**European Journal of Applied Sciences – Vol. 13, No. 05**
**Publication Date:** September 14, 2025
**DOI:**10.14738/aivp.1305.19229.
Sissoko, S., Dembele, B., Maïga, A. D., Dembele, M., Rueff, M., & Soumare, M. (2025). Diagnosis of Farmers' Sowing Practices of Cotton (*Gossypium Hirsutum* L.) to Improve Plant Density per Hectare in Mali. *European Journal of Applied Sciences, Vol - 13(05).* 80-91.

# Diagnosis of Farmers' Sowing Practices of Cotton (*Gossypium Hirsutum* L.) to Improve Plant Density per Hectare in Mali

**Sory Sissoko***
ORCID: 0000-0003-0854-5315
Department of Biology, Faculty of Science and Technology (FST), University of Science, Techniques and Technologies of Bamako (USTT-B), Mali. Badalabougou, P.O. BOX 3206 Bamako, Mali and Rural Economy Institute (IER), Regional Agricultural Research Center (CRRA) of Sotuba, P.O. BOX 262, Bamako, Mali

**Bandiougou Dembele**
Rural Economy Institute (IER),
Sector Economics program (ECOFIL),
P.O. BOX 438 Bamako, Mali

**Aliou D. Maïga**
Rural Economy Institute (IER),
Regional Agricultural Research Center
(CRRA) of Sotuba, P.O. BOX 262, Bamako, Mali

**Moussa Dembele**
Rural Economy Institute (IER),
Regional Agricultural Research Center
(CRRA) of Sotuba, P.O. BOX 262, Bamako, Mali

**Marine Rueff**
Rural Economy Institute (IER), Regional Agricultural Research Center (CRRA) of Sotuba, P.O. BOX 262, Bamako, Mali and CIRAD (Center for International Cooperation in Agronomic Research for Development), Montpellier, Avenue Agropolis, 34398 Montpellier Cedex 5, France

**Mamy Soumare**
Rural Economy Institute (IER), Regional Agricultural Research Center (CRRA) of Sotuba, P.O. BOX 262, Bamako, Mali and Geography Department, Faculty of History and Geography, Bamako University of Social Sciences and Management (USSGB), P.O. BOX. E2575, Bamako, Mali

## ABSTRACT

**In Mali, cotton production faces a number of constraints that partly limit its yield. The low planting density is the most significant of these constraints. The objective**

* Corresponding author: E-mail. sorysis@yahoo.fr or s.s382@mesrs.ml

**of the study is to identify practices that are more or less suitable for improving cotton planting density in the field. A quantitative and qualitative survey of current sowing densities on farms in Mali's cotton-producing zones was carried out among 300 farmers in 20 villages. Simple descriptive statistics, frequencies or percentages, and analyses of variance were applied to the data collected to determine means, significance of differences between means, and other parameters. The results showed low densities, with an average of 44,200 plants per hectare, well below the recommended density of 83,333 plants per hectare. The best practices identified included using recent generation seed (R1) (57,600 plants/ha), fungicide treatment of the seed before sowing (56,500 plants/ha), sowing after scraping the plot (54,500 plants/ha), and sowing with a drill (53,100 plants/ha). Low densities were recorded with the use of two types of mixed seed (delinted and undelinted) (25,600 plants/ha), the use of the old seed variety NTA 90-5 (25,600 plants/ha), and children removing seedlings (27,400 seedlings/ha). The results show that the low densities are linked more to practices than to the climatic conditions often mentioned.**

**Keywords:** Cotton, sowing density, cultural practices, Mali.

## INTRODUCTION

The cotton sector provides around 15% of Mali's gross domestic product (GDP) (Westerberg et al., 2020). At the continental level, Mali ranked first in cotton production in 2018, with 725,000 tons of seed cotton [1]. While this total production of seed cotton is a source of pride for the entire country, it is worrying to note that at the national level, the average yield per hectare, which was around 1,300 kg/ha in the mid-1980s (Ton, 2001), has fallen in recent years to 1,079 kg/ha in the 2021/2022 season [2]. This decrease in average yield per hectare is now one of the major concerns of cotton sector stakeholders.

Production is restricted by numerous constraints associated with cotton cultivation. Of all the constraints leading to lower cotton yields in Mali, low planting density is the most important.

A number of studies carried out on cotton planting densities in Mali have highlighted the limits to cotton production associated with low plant density [3]. The results of a survey carried out by CMDT (*Compagnie Malienne pour le Développement Textile*) show that average cotton planting densities in rural areas are fairly low (55,000 to 60,000 plants/ha) compared with the sowing density recommended by research and extended by technical services (83,333 plants per hectare). The study points out that the low densities have been observed since sowing, as the count of seedlings at emergence reveals that most plots have less than 30,000 seedlings per hectare.

The same observation of low density has been observed in Burkina Faso and Benin, where densities in cotton growers' fields are low [4, 5]. The reasons given for low density are mainly the failure to apply cultivation techniques correctly, and the type of soil preparation. Sowing spacing (0.30 m x 0.80 m) is only respected by a minority of growers, and the practice of ridging does not enable sowing spacing to be respected. It was also noted that growers do not follow the recommendations of technical services on density.

An improvement in the control of cotton planting density is a key lever for improving crop yields. Several cotton-producing countries have begun to adopt very high-density techniques for cotton plants, which have an impact on production [6]. In Mali, extension service efforts have focused on improving the density of cotton plantations by disseminating the 15-notch seeding disc for seed drills and generalizing seed treatment with fungicides.

Faced with the difficulties of achieving the theoretical recommended planting density (83,333 plants/ha) in the plots, this study was initiated.

The aim of this research is to identify the links between sowing practices, field management and the density of cotton plants per hectare.

## MATERIAL AND METHODS

### Study Sites and Choice of Farms

The survey was carried out in 20 villages in four regions, based on the division of the cotton-growing zone into agricultural regions drawn up by Mali's Rural Economy Institute (IER) and the Malian Textile Development Company (CMDT) [7]. The four zones are: the upper Niger valley, the old cotton basin, the new cotton zone, and the southern zones in equilibrium or extension (Fig. 1). In these regions, cotton is the primarystay of production systems that combine this crop with dry cereals maize (*Zea mays* (L.), millet (*Pennisetum glaucum* (L.) R.Br) and sorghum (*Sorghum bicolor* (L.) Moench) and cattle and small ruminant farming. Climates are pre-Guinean and Sudanian in the southern parts and Sahelian in the northern extremity. Rainfall ranges from 600 to 1,000 mm/year [8].

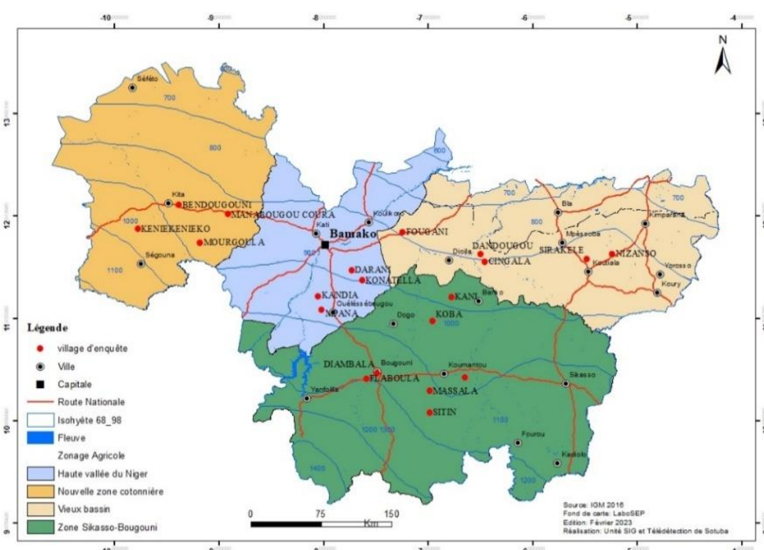


**Fig 1: Map of study area (Survey 2022)**

Given the favorable climate for this crop and the support provided to growers, farming practices in this area have become the most intensive and mechanized in the country: use of animal traction and mineral or organic fertilizers. Based on this regional subdivision, 20 villages were selected by spatial sampling to cover the area. In each village, 15 farms were randomly selected on the basis of a time step established from the ratio between the number of farms in the village and the size of the sample (15).

## Collecte Des Données

A questionnaire was designed to take into account the practices identified in the literature as possible causes of low densities: cotton variety, seed type and purity, tillage before sowing, re-sowing, sowing method, treatment product, sowing and weeding operators, weed control, real density on the plot, etc. These variables are completed by information on the farm.

Ten interviewers were engaged and trained to use the questionnaire and the KoboToolbox software to collect data on the tablets. The data collected was input directly into the tablets and transferred to a computer spreadsheet for verification and correction.

During the visit, the interviewers estimated the density in the field. In each plot surveyed, three density squares (on one hectare) with a surface area of 100 m$^2$ (10 m x 10 m) were set up to estimate the density of the cotton plants. The plots were chosen on the one-hectare diagonals of each farm. The number of plants in each of the three squares was summed and divided by three to obtain the average. The average obtained was then extrapolated to the hectare at a rate of 83,333 plants/ha (0.80 m between rows x 0.30 m between bunches).

## Data Analysis

Analyses of variance were performed to compare the means of the observed parameters. A significance level of 10% was used, given the conditions under which cultivation operations are carried out on the farm. Tukey's multiple comparison test was used for pairwise separation of different homogeneous groups for each parameter studied.

# RESULTS

## Density by Cotton Variety and Seed Treatment

### Cotton Varieties:

Throughout the zone, four varieties of cotton seed are grown (Fig. 2). The most widely grown is NTA MS 334, followed by NTA 93-15 with 46% and 31% respectively. In the Upper Niger Valley zone, NTA 93-15 and NTA 90-5 are the dominant varieties. In the new cotton zone, NTA MS 334 and NTA 93-15 are grown on equal acreage. These two varieties are present in the old basin, where they occupy over 70% of the sown area. All four varieties are grown in the southern zone, with dominance of NTA MS 334 and STAM 279A.

Analysis of variance revealed a significant difference between seed varieties grown in relation to density ($p = 0.0000$). Four homogeneous groups (A, AB, B and C) were obtained using the Tukey test. The best average density was obtained with NTA MS 334, forming homogeneous group A with 48,200 plants/ha. NTA 93-15 forms the AB homogeneous group, with 45,662 plants/ha. STAM 279A forms homogeneous group B with 38,800 plants/ha. Finally, NTA 90-5 alone forms homogeneous group C with an average of 25,600 plants/ha.

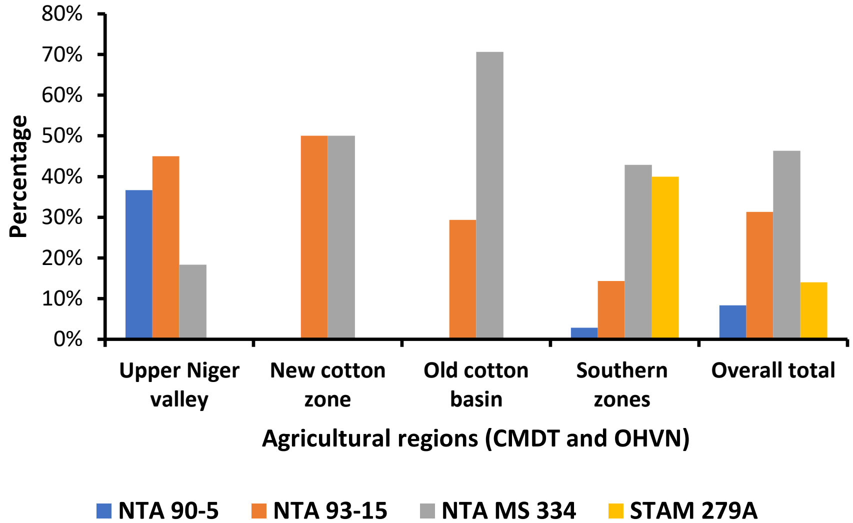


**Fig 2: Distribution of surveyed farm fields in the agricultural regions according to cotton varieties grown during the 2021/2022 agricultural Season in Mali.**

## Delintage and Seed Generations:

The types of seed used by growers are delinted, undelinted or both. In the New Cotton Zone, undelinted seed is used by 100% of growers. Across the whole cotton zone, the use of undelinted seed is dominant, with an average rate of 68%. Only in the Upper Niger Valley zone is the delinted seed used by the largest proportion of producers. A highly significant difference ($p$ =0.0000) was observed between seed types in relation to sowing density. The Tukey test was used to obtain two groups (A and B). The best sowing density was obtained in the fields of growers using undelinted seed with 48,000 plants/ha; they form the homogeneous group A with growers using delinted seed (43,700 plants/ha). Growers using both types of seed form homogeneous group B, with 25,600 plants/ha. The certified seeds used are of generations R1, R2 and R3. The R2 generation is the most widely sown, followed by the R3. The R1 generation is found only in the old basin, where it covers 20% of the area sown to cotton. Growers using G4 generation foundation seed have not been identified. The main source of seed supply is Malian Textile Development Company (CMDT) (80%), with the remaining 20% coming from the Upper Niger Valley Office (OHVN). The analysis revealed that the seed generation used had a highly significant influence on cotton plant stand density ($p = 0.0000$). With the application of Tukey's test, three groups (A, B and C) were obtained. Homogeneous group A is made up exclusively of growers who used the R1 seed generation, with 57,600 plants/ha; homogeneous group B those who used the R2 seed generation (47,200 plants/ha) and the R3 generation (38,000 plants/ha) make up group C.

## Seed Treatment:

Seed treatment before sowing is practiced by 71% of producers surveyed in agricultural regions. Three types of product are used: fungicides, insecticides and a fungicide plus insecticide mixture. Analysis of variance revealed a highly significant difference between types of product in relation to sowing density, and Tukey's separation test showed three groups (A, B and C). Producers who treated the seeds with fungicide made up homogeneous group A (56,500 plants/ha), followed by homogeneous group B (41,400 plants/ha), made up of producers who used fungicide plus insecticide. Producers who treated the plot with insecticide form homogeneous group C, with a sowing density of 35,100 plants/ha.

**Influence of Farming Practices on Density:**

All active persons in the farm take part in sowing operations, but it's mostly men who do it, with an average percentage of 49%, followed by groups of men and children aged between 10 and 15 (41%). An average of four people sow cotton in the field, with a maximum of 50 per farm. A highly significant difference (p = 0.0000) was revealed between the people in charge of cotton sowing in relation to sowing density. Three groups (A, AB and B) were obtained using Tukey's test. The best average planting density was obtained in fields sown by men and children aged 10-15. They form homogeneous group A with an average density of 50,300 plants/ha. Homogeneous group AB was formed by men, women and children aged 10-15 at the same time, with an average sowing density of 40,900 plants/ha. The lowest density was observed in fields where sowing was carried out only by children aged 10-15, forming group B with 36,800 plants/ha.

On average, 36% of producers sow their cotton after flat plowing of plot, followed by 31% who sow after plowing the plot in ridges. An average of five cotton seeds are sown per seeding hole, with a maximum of 10 seeds and a minimum of one seed. The average spacing between rows was 77 cm, while the average spacing between holes was 28 cm, with a maximum of 100 cm and a minimum of 10 cm for both parameters. Analysis of variance showed a highly significant difference (p = 0.0000) between seeding methods in relation to seeding density. Tukey's test indicated two groups (A and B). The best average sowing density is obtained in plots sown after scraping. They are in homogeneous group A with 54,500 plants/ha. The direct cotton seed sowing without plowing, the sowing after ridge plowing and sowing after flat plowing make up homogeneous group B, with 45,300 plants/ha, 41,000 plants/ha and 40,500 plants/ha respectively. Across the zone, some producers use two types of seeding (manual or drill), while others use both types at the same time. Drill seeding is the most common in all farming regions, with an overall average of 45%, followed by manual seeding at 40% (Fig. 3).

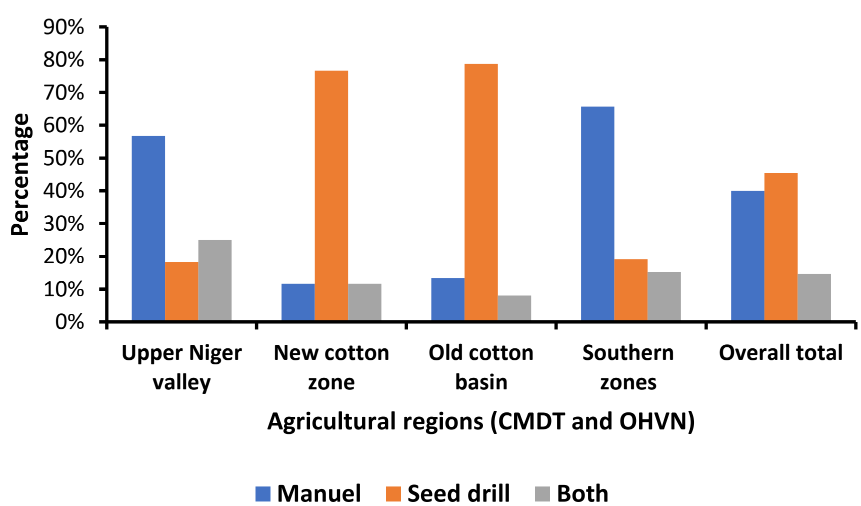


**Fig 3: Distribution of surveyed farm fields in the agricultural regions according to sowing methods during the 2021/2022 Agricultural Season in Mali.**

A highly significant difference between seeding type and seeding density per hectare with probability (p = 0.0000) was revealed and two homogeneous groups (A and B) were identified. Seeding with a drill forms homogeneous group A, with a seeding density of 53,100 plants/ha. The other two types form homogeneous group B, with 37,000 plants/ha for growers using both (drill and manual) and 36,700 plants/ha for those using manual seeding. Re-sowing after emergence in the field is practiced by over 63% of producers. After sowing operations, a quarter of farmers often keep the rest of the seed for the following season. Over 90% of producers carry out seedling stripping before weeding, with an average of 64%. On the other hand, 28% carry out seedling stripping during weeding. Stripping is carried out around 19 days after sowing, and no later than 45 days. On average, producers leave two plants per seeding hole, with a maximum of four and a minimum of one.

The persons in charge of seedling stripping were predominantly men (52%) and men and children (26%). Analysis of variance showed a highly significant difference (p = 0.0000) between those in charge of seedling stripping, and three homogeneous groups (A, AB and B) were separated by Tukey's test. Homogeneous group A is made up of fields where seedling stripping was carried out by men plus children aged 10-15, and by women alone, with an average of 50,300 plants/ha and 50,100 plants/ha respectively. Men plus women and men alone forming the AB homogeneous group, with respective averages of 45,300 plants/ha and 38,300 plants/ha. The lowest planting density was observed among children aged 10-15, forming the homogeneous group B with an average of 27,400 plants/ha. The correlation matrix between some of the parameters collected from the farms surveyed is shown in Table 1. The results revealed a significant, negative correlation between sowing density and spacing between seeding hole (-0.141*). A lower but negative correlation (-0.110) was observed between seeding density and row spacing. The number of years of experience in cotton cultivation had a positive and significant correlation with the number of seeds sown per seeding hole (0.202**) and the total cotton area of the farm (0.344**). On the other hand, a significant but negative correlation was observed between the number of weedings and the number of seeds per seeding hole (-0.205**) and the number of plants per poquet (-0.252**) (Table 1). The yield parameter is not taken into account, because the survey was carried out before harvesting.

**Table 1: Correlation matrix between some parameters collected on farms surveyed in the agricultural regions during the 2021/2022 Agricultural Campaign in Mali.**

| | Nb_YE | Nb_S/hole | Sp_Rows | Sp_holes | Nb_S/hole | Nb_W | PD/ha | TAPC |
|---|---|---|---|---|---|---|---|---|
| **Nb_YE** | **1** | | | | | | | |
| **Nb_S/hole** | **0,202****| **1** | | | | | | |
| **Sp_Rows** | -0,030 | -0,057 | **1** | | | | | |
| **Sp_holes** | 0,071 | **0,234**** | **0,236**** | **1** | | | | |
| **Nb_S/hole** | -0,016 | **0,177**** | **-0,160*** | 0,015 | **1** | | | |
| **Nb_W** | 0,007 | **-0,205**** | 0,109 | -0,118 | **-0,252**** | **1** | | |
| **PD/ha** | 0,011 | 0,064 | -0,110 | **-0,141*** | 0,083 | 0,052 | **1** | |
| **TAPC** | **0,000** | **0,176**** | 0,059 | 0,054 | 0,054 | -0,056 | 0,060 | **1** |

**. *Correlation is significant at 0.01 level (bilatéral).* *. *Correlation is significant at 0.05 level (bilatéral).*
Nb_YE = Number of years' experience; Nb_S/hole = Number of seeds sowed per hole; Sp_Rows = Spacing between rows; Sp_holes = Spacing between seeding hole; Nb_S/hole = Number of seedlings per hole (after

seedling stripping); Nb_W = Number of weeding operations; PD/ha = Planting density per hectare; TAPC = Total area planted to cotton

## Cotton Plant Densities on Producers' Fields

The average density was 44,200 plants/ha, with a minimum of 10,900 plants/ha and a maximum of 112,700 plants/ha throughout the study area (Table 2). The highest average density was obtained in the new cotton zone, with 59,600 plants/ha. The lowest average densities were recorded in the Upper Niger Valley zone, with 23,500 plants/ha.

**Table 2: Average number of plants per hectare on farms surveyed during the 2021/2022 Agricultural Season in Mali.**

| Agricultural region | Average density | Standard deviation | Max | Min |
|---|---|---|---|---|
| Upper Niger Valley | 23,500 | 42,59.44 | 31,800 | 15,500 |
| New cotton zone | 59,600 | 17,786.11 | 106,300 | 25,900 |
| Old cotton basin | 51,800 | 17,489.52 | 112,700 | 10,900 |
| Southern zones | 41,800 | 11,892.73 | 71,600 | 15,200 |
| Overall total | 44,200 | 18,467.03 | 112,700 | 10,900 |

The densities obtained were classified into five groups: ≤ 25%; 25-50%; 50-75%; 75-100% and ≥100% of the recommended density (83,333 plants/ha). The results show that in the Upper Niger Valley agricultural region, 28% of fields have a density below the recommended density and 72% a density between 25% and 50% of the recommended density. In this region, no field exceeded 50% of the recommended density. In the 50-75% density class, the Old Basin region leads with 56% of fields. This is followed by the New Cotton Zone and the Southern Zone, with 47% and 43% of fields respectively. For the 75 - 100% density class, the new zone leads with 27% of fields, followed by the old basin and the southern region. In around 8% of fields in the New Cotton Zone and Old Basin regions, densities are above 100% of the recommended density.

## Producers' Appreciation on their Field's Sowing Density:

After counting in the fields, each producer gave an appreciation of the density of his field according to the following modalities: very satisfied, satisfied and not satisfied. Across the four regions, 18% of producers were very satisfied with the density of their plot, 63% were satisfied and only 19% were not satisfied. In the Upper Niger Valley region, where plot counts revealed very low densities, 18% of producers said they were very satisfied, 57% were satisfied and 25% were not satisfied.

It is in the new cotton zone that the greatest number of producers are satisfied with the density in the field (90%). In the regions of the old cotton basin and the southern zone, 55% and 57% respectively are satisfied with the density, and 25% and 21% are very satisfied with the density in the field.

# DISCUSSION

In Mali, the low density of sowing in the field is one of the major constraints contributing to the drop-in cotton yields. Sowing cotton after plowing flat is the sowing method most widely used by producers. But the best densities were obtained mainly on plots sown after scraping and direct sowing of cotton without plowing. These two sowing methods promote early sowing and good seed germination, ensuring good density in the field.

According to [9], scraping helps to loosen the soil and facilitate the first rains' infiltration. Direct seeding reduces tillage time and energy costs for producers, notably improving soil structure and porosity [10]. The lowest average seeding densities were observed in flat- or ridge-tilled fields in this study. They differ from the findings of [11], which reveals that flat plowing improves the germination rate that is a guarantee of good seeding density in the fields. But when plowing is repeated several times on the same soil, the opposite effect can be observed [11]. The results obtained in this study are probably due to late plowing as a result of the late onset of the rains required to plow the plots. As a result, late sowing and poor plant growth.

Seed treatment before sowing is practiced by the majority of producers surveyed. Seeds treated with fungicide have the best density. This result is in line with those obtained in previous research by [12]. In this study, the authors show an improvement in the average sowing density per hectare for the whole of Mali's cotton zone in 2022 with the adoption of fungicide seed treatments. The results obtained in this study show that seed variety, seed type and seed generation significantly influence cotton plant population density in the field. The best densities were obtained with the NTA MS 334 variety, followed by the NTA 93-15 variety, in the fields of producers using undelinted seeds and having used the R1 seed generation. The lowest density was recorded on plots sown with the seed variety NTA 90-5. This very old variety was first experimented with in 1990 and released in 1997/1998. Inadaptation to current agro-climatic conditions may be one of the reasons for the low density of this variety.

The multiplication process takes place in different steps or stages: basic seed from stage G1 to stage G4, then commercial or certified seed from stage R1 to stage R3 or R4 [13]. Low density has been observed among growers using the R3 seed generation. Seeds produced in R3 are multiplied over a fairly wide area, often involving a larger number of producers, which reduces the quality and germinative power of the seeds.

Delinted seeds are less used by producers and have a lower stand density than undelinted seeds. In favorable rainfall conditions, seed delinting improves seed germination, promotes faster, more uniform emergence and offers better emergence density [14]. In unfavorable conditions, there is no difference in density between delinted seeds, which are more fragile, and dressed seeds, which offer constant regularity.

Producers use manual seeding or mechanical seeding with an animal-drawn seeder, while others use both methods at the same time. The use of animal-drawn seeders is the dominant practice, as it began with cotton and maize cropping in Mali and especially with the impact of cotton and groundnut projects in Mali and West Africa in general [15]. A highly significant difference between seeding methods on seeding density per hectare with probability $p = 0.0000$ was observed. Producers who used the animal-drawn seed drill for seeding obtained the best plant density in the field. This is undoubtedly due to the advantages of using the seeder, especially the uniformity of seeding depths, distances between rows and the number of seeds in the seeding hole, as well as the speed with which seeding operations can be carried out and the reduction in production costs.

According to the results, adult men are mainly responsible for these activities, with a small number of adult women and children aged 10 to 15 taking part. The low participation rate of women is mainly due to their involvement in housework and other social activities. Children, because of their "immaturity", are generally associated with adult men in the achievement of some tasks. Analysis of variance of the influence of sowing and weeding personnel on cotton density showed a highly significant difference at $p = 0.0000$. Plant densities are low when only 10-15-year-old children are in charge of sowing and seedling stripping.

The seeding rate per hectare of cotton is one of the determining factors in improving cotton productivity [16]. Estimated sowing densities in surveyed producers' fields were very low across all agricultural regions. According to the results, the average density was 44,188 plants/ha, compared with the recommended 83,333 plants/ha. A fact already observed since the 2000s, according to the results of a survey carried out by [3], which reported that average cotton planting densities in farmers' fields were fairly low (55,000 to 60,000 plants/ha). The same observation was made by [17] on the research varietal experimental trial plots at the Finkolo and N'Tarla agronomic research stations of the Rural Economy Institute (IER) in Mali, during the 2019 - 2020 crop year. Mean densities of 64,851 plants/ha and 51,607 plants/ha were obtained at Finkolo and N'Tarla respectively. The low density observed could be one of the main reasons for the low field yield (kg/ha) of cotton in Mali. The growth of reproductive organs is unfavorable to the vegetative organs under low-density conditions [5] (Hermann et al., 2015). However, others have reported that crop yield does not necessarily depend on low or high plant density [18]. [19] reported a negative effect of high seeding rate on seed cotton yield. In contrast, [20] reported that there was no relationship between cotton productivity and seeding rate per hectare. Despite the low density observed during the study, the majority of producers declared that they were satisfied with the density obtained in their fields. This indicates that farmers do not sufficiently perceive the impact of low densities on yields. The same observation was made by [3] in its density survey, where 92.0% of growers said they were satisfied with the densities they obtained.

## CONCLUSION

The average sowing density observed in the agricultural regions surveyed is low compared with the density recommended by research (IER) and technical services in Mali (CMDT and OHVN). The study confirms CMDT's findings on the low density of cotton planting in the field in Mali. This low density is often linked to the non-practice of recommended technical itineraries, or often to poor practices. Producers lack of understanding of the impact of low density on production is also an important element of the problem.

In order to improve cotton plant density in the field, it is important to select suitable seed varieties, apply appropriate cultivation techniques and choose the right time to establish fields according to each growing zone. Producers also need to be made aware of the impact of low densities on yields.

## Acknowledgements

The authors express their deep gratitude to the members of the AgrECo CML1430 project who kindly agreed to improve this manuscript.

## Authors' Contributions

The study protocol, training surveyors on how to use the KoboToolbox software to collect data on tablets, supervising surveyors in the field, cleaning the data, analyzing and interpretation, of the data, and writing the manuscript were all done by different authors.


## Funding

This work was carried out thanks to funding from the Projet of Support to the Agro-Ecological Transition in the cotton-growing zone of Mali: AgrECo CML1430, whose financing agreement was signed between the Government of Mali and the French Agency for Development (AFD).


## Declarations

### Ethics Approval and Consent to Participate:

Not applicable.

### Consent for Publication:

Not applicable.

### Competing Interests:

The authors declare that they have no competing interests.

## References


Westerberg, V., Diarra, A., Diallo, H., Diallo, S., Koné, B., Domergues, M., Keïta, O., Doku, A., Di Falco, S., 2020. L'économie de la production du coton au Mali et les enjeux de la dégradation des terres : Cas d'étude à Koutiala et Bougouni (Rapport de l'Initiative ELD dans le cadre du projet « Inverser la dégradation des terres en Afrique par l'adoption à grande échelle de l'agroforesterie ») Mali, 64 p

CMDT (Compagnie Malienne pour le Développement Textile), 2022. Evolution of cotton production over 6 years. https://cmdt-mali.net/index.php?view=category&id=9 accessed 03/04/2025

CMDT, (Compagnie Malienne pour le Développement Textile), 2000. Development of technical alternatives for fertility management and cotton-based cropping systems (Agricultural Survey). IER/CMDT/OHVN, Station de N'Tarla, 30 p.

Sanou, E.I.R., 2011. Study of the yield components of transgenic cotton in agrosystems of western Burkina Faso: case of the Daboura, Gombélédougou and Sidéradougou zones. Thesis, Polytechnic University of Bobo-Dioulasso. (UPB) 78 p. https://doi.org/10.13140/RG.2.2.20486.52801

Hermann, M.B.H., Moumouni, I., Tokore Orou Mere, S.B.J., 2016. Contribution to improving sustainable cotton (*Gossypium hirsutum*) production practices in Benin: the case of the Banikoara district. *Int. J. Bio. Chem. Sci* 9(5), 2401–2413. https://doi.org/10.4314/ijbcs.v9i5.12

Fok, M., 2007. Multifactorial analysis of cotton yield decline in the CMDT zone: from physiology to ideology, Cirad. Montpellier 160 p.

Soumaré, M., 2008. Dynamics and sustainability of cotton-based agrarian systems in Mali (Doctoral dissertation: Human, economic and regional geography). Université de Paris-Nanterre, France, 372 p

Diawara, H., 2019. Analysis of Contemporary Evolution of Air Temperature and Precipitation in Mali. *European Scientific Journal ESJ* 15(2). https://doi.org/10.19044/esj.2019.v15n2p154

IER, 1990. Memento of cultivation techniques for agricultural supervisors, 124 p. ISNB: 978-90-6832-038-1

Šarauskis, E., Buragienė, S., Masilionytė, L., Romaneckas, K., Avižienytė, D., Sakalauskas, A., 2014. Energy balance, costs and CO2 analysis of tillage technologies in maize cultivation. *Energy* 69, 227–235. https://doi.org/10.1016/j.energy.2014.02.090

Boko, C.S.A., Bagan, G.C., Fandohan, A.B., 2021. Impacts of conventional plowing on cotton yields in the district of Kétou, Benin. R*ev. Mar. Sci. Agron. Vét.* 9(1), 115–122

IER, CMDT, OHVN, 2003. Concertation meeting IER-CMDT-OHVN 19, 20, 21 February 2003 N'Tarla (Meeting report). IER, N'Tarla/Koutiala. 26 p.

Cretenet, M., Dessauw, D., 2006. Production of quality seedcotton. Quality manual for the cotton industry. UEMOA. UNIDO Publication, Impression Svi-Publicep (34, France), 116 p

Ashburner, J.E, Ashburner, J, 2011. Review of public and private sector mechanization models. In: Investments in agricultural mechanization in Africa (Technical report on agricultural and food engineering). (Eds.), FAO, Rome p 51-58.

Bono, M., 1980. Multiplication of tropical food seeds, Fondation de France. ed, Agency for Cultural and Technical Cooperation, 445 p.

Amonmidé, I., Fayalo, G.D., Dagbenonbakin, G.D., 2020. Effect of sowing period and density on cotton growth and yield in Benin. *Journal of Applied Biosciences* 152, 15676–15697. https://doi.org/10.35759/JABs.152.7

Sissoko, S., Diawara, M.O., Kassambara, E.M., Bayoko, G., Coulibaly, M.M., 2023. Correlations between some morpho-physiological and agronomic traits of cotton (*Gossypium Hirsutum L*) varieties grown in two agroecological areas of Mali. *ÈKOBIOTEH* 6(1), 14–23. https://doi.org/10.31163/2618-964X-2023-6-1-14-23

Ciampitti, I.A., Xia, Y., Camberato, J., Vyn, T.J., 2011. Plant density consequences on nitrogen uptake dynamics of maize plants from vegetative to reproductive stages. *Field Crops Research* 121, 2–18. https://doi.org/10.1016/j.fcr.2010.10.009

Jagannathan, N., Venkitaswamy, R., 1996. Effect of plant density and nutrient levels on new cotton varieties. *Madras Agricultural Journal* 83(3), 159–160

Shah, S., Khan, M., Sajjad, T., Malik, W., 2005. Effect of various plant populations on seed cotton yield and other yield components. *Indus Cottons* 2(3), 216–218