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RESEARCH ARTICLE

COMBINED MICRODOSING OF NPK AND UREA: EFFECTS ON PRODUCTIVITY AND ECONOMIC PROFITABILITY OF SESAME (*SESAMUM INDICUM* L.) IN SEMI-ARID BURKINA FASO

Ouedraogo Jean¹, Sawadogo Achille², Nignan Iliassou³, Ouedraogo Mactar¹ and Serme Idriss¹

1. Centre National de la Recherche Scientifique et Technologique. Institut de l'Environnement et de Recherches Agricoles. Laboratoire Ressources Naturelles et Innovations Agricoles, 01 BP 476 Ouagadougou 01 Burkina Faso.
2. Université de Dédougou, Institut des Sciences de l'Environnement et du Développement Rural (ISEDUR), BP 176 Dédougou Burkina Faso.
3. Ministère de l'Agriculture, de l'Eau, des Ressources Animales et Halieutiques. Société d'Exploitation des Phosphates du Burkina, 03 BP 7194 Ouagadougou 03, Burkina Faso.

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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 control. 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.

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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 experienced rapid 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; Miningouet al., 2020), limit its productivity. 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 localized fertilization 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). Although, Siri 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 role of nitrogen in vegetative growth, flowering, and capsule formation of sesame (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 improvement (Gebremariam, 2015). Moreover, the sesame seed production manual recommends supplementary urea application whenever necessary (Miningouet al., 2018).

Given that current mineral fertilization practices in Burkina Faso are largely restricted to a single application of 100 kg NPK ha⁻¹ (Miningouet al., 2020), this study hypothesized that the combined application of NPK and urea via microdosing would significantly improve agronomic productivity and economic profitability for smallholders compared to NPK alone. Therefore, this study aimed to contribute to the sustainable intensification of sesame production in semi-arid zone of Burkina Faso, by evaluating a mineral fertilizer microdosing strategy combining NPK 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 2020 rainy seasons at the same experimental site and with the same plots in both years. A randomized complete block design with four (04) repetitions was used.

Five treatments, including an unfertilized control and four fertilizer microdosing combinations 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 2 m wide alleys, whereas 1 m wide alleys were maintained between adjacent plots. Land preparation 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 performed at 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, and seed 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 key indicators 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 USD ha⁻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):

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

Where:-

GP: gross revenue (USD.ha⁻¹), calculated by 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 and hired labor and fixed costs (CF) corresponding to equipment depreciation;

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

Benefit–Cost Ratio (BCR):-

The Profit-to-Cost Ratio (BCR) measures the gross revenue generated per unit of monetary expenditure incurred. Its calculation is based on the following relationship (Labiya et al., 2019):

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

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 currency invested in fertilizer inputs compared to the unfertilized control:

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

Where GP_{ti} is the gross revenue of fertilized treatment i , GP_{T1} is the gross revenue of the unfertilized control, and C_{add} is the additional cost of fertilizers compared to the unfertilized 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 using GraphPad 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.

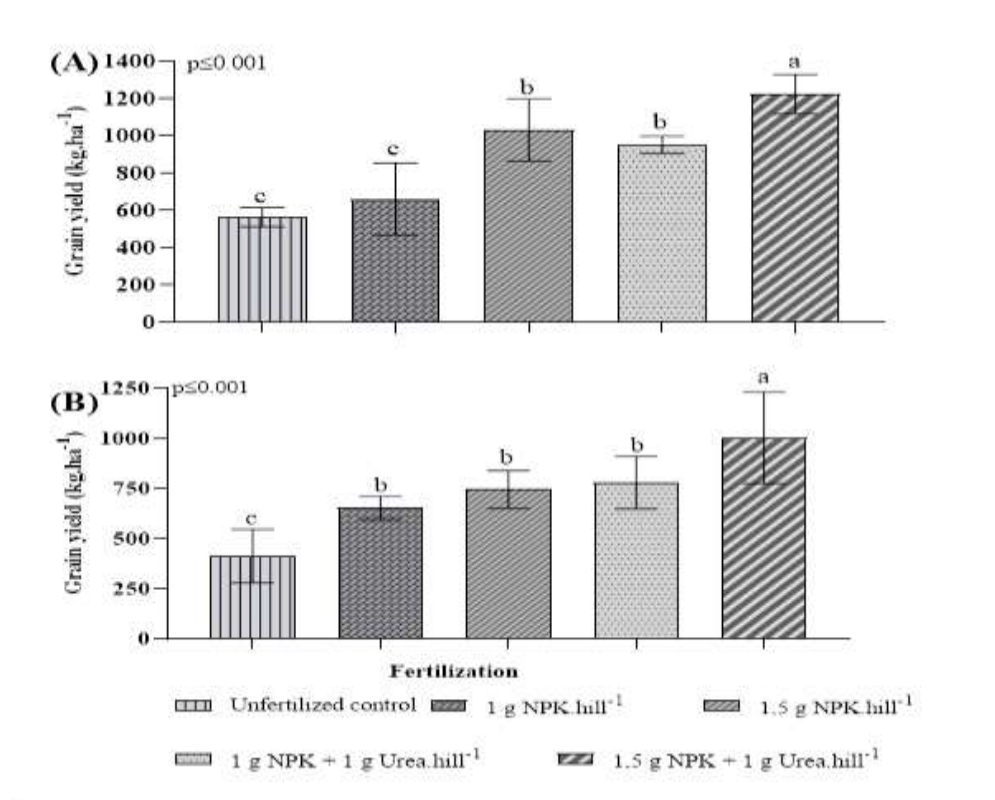


Figure 1: Effect of fertilization on the average seed yield (kg.ha⁻¹) of sesame(A: year Cropping season 2019 and B: Cropping season 2020)

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 highest grain yield was recorded for the treatment of 1.5 g of NPK + 1 g of urea per hill, reaching 1,224.6 kg.ha⁻¹. This treatment differs significantly from other treatments available, representing an increase of 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), where the 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 the unfertilized 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 highest straw yield was recorded with 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 hill treatment (2,850 kg.ha⁻¹), with no significant difference observed between them. The lowest straw yield was obtained in the unfertilized control (2,200 kg.ha⁻¹). Compared with the unfertilized control, fertilizer microdosing increased straw yield, with increases ranging from 22.73% under the 1 g of NPK per hill treatment to 43.18% under 1.5 g of NPK + 1 g of urea per hill treatment. In 2020, the 1.5 g NPK + 1 g urea per hill treatment produced the highest straw yield reaching 4,500 kg.ha⁻¹ (Figure 2B). This differs significantly from other treatments. The lowest yield was observed in

the unfertilized control ($2,166 \text{ kg.ha}^{-1}$). Fertilizer microdosing increased straw yield, with increases ranging from 50.05% with the 1 g NPK + 1 g urea per hill treatment to 107.76% with 1.5 g NPK + 1 g urea per hill treatment.

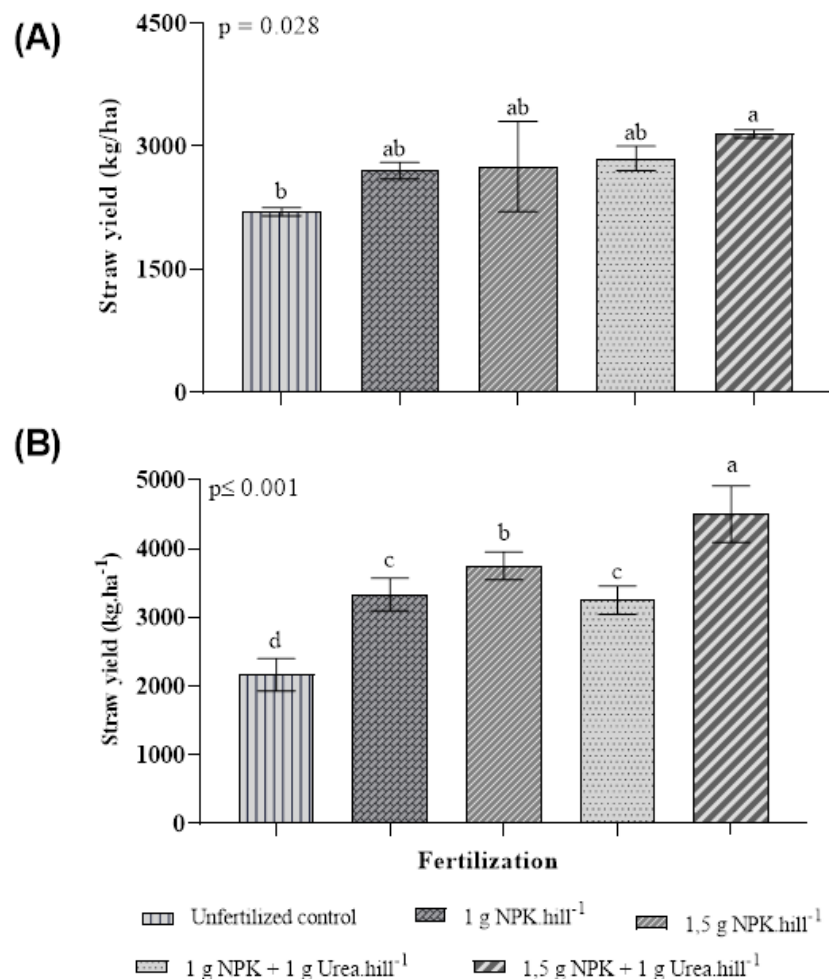


Figure 2: Average straw yields (kg.ha^{-1}) of sesame from treatments (A: Cropping season 2019 and B: Cropping season 2020).

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 is an effective and accessible strategy for sustainably improving 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 yields in both cropping seasons. The average grain yield increase of +114.5% compared to the unfertilized control is particularly noteworthy in a context where most Burkinabe farmers typically produce less 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 of NPK provides an immediate supply 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 split application enhances nitrogen use efficiency while reducing nitrogen losses through volatilization, which are exacerbated by the high temperatures typical of the Sahel (Amare et al., 2019; Gebregergis et al., 2020; Sajjad et al., 2025). Previous studies have shown that microdosing concentrates nutrients in the rhizosphere, thereby stimulating root growth and improving water use efficiency (Aune and Bationo, 2008; Sermé et al., 2016; Tounkara et al. 2023). These advantages are particularly important under the recurrent rainfall deficits that characterize the North Sudanese zone. Our findings confirm and extend previous evidence on the effectiveness of fertilizer microdosing in West African farming systems (Sissoko, 2019; Tounkara et al., 2023). Similarly, Saba et al. (2017) reported grain yield increases of 134-155% in millet, sorghum, and cowpeas, while Sermé 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 showing that supplementing NPK microdosing with urea application at 40 DAS provides additional grain yield advantage of 18–35% compared to NPK microdosing alone. This improvement is attributed to enhanced nitrogen availability during 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 reaching 857 USD ha⁻¹ with benefit-cost ratios exceeding 2.5 and value to cost ratios well above the profitability threshold of 2 (Crawford & Kamuanga 1987). These findings agree are consistent with previous studies conducted 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, particularly when supported by access to microcredit or warrantage mechanisms that are already 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 hill consistently produced the 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) exceeding 2.5. 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-Sudan zone of Burkina Faso.

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