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Transforming sorghum farming in semi-arid Burkina Faso through agroecological intensification

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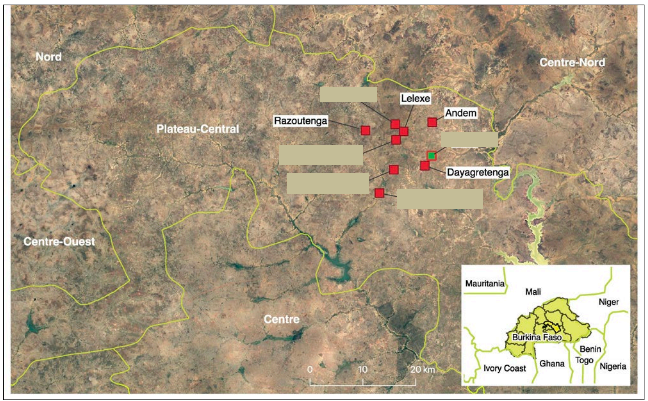
Abstract
Sorghum (Sorghum bicolor (L.) Moench) is the most crucial staple crop for rural households in Burkina Faso. The changing climate and declining soil fertility are reducing sorghum yields. In 2021, the average yield was 900 kg/ha, and in the Plateau-Central it was only 625 kg/ha. In 2023, an inter-farm comparison trial was set up in the Plateau-Central of Burkina Faso in cooperation with the NGO Koassanga. This trial was supported by the European Research Area Network Cofund (ERA-NET) Food Systems and Climate (FOSC) of the project Nutrigreen. It quantified the yield gains by applying up to seven agroecological principles. In this study, several soil and yield parameters were assessed.
A randomised block design was used with four treatment plots of 10 x 10 metres (simplified mother trial). The replication was done inter-village, in four villages under similar agro-climatic and soil fertility conditions. Soil samples were taken before planting and after harvest. The two-factorial trial was each combined at two levels: local sorghum seed/ Sorghum vr. Kapelga/Flagnon with manure (farmer-style) T1(control)/T2, and with 2 tonnes/ha of composted manure T3/T4, respectively. The farmers were trained to design the research, implement the agroecological itinerary, maintain the plots, and evaluate the harvests by measuring specific traits. Many farmers established copy fields (baby trials), and the fields of 36 farmers were assessed. The data analysis included normal distribution check, Levene's homogeneity test, ANOVA and post-hoc tests. The results show significant differences between treatments in all traits. In two villages with higher soil fertility, T4 yields tripled or increased fivefold compared to T1 (control). This study highlights the potential of the application of composted manure and improved seed to lift the rural population out of food insecurity in record time.

Keywords: sorghum, food security, agroecological intensification, agroecology, inter-village comparison trial, mother and baby trial, farmer-led research, farmer field school, farmer-to-farmer, Burkina Faso

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is the most crucial staple crop for rural households on the Plateau Central in Burkina Faso (Henze and Stöber, 2022). The changing climate and declining soil fertility are reducing sorghum yields (Arumugan et al., 2023). In 2021, the average yield was 900 kg ha^{-1}, and in the Plateau-Central it was only 625 kg ha^{-1} (Kondombo et al. 2024, Koassanga 2024). The Plateau-Central belongs to the semi-arid Sudano-Sahelian region with

rainfall from 600 to 900 mm per year. Hunger is a serious challenge, apart from peace, weather extremes (heat, droughts, irregular rain), lack of access to money, high illiteracy and gender inequality (Henze and Stöber, 2022). Climate change is a key driver of the rise in food insecurity and undernourishment. The proportion of the population affected by severe food insecurity has risen to 21% (FAO et al., 2023). The Global Hunger Index (GHI) shows no significant improvement with a score of 25.6 in 2016 and 24.6 in 2024, remaining at a serious level (GHI, 2024). The project team, while working in six villages in Burkina Faso with local weather observers to promote agrometeorological learning, discovered that some of the villages are facing serious food shortages and require food aid support. In 2022, food aid was provided to compensate for the research on weather observation. In 2023, the project team worked with the local NGO Association Koassanga to set up farmer-led research on sorghum and cowpea productivity trials with improved organic fertilisers, improved seed and agroecological management practices, in order to tackle the food insecurity situation, head on. This paper sets out the findings of the field trials in relation to productivity and soil fertility.

Methods



In the Plateau-Central region of Burkina Faso, four 10×10-metre plots were set up to test four treatments using a simplified mother and baby trial design (Snapp, 2002). The "mother" plot was the 400 m² on-farm demonstration plot with four treatments. Farmers established copy fields or “baby” plots on their own fields. We evaluated selected yield parameters for 36 farmers who established copy fields. The actual number of farmers with copy fields was much higher.

Figure 1: Villages of farmer-led sorghum and cowpea research on the Plateau-Central

The four villages of Lelexé, Andem, Razoutenga and Dayagretenga took part in the sorghum field research during the 2023 and 2024 rainy seasons (Figure 1). The treatment was designed as a two-factorial trial with two factors: seed variety and agroecological intensification system. Each factor was combined at two levels. The seed factor was tested using local sorghum seed (T1/T3) with Sorghum vr. Kapelga/Flagnon (T2/T4). The agroecological intensification system comprised two components: farmer-style methods (T1/T2) and improved agroecological production methods (T3/T4). The soil was analysed at the National Soil Research Institute, BUNASOLS, before planting in June 2023 and after harvest in December 2023. The organic matter, Corg, N, P, K, pH and soil texture parameters were analysed. The seven agroecological practices that were followed on T3 and T4 plots were as follows: a dose of 2 tonnes ha-1 of composted manure, the respected planting date, the exact number of grains per hole, spacing of 80 cm between rows and 25 cm within the row, dethatching to one sorghum plant per hole, regular weeding, and ridging to ensure roots are well covered by the soil.

Seven traits were monitored. The field experiment was set up as a farmer-led trial to enhance farmer-to-farmer upscaling. Farmers were trained to implement the agroecological techniques, maintain the demonstration plots and evaluate the harvests by measuring the traits, including the number of plants, stem size in cm, panicle length in cm, panicle weight in g, 1000 grain weight and harvest weight of stem and grains. The farmers established copy fields following the seven principles in the baby trials. The copy field farmers were categorised into five distinct groups.

Category 1 comprises farmers who followed at least six practices. Category 2 used four to five practices. Category 3 farmers followed three practices. Category 4 farmers only followed one practice. The control copy fields were their traditional farming practice. During and after harvest, the results were assessed in participatory yield and soil fertility restitution meetings. Video testimonies of the research farmers were also taken for further outreach. The statistical analysis included a normal distribution check, a Levene's homogeneity test, ANOVA and post-hoc tests.

Results and Discussion

The seven-step agroecological itinerary with improved seed varieties, as practised on T4, demonstrated the most productive results across all villages (Figure 2, 3). Figure 2 and 3 shows the drone picture of the demonstration plot in Dayagretenga, which clearly demonstrates the significant differences between T1 and T4. In plots with lower soil fertility (Dayagretenga and Razoutenga), the control fields T1 suffered a total crop failure. In stark contrast, the T4 treatment yielded 800 to 1200 kg/ha. The Two-way ANOVA shows statistically significant (p-values < 0.001) differences with F-values of 33.87 (village) and 4.99 (treatment). The Honestly Significant Difference (HSD) Tuckey test indicates the differences of harvest weight grains. The HSD tests reveal that the groups of T3 and T4 along with villages Andem and Lelexé (such as T3: Andem=1.833, T3: Lelexe=1.600, T4: Andem=1.766) were the best performers with harvest weight grains (kg).

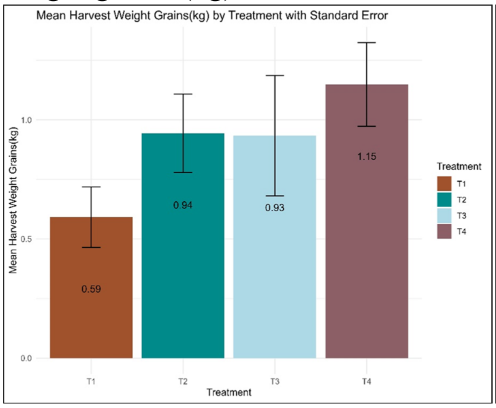


Figure 2, 3: Mother trial: Mean harvest weight of grains (in kg/10m²) across all villages, with T1= local seed/farmer-style soil fertility; T2: improved seed/farmer-style soil fertility; T3: local seed/agroecological intensification, T4: improved seed/ agroecological intensification (left); drone photo of treatments (left T3 and T4; right T1 (control front) and T2) of Lelexé village (right).

The baby trials confirm the results of the mother demonstration plot. Figure 4 illustrates, that the more agroecological itineraries are pursued, the better the yields across all villages. The results of the baby trials did not show any significant differences between the villages. Still, in 2 villages, Andem and Lelexé, the measured yields of the farmer trials with 2.5 and 2.6 tonnes/ha almost reached the theoretical yield potential of 2.8 tonnes/ha.

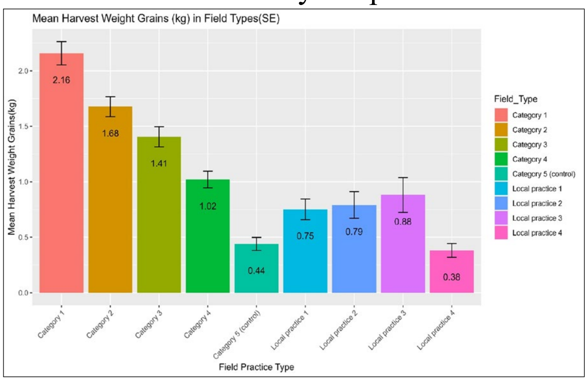


Figure 2: Baby trial: Mean harvest weight of grains (in kg/10m²) across all villages: Category 1 farmers follow all seven agroecological practices compared with their local practice on the same field (local practice 1); Category 2 farmers follow 4 to 5 practices compared with their local practice 2; Category 3 farmers follow 3 intensification practices compared with their local practice 3; Category 4 farmers follow one practice compared with their local practice 4; Category 5 is control field (local practice).

In feedback meetings, farmers, scientists and the NGO discussed results in farmer-friendly manner. The chosen method with a simple two-factorial demonstration plot (mother trial) and farmer-managed copy fields (baby trials) empowered the farmers to decide on the intensification practices.

Treatment	Phosphorus content (mg/kg) 2023 (before)	Phosphorus content (mg/kg) 2024 (after)
Fertiliser - local Seed: local (T1)	9,12	1,88
Fertiliser: Koassanga Seed: local (T2)	9,12	29,02
Fertiliser: local Seed: Koassanga (T3)	9,12	2,82
Fertiliser: Koassanga Seed: Koassanga (T4)	9,12	13,86

Figure 5 and 6: Results of soil analysis have been reported back to farmers in an easy-to-understand manner, example of village Lelexé for phosphorus content, explaining the function of phosphorus for the yield and the content in the soil (Fig.5); Farmers were involved in measuring yield parameters to get to know the metrics of growth and productivity (Fig.6).

Conclusion and Outlook

The seed and fertiliser effects were less visible in villages with better soil fertility than in two villages with general lower soil fertility. In two villages with higher soil fertility, T4 yields were at least three times higher than T1 (control). In plots with lower soil fertility, the control field was entirely unsuccessful, while the T4 treatment still yielded 500 to 800 kg ha-1. The fertiliser effect was even more pronounced here. The yield potential of 2.8 tonnes ha-1 for improved Kapelga seed was definitively reached in Andem under agroecological intensification treatment. The chosen harvesting method was highly correlated with the total harvest per plot, as measured after drying. However, to get more exact results, moisture meters will be used in 2024 to verify the moisture content of yields from 4 m² which are directly measured after harvest with the entire harvest per plot after drying. The farmer-self-organised baby trials revealed similar results. Moreover, farmers report that dethatching is a culturally unusual practice and it requires courage to do. Furthermore, regular weeding and striga control are major challenges. It is labour-intensive and farmers simply do not have the time to pursue it. Ridging and sowing at the right time are straightforward and easy to follow. In all four villages, farmers are willing and ready to replicate the tested agroecological intensification itinerary. The mother trial is also repeated in 2024. This study proves that the application of composted manure and improved seed can lift the rural population out of food insecurity in record time. However, in order to transform sorghum farming for improved food security, accompanying collective action and marketing and saving strategies in needed to reduce the risks related to climate variability and markets.

Acknowledgement

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