000 plants per hectare. Fertilizers (F1, F2, F3, F4) were applied to the plants in three or four fractions. The trials were arranged in completely randomized blocks with three replications of four factors. Quantitative data were analyzed using STATISTICA 7.1 for analysis of variance (ANOVA) and XLSTAT version 2019 for principal component analysis (PCA). The results show that planting beds, planting density, fertilizer types, and application frequency significantly influenced vegetative parameters and okra weight ($P < 0.001$ at 5%). The highest weights were obtained with BAP (428.7 g), D20 density (610.2 g), and F4 fertilizer (856.4 g). The combination of these factors led to 48 technical itineraries. Principal component analysis (PCA) of the technical itineraries based on recorded growth and yield parameters revealed that all variables are positively oriented and strongly correlated with the F1 axis (86.06%). The distribution of the different technical itineraries along the axes allowed for the identification of the best technical itinerary: BAP/D20/F4/3AP. The correlation matrix revealed significant positive correlations between the parameters studied ($r > 0.5$; $P < 0.001$). This suggests that choosing this technical approach could contribute to food security and increase producers' income.

Keywords— okra, technical itinerary, production, Côte d'Ivoire.

I. INTRODUCTION

Okra [*Abelmoschus esculentus* (L.)], belonging to the Malvaceae family, is a vegetable cultivated in tropical, subtropical, and warm temperate regions worldwide (Siddhartha et al., 2017). Global annual okra production was estimated at 11,232,656 tonnes

in 2022. Africa accounts for 31.57% of total production (FAOSTAT, 2024; Massrie, 2025). In Côte d'Ivoire, production was estimated at 183,832 tonnes, ranking it as the third-largest okra producer in West Africa, after Nigeria and Mali (FAOSTAT, 2024; Seydou et al., 2025). Okra cultivation is highly valued for its edible leaves and immature fruits (Khomsug et al., 2010). Its fresh and dried fruits, sliced into rounds or processed into flour, are used to prepare sauces, and the seeds are used to make oil (Legba et al., 2018; Marius et al., 1997). Okra is packed with important nutrients, including protein, carbohydrates, lipids, and fiber, and is rich in vitamins and minerals (Laameche and Benaichaoui, 2021; Legba et al., 2018). Okra leaves are often used to eliminate oxygen free radicals, improve kidney function, and reduce proteinuria (Siemonsma and Kouamé, 2004). It has been used as a blood plasma substitute or to increase blood volume (Siemonsma, 1982). The leaves are sometimes used as a base for poultices, as an emollient, a diaphoretic (Khomsug et al., 2010), or for making fishing lines and game traps. The diverse uses of okra make it a potential export crop, contributing to food security and producer incomes. However, its cultivation is facing increasing difficulties, including diseases and pests, climate change, the unavailability of improved varieties, and a lack of mastery of techniques that directly affect already insufficient production (Déclert, 1990; Gnago et al., 2010). To ensure food security and increase production, our overall objective was to provide producers with a high-potential technical guide to contribute to increased okra productivity. Specifically, this involves:

- studying the effect of planting beds, planting density, types of fertilizers and their number of applications on okra yield;
- selecting high-performing technical itineraries for which the plants exhibit the best agrophysiological characteristics.

II. MATERIAL AND METHODS

2.1 Material

2.1.1 Plant material

The plant material consisted of seeds from two varieties obtained at the Korhogo market in the Poro region of Côte d'Ivoire. These are Tomi, belonging to *A. callei* (Figure 1A), an improved variety, and a local variety, Koto, belonging to *A. esculentus* (Figure 1B) (Fondio and Djidji, 2007).



FIGURE 1: Variety of okra

2.1.2 Fertilizing material

Chicken manure was a heterogeneous mixture of faeces, feathers, eggshells, and bedding. It was collected from farms surrounding the study site. The mixture of chicken manure and sawdust constituted the organic fertilizer used in this study. An application rate of 300 kg/ha of organic fertilizer was applied one week before sowing, and 150 kg/ha was applied one week after sowing.

2.2 Methods

2.2.1 Study site

The study was conducted at the experimental farm of the agroforestry department of Peleforo Gon Coulibaly University (Korhogo). The farm is located at approximately 9°25'54.8" N and 5°38'1.3" W. The soil at the site is sandy loam with a C/N ratio of 11 (Traoré et al., 2021). Monthly rainfall ranged from 0 mm to 884.40 mm. The average monthly temperature ranged between 26.93 °C and 28.02 °C. The climate is of the Sudanese type, characterized by two seasons: a dry season from November to April and a rainy season from May to October.

2.2.2 Soil Preparation

On flat land, deep ploughing to a depth of 30 cm was carried out, followed by soil loosening. On ridges, it was necessary to plough, break up large clods of earth, and then create ridges 30 cm high and 1 m wide using a daba (Fondio and Djidji, 2007). Okra cultivation took place during the dry season, between January and April.

2.2.3 Sowing

The seeds underwent a flotation test to select healthy, mature seeds. For this purpose, the seeds were placed in a jar of plain water, and the floating seeds were removed, leaving only those that settled at the bottom. One week after spreading organic fertilizer in the planting holes, sowing took place at a rate of 3 seeds per hole and a depth of 5 cm on flat ground and on ridges (Kouamé et al., 2021).

2.2.4 Thinning

Thinning was carried out ten days after emergence to retain only one plant per planting hole. Only the most vigorous plants were kept (Kouamé et al., 2021).

2.2.5 Watering

The plants were watered regularly using a watering can from sowing until fruiting, that is, 20 litres of water per square metre every two days (Fondio and Djidji, 2007; CNRA, 2007).

2.2.6 Weeding

Weeding was carried out manually every two months using hoes. This action aimed to prevent competition for nutrients and to destroy predator nests. Three weeding were performed during the experiment, from setup to data collection.

2.2.7 Phytosanitary Treatment

The use of certain bioinsecticides, such as Levo 2,4 SL, helps control insect pests of okra. Cypermethrin and deltamethrin treatments were used to control flea beetles and lepidopteran caterpillars (Adja et al., 2019).

2.2.8 Effect of planting beds, planting density, types of fertilizers and their number of applications on okra yield

Planting beds consisting of flat ground (TP), ridges without polyethylene film covering (BSP), and ridges with polyethylene film covering (BAP) were studied. Okra planting densities were set at 20,000 and 80,000 plants per hectare (D20 and D80, respectively). The 20,000 plants/ha density was achieved with 0.50 m between planting holes and 1.00 m between rows, and the 80,000 plants/ha density with 0.25 m between planting holes and 0.50 m between rows. The mineral fertilizer used for crop maintenance had a basic formulation of urea and potash. To create fertilizers from this basic formulation, additives were added: either trace elements (boron and zinc), complete fertilizer (NPK/MgO), or a combination of both. Fertilizer application was carried out in three or four stages. Four fertilization methods were therefore tested (Table I).

TABLE 1
MINERAL FERTILIZATION

Manures	Fertilizing elements	Total quantities of fertilizers per plant
F1	Urea (46% nitrogen)	11 g
	Potash [potassium sulfate: potassium oxide (K ₂ O) 50%; sulfur (S) 17%]	25 g
F2	Urea (46% nitrogen)	11 g
	Potash [potassium sulfate: potassium oxide (K ₂ O) 50%; sulfur (S) 17%]	25 g
	Trace elements: boron 0.51 g/L; chelated copper EDTA 0.25 g/L; EDTA chelated iron 0.16 g/L; molybdenum 0.05 g/L; zinc 0.47 g/L including Zn chelated EDTA 0.0065 g/L; manganese chelated EDTA 0.51 g/L	0.06 mL (4 L/ha)
F3	Urea (46% nitrogen)	10 g
	Potash [potassium sulfate: potassium oxide (K ₂ O) 50%; sulfur (S) 17%]	22 g
	Complete fertilizer: nitrogen (N) 11%; phosphate (P ₂ O ₅) 5%; potassium oxide (K ₂ O) 27%; sulfur (S) 15%; magnesium oxide (MgO) 5%	15 g (200 kg/ha)
F4	Urea (46% nitrogen)	10 g
	Potash [potassium sulfate: potassium oxide (K ₂ O) 50%; sulfur (S) 17%]	22 g
	Trace elements: boron 0.51 g/L; EDTA-chelated copper 0.25 g/L; EDTA-chelated iron 0.16 g/L; molybdenum 0.05 g/L; zinc 0.47 g/L, of which EDTA-chelated zinc 0.0065 g/L; EDTA-chelated manganese 0.51 g/L	0.06 mL (4 L/ha)
	Complete fertilizer: nitrogen (N) 11%; phosphate (P ₂ O ₅) 5%; potassium oxide (K ₂ O) 27%; sulfur (S) 15%; magnesium oxide (MgO) 5%	15 g (200 kg/ha)

Source: Kanga, 2022

2.2.9 Effect of combining levels of simple factors (planting beds, types of fertilizer, number of fertilizer applications, planting density) on agronomic parameters

The combination of factors related to planting beds, density, fertilizer types, and the number of fertilizer applications allowed for the development of 48 technical itineraries (Table II) (Kanga, 2022). The following data were collected from 10 plants. Plant height (cm): measured from the furthest leaf to the soil surface using a tape measure. Number of leaves: count the first leaves at the base of the main stem, at the crown, up to the last leaves at the tip. Leaf area (cm²): product of the length and width of a leaf, measured with a tape measure. Crown circumference (cm): measurement of the diameter of the part of the plant in contact with the soil, measured with a tape measure. Branching: counting of primary and secondary branches. Fruit weight (g): weights measured using an electronic balance. Vegetative parameters were recorded on each plant from flowering onwards, while fruit weight was determined at fruit maturity (Kouamé et al., 2021).

2.2.10 Experimental Design

This completely randomized Fisher block design consisted of three blocks, or replicates, of four factors (planting bed, density, fertilization, and application frequency). Each block was subdivided into 48 plots, each planted with a different okra variety. Each plot constituted a treatment modality represented by 20 plants in two rows of 10 plants each. The spacing between okra plants was 0.6 m. The spacing between plots within the same block was 1 m, and 1.5 m between blocks.

TABLE 2
TECHNICAL ITINERARY FOR OKRA PRODUCTION

Code	Technical itinerary	Code	Technical itinerary	Code	Technical itinerary	Code	Technical itinerary
ITK1	TP/D20/F1/3AP	ITK13	TP/D80/F3/3AP	ITK25	BSP/D80/F1/3AP	ITK37	BAP/D20/F3/3AP
ITK2	TP/D20/F1/4AP	ITK14	TP/D80/F3/4AP	ITK26	BSP/D80/F1/4AP	ITK38	BAP/D20/F3/4AP
ITK3	TP/D20/F2/3AP	ITK15	TP/D80/F4/3AP	ITK27	BSP/D80/F2/3AP	ITK39	BAP/D20/F4/3AP
ITK4	TP/D20/F2/4AP	ITK16	TP/D80/F4/4AP	ITK28	BSP/D80/F2/4AP	ITK40	BAP/D20/F4/4AP
ITK5	TP/D20/F3/3AP	ITK17	BSP/D20/F1/3AP	ITK29	BSP/D80/F3/3AP	ITK41	BAP/D80/F1/3AP
ITK6	TP/D20/F3/4AP	ITK18	BSP/D20/F1/4AP	ITK30	BSP/D80/F3/4AP	ITK42	BAP/D80/F1/4AP
ITK7	TP/D20/F4/3AP	ITK19	BSP/D20/F2/3AP	ITK31	BSP/D80/F4/3AP	ITK43	BAP/D80/F2/3AP
ITK8	TP/D20/F4/4AP	ITK20	BSP/D20/F2/4AP	ITK32	BSP/D80/F4/4AP	ITK44	BAP/D80/F2/4AP
ITK9	TP/D80/F1/3AP	ITK21	BSP/D20/F3/3AP	ITK33	BAP/D20/F1/3AP	ITK45	BAP/D80/F3/3AP
ITK10	TP/D80/F1/4AP	ITK22	BSP/D20/F3/4AP	ITK34	BAP/D20/F1/4AP	ITK46	BAP/D80/F3/4AP
ITK11	TP/D80/F2/3AP	ITK23	BSP/D20/F4/3AP	ITK35	BAP/D20/F2/3AP	ITK47	BAP/D80/F4/3AP
ITK12	TP/D80/F2/4AP	ITK24	BSP/D20/F4/4AP	ITK36	BAP/D20/F2/4AP	ITK48	BAP/D80/F4/4AP

ITK: Technical itinerary; TP: Flat ground; BSP: Ridge without polyethylene; BAP: Ridge with polyethylene; D20: Density 20,000 plants/ha; D80: Density 80,000 plants/ha; F: Types of fertilizers; 3AP: Three applications of fertilizer; 4AP: Four applications of fertilizer

2.2.11 Statistical Analysis

Data processing was performed using STATISTICA 7.1 software. An analysis of variance (ANOVA) was used to evaluate the effect of planting beds, density, fertilizer types, and the number of applications on fruit weight, as well as the effect of variety. The Student-Newman-Keuls test was used to compare significant differences at a p-value < 0.05. Furthermore, a principal component analysis (PCA) using XLSTAT 2019 software was used to select the best technical approaches.

III. RESULTS

3.1 Influence of planting beds, planting density, types of fertilizers and their number of applications on the yield of okra of the Koto variety

Analysis of Figure 2 shows that the different types of planting bed, density, and fertilization significantly influenced ($P < 0.001$) fruit weight at the 5% significance level. The highest fruit weight was obtained on a ridge with BAP polyethylene film (428.7 g), followed by a ridge without BSP polyethylene film (265 g) and flat ground (TP) (124.2 g). Fruit weight varied significantly ($P < 0.05$) according to density. Fruit weight at a density of 20,000 plants/ha (D20) was higher (610.2 g) than at a density of 80,000 plants/ha (D80) (250 g). A significant difference ($P < 0.05$) was observed in fruit weight according to fertilization levels F1 (346 g), F2 (345 g), F3 (744.2 g), and F4 (856.4 g). Fertilization levels F1 (346 g) and F2 (345 g) were statistically identical. The highest weight was obtained with F4 (856.4 g).

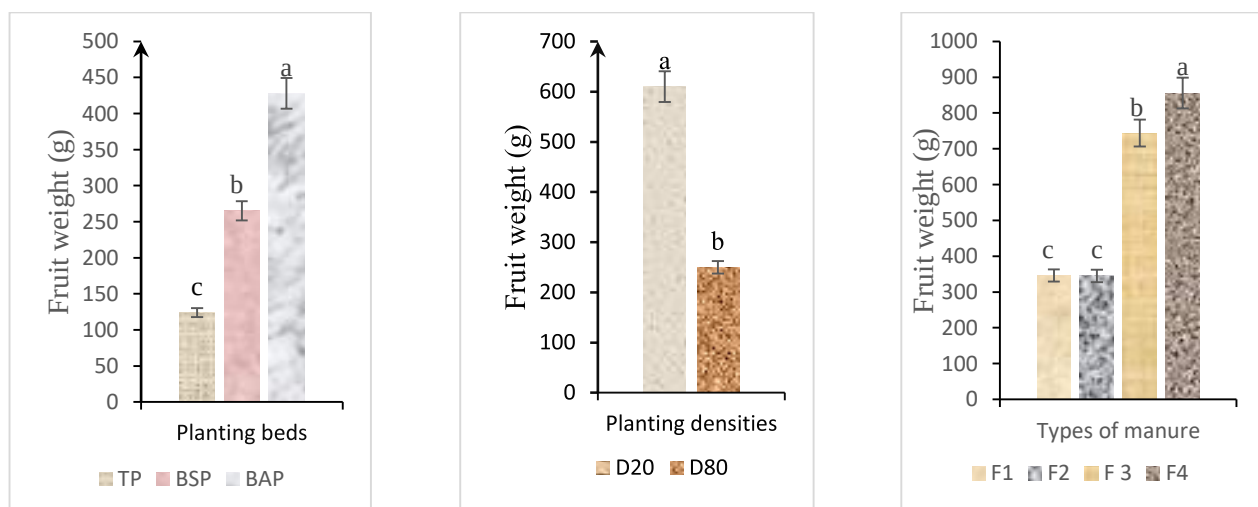


FIGURE 2: Okra fruit weight as a function of planting bed, planting density, and type of fertilization

TP: flat land; BSP: ridge without polyethylene; BAP: ridge with polyethylene; D20: 20,000 plants per hectare; D80: 80,000 plants per hectare; F1, F2, F3, F4: types of fertilizer

3.2 Effect of F4 fertilizer application frequency on okra weight

The results in Table III reveal the impact of the application frequency of fertilizer 4 on the average fruit weight of the Koto variety. The observed differences are significant ($P < 0.05$). Fertilizer 4 applied three times resulted in a weight of 743 g, and 860 g when applied four times.

TABLE 3
FREQUENCY OF F4 FERTILIZER APPLICATION PER KILOGRAM OF OKRA

Fertilizer 4	Average weight of the fruit (g)
3AP	743b
4AP	860a
P	0.006

Within the same column, numbers followed by the same letter are statistically identical at the 5% level (Newman-Keuls test); 3AP: three applications; 4AP: four applications; P: probability

3.3 Effect of sowing period on the yield of okra of the Koto variety

Analysis of Figure 3 shows that the sowing period significantly influenced okra yield ($P = 0.00$) at the 5% significance level. Sowings in January, February, March, and April produced 2, 5, 5.5, and 7.5 t/ha of okra, respectively. The yield of okra sown in April was higher than that sown in March. There was no significant difference between the yields of okra sown in February and March. The yield from sowing in January was the lowest.

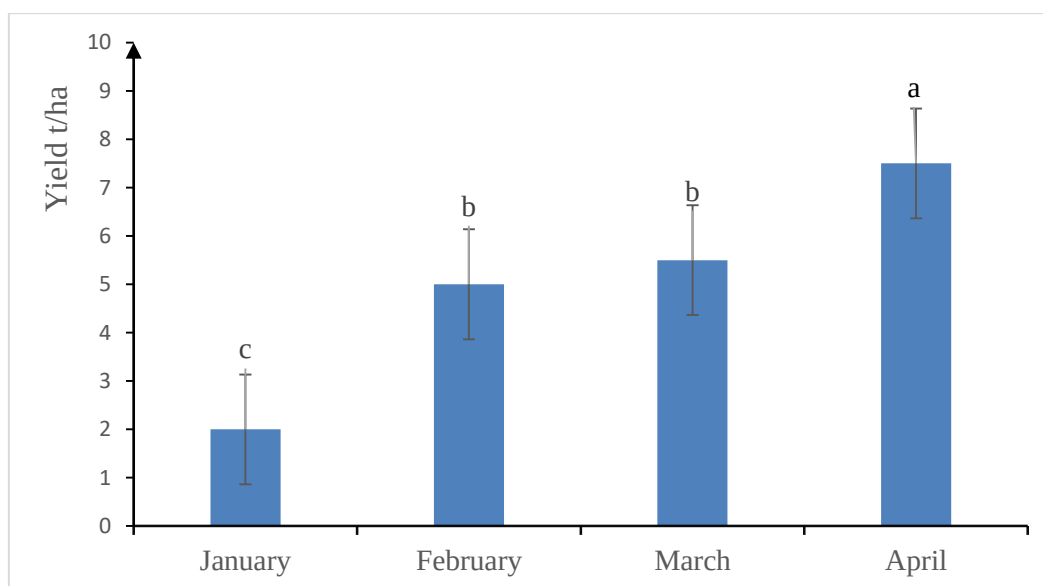


FIGURE 3: Yield as a function of sowing period

3.4 Selection of technical itineraries with high production potential

The results of the principal component analysis based on the growth and yield parameters recorded on the plants are presented in Figure 4. The correlation circle showed that axes 1 and 2 account for 86.06% and 6.33% of the variability, respectively. All variables are positively oriented and strongly correlated with axis F1. The distribution of the different technical approaches along the two axes allowed for the identification of three groups (Figure 5). Group C, consisting solely of the BAP/D20/F4/3AP (ITK39) technical itinerary, is characterized by high growth and production values and is positively correlated with the number of live leaves, plant height, crown circumference, number of branches, leaf area, and fruit weight. Group B is characterized by average growth values. Group A, characterized by low growth values, is negatively correlated with the factors studied. Data analysis (Table IV) showed that the quantitative variables studied in plants from the different technical approaches exhibited

significant differences between minimum and maximum values. The measured parameters showed very high standard deviations (SFE: 82.240; HP: 30.204; NFE: 21.846), with the exception of CCO and NRA, which showed very low standard deviations (1.726 and 1.412, respectively). Table V presents the correlations between the variables. Correlations were observed between vegetative parameters and fruit weight. Increasing these vegetative parameters led to a significant increase in fruit weight ($P < 0.0001$). The results showed that all vegetative and yield parameters exhibited considerable positive correlations with each other ($r > 0.5$). Fruit weight was positively correlated with plant height (0.908), number of leaves (0.845), leaf area (0.750), number of branches (0.908), and collar circumference (0.874). Increases in collar circumference and leaf area resulted in a significant increase in fruit weight.

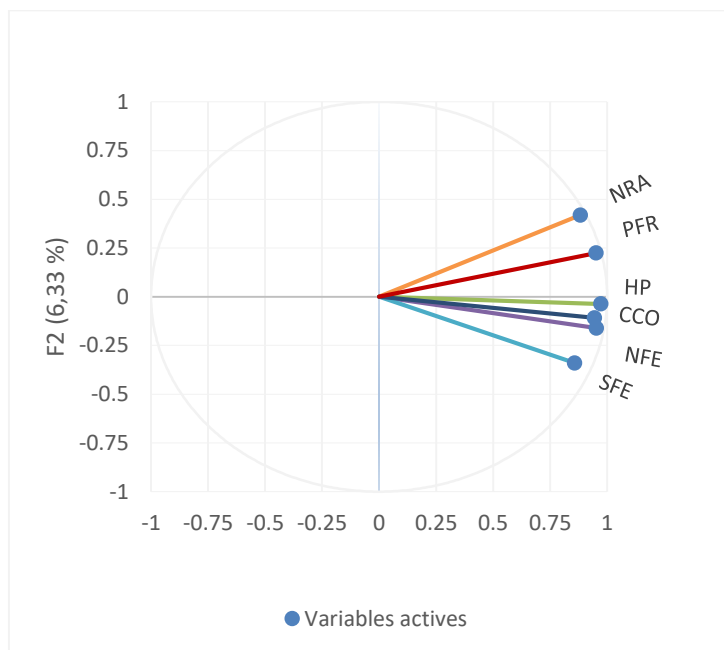


FIGURE 4: Correlation circle

NRA: Number of branches; PFR: Fruit weight; HP: Plant height; CCO: Collar circumference; NFE: Number of leaves; SFE: Leaf area

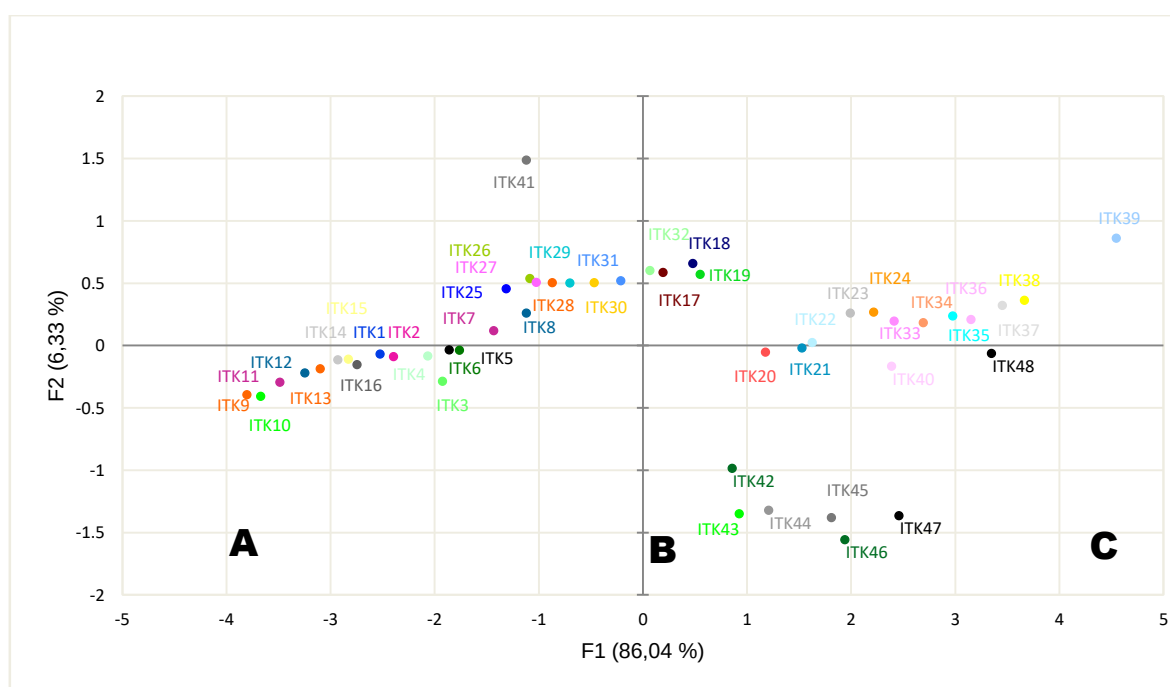


FIGURE 5: Dispersion of technical itineraries

ITK: technical itinerary

TABLE 4
DESCRIPTIVE ANALYSIS OF QUANTITATIVE DATA

Variable	Minimum	Maximum	Average	Standard deviation
HP (cm)	50	160	94.333	30.204
NFE	28	96.7	60.306	21.846
SFE (cm ²)	40	426	324.177	82.24
NRA	8	14.8	10.671	1.726
CCO (cm)	3.8	8	5.879	1.412
PFR (g)	52	90	70.96	9.368

HP: Plant Height; NFE: Number of Leaves; SFE: Leaf Area; NRA: Number of Branches; CCO: Collar Circumference; PFR: Fruit Weight

TABLE 5
CORRELATION MATRIX

	HP	NFE	SFE	NRA	CCO	PFR
HP	1	0.936	0.812	0.826	0.92	0.908
NFE	0.936	1	0.8	0.762	0.946	0.845
SFE	0.812	0.8	1	0.674	0.749	0.75
NRA	0.826	0.762	0.674	1	0.746	0.908
CCO	0.92	0.946	0.749	0.746	1	0.874
PFR	0.908	0.845	0.75	0.908	0.874	1

HP: Plant Height; NFE: Number of Leaves; SFE: Leaf Area; NRA: Number of Branches; CCO: Collar Circumference; PFR: Fruit Weight

3.5 Effect of Koto and Tomi varieties on okra growth and production parameters

The results recorded in Table VI reveal that all the parameters studied, as a function of variety, had P values less than 0.05 ($P < 0.05$), with the exception of the plant collar circumference ($P > 0.05$). The best parameters were obtained with variety VA1 ($160.25 \pm 0.84b$; $98.04 \pm 0.41a$; $425.52 \pm 0.70a$; $14.39 \pm 0.11a$; $7.80 \pm 0.20a$; $91.70 \pm 0.53a$). Variety therefore has a significant effect on the morphological and yield parameters of okra.

TABLE 6
EFFECT OF OKRA VARIETIES ON AGRONOMIC PARAMETERS

	HP	NFE	SFE	NRA	CCO	PFR
VA1	$160.25 \pm 0.84b$	$98.04 \pm 0.41a$	$425.52 \pm 0.70a$	$14.39 \pm 0.11a$	$07.80 \pm 0.20a$	$91.70 \pm 0.53a$
VA2	$173.704 \pm 0.54a$	$84.69 \pm 0.18b$	$405.72 \pm 0.81b$	$12.70 \pm 0.04b$	$08.00 \pm 0.31a$	$83.58 \pm 0.89b$
F	177.6	855.1	339.2	175.53	0.28	60.47
P	0	0	0	0	0.6	0

HP: Plant Height; NFE: Number of Leaves; SFE: Leaf Area; NRA: Number of Branches; CCO: Collar Circumference; PFR: Fruit Weight; VA1: Koto Variety; VA2: Tomi Variety

IV. DISCUSSION

4.1 Effect of planting beds, planting density, types of fertilizers and their number of applications on okra yield

The results obtained show that planting beds significantly influenced okra yield. The significant difference observed between ridged planting beds (BAP and BSP) and ridgeless planting beds (flat terrain) in terms of fruit weight is due to the fact that ridged beds provide well-aerated, soft, porous soil, less susceptible to leaching, and have a good capacity for retaining water and nutrients. The polyethylene film helps retain soil moisture and reduces weed growth, thus limiting competition. This

facilitates water and mineral nutrition for the plant and therefore promotes good growth (Kanga, 2022). These results are consistent with those of Kouelo et al. (2012), who showed that tillage influences the productivity of *Macrotyloma geocarpum*. Furthermore, the results also showed that okra planting density influenced okra yield. These results are consistent with those of Fondio et al. (1999), who explained that higher planting density reduces branching in okra plants. At 20,000 plants/ha, with plants spaced further apart, competition between them is reduced, and the plants produce more fruiting branches. Thus, the study of the effect of different fertilizer types on okra weight revealed a significant difference. This demonstrates the role of manure in plant nutrition (Ojetayo et al., 2011). Mulaji (2011) showed that plant growth was closely linked to nutrient availability in the soil. These results are consistent with those of Bhardwaj et al. (2000) in a study comparing the economic viability of inorganic and organic fertilizers in okra and cabbage cultivation. Similarly, Kimuni et al. (2014) showed that increasing doses of manure improve the yield of Chinese cabbage (*Brassica chinensis*).

4.2 Sowing Period and its Impact on Okra Yield

Furthermore, the sowing period impacts yield. The best period was April compared to January, February, and March. This would be justified by high yields. The effect of soil and climate factors would explain the lower yield for sowings in January, February, and March.

4.3 High-Production Technical Approaches

Principal component analysis (PCA) indicated that the best technical approach would be BAP/D20/F4/3AP. These results can be attributed to the combined effects of ridging with polyethylene film (BAP), low planting densities (D20), and fertilizer applications (F4) with three applications (3AP), which were conducive to maintaining good plant vigour. These results are similar to those of Kanga (2022). The three fertilizer applications induced optimal plant growth, while the four fertilizer applications caused an excess of minerals and therefore plant toxicity. These results contradict those of Ouattara (2015), who demonstrated that all four applications improved pineapple plant growth in the Bonoua area. This difference in the number of applications likely depends on the crop, soil type, or a combination of the factors studied.

4.4 Varietal effect of Okra

The local variety obtained higher values for all parameters than the improved variety. This result could be explained by the fact that the local variety is better adapted to the soil and climate conditions. This difference could also be due to the genetic characteristics of each species. In a study on chili pepper varieties, Muwo et al. (2018) stated that the observed yield differences can be explained by the specific genetic characteristics of each variety. Another study conducted by Thiaw et al. (2019) on yield classified the okra varieties Clemson spineless and Rouge de Thiès as very low-yielding varieties.

V. CONCLUSION

The objective of this study was to provide producers with an effective technical itinerary to optimize okra production in the north of the country. The effect of planting beds consisting of flat ground (TP), ridges without polyethylene film covering (BSP), and ridges with polyethylene film covering (BAP), prepared at densities of D20 and D80, followed by the application of fertilizers F1, F2, F3, and F4, improved okra production. The highest yields were obtained with BAP (428.7 g), the D20 density (610.2 g), and fertilizer F4 (856.4 g). The combination of these factors resulted in 48 technical itineraries. The distribution of these different itineraries along the axes allowed for the identification of the best itinerary: BAP/D20/F4/3AP. This study concluded that choosing this itinerary would contribute to food security and increase producers' income.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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