American Journal of Applied Sciences

Research Article

Adaptation and Use of the Gangaria Seed Drill for the Improvement of Peanut (*Arachis hypogaea*) Cultivation in Niger: Case of the Maradi and Zinder Regions

Abdoulahi Mamane[1,2], Arifa Warouma[1], Saidou Addam Kiari[2] and Jens Bernt Aune[3]

[1]*Department of Rural Engineering, Water and Forests, Dan Dicko Dankoulodo University of Maradi, BP 465 Maradi, Niger*
[2]*National Institute of Agronomic Research of Niger (INRAN), BP 429 Niamey, Niger*
[3]*Department of International Environment and Development Studies, Norwegian University of Life Sciences, 1432 Ås, Norway*

Article history
Received: 14-05-2025
Revised: 05-12-2025
Accepted: 08-12-2025

Corresponding Author:
Abdoulahi Mamane
Department of Rural Engineering, Water and Forests, Dan Dicko Dankoulodo University of Maradi, BP 465 Maradi, Niger
Email: kymyat@yahoo.fr

Abstract: In Niger, peanut cultivation plays a significant role in food security and improving the incomes of rural households, particularly in the Maradi and Zinder regions. However, this crop remains hampered by low mechanization, the use of traditional tools, and inefficient fertilization, resulting in consistently low yields of around 600 to 800 kg/ha. Faced with these constraints, this study aims to investigate the effect of the Gangaria seed drill, powered by animal traction, combined with organomineral fertilization on peanut cultivation. An experiment was conducted over two growing seasons (2023-2024). The results allowed for a comparison of four treatments combining sowing methods (manual/mechanized) and fertilization (with/without) using a randomized complete block design. These results show that the grain yield for mechanized sowing combined with localized organomineral fertilization (T3) is 1,372 kg/ha compared to 654 kg/ha for the control (T0), representing an increase of 108%. The haulm yield averaged 1,721 kg/ha for Treatment (T3) compared to 1,111 kg/ha for the control (T0), an increase of 55%. Treatment (T3) also had the highest net margin (453,158 FCFA/ha). Labor requirements were reduced from 10.28 person-ha for treatment T1 to 2 person-ha for the mechanized treatments T3, with a labor output of 1.02 days/ha. The hourly productivity is 7.5 hours/ha for treatment T3 compared to 27 hours/ha for treatment T1, representing a gain of 19.5 hours/ha or a 72% reduction in sowing time. The study thus confirms that adapting the Gangaria seed drill is a promising avenue for increasing productivity, improving profitability, and strengthening the resilience of the agricultural system. However, the local availability of compost and access to equipment for small-scale producers will determine the large-scale adoption of this innovation.

Keywords: Animal Traction, Gangaria Seed Drill, Peanut, Localized Fertilization, Yield

Introduction

Agriculture is the engine of Niger's economy, employing over 80% of the population and contributing 40% to the national GDP (Diao *et al*., 2023). However, it remains largely dominated by traditional practices characterized by the use of rudimentary tools. Agricultural mechanization, which involves the use of machinery and equipment, represents a solution for improving productivity and ensuring food security. Population growth, increasing urbanization, and more pronounced economic and food aspirations make it essential to increase agricultural production to guarantee food security and self-sufficiency; therefore, it is important to consider the influence of animal traction in agricultural production (Warouma *et al*., 2021).

Technological advancements have led to the development of equipment such as animal-drawn seed drills, which, compared to manual mechanization, offer time savings and require less labor. Seed drills have also made it possible to cultivate larger areas (Houmy, 2008). Mechanization allows farmers to improve their financial situation (Jiquan *et al*., 2022). The presence of cash crops is a determining factor in the profitability of animal-drawn cultivation (Idelphonse *et al*., 2020).

Mechanized seeding accelerates crop establishment and eliminates the need for thinning when the seed drill is properly adjusted. It also saves seed when the distribution system is correctly set, which is beneficial for relatively expensive seeds such as peanuts (Vall and Bayala, 2006).

The economic viability of microdosing with 2 g of DAP per planting hole has recently been called into question. Indeed, lower microdoses may be justified. It is possible to mechanize low fertilizer doses using a seed drill with a separate hopper for seed and fertilizer (Aune and Adama, 2020).

Although the technique was introduced at the beginning of the 20th century, Ulysse Fabre's Super-Eco seeder was introduced in Senegal in the 1920s. It was only from the 1960s onwards, under the impetus of agronomists, that animal traction truly contributed to a profound transformation of production systems in the Sahelian zones engaged in peanut cultivation (Philipe *et al*., 2010).

Peanut cultivation plays a significant role, particularly in the Maradi and Zinder regions, where it represents a vital source of income and food security for smallholder farmers (Bank, 2023). However, despite its importance, average yields remain low, ranging between 600 and 800 kg ha^{-1} (INS, 2023), due to manual farming practices, limited use of inputs, and a similarly low level of mechanization (Moussa and Tougiani, 2023).

Agricultural mechanization, particularly through tools adapted to local conditions, is identified as a key lever for improving the productivity and resilience of farming systems in sub-Saharan Africa (Sims and Kienszle, 2017). However, in Niger, less than 35.3% of family farms have access to mechanized equipment, mainly due to the high cost of imported machinery and a lack of maintenance infrastructure (INS, 2019). In this context, improved traction is emerging as a viable solution for reconciling modernization and accessibility, particularly for labor-intensive crops such as groundnuts (Baudron *et al.,* 2015).

The Gangaria seed drill, developed by the National Institute of Agronomic Research of Niger (INRAN), illustrates this approach; initially designed for cereals, its adaptation to sowing peanuts requires technical adjustments (spacing, sowing depth, dosage of inputs). This is a single-row seed drill capable of simultaneously sowing seeds and applying fertilizers, thus reducing labor time and improving input use. The drill can be operated by draft animals, ensuring accessibility for smallholder farmers. It also facilitates row seeding, guaranteeing regular spacing and higher crop density (Fanigliulo *et al*., 2022).

Previous studies highlight that the adoption of multifunctional seed drills reduces sowing time by 84% and optimizes yields through better fertilizer distribution. However, few studies have evaluated the economic and agronomic impact of these adaptations on peanut cultivation in the Niger region.

This study aims to fill this gap by analyzing the performance of the modified Gangaria seeder for peanut cultivation, comparing its effectiveness to traditional methods. It evaluates not only productivity and yield gains but also economic viability for smallholder farmers within the context of a transition to sustainable and resilient agriculture.

Materials and Methods

The experiment utilized a range of equipment to meet the technical requirements of peanut cultivation. The peanut (*Arachis hypogaea*) seed used was the JL24 variety. This improved variety is recommended by INRAN due to its good adaptability to the soil and climate conditions of Niger. It has a sowing-to-maturity cycle of 90 days and a potential yield ranging from 1.7 to 2 t/ha. It is drought-tolerant. The main planting tool was the Gangaria seed drill. The seed drill was pulled by a pair of oxen, requiring a driver and guide to ensure even sowing. The field equipment used for data collection included a GPS for georeferencing the study sites, a stopwatch to measure the duration of cultivation operations, and stakes and string for marking the experimental plots according to the defined dimensions. A precision electronic scale was used to weigh the seeds, compost, triple NPK 15 fertilizer, and harvested crops. For manual treatments, a traditional hoe was used to open the planting holes. Weeding was carried out by a farmer using animal traction for the mechanized sowing areas. A hand weeder was used for manual weeding in the plots that had been sown by hand.

Gangaria Seed Drill (Adapted)

The Gangaria seed drill (Figure 1) is manufactured by metal workshops in Niger. It has two independent hoppers for seeds and compost (Figure 1), each equipped with a perforated disc (Figure 2) adapted to the type of input. Each disc has four cells spaced 25 cm apart. Each drive wheel has a circumference of 100 cm. With each wheel rotation, four planting holes are created in the furrow. The rotation of the wheels distributes the seeds and fertilizer via elements such as openers, skimmers, and a press wheel (Figure 1). The marker indicates the next row. The hitch system regulates the traction exerted on the seed drill via the chain.

The trial was conducted over two years (2023 and 2024) at the Regional Agricultural Research Centers (CERRA) of Maradi (13°30'00N, 07°06'06"E) and Zinder (13°48'19"N, 08°59'18"E) (Figure 3). These two regions are the country's main agricultural hubs, contributing 79% to national peanut production (Ministry of Agriculture and Environment, 2023). The Maradi and Zinder regions are located in south-central Niger and have predominantly sandy soils. Annual rainfall in these regions ranges from 400 to 500 mm (Bakoye *et al*., 2019).

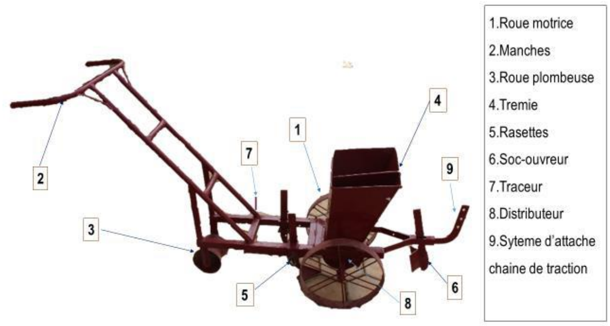

Fig. 1: "Gangaria" animal-drawn seed drill (source Abdourahamane *et al*., 2020)

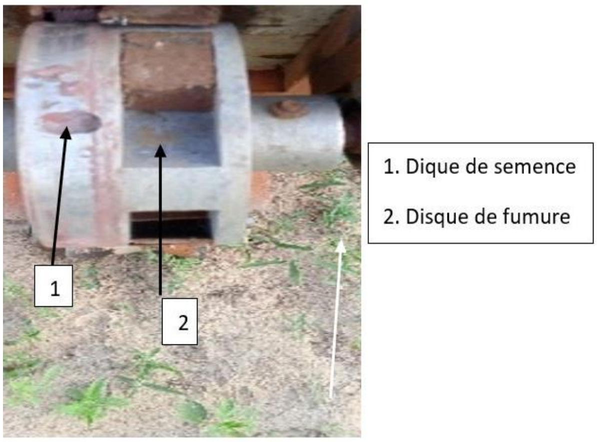

Fig. 2: Seed and fertilizer distribution system

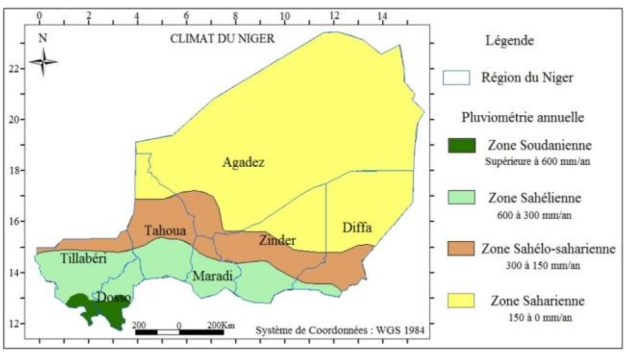

Fig. 3: Map of the study area

Study Area

Experimental Setup

An experimental design was established to evaluate the combined effect of mechanization and fertilization on peanut cultivation. Four (4) Treatments (T0, T1, T2, T3) were defined according to a factorial structure combining two sowing methods (manual and mechanized) and two fertilization levels (with or without inputs). The experiment was conducted using a randomized complete block design with 4 replications. In a block, each plot had an area of 54 m² (30x1.8 m), and the spacing between plots was 1.5 m. The blocks were spaced 2 m apart. The total area of the experimental design, consisting of 4 blocks and 16 plots, was 1584 m². Each block contained the 4 treatments arranged randomly and was laid out as follows:

- Block 1: T2 – T1 – T3 – T0
- Block 2: T1 – T3 – T0 – T2
- Block 3: T0 – T2 – T1 – T3
- Block 3: T3 – T0 – T2 – T1

Description of Treatments

Treatment T0 – Manual sowing without fertilization:

- This treatment corresponds to the traditional practice, without any addition of fertilizers. Two people carried out the sowing: one opened the holes with a hoe, the other placed the seeds before closing the holes
- Treatment T1 Manual sowing with organomineral fertilization
- Three people were involved in this treatment. The first opened the holes, the second introduced a mixture of 25 g of compost and 0.6 g of NPK (15-15-15) into each hole, and the third placed the seeds before closing the holes
- Treatment T2 Mechanized sowing without fertilization
- Sowing was carried out using a modified Gangaria seed drill, pulled by a pair of oxen. One person drove the team while another guided the seed drill. Only the seed hopper was used, without the application of fertilizers
- Treatment T3 Mechanized sowing with organomineral fertilization

This treatment combines mechanization and the application of inputs. The Gangaria seed drill was simultaneously supplied with seeds and fertilizers (25 g of compost and 0.6 g of NPK per planting hole). The equipment was always pulled by a pair of oxen and operated by two people (driving and guiding).

In each mechanized treatment (T2 and T3), peanuts are sown with a spacing of 30cm x 25cm. Each plot comprises 6 rows, and each row contains 120 plants. One plot will therefore consist of 720 peanut plants.

Measured Variables

The effects of the treatments were assessed using several indicators, including:

- Peanut yield (kg ha $^{-1}$)
- The required working time (hours)
- Man-day yield (hj/ha)
- The economic profitability of different farming techniques

Data Collection and Analysis

Agricultural Labor Yield

The collected data allowed us to calculate the time required to sow one hectare for each treatment. This information enabled us to determine the hourly yield (hours/ha) and labor requirements for each sowing method. Labor output in agriculture corresponds to the working time required to complete an agricultural operation on a given area (ha). It is expressed as:

- Hours per hectare (h/ha)
- Man-days per hectare (hd/ha), considering a standard 8-hour day
- Yield is expressed by the following formulas
- Hourly output = T/S
- Man-day output = T / (8 × S)
  With
- T: total working time (hours), - S: Area worked (hectares)

Grain and Hay Yield

The seed yield of tropical legumes is a multifactorial result that combines several agro-physiological components: The number of harvested hills per unit area, the number of pods per hill, the number of seeds per pod, the seed hulling rate, and the 100-seed weight. Each component develops at a specific stage of the vegetative cycle, under the direct influence of agro-climatic conditions, soil type, and cultivation practices. These components interact in a cascading manner, such that a change in one factor can have amplifying or limiting effects on the final yield. Before harvesting the Usable Plot (UP), a standard sample of 13 plants per square meter is harvested from each UP for the purposes of analyzing the yield components. The usable plot consists of four rows, excluding the hills at the ends of the rows. Each usable plot has an area of 35.4 m^2. The total number of plants harvested from each usable plot is 472. The fresh pods were air-dried for 15 days. The seed yield per hectare is estimated from the product of (seed weight of the usable plot + seed weight of the standard sample) and (10,000 m^2 / area in m^2 of the usable plot). The haulm yield per hectare is estimated from the product of (haulm weight of the usable plot + haulm weight of the standard sample) and (10,000 m^2 / area in m^2 of the usable plot) (ECOWAS, 2021).

Economic Evaluation

Finally, farm incomes were estimated based on yields and average selling prices observed in local markets for grains and haulms. Gross margin was calculated as the difference between total revenue and operating expenses, while net margin incorporated all costs, including depreciation. The economic evaluation was conducted using technical and financial data collected from 235 peanut farmers located in the Maradi and Zinder regions. This data included input costs (seeds, fertilizers, compost, pesticides), labor costs (land clearing, sowing, weeding, harvesting), and transportation costs. In addition, fixed costs were included through depreciation of the farm equipment used (seeder and cultivator), calculated based on its useful life.

Economic Analysis

Margin = (Quantity of grain harvested × Grain price) + (Quantity of haulm harvested × Haulm price) Operating costs - Cultivator depreciation - Seed drill depreciation

Selling prices: The data collected indicates that the average price of a 100 kg bag of shelled peanuts varies between 58,000 and 65,000 FCFA during the year, while that of a 45 kg bag of dried hay fluctuates between 750 and 2,000 FCFA.

The revenues from the sale of peanut grains and haulms were estimated by multiplying the average yields observed during the trial for grains (Table 3) and for dried haulms (Table 5) by the corresponding average prices.

In this study, two main categories of costs were identified: Variable costs, which change according to the level of activity, and fixed costs, which are independent of the volume of production.

Variable costs encompass all expenses directly related to agricultural production activities. These include, in particular, the costs of seeds, fertilizers, plant protection products, labor, and transportation.

The planting density used is 133,333 planting holes per hectare. Based on this, the estimated requirements per hectare are approximately 3,333 kilograms of compost and 80 kilograms of triple-strength NPK fertilizer (15-strength). Seed requirements vary depending on the planting method used. Mechanized planting requires 55 kilograms of seed per hectare, while manual planting requires 60 kilograms per hectare.

The unit price of seeds is set at 1,000 FCFA Kg^{-1} Other inputs include pesticides, sold at 350 FCFA per 20-gram sachet, triple NPK fertilizer 15 at 360 FCFA Kg^{-1}, and compost, valued at 80 FCFA Kg^{-1}.

The cost of labor is set at 1,500 FCFA per man-day. Two phases are distinguished in the analysis of labor costs.

The cost of non-harvest farming operations, from initial land clearing to final weeding, is estimated at 2,000 FCFA per hectare for mechanized farming that incorporates micro-dosing of organo-mineral fertilizers. However, for manual farming requiring fertilizer application, this amount reaches 72,000 FCFA per hectare.

The harvesting phase encompasses a series of successive operations including uprooting the plants, piling them up, threshing, separating the pods from the foliage, hulling, and packaging. This stage remains particularly labor-intensive. Of these operations, only hulling benefits from partial mechanization. The labor cost allocated to harvesting varies significantly depending on the processing method, ranging from 38,400 FCFA $^{ha^{-1}}$ for Treatment (T0) to 80,500 FCFA $^{ha^{-1}}$ for Treatment (T3) (Table 7).

Transportation also represents a significant variable cost. The average price for transporting a 100-kilogram bag of peanuts to a weekly market is 300 FCFA. Transportation costs vary depending on production volume and method. Since each farmer using animal traction has a cart, transportation costs are zero in mechanized farming (Table 7).

Fixed costs primarily relate to the depreciation of equipment used, particularly the seed drill and cultivator. The annual depreciation allowance was calculated by dividing the acquisition cost of each piece of equipment by its average lifespan, estimated at ten years. Thus, the annual depreciation amounts to 15,000 FCFA for the seed drill and 11,000 FCFA for the cultivator (Table 7). The collected data were processed using SPSS 26 and Statistic 8.1 software to analyze and compare the averages.

Results

Work Efficiency in Manual Sowing and With Draft Animals

Analysis of labor time according to the different sowing methods shows significant differences between treatments, sites, and cultivation methods (Table 1). On average, the time required for mechanized sowing combined with organomineral fertilization is 7.5 hours/ha compared to 27 hours/ha for manual sowing coupled with localized application of organomineral fertilizer, representing a reduction of 19.5 hours/ha, or 72%. Furthermore, the time required for mechanized sowing without fertilizer application is 6.75 hours/ha compared to 18.50 hours/ha for manual sowing without micro-dosing of fertilizer, representing a reduction of 11.75 hours/ha, or 64% (Table 1). Analysis of variance (ANOVA) revealed significant differences between the treatments ($p<0.01$), confirming that sowing methods have a highly significant effect on labor efficiency.

Regarding labor requirements, it appears that manual sowing without fertilization (T0) requires 7.13 person-days/ha, compared to 10.28 person-days/ha (Table 2) for manual sowing with fertilization (T1), reflecting a significant increase in labor requirements for micro-dosing. In contrast, mechanized sowing requires only 2 person-days/ha, with an average yield of 0.88 and 1.02 person-days/ha respectively for sowing without micro-dosing of fertilizer and sowing with micro-dosing of fertilizer (Table 2).

Peanut Grain Yield as a Function of Treatments

The average yields obtained during the two growing seasons indicate a clear superiority of treatment T3, which reached 1,372±89 kg ha^{-1} ^{compared} to 654±43 kg ha^{-1} ^{for} the control (T0), representing an increase of 108% (Table 3). Treatment T1 reached 1,075 kg ha^{-1} ^{while} T2 was limited to 789 kg ha^{-1}

Table 1: Work output as a function of sowing time

Treatment	Work output (hours/ha)		
	Maradi site	Zinder site	Average
T0	16.80±2.38 B	20,250±2.77 A	18.50±3.06 B
T1	27.00±3.62 A	27.00±5.51 A	27.00±4.32 A
T2	7.50±0.23 C	6.00±0.20 B	6.75±0.87 C
T3	7.25±0.82C	7.75±0.62 B	7.5±0.77 C

Table 2: Comparative study of labor efficiency according to sowing method

Productivity	h /d/ha	h /d/ha	j /ha	Workforce	j /ha	Workforce
Treatment	T0	T1	T2	T2	T3	T3
Average	7.13	10.28	0.88	2	1.02	2
Standard deviation	0.02	0.03	0.04	0	0.05	0

Table 3: Peanut grain yield as a function of treatment

		Grain yield (kg ha $^{-1}$)			
Site	Year	T0	T1	T2	T3
Zinder	2023	679±620 D	1128 ±19.98 B	835±17.53 C	1139±14.66 A
	2024	708 ±6.45 D	1175±20.82 B	870±18.16 C	1575±12.91 A
Maradi	2023	602±9.99 D	978±8.20 B	710±8.76 C	1359±10.64 A
	2024	628±10.41 D	1019±8.54 B	740±9.13 C	1416±11.09 A
Average	2023	640±41.77 D	1053±81.42 B	772±67.93 C	1249±83.09 A
	2024	668±43.50 D	1097±84.80 B	805±70.76 C	1496±85.58 A
Average	2023-2024	654±43.45 C	1075±83.44 B	789±69.04 C	1372 ±89.04 A

Effect of Site-Year-Treatment Interaction on Grain Yield

Analysis of variance reveals that site, year, and treatment each have a highly significant effect (p = 0) on peanut grain yield (Table 4). This reflects the importance of spatial (Maradi and Zinder), temporal (2023, 2024), and technological (treatment T0 to T3) variability in determining agronomic performance. In contrast, the site-year interaction is not significant (p = 0.416), suggesting that the effect of climate in a given year is comparable across sites (Table 4). Similarly, the site-year-treatment interaction is not significant (p = 0.998), indicating that the response to different treatments is generally stable regardless of site and year (Table 4).

Table 4: Effect of site-year-treatment interaction on grain yield

Source of verification	Significance(p)
Site	0
Year	0
Treatment	0
Site*Year	0.416
Site * Processing	0
Year * Processing	0.003
Site * Year * Treatment	0.998
resume	7.49

Dried Peanut Hay Yield as a Function of Treatment

Dried haulm yields followed a similar trend to grain yields, with significantly higher performance under treatment T3, which averaged 1,721±109 kg ha⁻¹, compared to only 1,111±118 kg ha⁻¹ for the control treatment (T0), representing a 55% increase (Table 5). Yields obtained with T1 (1,331 kg ha⁻¹) and T2 (1,231 kg ha⁻¹) also showed improvements, albeit smaller, compared to the control (T0). Statistical analyses indicated a highly significant difference between the treatments (p<0.001).

Effect of Site-Year-Treatment Interaction on Leaf Yield

The results show that site, year, and treatment factors highly significantly influence (p<0.001) haulm production (Table 6). This confirms that the availability of plant biomass, like grain, depends on both environmental conditions and cultivation practices. The site × year interaction is not significant (p = 0.68), suggesting inter-site stability in annual responses (Table 6). The year × treatment interaction is also not significant (p = 0.097), indicating that the effect of cultivation methods is relatively constant from year to year (Table 6). The site × year × treatment interaction is also not significant (p = 0.909), confirming that haulm yields exhibit a robust response to treatments, regardless of soil, climate, and time conditions (Table 6). In contrast, the site × treatment interaction is highly significant (p<0.001) (Table 6). This means that the effect of cultivation practices (manual and mechanized sowing, with or without fertilization) is strongly site-dependent. For example, treatment T3 generated greater increases in biomass in Zinder than in Maradi, likely due to differences in initial soil fertility and rainfall regularity.

Economic Evaluation

Analysis of the results shows that treatments T0, T1, T2, and T3 recorded net margins of 354,965, 150,685, 394,646, and 453,158 FCFA ha⁻¹ respectively (Table 7). The net margin obtained was 453,158 FCFA ha⁻¹ with mechanized cultivation combined with organo-mineral fertilization, compared to 3,544,965 FCFA ha⁻¹ with manual cultivation without fertilizers. Mechanized cultivation with fertilizers also had a higher net margin than mechanized cultivation without fertilizers (Table 7).

Table 5: Dried hay yield over two (2) years at the different sites

Site	Year	Dried hay yield (kg ha $^{-1}$) T0	T1	T2	T3
Zinder	2023	1187±33.81C	1252±16.22B	1198±18.35 C	1770±10.12 A
	2024	1250±35.59 C	1318±17.08 B	1261±19.31 C	1863±9.57 A
Maradi	2023	977±10.53 D	1347±8.11B	1201.5±12.26 C	1584±16.22 A
	2024	1029±11.09 D	1419±8.54 B	1265±12.91 C	1668±17.08 A
Average	2023	1082±114.77 C	1299±52.77 B	1200±14.57BC	1677±100.27 A
	2024	1139±120.75 C	1368±55.55 B	1263±15.34 BC	1765±105.02 A
Average	2023-2024	1111 ±117.52 D	1331±63.14 B	1231C±35.67 C	1721A±109.06 A

Table 6 Results of Site-Year-Treatment Effect Analysis with Univariate ANOVA

Source of verification	Significance (P)
Site	0
Year	0
Treatment	0
Site *Year	0.68
Site * Processing	0
Year * Processing	0.097
Site * Year * Treatment	0.909
resume	6.69

Table 7: Economic analysis of peanut production

Treatment	T0	T1	T2	T3
Grain sale	492000	621150	495075	870840
Fan sale	34815	41800	38596	53983
Recipes	526815	662950	533671	924823
		Production cost		
Seeds	60,000	60,000	55000	55000
Pesticides	4200	4200	3850	3850
Chemical Fertilizer	____	28800	____	28800
Organic fertilizer (compost)	____	266,640	____	266640
Non-Harvest Labor	57000	72000	2000	2000
Harvest Labor	38400	63000	46300	80500
Buy Bag	5250	6625	5875	8875
Transportation	7000	11000	____	____
Seed drill depreciation	____	____	15,000	15,000
Farmer Depreciation	____	____	11000	11000
Total charge	171850	512265	139,025	471665
Net margin	354965	150685	394646	453158

Manual cultivation without fertilizers also had a higher margin than manual cultivation with fertilizers. Seed costs per hectare were reduced from 60,000 to 55,000 FCFA thanks to mechanized sowing. Indeed, the Gangaria seed drill allows for savings of 5000 FCFA per hectare (Table 7) on seed costs. Compost is the organic fertilizer used in micro-doses with the Gangaria seed drill and in manual sowing with fertilizer.

Discussion

The adaptation of the *Gangaria seed drill* has significantly reduced both the time spent sowing and the labor required. Manual sowing requires 10.28 person-hectares, while using the seed drill with animal traction requires only 2 people and an operating time of 1.02 days per hectare. These results are not only superior to those of manual sowing, but also more advantageous than the results reported by Warouma *et al*. (2021) in the same area, where manual peanut sowing required 14 person-hectares and sowing with animal traction required 2 days per hectare. This comparison shows that the improvement observed in our study is not solely due to mechanization in general, but rather to the specific efficiency of the *Gangaria seed drill* which further optimizes operating time compared to existing technologies. Such an advancement is particularly beneficial for smallholder farmers, for whom labor availability is often a limiting factor. This advancement is particularly beneficial for smallholder farmers. It will allow them to better allocate their time between different agricultural and non-agricultural activities and to sow at the optimal time. The absence of a significant difference between T2 and T3 shows that the addition of fertilizers does not increase the workload when mechanization is used, unlike manual sowing (Table 1). The simultaneous application of seeds and fertilizers using the *Gangaria seed drill* led to more efficient use of inputs, resulting in a 108% increase in grain yield and a 55% increase in haulm yield compared to the control (T0). These results are consistent with the work of Abdelrahman and Jens (2011) conducted in eastern Sudan, which indicates that a localized application of 0.6 g/hill of fertilizer in peanut crops increases grain yield by 67.6%. The convergence of these observations underscores the importance of fertilizer placement for improving nutrient uptake efficiency and, consequently, peanut productivity, regardless of specific agroecological conditions. Mechanization combined with judicious fertilization not only benefits grain production but also optimizes haulm production. According to Jens *et al*. (2017), mechanized peanut cultivation, combined with organomineral fertilization, significantly improves overall yields while reducing labor requirements.

The transition from manual sowing (T0) to mechanized sowing (T3) reduced the labor component from 56 to 17%, clearly demonstrating the *Gangaria seed drill's* ability to lower production costs. This trend aligns with the findings of Aune *et al.* (2019), who concluded that mechanization combined with localized fertilizer application not only reduces fertilizer losses but also optimizes resource use. The cost reduction observed in this study thus confirms the overall efficiency achieved through mechanization as described in their work.

Economic analysis shows that treatment T3 generates the highest net margin, at 453,158 FCFA ha^{-1}, compared to 354,965 FCFA ha^{-1} for the control (T0) and 150,685 FCFA/ha for T1. Despite higher operating costs due to the cost of compost (266,640 FCFA ha^{-1}), fertilized mechanized sowing remains the most profitable thanks to a significant increase in yields (Table 5).

These results corroborate the work of Abdourahamane *et al*. (2020) on the mechanization of millet sowing, which highlights the economic efficiency of initial investments in suitable equipment and fertilization. These results are also similar to those of Guthiga *et al*. (2007), who showed that farms using animals achieve better yields and higher economic efficiency than those using only hoes. The labor savings achieved with the Gangaria seeder are significant: Non-harvest labor costs fall to 2,000 FCFA/ha for T3, compared to 72,000 FCFA/ha for T1, which aligns with the findings of Sims and Kienzle (2017) on the reduction of labor arduousness and associated costs through appropriate mechanization in sub-Saharan Africa.

However, the cost of compost remains a significant challenge, amounting to 266,640 FCFA $^{ha^{-1}}$ To minimize production costs, farmers should be trained and encouraged to produce their own compost, which would improve the profitability of mechanized fertilized sowing (T3). According to Rosário *et al*. (2023), the adoption of composting practices remains low in various sub-Saharan African countries where the factors influencing their adoption are not well understood. Although overhead costs are higher in mechanized farming due to the cost of compost, the net profit margin is greater than that of manual farming. The use of compost and the reduction of soil erosion through more regular sowing strengthen the resilience of farms to climate change (Lal, 2015). However, further studies are needed to assess the long-term impact of this innovation on soil health and farmer adoption.

Conclusion

This study, conducted in the Maradi and Zinder region, made it possible to understand the effect of the adapted Gangaria seeder on the improvement in grain and dried haulm yield, labor efficiency, and profitability of peanut cultivation was significant. Mechanized sowing combined with organomineral fertilization (T3) increased grain yield by 108% compared to the control (T0). Haulm yield improved by 55%. Labor requirements were reduced from 10.28 man-ha for treatment T1 to 2 man-ha for mechanized treatments T3, with a labor efficiency of 1.02 man-ha. The hourly efficiency for treatment T3 resulted in a gain of 19.5 man-ha compared to treatment T1, corresponding to a 72% reduction in sowing time. Treatment T3 generated a net margin of 453,158 FCFA/ha. However, the high cost of compost and limited access to seed drills remain the bottlenecks to its large-scale adoption. Promoting local compost production and training farmers in the use of the seeder are necessary to enhance the impact of this technology. Finally, the adapted Gangaria seeder offers a promising solution to the challenges of mechanizing and micro-dose fertilization of peanut crops by improving productivity, profitability, and resilience to climate change.

Acknowledgment

The authors extend their sincere thanks to the Dan Dicko Dankoulodo University of Maradi (UDDM), the National Institute of Agronomic Research of Niger (INRAN), and the Research and Development Project for Food Security and Adaptation to Climate Change Phase 2 (RED-SAACC2) for their technical and financial support, which made this study possible. We also thank the farmers and field agents in the Maradi and Zinder regions for their invaluable collaboration during the various phases of the experiment. The authors declare that they have complied with all ethical standards applicable to scientific research. No conflicts of interest have been declared.

Funding Information

This research was funded by the Research Development, Food Security and Adaptation to Climate Change (REDSAACC 2) project in partnership with the National Institute of Agronomic Research of Niger (INRAN).

Authors' Contributions

Abdoulahi Mamane: Conceived and designed the study; executed the trial; collected and analyzed data; and drafted the manuscript.

Arifa Warouma: Provided methodological guidance and scientific supervision; critically reviewed the manuscript; and validated the final content.

Saidou Addam Kiari: Served as field supervisor, overseeing the implementation of the tests.

Jens Bernt Aune: Offered consulting expertise and technical support throughout the study.

Ethics

All experimental procedures were conducted in accordance with the ethical principles of agronomic research. Trials were carried out on research plots and on farms with the informed consent of volunteer producers. No animals or humans were subjected to unethical treatment during this study. Data were collected and processed in compliance with confidentiality and good scientific practices.

References

Aune, B., & Adama, C. (2020). Precision agriculture: an option for improving land and labor productivity in the Sudanian-Sahelian zone of West Africa. *Precision Farming*, *9*(2), 135–144.

Aune, J. B., Coulibaly, A., & Woumou, K. (2019). Intensification of dryland farming in Mali through mechanisation of sowing, fertiliser application and weeding. *Archives of Agronomy and Soil Science*, *65*(3), 400–410. https://doi.org/10.1080/03650340.2018.1505042

Abdourahamane. N. I. M., Saidou, A. K., & Aune, J. B. (2020). Development and Use of a Planter for Simultaneous Application of Seed, Fertilizer and Compost in Pearl Millet Production in Niger—Effects on Labor Use, Yield and Economic Return. *Agronomy*, *10*(12), 1886. https://doi.org/10.3390/agronomy10121886

Bakoye, O., Baoua, I., Sitou, L., Moctar, M. R., Amadou, L., Njoroge, A. W., Murdock, L. L., & Baributsa, D. (2019). Groundnut Production and Storage in the Sahel: Challenges and Opportunities in the Maradi and Zinder Regions of Niger. *Journal of Agricultural Science*, *11*(4), 25. https://doi.org/10.5539/jas.v11n4p25

Bank, W. (2023). *Technical Report, Transforming Niger's Agri-Food System © World Bank*.

Baudron, F., Sims, B., Justice, S., Kahan, D. G., Rose, R., Mkomwa, S., Kaumbutho, P., Sariah, J., Nazare, R., Moges, G., & Gérard, B. (2015). Re-examining appropriate mechanization in Eastern and Southern Africa: two-wheel tractors, conservation agriculture, and private sector involvement. *Food Security*, *7*(4), 889–904. https://doi.org/10.1007/s12571-015-0476-3

Diao, X., Ellis, M., Randriamamonjy, J., Thurlow, J., & Ulimwengu, J. M. (2023). *Niger's agrifood system structure and drivers of transformation*. https://doi.org/10.2499/p15738coll2.136798

ECOWAS. (2021). *Technical document, Peanut yield development*.

Fanigliulo, R., grilli, R., Benigni, S., Fornaciari, L., Biocca, M., & Pochi, D. (2022). Effect of sowing speed and width on spacing uniformity of precision seed drills. *INMATEH Agricultural Engineering*, *66*(1), 9–18. https://doi.org/10.35633/inmateh-66-01

Guthiga, P. M., Karugia, J. N., & Nyikal, R. A. (2007). Does use of draft animal power increase economic efficiency of smallholder farms in Kenya? *Renewable Agriculture and Food Systems*, *22*(4), 290–296. https://doi.org/10.1017/s174217050700186x

Houmy, K. (2008). *Technical document, Guide to formulating an agricultural mechanization strategy*.

INS. (2023). *Agricultural Statistical Yearbook of Niger*.

Idelphonse, Q., Afio, Z., Augustin, A., Nouatin, K., & Honlonkou, A. N. (2020). Drivers of Mechanization in Cotton Production in Benin. *Agriculture*, *10*(11), 549.

INS, N. (2019). *Technical document: Household conditions in Niger*.

Jens, B., Adama, A., & Ken, C. (2017). Precision farming for increased land and labor productivity in semi-arid West Africa. A review. *Agronomy for Sustainable Development*, *37*(3), 1–16.

Jiquan, P., Zhao, Z., & Liu, D. (2022). Income, and Mechanism: Evidence From Hubei Province, China. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.838686

Lal, R. (2015). Sustainable soil management practices in arid zones. *Journal of Soil and Water Conservation*, *70*(4), 82–89.

Ministry of Agriculture and Environment. (2023). *Final Technical Report: Wintering Campaign Results*.

Moussa, S., & Tougiani, A. (2023). *Farmers' strategies for adapting to climate change in Niger*.

Rosário, J., Quintas, M., Chiteculo, V., Santos Velho, J., Muhepe, S., Morais, B., & Sapanga, N. (2023). Factors affecting the adoption of compost use by small farmers in Angola: the case of Benguela province. *Progress in Industrial Ecology, An International Journal*, *16*(1/2/3), 161–175. https://doi.org/10.1504/pie.2023.132691

Philipe, L., Michel, H., & Vall, E. (2010). Animal traction in West Africa. *African Rural Studies*, *6*(1), 55–72.

Sims, B., & Kienzle, J. (2017). Sustainable Agricultural Mechanization for Smallholders: What Is It and How Can We Implement It? *Agriculture*, *7*(6), 50. https://doi.org/10.3390/agriculture7060050

Vall, E., & Bayala, I. B. (2006). Technical report on animal traction. *IFAD Technical Papers*, *17*, 33–41.

Warouma, A., Chaibou, M., & Saley, A. L. (2021). *Animal Traction and Agricultural Productivity In Niger*. *52*(01), 11, 00845841.