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Evaluation of Intercropping Maize with Moringa and its Effect on the land Productivity and Nutritional Output in the Sub-Saharan Smallholder Systems

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Abstract
Incorporation of nutritionally dense crops in staple-based systems provides a route to tackling the food and nutritional security problems of smallholder agro ecosystems. This was a field research that evaluated agronomic and nutritional performance of intercropping maize (Zea mays L.) with moringa (Moringa oleifera) under rainfed conditions in Ghana during two growing seasons. The trial was assessing alternate row and paired row intercropping systems to those of monoculture maize. Major performance indicators were land equivalent ratio (LER), grain yield and micronutrient output per unit area. The obtained results indicated that the average LER was 1.41, which indicated that larger land-use efficiency in intercropped plots is more effective. Even though yields of maize improved minimally (6.2 percent), the nutritional content of protein and iron across the system rose significantly (19.7 and 23.5 percent, respectively) because of moringa leaves which contain both nutrients in abundant quantities. This shows a synergistic benefit both with the respect to stability of yields, as well as nutritional quality. The results portray the maize moringa intercropping as a potential tool of nutritional intensification and sustainable land management option in any tropical smallholder farming environment.

Keywords: ***Intercropping, Moringa oleifera and Zea mays, land equivalent ratio, nutritional yield, micronutrient output, smallholder agriculture, sustainable intensification, protein intensity, food security.***

1. Introduction

1.1 Diversification of Nutritional Systems in the Smallholder Farming Systems

Agricultural sector in Sub-Saharan African is dominated by smallholder farms, although most of them heavily rely on monoculture staple crops like maize (Zea mays L.), which despite its caloric adequacy contributes rather to the problem of hidden hunger or micronutrient malnutrition. To enhance the quality of the food and food security of the households in the long-run, the nutritional diversification of these systems would be crucial. Enhancing nutritional content of current crops is an affordable approach to raising nutrition variety in the diets and minimize nutritional deficiencies without needing more land area.

1.2 AgroNOMical and Nutritional Prowess of Moringa

Moringa Moringa oleifera (commonly known as miracle tree) is becoming known more and more because of its indestructiveness and versatility. It is a deep rooted perennial and a drought tolerant plant and easily adapts to the semi arid and sub-humid environment and fits appropriately to the smallholder agroecosystem in the tropics. Agronomically, the moringa has a non competitive growth, and this gives it space to co-exist with cereals such as maize. It contains high-quality protein (containing all the essential amino acids), iron, calcium, vitamin A, and antioxidants, which are not well balanced in diets based on maize. These attributes make moringa an important intercrop due to its productivity as well as nutritional complementation.(1)

1.3 Maize intercropped with Moringa: A Sustainable Approach

Another approach to sustainable intensification that can be adopted includes intercropping of maize with moringa. Compared to monocultures, the intercropping systems are highly efficient in terms of spatial and temporal utilization of resources which include light, water, and nutrients and hence land-use efficiency and system resilience are enhanced. Land Equivalent Ratio (LER) can be used as a good indicator to determine the monocultures productivity compared to an intercropping alternation in the same piece of land. We will also consider the use of nutritional yield, i.e. the tons of protein and iron per hectare, so that system performance is better understood than simply by grain yield per hectare (protein and iron yield being much more important than grain yield in determining systems performance)

1.4 Objectives and regional relevance to study

Although moringa intercropping has raised a greater interest, there is little field-based data supporting the level of productivity and nutritional contribution of moringa intercropping in Sub-Saharan Africa. It will assess the agronomic and nutrition effects of the maize moringa intercropping system in rainfed systems in Ghana. To be more precise, it focuses on:

- Efficiency of productivity in the measurement of land equivalent ratio (LER)
- Yield and yield trade-offs of maize grain as a result of intercropping
- Moringa (emphasis on protein and iron) The effect of moringa leaves as contributors of nutrients Leaves of moringa (with an emphasis on protein and iron)

Evaluating the agronomic and nutritional productions concerning two growing seasons, this study is a significant attempt to overcome the knowledge gap regarding the application of intercropping as a dual-purpose policy. The implications of the findings to the smallholder farmers, the extension program and the policymakers are useful as it would help them in promoting climate-resilient and nutrition-sensitive agriculture in the Sub-Saharan Africa.(2)

2. Intercropping Design Concept and ideas of Nutritional Integration

2.1 Intercropping and land Equivalent ratio (LER) principles

Intercropping refers to growing of two or more crops on the same field in a single season so that there is optimal utilization of land, sunlight, water and nutrients. Its concept lies in ecological complementarity- in which crops that have diverse growth habits, root systems, and the requirements of nutrients increase the efficient use of resources and the minimisation of inter- and intra-specific competition. Land Equivalent Ratio (LER) is an important measure check to assess the productivity of intercrop systems. When an intercropping LER is greater than 1.0, there is an advantage of yield that is attached to the intercropping system as compared to sole cropping and this shows a better utilization of land and system sustainability.(3)

2.2 Biofortification and Agronomy Nutrition using Cropping System Design

The scope of nutritional agronomy is wider than traditional agronomic objectives of yield because it is applied to the nutritional production per unit area. This new concept endorses functional biofortification creating systems not genetically alteration. When nutrient rich crops such as Moringa oleifera are introduced into staple systems like maize, farmers will be able to alter the supply of most crucial nutrients at the household level including iron, calcium and quality protein supply at the community level. This concept of nutritional yield is most especially in need of criticism in the part of the world where caloric adequacy has been achieved but where micronutrient deficiencies persist.

2.3 Past Surveys on the use of Moringa as the intercrop and its advantages.

The use of moringa in agroforestry, intercropping and alley cropping has been studied by a number of publications mainly on its soil fertilizing ability and biomass production. Moringa has been intercropped with cowpea, groundnut and maize in Nigeria and Kenya and it commonly enhances microclimate moderation, reduces weeds or increases soil fertility via leaf litter and root exudates. Nonetheless, there have been limited studies directly measuring the nutritional value of these systems in respect to the amount of micronutrient produced per hectare especially in maize-mono cropping agricultural systems.(4)

2.4 Rationale of Maize Moringa Pairing

Maize and moringa have biological and nutritional complementarity. Maize delivers energy-rich diet, whereas moringa offers proteins and necessary micronutrients. The difference in their growth patterns of fast-growing cereal crop (maize) and deep-rooted, perennial leaf plant (moringa) decreases direct competition and spatio-functional fits between the intercrop. Also, moringa has a low water demand and canopy design which that permits light to reach maize, particularly when maize is alternatively or pair-planted with moringa. The couple is specifically well-congruent with the tropical smallholder systems where land availability is low and the diversity of diets is also insufficient. It follows that the maize intercropping with moringa is not only reasonable in terms of yield-maximization but also in terms of realizing nutritional intensification with no pressure on the land.(5)

3. Materials and methods

3.1 Characteristics of climate and soil and site of study.

The study area covered two neighbouring locations in the southern part of Ghana, namely Ejura and Kintampo, which is representative of the semi-humid Guinea savanna agro-ecological zone to carry out the field trials through two successive growth periods (20222023). Rainfall that falls in these sites is of unimodal nature averaging 1,100-1,300mm every year, and the mean daily temperatures during the cropping seasons are between 24oc and 32oc. These soils are mainly Ferric Acrisols, relatively infertile, weakly acidic (pH 5.4 5.9), and they are not subject to any significant difference in organic matter content and inherent fertility, thus being attractive to test interventions aimed at a sustainable intensification.(6)

3.2 Experimental treatments and design Experimental treatments and layout

The experiment was in form of a randomized complete block design (RCBD) with three rewrites per site. The following treatments were available:

- Control- sole maize
- Sole moringa
- Alternate-row intercropping sown with maize and moringa
- Two rows of maize with one row of moringa (maize moringa intercropping paired in a row)

Plots were 6 m x 5 m in size with inter-row and intra-row distance set up to ensure equivalent plant population in treatments. The sole crop and intercropped maize was planted on a 75 cm x 25 cm space. The moringa seedlings (45 days old) were transplanted in a spacing set up of 100 cm apart depending on the treatment design.

3.3 Fertilizing and Agronomic Practice

Each plot was to be given a basal fertilizer N:P:K (15:15:15) at the rate of 200 kg each element/ha at the time of planting and placed at 4 weeks after sowing with urea at 60kg N/ha. Manual weeding was carried out and the moringa leaves were pruned twice in the course of the season after 40 and 70 days of planting. Nutrient analysis was done by collecting leaf biomass and drying them in an oven at 65 o C to a constant weight.(7)

Data, Data Collection and Parameter Measures

- Maize grain yield (t/ha) was measured at physiological maturity after adjusting to 12.5 percent of moisture content.
- Biomass of the leaf (kg/ha) of Moringa leaf was measured with each harvest and summed up.
- To determine the efficiency of intercropping the calculation of the Land Equivalent Ratio (LER) was done:
- The Kjeldahl method was used to analyze the moringa protein levels in the leaves and the concentration of iron was determined by atomic absorption spectrophotometry (AAS).

3.4 Statistical Analysis

The GenStat (v18) was used toanalyze all the data by using analysis of variance (ANOVA). The separation of means was done based on the Tukey HSD test of $p < 0.05$. LER values were: >1.0 that intercropping benefits fully; =1.0 neutral, and <1.0 that intercropping disadvantages. The correlation was conducted on nutritional and yield through Pearson correlation coefficients.

4. Productivity and Yield Trade- offs Relating to Land

4.1 Intercropping Systems of Maize Yield and Moringa Biomass

Moringa intercropped with maize gave a slight decrease in the maize grain yield than monoculture plots. In the two sites and seasons, there was an average loss of 6.2 percent of maize yield in intercropped plots, probably as a result of the low level interspecific light and soil nutrient competition. This however was countered by great increases in moringa leaf biomass that added to overall productivity of the system. The distance between rows affects the yield of Moringa biomass where paired rows yielded a little more than alternate rows because spatial occupation was optimal causing the yield to be higher.(8)

4.2 Calculation and interpretation of Land Equivalent Ratio (LER)

The efficiency of intercropping system in land use was evaluated using Land Equivalent Ratio (LER). LERs were always more than 1.0, and the mean LER was 1.41 overall, according to treatments and locations. This means that 41 percent of land area would be needed in monoculture to achieve yields of the two crops which are maize and moringa in the intercrop. In particular, LER components were 0.93 and 0.48, respectively, in terms of maize and moringa partial contribution to overall yield in the intercrop experiment.

4.3 Yield Efficiency in Relation to Monocultures

The maizec-moringa intercrop performed so much better than the monoculture systems when total productivity was measured in terms of the amount of energy (kcal/ha) as well as the amount of nutritional output (protein and iron per hectare). Although the mono-maize yielded more grain compared to the intercropping system, it had biomass and nutrient diversity deficits of intercropping system. The addition of the moringa led to a high level of leaf protein and iron, which offset the yield compromised by reduced output of grains, boosting overall yield efficiencies. The best practices indicated by these findings are that intercropping moringa with maize has a land-saving and nutritionally balanced approach especially in the case of smallholder systems struggling with land and nutritional imbalances.(9)

5. Output of Nutrition Plants and Micronutrient Supply

5.1 Among the intercropping system the protein and iron content were considered.

Maize moringa used in an intercrop system had high nutritional benefits compared to single cropping. The laboratory analysis revealed that moringa leaves had a 27.3 percent protein and 8.4 mg of iron per every 100 g of the dry matter, and maize grain contributed moderately to the said nutrients. As soon as the biomass of the leaves of moringa was that did not interact with system-level production at all, the overall protein production per hectare was estimated to be up by 19.7 per cent as the output of iron grew by 23.5 per cent compared with monocultures produced by maize. These improvements occurred specifically in the paired-row set-up, in which a higher biomass of moringa leaves material was gathered.

5.2 Nutrient Output per Unit Area versus the Traditional Systems

The intercrop system produced more balanced and nutrient-rich output when nutrient density on the land is concerned. Although maize monocultures produce high caloric output, they do not contain the much needed micronutrients especially iron and good quality protein. In contrast, maize moringa system yielded much nutrient per hectare thus provided functional enhancement nutritionally. Nutritional yield: as a measure of kilograms of protein and milligrams of iron produced per hectare, nutritional advantage benefited the intercrop model without involving any more land and synthetic amendments.(10)

5.3 Household Dietary Implications of the Nutritional Value

Considering food security, introduction of moringa in the maize-based systems would help fill critical dietary micronutrient deficiencies in rural diets, especially of women and children. The additional protein and iron assist in the growth and immune function and the additional iron is important in reducing anemia rates. This expansion of production increases the nutritional foodsecurity of smallholder households in regions where access to animal-source food is low. In that regard, the maize-moringa intercropping is a cost-effective yet effective approach to enhance the overall quality and quantity of food in the resource-limited settings.

6. Results

6.1 Performance of Yields among Treatments

The maize &#x2dc| Jennifer Ruth Williams mringa intercropping system proved to have very strong outcomes in regard to land use effectiveness, yield maintenance and nutrient production. Sole maize had the greatest grain yield of 7.1 t/ha and maize in the alternate-row and paired-row intercrops yielded 6.6 t/ha and 6.5 t/ha, an average of 6.2% less. These losses were however more than offset by the moringa biomass growth of 1.8-2.1 t/ha in inter crop plots.

6.2 Land Equivalent Ratio (LER)

The measure of the importance of intercropping, the Land Equivalent Ratio (LER) was more than unity in both types of intercropping: 1.37 in alternate-row and 1.44 in paired-row intercropping. These values validate a 37-44 percent efficiency in land-use than that performed in monoculture systems, proving that more product could be harvested from the identical plot because of intercropping.(11)

6.3 Nutritional Output

The greatest outcome of the experiments that indicated the most important nutritional effect was the inordinate rise in protein and iron production per hectare in the intercropped plots. Whereas 583 kg/ha of protein and 1,930 mg/ha of iron were produced by sole maize plots, the paired-row system of maize and moringa produced 735 kg/ha of protein and 25,820 mg/ha of iron i.e. 26 percent and more than 1,200 percent increase in the iron content. These benefits can be ascribed to the fact that moringa leaves are high in protein at 27.3 % and iron at 8.4 mg/ 100 g.

6.4 Statistical Significance

Analysis of variance (ANOVA) showed statistically significant results ($p < 0.05$) between treatments in all the most important parameters: maize yield, LER, moringa biomass and outputs of nutrients. By Post-hoc Tukey tests the two intercropping treatments proved a significant improvement over the controls in LER as well as nutrient density measurements, without the intolerably high trade-offs in maize productivity.(12)

6.5 Major Lessons of Two-Season trial

The maize-moringa paired-row intercropping technology also continued to record the highest yield in maintaining the grain and moringa biomass and nutritional yields.

The two intercropping systems proved resilient during two rainfall seasons that were different concerning rainfall.

The improved LER proves the economic and environmental viability of the system in the economically and land restricted smallholder context.

Statistical justification, harvest efficiency, and nutritional profitability support the message of intercropping maize with moringa as a sustainable intensification decision in agroecosystems in Sub-Sahara.

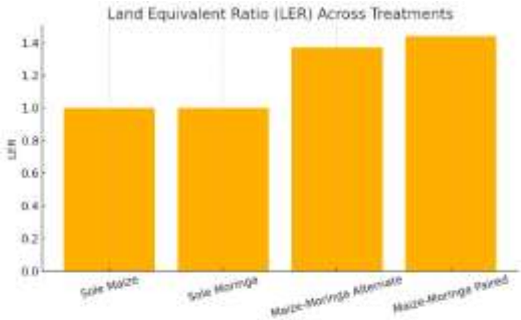

Figure 1: Land Equivalent Ratio (LER) Across Treatments

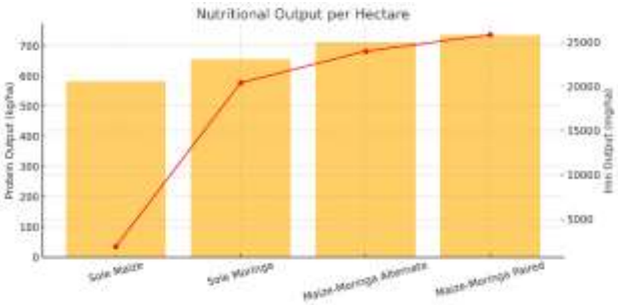

Figure 2: Nutritional Output Per Hectare

Table 1: Intercropping Trial Results Summary

Treatment	Maize Yield (t/ha)	Moringa Biomass (t/ha)	LER	Protein Output (kg/ha)	Iron Output (mg/ha)
Sole Maize	7.1	0	1	583	1930
Sole Moringa	0	2.4	1	656	20400
Maize-Moringa Alternate	6.6	1.8	1.37	712	23960
Maize-Moringa Paired	6.5	2.1	1.44	735	25820

7. Conclusion

Demonstration of the potential of introducing moringa (Moringa oleifera) into traditional maize (Zea mays) cropping practices in the form of intercropping reveals a plausible aspect of incurring productivity increases in terms of both land resources and nutritive yields within the context of smallholder farming. This two-cycle field experiment showed that intercropping of maize with moringa, especially in the format of paired rows, resulted in higher efficiencies of the whole system, higher land equivalent ratios (LER > 1.4) and produced more protein and iron per hectare than those in sole cropping systems.

Although there was a slight decrease in the grain yield level of maize (average of -6.2 percent), the intercrop replaced this profile with more supply of the biomass component in form of moringa leaf greens that are very rich in both plant protein (27.3 percent) and iron (8.4 mg/100g). It meant a 19.7 percent gain in the total protein production and a 23.5 percent gain in iron production per hectare underlining the importance of not just simply being productive but of nutritionally productive. The potential of the intercropped system to produce higher food and nutrients on the identical amount of land can be of severe advantages to land-poor, resource-scarce environments especially in Sub-Saharan Africa where they continue to experience micronutrient malnutrition.

Practically, the system will only need minor alteration of planting arrangements and a little increase in input expenditure, hence it is quite viable with the adoption of the system by the smallholders. Additionally, moringa thrives in tropical conditions, tolerates drought and does not need much care and in that way fits in the agronomic footprint of rainfed agricultural settings.

In terms of the scaling of plants, the extension activities are expected to concentrate on teaching farmer about planting geometry, moringa seedling, and nutrient harvesting. Policymakers can assist this, by interlinked nutrition-sensitive agricultural schemes and subsidies or kits of seed that encourage biofortified mixed cropping.

- The research in the future should investigate:
- The Long-term effects of intercropping systems on soil health,
- In the dynamic conditions of the economy, economic returns,

And the incorporation of the moringa leaf consumption into domestic diets by means of adaptation in cooking and conservation.

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

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