Combined microdosing of NPK and Urea: Effects on productivity and economic profitability of sesame (*Sesamum indicum* L.) in Semi-Arid Burkina Faso.

Abstract

The combined microdose of NPK and urea could be a sustainable intensification strategy for sesame cultivation in semi-arid areas of West Africa.This study evaluated the effects of different NPK microdose treatments, both alone and in combination with urea, on sesame productivity and economic profitability in the North Sudanese zone of Burkina Faso.The trial was conducted in 2019 and 2020 at the Saria Research Station using a completely randomized block design with four replications. Five treatments were tested: T1 (unfertilized control), T2 (1 g NPK/hill), T3 (1.5 g NPK/hill), T4 (1 g NPK + 1 g urea/hill), and T5 (1.5 g NPK + 1 g urea/hill). Results showed that T5 recorded the highest grain yield (average 1,114 kg.ha^{-1}), representing a 114.5% increase compared to the unfertilized controlkg.ha-1. This combination also significantly improved the straw yield.Economic analysis revealed that T5 achieved the highest net margin (on average >741 USD ha^{-1})) with a Benefit/Cost Ratio exceeding 2.5, confirming its profitability for smallholder producers.These findings demonstrate that the application of 1.5 g of NPK and 1 g of urea per microdose is a promising techno-economic option for the sustainable intensification of sesame cultivation in smallholder farming systems.

Keywords: Fractional nitrogen fertilization, sesame, economic profitability, semi-arid zone, Burkina Faso

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Introduction

Sesame (*Sesamum indicum* L.) is the second largest cash crop in Burkina Faso after cotton and representing a major pillar of the country's rural economy and a key source of foreign exchange.In 2022, national sesame seed production was estimated at approximately 208,794 tons, despite a decline attributed to security crises (FAOSTAT, 2024), making the country 7th largest producer in the world and 4th in Africa.Historically, sesame exports contributed over US$169,857,000 to the Burkinabe economy (Kafando *et al.*, 2020).Thus, the development of sesame sector in Burkina Faso offers significant potential for enhancing farmer incomes and foreign exchange inflows.

While the sector has experiencedrapid expansion of cultivated areas, with cultivated areas increasing from 165,575 ha in 2012 to nearly 389,000 ha in 2021 (a 134% increase; DGESS, 2022), this growth remains extensive, characterized by persistently low average yields ranging from 162 to 550 kg ha^{-1} (Siri *et al.*, 2024a; Muthoni & Shimelis, 2023).This low productivity can be explained by several structural constraints typical of semi-arid areas in West Africa.On the one hand, soils, mainly leached with a sandy silty texture, have an inherently low fertility, characterized by very low levels of organic matter (< 1%), total nitrogen (< 0.05%), and assimilable phosphorus (Bationo & Fening, 2018; Myint et al., 2020); on the other hand, the poor application of technical itineraries and the marginal use of mineral fertilizers on sesame (< 13% of plots), unlike cotton (Siri et al., 2024a and b; Miningou*et al.*, 2020), limititsproductivity.These constraints also accentuate the progressive degradation of soil fertility and limit the response to investment.Consequently, there is an urgent need to develop and disseminate sustainable and efficient agricultural intensification options to improve sesame yield.

These intensification strategies can be based on organic and mineral fertilization.However, the high cost of mineral fertilizers is a constraint to their large-scale use, especially among smallholder farmers (Siri et al., 2024c).Thus, the technique of microdosing mineral fertilizers, which makes it possible to optimize the efficient use of fertilizers while substantially increasing crop yields and thus producers' incomes, could be an alternative solution.This technique, also called localizedfertilization with small doses of fertilizer (Hayashi *et al.*, 2008), has led to significant increases in the yields of various crops in different countries (Sermé *et al.*, 2016 ; Saba *et al.*, 2017; Somda *et al.*, 2017; Sissoko, 2019; Ouédraogo *et al.*, 2020; Tounkara *et al.*, 2022; 2023).AlthoughSiri *et al.* (2024b) demonstrated that NPK microdosing can substantially improve sesame yields, nitrogen fertilization remains an underexploited lever.Several studies have consistently highlighted the critical roleof nitrogen invegetative growth, flowering, and capsule formation ofsesame (Muhamman *et al.*, 2009; Berhanu *et al.*, 2016;Amare *et al.*, 2019; Zenawi & Mizan, 2019; Saad-allah *et al.*, 2025), with a fractional application of nitrogen during the cycle showing potential for yield improvementt(Gebremariam, 2015).Moreover, the sesame seed production manual recommends supplementary urea application whenever necessary(Miningou *et al.*, 2018).

Given that current mineral fertilization practices in Burkina Faso are largely restricted to a single application of 100 kg NPK ha^{-1} (Miningou*et al.*, 2020), this study hypothesized that the combined and fractional application of NPK and urea via microdosing would significantly improve agronomic productivity and economic profitability for smallholders compared to NPK alone.Therefore, this study aimedto contribute to the sustainable intensification of sesame productionin semi-arid zone of Burkina Faso,by evaluating amineral fertilizer microdosingstrategy combiningNPK and urea.

Materials and methods

Presentation of the study area

The study was conducted at the Saria Research Station (12°16 ‘N, 2°9' West longitude).The climate of Saria is of the North Sudanese type (Fontes and Guinko, 1995), characterized by alternating rainy season (June to October) and dry season (November to May).The cumulative rainfall in 2019 and 2020 was 911.9 mm and 949.3 mm, respectively.However, the Saria area often faces water deficits caused by irregular and poor spatial and temporal distributions of rainfall.The average annual temperature of Saria is approximately 28°C.In the rainy season, moderate temperatures of approximately 25° to 35°C are recorded.This study was conducted on a lixisol with a sandy silty texture on the surface.The physicochemical characteristics of the soil at the site are presented in Table 1.

Table 1: Physicochemical characteristics of the soil at the study site.

Measured parameters	Values
Clay (%)	12.5
Silt (%)	22.8
Sands (%)	64.7
Total organic matter (%)	0.66
Total Nitrogen (%)	0.03
Total Phosphorus (ppm)	81.3
Available phosphorus (ppm)	2.23
Total potassium (ppm)	531.24

Plant material

The S42 variety of sesame, registered in the 2014 edition of the National Catalogue of Agricultural Varieties was used.It is a white-grained variety that is adapted to local conditions.It has a seed-to-maturity cycle of 88–90 days with a potential yield of 1.0–1.8 t.ha^{-1}.

Experimental design and field management

This study was conducted during the 2019 and 2020rainy seasons.A randomized complete block designwith four (04) repetitions was used.Five treatments, includingaunfertilized control and four fertilizer microdosingcombinations of NPK and urea, were evaluated as follows:

- T1: Unfertilized control;
- T2: 1 g NPK per hill;
- T3: 1.5 g NPK per hill;
- T4: 1 g NPK + 1 g urea per hill;
- T5:1.5 g NPK + 1 g urea per hill.

The elementary plots measured 12 m² (4 m × 3 m). Adjacent blocks were separated by 2mwide alleys, whereas 1mwide alleys were maintained between adjacent plots. Landpreparation consisted of plowing to a depth of approximately 20 cm using animal traction,followed by harrowing. Sowing was performed manually at a spacing of 60 cm × 20 cm, with three to four seeds per hill. Thinning was carried out at 15 days after sowing (DAS) to leave two plants per hill. Two manual weedings were performedat 15 and 45 DAS. NPK fertilizer was applied at 15 DAS using the microdosing technique, placed 5–10 cm from the base of the plants according to the respective treatment doses. Urea was applied at 45 DAS, also following the microdosing method. Harvesting was carried out on two 1 m² yield quadrats per elementary plot. Plants were cut at ground level and bagged for field drying. Threshing was performed manually two weeks after harvest. Seed and straw weights were recorded, andseed and straw yields were calculated Seed and straw weights were recorded, and yields were calculated by extrapolating the plot-level weights to a hectare basis (kg ha^{-1}).

Economic analysis

Three keyindicators were used to assess the profitability and economic viability of the different treatments, accounting for the specific constraints faced by smallholder farmers in semi-arid regions.

Net Margin (NM)

The Net Margin (NM), expressed in USDha^{-1}, reflects the ability of a production system to generate a positive balance after covering all its monetary costs. Its calculation is based on the following relationship (Yegbemey et al., 2014):

$$NM = GP - TC \qquad (1)$$

Where:

GP: gross revenue (USD.ha^{-1}), calculatedby multiplying the seed yield by the unit selling price of sesame.

TC: total monetary costs per hectare (FCFA ha^{-1}), including variable costs (VC) such as inputs andhiredlabor) and fixed costs (CF) corresponding toequipment depreciation;

When **NM> 0**, indicates that the activity generates an economic surplus sufficient to covers all monetary costs.Otherwise (**NM< 0**), indicates that the activity is economically unprofitable.

Benefit–Cost Ratio (BCR)

The Profit-to-Cost Ratio (BCR) measuresthe gross revenue generated per unitof monetary expenditure incurred. Its calculation is based on the following relationshipLabiyi *et al*. (2019):

$$BCR = \frac{GP}{TC} \qquad (2b)$$

When BCR > 1 indicates that gross income exceeds direct monetary costs

Marginal Value-Cost Ratio (VCR)

The Marginal Value-Cost Ratio (VCR) evaluates the additional revenue generated per additional unit of currencyinvested in fertilizer inputs comparedto the unfertilized control:

$$VCR = \frac{GP_{ti} - GP_{T1}}{C_{add}} (2b)$$

Where $GP_{ti}$is the gross revenueof fertilized treatment i, $GP_{T1}$is the gross revenueof the unfertilized control, and C_{add} is the additional cost of fertilizers compared to theunfertilized control.This indicator is particularly relevant for assessing the economic attractiveness of intensification technologies for resource-constrained smallholder farmers (Crawford & Kamuanga, 1987).

Inputs prices used were 739 USD t^{-1} for NPK (14-23-14) and 601 USD t^{-1} for urea (46% N). Other production costs (ploughing, weeding, harvesting, transportation, etc.) were estimated from baseline data of the Lutheran World Relief/CNFA (2017), updated to the local context of the North Sudanese zone in 2019-2020 (Table 2).

Table 2: Other sesame production costs in CFA francs

Designation	Cost ($/ha)
Labor	60
Weeding	67
Treatment Product	32
Harvesting	31
Transport and packaging	8
Production Equipment	14
Harvesting Equipment	3
Packaging	9
Transport	13
Other	16

Source : IMCG, November 2017

Data analysis

Data were processed using Microsoft Excel 2016 and subjected to an analysis of variance (ANOVA) at the 5% significance level using GenStat software (version 9.2).The Student Newman-Keuls test was used to compare the means when differences were significant.Figures were generated usingGraphPad Prism (version 8).

Results

Effect of microdose on sesame seed yield

The effect of microdose fertilization with NPK and urea on sesame seed yield is shown in Figure 1.

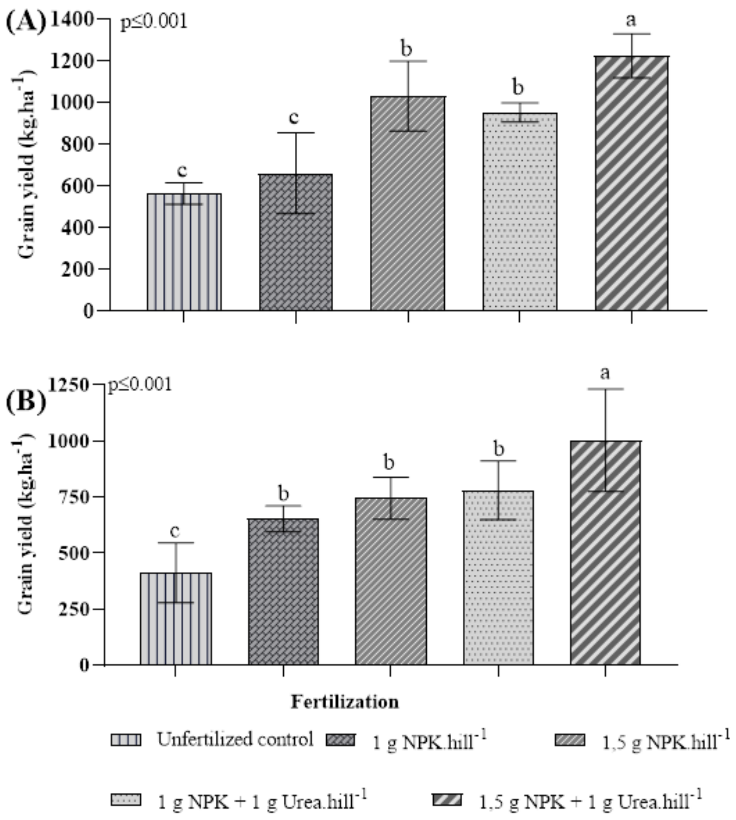

Figure 1: Effect of fertilization on the average seed yield (kg.ha^{-1}) of sesame(A: year Cropping season 2019 and B: Cropping season 2020)

Histograms affected by the same letters are not significantly different at the 5% probability threshold; Error bars represent standard deviations.

The results showed that microdose fertilizer application had highly significant effects on sesame grain yield across both years.In 2019 (Figure 1A), the highestgrain yield was recorded for the treatment of 1.5 g of NPK + 1 g of urea per hill, reaching1,224.6 kg.ha^{-1}.This treatment differs significantly from other treatments availablerepresenting an increase of 116.97% 116.97% over the unfertilized control and 18.72% over the 1.5 g NPK treatment.The unfertilized control plot recorded the lowest grain yield (564.4 kg.ha^{-1}).Similar trends were observed in 2020 (Figure 1B), wherethe 1.5 g of NPK + 1 g of urea per hill again achieved the highest seed yield (1003.2 kg.ha^{-1}).It differed significantly from other treatments, except for the treatment consisting of the addition of 1 g of NPK + 1 g of urea per hill.The lowest yield was observed in theunfertilized control (412.5 kg.ha^{-1}).The treatment of 1.5 g NPK + 1 g urea per hill increased the yield by 143.20% compared to the unfertilized control and by 34.66% compared to the 1.5 g NPK treatment.

Effect of microdose on sesame straw yield

The results showed that in 2019, the higheststraw yield was recordedwith the treatment of 1.5 g NPK + 1 g urea per hill, with a yield of 3,150 kg.ha^{-1} (Figure 2A).This was followed by the 1 g NPK + 1 g urea per hilltreatment (2,850 kg.ha^{-1}), with no significant difference observed between them. The lowest straw yield was obtained in theunfertilized control (2, 200 kg.ha^{-1}).Compared with the unfertilized control, fertilizer microdosingincreased straw yield, with increases ranging from 22.73% under the1 g of NPK per hilltreatment to 43.18% under1.5 g of NPK + 1 g of urea per hill treatment.

In 2020, the 1.5 g NPK + 1 g urea per hill treatmentproduced the higheststraw yield reaching4,500 kg.ha^{-1} (Figure 2B).This differs significantly from other treatments.The lowest yield was observed in the unfertilized control (2,166 kg.ha^{-1}).Fertilizer microdosing increased straw yield, with increases ranging from 50.05% with the 1 g NPK + 1 g urea per hilltreatment to 107.76% with 1.5 g NPK + 1 g urea per hill treatment.

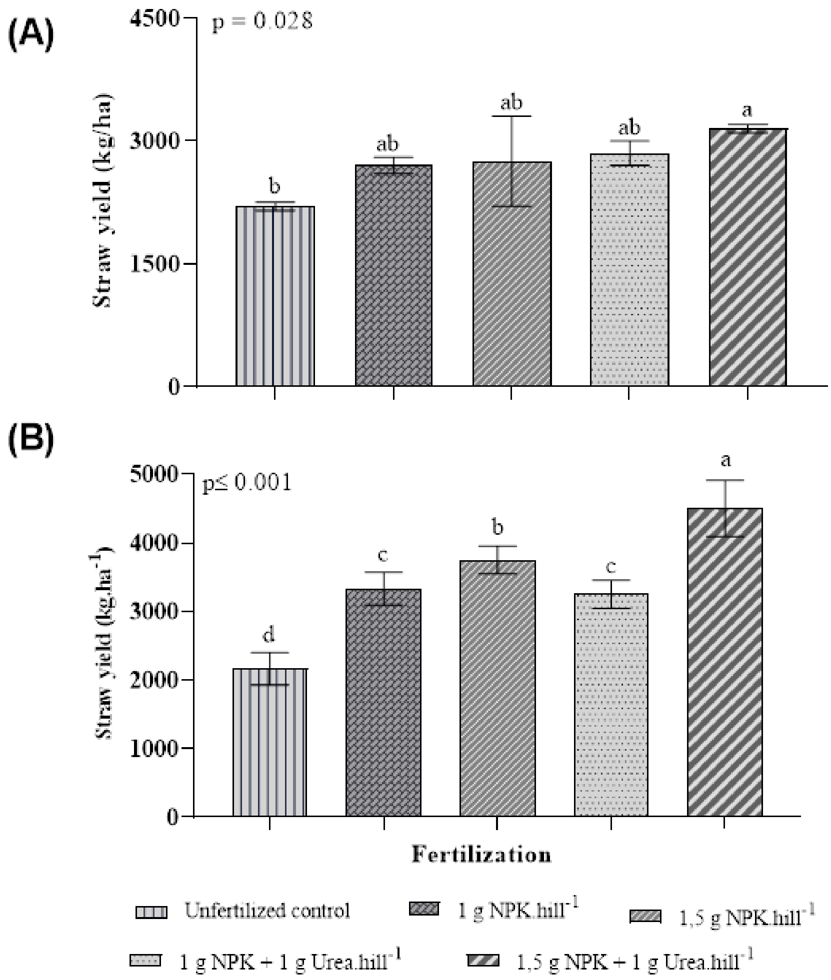

Figure 2: Average straw yields (kg.ha^{-1}) of sesame from treatments(A: Cropping season 2019 and B: Cropping season 2020).

Histograms assigned to the same letters in the same column are not significantly different at the 5% probability threshold; error bars represent standard deviation.

Economic Profitability of Microdosing

The economic analysis revealed the clear superiority of the T5 treatment in terms of cost-effectiveness, confirming that the additional investment in combined NPK + urea microdose is not only agronomically effective, but also financially beneficial for smallholder producers.

The total production costs increased with the level of fertilization, from 267 USD ha^{-1} for the unfertilized control (T1) to 410 USD ha^{-1} for T5 (Table 3). This additional cost (143 USD ha^{-1}) was exclusively related to fertilizers purchase, as other cultivation operations (ploughing, weeding, harvesting, etc.) remained consistent across treatments.

Table 3**.** Structure of production costs (USD ha^{-1}) by treatment (2019-2020 average).

Labels	T1 (Unfertilized control)	T2 (1g NPK)	T3 (1,5g NPK)	T4 (1g NPK + 1g Urea)	T5 (1.5g NPK + 1g Urea)
Seeds (USD ha^{-1})	13	13	13	13	13
Land preparation (USD ha^{-1})	60	60	60	60	60
Weeding (USD ha^{-1})	68	68	68	68	68
Phytosanitary products (USD ha^{-1})	32	32	32	32	32
Harvesting (USD ha^{-1})	31	31	31	31	31
Transport & packaging	8	8	8	8	8
Equipment & others	42	42	42	42	42
Fertilizer input cost (USD ha^{-1})	0	62	93	112	143
Total costs (USD ha^{-1})	267	329	360	379	410
Additional cost vs T1 (USD ha^{-1})	-	+62	+93	+112	+143

T1: Unfertilized control; T2: 1g NPK/hill; T3: 1.5g NPK/hill; T4: 1g NPK + 1g Urea/hill; T5: 1.5g NPK + 1g Urea/hill.

Regarding profitability indicators (Table 4), T5 treatment consistently achieved the best economic performance. In 2019, it recorded a net margin of 857 USD ha^{-1} and a benefit-cost ratio (BCR) of 3.09, which were significantly higher than those of the control and NPK treatments alone. In 2020, T5 remained the most profitable treatment with a net margin of 628 USD ha^{-1} and a BCR of 2.53. The value-cost exceeded the critical threshold of 2 for all fertilized treatments and reached a maximum of 4.78 for T5 in 2019. These results indicate that each dollar invested in fertilizer microdosing generated more than 4 dollars of additional revenue.

Table 4. Average Economic Indicators by Treatment

Treatment	Cropping season 2019			Cropping season 2020		
	NM ($USD.ha^{-1}$)	BCR	VCR	NM ($USD.ha^{-1}$)	BCR	VCR
T1 (Unfertilized control)	317 ± 53^{c}	2,19 ± 0,20^{b}	-	160 ± 139^{c}	1,60 ± 0,52)	-
T2 (1g NPK)	355 ± 201^{c}	2,08 ± 0,61^{b}	1,62 ± 2,92	347 ± 60^{bc}	2,06 ± 0,18	6,08 ± 0,97
T3 (1,5g NPK)	708 ± 173^{b}	2,97 ± 0,48^{ab}	5,21 ± 1,29	411 ± 97^{bc}	2,14 ± 0,27	5,08 ± 1,05
T4 (1g NPK+1g Urea)	608 ± 48^{bc}	2,60 ± 0,13^{ab}	3,59 ± 0,45	428 ± 135^{b}	2,13 ± 0,36	4,52 ± 1,20
T5 (1.5g NPK+1g Urea)	857 ± 110^{a}	3,09 ± 0,27^{a}	4,78 ± 0,67	628 ± 237^{a}	2,53 ± 0,58	5,16 ± 1,65
p-value	0,002	0,031	0,105	0,007	0,075	0,397
Signification	HS	S	NS	HS	NS	NS

Values in the same column followed by different letters are significantly different at the 5% threshold (SNK test); HS: Highly significant; S: significant; NS: Not significant

Discussion

The results of this study demonstrate that the combined application of NPK and urea as fertilizer microdose isan effective and accessible strategy for sustainablyimproving both the productivity and economic profitability of sesame cultivation in the semi-arid zone of Burkina Faso.Among the treatment evaluated,T5 treatment (1.5 g NPK + 1 g urea per hill) consistently achieved the highest seed and straw yieldsin both cropping seasons.The average grain yield increase of +114.5% compared to the unfertilized control is particularly noteworthyin a context where most Burkinabe farmers typically produceless than 400-550 kg ha^{-1} of sesame (Siri et *al.*, 2024a).

This superior performance of T5 can be explained by better synchronization between the supply of nutrients and crop nutrient demand(Lu et *al.*, 2018). The early application ofNPK provides animmediatesupply of phosphorus and potassium, nutrients that are essential for root development and early plant vigor, particularly in soils with low available phosphorus (Boureima&Mahaman, 2020; Hanif *et al.*, 2024). Urea applied at 45 DAS coincided with flowering and capsular filling stage, when nitrogen demand is greatest. This splitapplication enhancesnitrogen use efficiency while reducingnitrogen losses throughvolatilization, which are exacerbated by the high temperatures typical of the Sahel (Amare *et a*l., 2019; Gebregergis *et a*l., 2020; Sajjad *et al*., 2025)).Previous studies have shown that microdosing concentrates nutrients in the rhizosphere, therebystimulatingroot growth and improving water use efficiency (Aune and Bationo, 2008; Sermé et *al*., 2016; Tounkara et *al.* 2023). These advantagesare particularlyimportantunder the recurrent rainfall deficits that characterize the North Sudanese zone. Our findingsconfirm and extend previous evidence on the effectiveness of fertilizer microdosing in West African farming systems(Sissoko, 2019; Tounkara e*t* al., 2023).Similarly, Saba *et al.* (2017) reported grain yield increases of 134-155% in millet, sorghum, and cowpeas, whileSermé*et al.* (2016) reported yield improvements ranging from 50 to 146% in maize and soybean. More recently, Siri et *al.* (2024b) demonstrated the effectiveness of NPK microdosing in improving sesame productivity.The present study extends these findings by showingthat supplementing NPK microdosing with urea application at 40 DAS provides additional grain yield advantageof 18–35% compared to NPK microdosingalone. This improvementis attributed to enhancednitrogen availabilityduring the reproductive stage, which supports capsule development and seed filling(Saad-Allah et *al.*, 2025). The marked increase in straw yield, which reached 108% above that of the control in 2020 under T5, is of considerable practical importance. In addition to increasing total biomass production, higher straw yields contribute to improving dry-season feed availability in mixed crop–livestock systems while providing an additional source of income for rural households (Sermé et *al.*, 2016).

The interannual variability observed between 2019 and 2020 illustrates the strong influence of rainfall patterns on sesame cultivation.Indeed, a study by Siri et *al.* (2024c) showed that sesame agronomic performance declines as rainfall intensity and duration increase.

Sesame is known to be highly sensitive to excessive rainfall, even over relatively short periods, because temporary waterlogging restricts root aeration and reduces plant growth (Son et al., 2011). The greater rainfall variability recorded in 2020 may therefore have exposed the crop to transient flooding and excess soil moisture, leading to reduced yields (Son et *al.*, 2011).

Nevertheless, T5 consistently maintained the highest relative performance, suggesting that improved nutrient supply and enhanced root development increased crop resilience under variable moisture conditions (Elhanafi et *al.,* 2019).From economic perspective, T5 treatment generated the highest net margins reaching857 USD ha^{-1} withbenefit-cost ratios exceeding2.5 and value to cost ratios well above the profitabilitythreshold of 2 (Crawford & Kamuanga 1987).These findingsagree are consistent with previous studiesconducted in Burkina Faso (Sermé et *al.*, 2016; Saba et *al.*,2017; Somda et *al.*, 2017;Sigué et *al.*, 2019),), which demonstrated that the localized application of small fertilizer doses often provides greater economic returns than higher fertilizer rates.Moreover, the additional fertilizer cost 143 USD ha^{-1}) remains relatively affordable, particularlywhen supportedby access tomicrocredit or *warrantage*mechanisms that arealready widely promoted in the region (Cotty et *al.,* 2023).

Conclusion

This study demonstrated that the combined application of NPK and urea as fertilizer microdoses is an effective strategy for sustainably intensifying sesame production in semi-arid zones of Burkina Faso.The treatment consisting of 1.5 g NPK + 1 g urea per hill1.5 g NPK + consistently producedthe highest grain yield (1,113.9 kg ha^{-1} on average), representing a 114.5% increase compared to the unfertilized control and significantly outperforming NPK microdosing alone.This combination also substantially increased straw and achieved economic returns, with the highest net margin and a benefit–cost ratio (BCR) exceeding2.5.These findings demonstrate that split-nitrogen application using NPK and urea enhances crop productivity and fertilizer use efficiency under low-fertility soil conditions.Overall, the application of 1.5 g NPK combined with 1 g urea per hill represents a promising, technically effective, and economically viable option for resource-constrained smallholder farmers.Its adoption, together with improved access to fertilizer inputs, extension services, and farmer training, could contribute to sustainably increasing sesame productivity, improving rural livelihoods, and strengthening the resilience of farming systems to climate variability in the North-Sudanian zone of Burkina Faso.

Bibliographical references

Amare, M., Fisseha, D., & Andreasen, C. (2019). Effect of N and P Fertilisers on Yield and Yield Components of Sesame (Sesamum indicum L.) in.*Agriculture*, *9*(227), 1–12. https://doi.org/doi:10.3390/agriculture9100227

Aune, J. B., & Bationo, A. (2008). Agricultural intensification in the Sahel – The ladder approach. *Agricultural Systems*, *98*(2), 119–125. https://doi.org/https://doi.org/10.1016/j.agsy.2008.05.002

Bationo, A., & Fening, J. O. (2018). *Soil Organic Carbon and Proper Fertilizer Recommendation BT - Improving the Profitability, Sustainability and Efficiency of Nutrients Through Site Specific Fertilizer Recommendations in West Africa Agro-Ecosystems: Volume 1* (A. Bationo, D. Ngaradoum, S. Youl, F. Lompo, & J. O. Fening (eds.); pp. 1–10). Springer International Publishing. https://doi.org/10.1007/978-3-319-58789-9_1

Berhanu, S., Sharma, M. J. J., & Dechassa, N. (2016). Effects of nitrogen fertilizer rates on yield and yield components of sesame (Sesamumindicum L .) varieties under irrigation in Gode , South-Eastern Ethiopia. *International Journal of Plant Breeding and Crop Science*, *3*(1), 71–78.

Boureima, S., & Mahaman, L. I. (2020). Effects of soil phosphorus deficiency on the growth and development of sesame (*Sesamum indicum* L.). *International Journal of Biological and Chemical Sciences*, *14*(3), 1014–1024. https://doi.org/10.4314/ijbcs.v14i3.28

Cotty, T. Le, D'hôtel, É. M., Porgo, I., Subervie, J., & Soubeyran, R. (2023). Warrantage, a mechanism to improve food security in sub-Saharan Africa. *Perspective*, 0–4. https://doi.org/https://hal.science/cirad-04094506v1

Crawford, E., & Kamuanga, M. (1987). *L'Analyse Economique des Essais Agronomiques Pour la Formulation des Recommandations aux Paysans* (1987. Michigan State University & Michigan (eds.); Issue 6, p. 43). Department of Agricultural Economics, Michigan State University, East Lansing, Michigan 1188211-1039 U.S.A.

Elhanafi, L., Bouayad, K., Rais, C., Houhou, M., MansouRi, I., ElghadRaoui, L., & GREchE, A. (2019). Evaluation of the tolerance of sesamum indicum L. to water stress at the germinative and vegetative stages. *Bulletin de l'Institut Scientifique, Rabat, Section Sciences de La Vie*, *41*(1114–6834), 43–49.

FAOSTAT. (2024). *FAOSTAT (Food and Agriculture Corporate Statistical Database). . World Sesame Production Database 2004 to 2024. Excel database. Web: www.fao.org*.

Gebregergis, Z., Sibhatu, F. B., & Teame, G. (2020). Optimizing N fertilizer use for sesame under rain fed and irrigation conditions. *Preprints (Www.Preprints.Org)*, *October*. https://doi.org/10.20944/preprints202010.0396.v1

Gebremariam, G. (2015). Growth , Yield and Yield Component of Sesame (Sesamum indicum L .) as Affected by Timing of Nitrogen Application. *Journal of Biology, Agriculture and Healthcare*, *5*(5), 165–170.

Hanif, S., Nasir, T., Khizar, M., Tariq, M., Mehwish, S., Usman, M., Ali, M., Hira, S., Bilal, M., & Haseeb, M. (2024). *Enhancing Sesame Yield in Arid Conditions through NPK Fertilizer Optimization*. *12*(3), 1–11. https://doi.org/10.9734/APRJ/2024/v12i3248

Kafando, W. A., Hsu, C.-S., Chang, C.-C., & Hsu, S.-H. (2020). Factors Affecting Sesame Seed Exports in Burkina Faso : The Vector Error Correction Approach. *Developing Country Studies*, *10*(4), 20–31. https://doi.org/10.7176/DCS/10-4-03

Labiyi, I. A., Sigue, H., & Ouattara, D. C. (2019). Effect of innovative endogenous sustainable land management practices on the technical and economic performance of the network of producers in the commune of Mani in Burkina Faso Summary Abstract. *Afrique SCIENCE*, *15*(1), 432–447.

Lu, D., Jiang, S., Chen, X., Wang, H., & Zhou, J. (2018). Wheat Growth as Affected by Combinations of Phosphate Dose and Patch Size. *Agronomy Journal*, *110*(2), 1–8. https://doi.org/10.2134/agronj2017.05.0267

Lutheran World Relief / CNFA. (2017). *Investing in the Future*. https://lwr.org/technical-resources/2017-annual-report

Miningou, A., Golane, V., Sy, A., & Kambire, H. (2020). Détermination de la dose et de la date optimales d ’ application de la fumure minérale sur le sésame (Sesamum indicum L .) au Burkina Faso . Title : Determination of the optimal dose and date of application of mineral manure on sesame (sesamum indicum L. *Int. J. Biol. Chem. Sci.*, *14*(December), 2992–3000.

Miningou, A., Mémouna, T., & Nowaki, H. (2018). *Manual of Certified Seed Production Technique in Burkina Faso Sesame Manual of Certified Seed Production Technique in Burkina Faso Sesame*.

Muhamman, M. A., Gungula, D. T., & Sajo, A. A. (2009). Phenological and yield characteristics of sesame (Sesamum indicum L .) as affected by nitrogen and phosphorous rates in Mubi , Northern Guinea Savanna Ecological Zone of Nigeria لوصحَنةٌجبتَلاِوةٍهكشناتبفصناـهعيروفسفناويٍِجورتٍُناذ. *Emir. J. Food Agric.*, *21*(1), 1–9.

Muthoni, J., & Shimelis, H. (2023). *Chapter 24 - An overview of potato production in Africa* (M. E. Çalişkan, A. Bakhsh, & K. B. T.-P. P. W. Jabran (eds.); pp. 435–456). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-822925-5.00020-7

Myint, D., Gilani, S. A., Kawase, M., & Watanabe, K. N. (2020). Sustainable Sesame (Sesamum indicum L .) Production through Improved Technology : An Overview of Production , Challenges , and Opportunities in Myanmar. *Sustainability*, *12*(3515), 1–21.

Ouedraogo, J., Serme, I., Pouya, M. B., Sanon, S. B., & Ouattara, K. (2020). Improvement of sorghum productivity through introducing integrated soil fertili. *Int. J. Biol. Chem. Sci. 14(9):*, *14*(December), 3262–3274.

Saad-allah, K. M., Elkelish, A., Abu-elsaoud, A. M., Al-robai, S. A., Essa, D., Badji, A., Alammari, B., & Abo-shanab, W. A. (2025). Urea and potassium nitrate synergy in sesame cultivation : boosting growth , yield , and antioxidant resilience through tailored nitrogen fertilization. *Scientific Reports*, 1–20.

Saba, F., Jean, S., Taonda, B., Serme, I., Bandaogo, A. A., & Sourwema, A. P. (2017). Effets de la microdose sur la production du niébé , du mil et du sorgho en fonction la toposéquence Effects of fertilizer microdosing on cowpea , millet and sorghum production as a function of the toposequence. *Int. J. Biol. Chem. Sci.*, *11*(October), 2082–2092.

Sajjad, M., Hussain, K., Wajid, S. A., & Saqib, Z. A. (2025). The Impact of Split Nitrogen Fertilizer Applications on the Productivity and Nitrogen Use Efficiency of Rice. *Nitrogen*, *6*(1). https://doi.org/doi.org/10.3390/nitrogen6010001

Sanon, A., Gomgnimbou, A. P. K., Sigue, H., Coulibaly, K., Bambara, C. A., Sanou, W., Fofana, S., & Nacro, H. B. (2021). Economic and financial performance of strict rainfed rice fertilization in the southern Sudanian zone of Burkina Faso. *International Journal of Biological and Chemical Sciences*, *15*(4), 1581–1594. https://doi.org/10.4314/ijbcs.v15i4.22

Sermé, I., B, P. M., Iliassou, N., & Korodjouma, O. (2016a). Effet de l ’ application d ’ engrais solubles NPK et de l ’ Urée en microdose sur le soja et le maïs au Burkina Faso Effect of soluble NPK and Urea fertilizers microdosing on soybean and corn in Burkina Faso. *Science and Technology, Natural Sciences and Agronomy*, 67–80.

Sermé, I., B, P. M., Iliassou, N., & Korodjouma, O. (2016b). Effet de l ’ application d ’ engrais solubles NPK et de l ’ Urée en microdose sur le soja et le maïs au Burkina Faso Effect of soluble NPK and Urea fertilizers microdosing on soybean and corn in Burkina

Faso. *SNA*.

SIGUE, H., LABIYI, I. A., ISSAKA, K., YABI, J. A., & BIAOU, G. (2019). EFFECT OF MICRODOSE TECHNOLOGY COMPONENTS ON THE ECONOMIC AND FINANCIAL PERFORMANCE OF FARMS IN KOURITENGA AND ZONDOMA IN BURKINA FASO. *African Crop Science Journal*, *27*(3), 331–349.

Siri, A., Ouedraogo, J., Chabi, F., Sanon, A., Serme, I., Kouelo, A. F., Amadji, L. G., Dagbenonbakin, G., Management, C., Faso, B., Study, S. F., & Faso, B. (2024). DETERMINANTS OF SESAME CULTIVATION PRACTICES IN THE EAST REGION OF BURKINA FASO Sesame (Sesamum indicum L .) is an important oilseed crop , especially in West Africa , contributing to household economies (Savadogo et al ., 2018). The crop commands high. *African Crop Science Journal*, *32*(3), 235–250.

Siri, A., Ouedraogo, J., Sanon, A., Chabi, F., Kouelo, F. A., Sermé, I., & Amadji, G. L. (n.d.). Typology of sesame (Sesamum indicum L .) cropping systems in eastern region of Burkina. *International Journal of Innovation and Applied Studies*, *43*(3), 579–587.

Siri, A., Ouedraogo, J., Somda, B. B., Chabi, F., & Serme, I. (2024). Determination of optimal sowing periods for sesame cultivation (Sesamum indicum L .) in the context of cl. *Int. J. Biol. Chem. Sci.*, *18*(August), 1296–1312.

Sissoko, P. (2019). *Microdosing fertilizers: a technique to improve the livelihoods of poor producers in the Sahel. The case of millet and sorghum-based farms in Mali. Doctoral thesis (PhD). University of Liège, Gembloux Agro-Bio Tech (Belg*.

Somda, B. B., Ouattara, B., Serme, I., Pouya, M. B., Lompo, F., Baptiste, S. J., & Sedogo, P. M. (2017). Determination of optimal doses of organo-mineral fertilisers in microdoses in the Sudano-Sahelian zone of Burkina Faso. *Int. J. Biol. Chem. Sci. 11(2):*, *11*(April), 670–683.

Son D, Compaoré E, Bonkoungou S, Sangaré S. (2011). Effect of water stress on the growth and production of sesame (Sesamum indicum). Journal of Applied Biosciences, 37: 2460-2467.

Tounkara, A., Camara, B., Ndiaye, A., Sow, F. B., & Ngom, D. (2022). Agronomic performance of microdose on millet sanio (Pennisetum glaucum (L.) R. Br) in Lower Casamance (Senegal). *African Journal of Environment and Agriculture*, *5*(3), 2–10.

Tounkara, A., Sarr, S., Ngom, C. A. B., Ndiaye, N., & Faye, M. D. (2023). Microdosing, a fertilization technology for sustainable land management and improved market gardening yields in the Groundnut Basin in Senegal. *Rev. Mar. Sci. Agron. Vét.*, *11*(1), 59–63.

Yegbemey, R. N., Yabi, J. A., Aïhounton, G. B., & Paraïso, A. (2014). Simultaneous modelling of the perception and adaptation to climate change: the case of maize producers in northern Benin (West Africa) Rosaine. *Cah Agric*, *23*, 177–187. https://doi.org/10.1684/agr.2014.0697

Zenawi, G., & Mizan, A. (2019). Effect of Nitrogen Fertilization on the Growth and Seed Yield of Sesame (Sesamum indicum L .). *Hindawi International Journal of Agronomy*, *2019*.