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Beyond Standardized Fertilizers: Performance and Viability of Localized Fertilizer Blends in Central Malawi's Maize Production Systems

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ABSTRACT

Maize is the main staple food crop and dominates Malawi's farming systems. Maize farming covers 92% of Malawi's arable land and contributes 54% of national caloric intake. Over the decades, the Malawian Government has implemented annual fertilizer subsidy programs for maize production as a key strategy for food security. However, the national fertilizer (Basal 23:10:5+6S+1Zn and Top 46%N) remains the only standardized recommendation for maize farming systems. This research assessed the performance and viability of recently developed local fertilizer blends: Alpha (Basal 17:25:18 and Top 32:0:18) and Mwininthaka (Basal 23:10:5+6S and Top 23:10+5+6S) for maize production. Trials were conducted at four sites in Lilongwe District, central Malawi, using a completely randomized design with four treatments and two replications at each site. Primary data was collected on the number of cobs and grain yield, and secondary data on climate and fertilizer prices, and analyzed them using JMP SAS software version 14.0.0. Results indicated significant differences ($p<0.05$) in the number of maize cobs at three sites, with Alpha as the highest-performing blend (Mitundu 72, Nanthenje 88, and Kasiya 87 cobs). Similarly, significant differences were also observed in maize grain yield at the three sites, where the Alpha was the highest-performing blend in two sites (Mitundu 6.77 t ha-1 and Nanthenje 11.71 t ha-1), while Mwininthaka was the highest-performing blend in one site (Kasiya 7.41 t ha-1). Regarding viability, analysis indicated that the Alpha blend was the most cost-effective at two sites (Mitundu 33.7% and Nanthenje 83.6%), while the Mwininthaka and National blends were most cost-effective at one site each (Kasiya 75.8% and Mpingu 79.3%, respectively). Hence, it was concluded that local blends are site-specific alternatives beyond the national standardized fertilizer recommendations amid rising commodity prices and scarcity in Malawi.

KEYWORDS: Farming systems, national fertilizer, local fertilizer blends, and standardized recommendations

How to Cite

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1. Introduction

Maize (*Zea mays* L.) is the main staple food crop in Malawi, grown across all ecological zones under both rainfed and irrigation systems. Maize production is dominated by smallholder farmers who, on average, cultivate 0.4 hectares per household with an average yield of 1 tonne/hectare (FAO, 2018). The challenge of declining soil productivity is enormous, which is also exacerbated by the low economic status of most smallholder farmers who cannot afford enough quantities of inorganic fertilizers to effectively replenish nutrients in their farms (Druille and Barreto-Hurle, 2012). Smallholder production is thus limited by high costs and sub-optimal use of synthetic fertilizers under continuous cultivation.

For this reason, like in many Sub-Saharan African countries such as Ethiopia, Nigeria, Kenya, Tanzania, Ghana and Zambia, the Malawian government has intervened to provide subsidised inputs such as fertiliser to improve access and boost maize productivity (Jayne et al., 2016). The subsidy programmes in Malawi have evolved

since the 1990s from the Start-up packs, where selected farm households were given small packages of seed and fertilizers to help them boost their maize yield, to a large-scale Farm Input Subsidy Program (FISP) between 2005 and 2020, and currently the Affordable Inputs Program (AIP), where approximately 3.5 million smallholder farm households are being targeted with maize seed and fertilizers for increased maize production.

In Malawi, synthetic fertilisers are imported, and basal fertilisers for maize are composed of 23 % nitrogen (N), 10% phosphorus (P), 5% potassium (K), and 6% sulphur (S) as macronutrients, and 0.1% zinc (Zn) as a micronutrient (Mthambala et al., 2022). The top-dressing fertilizer for maize is urea, composed of 46 % N, and is applied about 3 weeks after the basal fertilizer application. Nitrogen (N) is very important as it fuels crop growth and development, whereas phosphorus (P) is particularly important for root development and good crop establishment, while sulphur (S) is equally important in making N effectively utilized by the maize plant. The fertilizer formulations in Malawi are therefore based on nitrogen (N) because declining soil fertility, with reference to nitrogen as the major limiting nutrient for crop growth, has been the biggest challenge in sustainably achieving optimum yields of maize, the main staple crop of the country (Kumwenda et al., 1997; Makumba, 2003).

The standard fertilizer application recommendations of 69 kg ha^{-1} or 92 kg ha^{-1} of N have been available for maize across Malawi since the 1990s. However, with the expansion of the subsidy programs, there has been an increase in application rates of N fertilizers to 200 kg ha^{-1} (Waddington et al., 2015). The implementation of fertilizer subsidy programs remains the only strategy by the government to achieve food security (Simwaka et al., 2011). Consequently, most soils in Malawi remain inherently fertile, although they are increasingly depleted of organic matter and certain nutrients such as nitrogen, phosphorus, and sulphur over time. A decline in soil organic carbon is associated with a decline in organic matter input into the soil and accelerated soil organic carbon decomposition due to intensive tillage. Soil organic matter helps to retain nutrients in the soil and make them available to plants in small amounts over a long period of time as it mineralizes.

According to the Ministry of Agriculture in Malawi (MoA), 2021, under the fertilizer subsidy programs, inorganic fertiliser use has increased from less than 10 kg ha^{-1} in 2005 to 55.8 kg ha^{-1} in 2016, a rate considered to be among the highest in Africa and surpassing the target of 50 kg ha^{-1} espoused in the 2006 Abuja declaration. This can be attributed to the strong commitment demonstrated by the Government of Malawi to ensure many smallholder farmers have access to fertilizers for maize production in Malawi. The Government, among others, developed the National Fertilizer Policy (NFP), which seeks to enhance the performance of the fertiliser industry by sustainably increasing profitable access to and use of soil- and crop-appropriate fertilisers by farmers. The policy therefore promotes the development of cost-effective fertilizer blends to enable farmers to benefit from their farming systems, besides increasing application rates of fertilizers, which is mostly uneconomical to smallholder farmers in Malawi. Results of a similar intervention in the neighbouring Tanzania showed that new soil fertility management options resulted in significantly higher financial benefits to farmers (Kotu et al., 2017).

Although commendable efforts have been made in implementing the fertilizer subsidy programs and the National Fertilizer Policy in the past decades, food insecurity continues to threaten many rural Malawians annually due to lower maize yields deriving from limited access to fertilizers due to scarcity and skyrocketing prices of the commodity, among others. Malawi remains one of the most food-insecure countries in the world, ranking 105 out of 133 in the global food security index in 2017 (CIAT and World Bank, 2018). The national fertilizer 23 % N, 10% P, 5% K, 6% S + 0.1% Zn and 46 % N remains the only basal and top-dressing blends being used by farmers in Malawi. At present, average maize yields range from 2, 000 to 3, 000 kg per hectare for hybrids, 1, 400 to 2, 400 kg per hectare for open pollinated varieties (OPVs) and 880 to 1, 300 kg per hectare for unimproved maize cultivars yet on average, potential yields of more than 10, 000 kg per hectare for hybrids and 5, 000 kg per hectare for OPVs can be attained with good soil fertility management (MoA, 2020).

Research indicates that efforts to develop appropriate fertilizer recommendations for maize in Malawi have evolved over a long period of time. Initial efforts led to the development of a blanket fertilizer recommendation of 23% N, 10% P, 5% K, 6% S + 0.1% Zn and Urea 46 % N for the whole country, and this was followed by programs to develop more site-specific fertilizer recommendations (Mutegi et al., 2015). Little is known if new recommendations have since been released and their economic viability in maize production. It is against this background that this study was conducted to assess the performance and viability of various local fertilizer blends per hectare to provide insight into their potential adoption as alternative solutions to soil fertility management problems among smallholder maize farmers in Lilongwe district, central Malawi.

2. Materials and Methods

The field experiments were laid out separately at each site in a Completely Randomized Design (CRD) with 4 treatments and 2 replications; that is, at each site, the 4 treatments were repeated twice in the layout; hence, each site had 8 treatment units, 30 m² plots in size. The 4 treatments were national recommendation (Basal 23:10:5+6S+1Zn and Top-dress 46% N), Mwininthaka blend (Basal 15:23:16+0.5Zn and Top-dress 30:0:16), Mwininthaka Alpha blend (Basal 17:25:18 and Top-dress 32:0:18), and Control (No fertilizer). The treatments were randomized on the experimental units using the drawing of lots method, where 8 pieces of paper, each bearing one of the 4 treatments written in 2 pairs, were thoroughly mixed and drawn one at a time without replacement and with constant shaking of the container after each draw to mix the contents. Each experimental unit had a plot of 5 ridges, 10 m long and spaced at 0.75 m apart. While employing a CRD is rare in field experiments with large variation among the experimental plots, the design was convenient for these experiments due to the small plot sizes and few replications at each site.

A hybrid maize seed variety, namely MH26 released in 2008 by the Department of Agricultural Research Services (DARS) and distributed by Demeter Agriculture Company, was planted uniformly at 1 seed per station, 25 cm spacing from one planting station to another, and a depth of 5 cm. The basal dress fertilizer treatments were applied at the planting stage using cup number 5, at 5 cm distance from the plant and 5 cm depth, while the top dress fertilizer treatments were applied 3 weeks after planting using cup number 5, at 7.5 cm distance from the plant and 5 cm depth. All agronomic practices on the experimental fields were conducted uniformly across all spatial and temporal patterns.

2.1 Study area

The field trials were conducted on research demonstration plots at four sites, namely Mitundu, Nanthenje, Mpingu and Kasiya in Lilongwe district, central Malawi. Lilongwe generally comprises sand clay loam soils classified as Chromic Luvisols in the World Reference Base System (Njira et al., 2017). The climate is generally warm, where the mean monthly temperature varies from 8°C to 30°C while annual rainfall ranges from 200 to 900 mm (Nalivata et al., 2017). The site in Mitundu was located on the latitude 14°53'68" South and longitude 33°60'99" East, Nanthenje was located on the latitude 12°05'37" South and longitude 33°60'07" East and Mpingu was located on the latitude 13°78'23" South and longitude 33°78'08" East while Kasiya was located on the latitude 7°78'31" South and longitude 34°14'09" East.

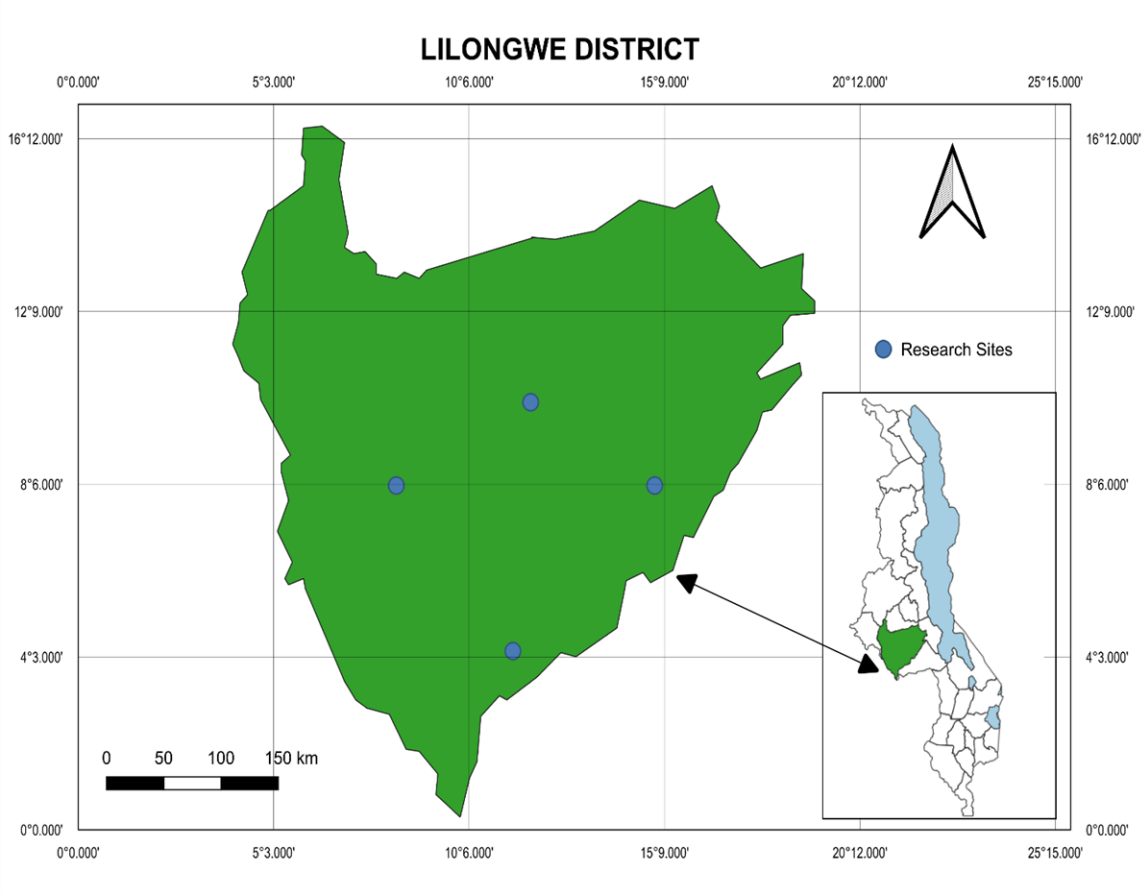


Figure 1. Location map of the study area

2.2 Data collection

Quantitative data on the number of maize cobs and maize grain yield were collected at harvest using a survey CTO platform on digital data-gathering devices. The data were collected from 3 middle ridges on net plots of 18 m², leaving out the 2 border ridges and a 1 m space at the edge of each of the 3 middle ridges. The number of cobs was determined by physically counting all the maize plant cobs produced on the net plots, while maize yield was determined by weighing dry shelled maize harvested on the net plots using digital scales in kilograms, subtracting the bag weight, and converting yield on each net plot to tons per hectare using the following formula:

$$\text{Yield}_{\text{t ha}^{-1}} = \left(\frac{10000\ m^2}{18\ m^2} \times W\ \text{kg}\right)/1000$$

Where W_{kg} is the weight of dry shelled maize in kg on each net plot.

Monthly rainfall data for the 2024-2025 farming season were also captured using the survey CTO application by collecting data from all the research sites where rain gauges were installed by extension staff. Fertilizer price data used to conduct economic viability analysis of the fertilizer blends were collected from the Malawi Fertilizer Company, the importers, manufacturers, and blenders of inorganic fertilizers in Malawi.

2.3 Data analysis

The data collected from each of the four experimental sites were independently subjected to one-way analysis of variance (ANOVA) using John Macintosh Project Statistical Analysis Software (JMP SAS) version 14.0.0. The independent ANOVA for each site was employed to separately account for any environmental errors since the CRD design assumes homogeneity in the experimental units and does not account for general site effects (Gomez and Gomez, 1984). Mean separation procedures were conducted using the Least Significant

Difference (LSD) at the 5% level of significance to compare the means at each site. The fertilizer price data were analyzed using the partial budget analysis method as discussed by Soha (2014).

3. Results

3.1 Seasonal rainfall patterns

The results indicated that the highest rainfall amounts at all the sites were received between December and February, which was suitable for crop production as planting commences in December at the onset of the rainy season in Malawi.

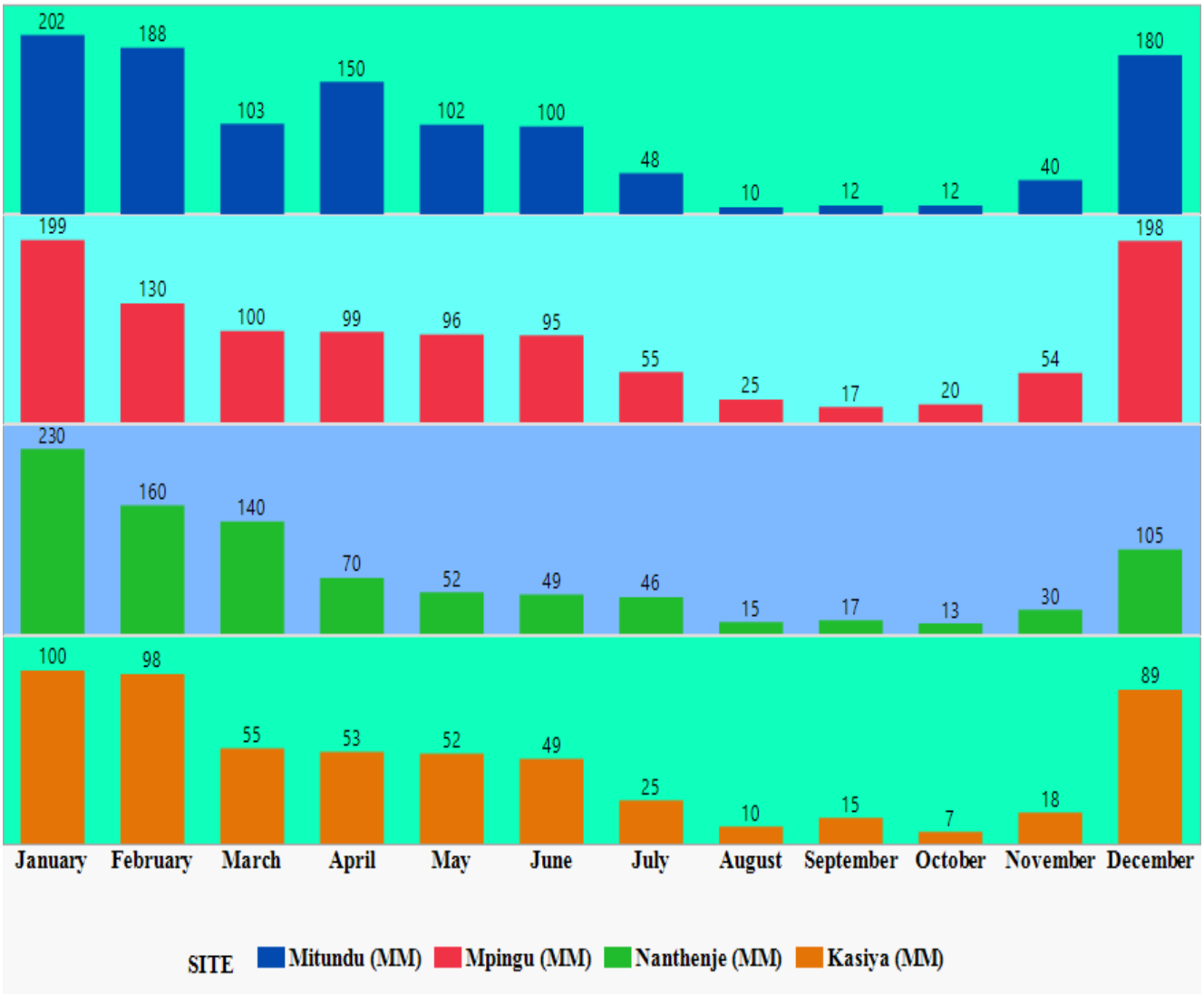


Figure 2. Seasonal rainfall pattern at the study sites

The total annual rainfall at the four research sites ranged from 571 mm to 1145 mm, which was within the required rainfall for maize production according to MoAFS (2012). Maize needs 450 mm to 600 mm of water per season, which is mainly acquired from the soil moisture reserves, of which about 15.0 kg of grain are produced for each millimetre of water consumed, and at maturity, each plant will have consumed 250 L of water (Plessis, 2003). Therefore, the rainfall distribution was favourable for the morphology, growth, and development of the maize crop at all the research sites.

3.2 Effects of the fertilizer blends on the number of maize cobs

The findings of the study on the effects of the fertilizer blends on the number of maize cobs were as presented in Table 1. The results indicated significant differences in Mitundu, Nanthenje, and Kasiya, while no significant difference was recorded in Mpingu. The mean separation results showed that in Mitundu, Alpha blend (72 cobs) and Mwininthaka (65 cobs) were the most effective fertilizers, seconded by the National blend (54 cobs), while the Control (0 cobs) did not produce any cobs; whereas in Nanthenje, Alpha blend (88 cobs) and Mwininthaka (80 cobs) were also the most effective blends, seconded by the National blend (61 cobs) and then the Control (15 cobs). In Kasiya, Alpha blend (87 cobs), Mwininthaka (85 cobs), and National blend (82 cobs) were more effective than the Control (51 cobs), while in Mpingu, Alpha blend (84 cobs), Mwininthaka (80 cobs), National blend (82 cobs), and Control (79 cobs) were all equally effective.

Table 1. Number of maize cobs as a result of different fertilizer treatments

Fertilizer Treatments	**Number of Maize Cobs**			
	Mitundu	**Nanthenje**	**Mpingu**	**Kasiya**
Alpha blend	72.0^{a}	88.0^{a}	84.0^{a}	87.0^{a}
Mwininthaka blend	65.0^{ab}	80.0^{a}	80.0^{a}	85.0^{a}
National blend	54.0^{b}	61.0^{b}	82.0^{a}	82.0^{a}
Control	0.0^{c}	15.0^{c}	79.0^{a}	51.0^{b}
F pr.	261.55	377.74	0.06	60.54
LSD (0.05)	7.92	6.59	31.76^{ns}	8.56
SE	2.02	1.68	8.09	2.18
CV %	5.99	3.90	14.15	4.04

Means not connected by the same letter in the same column are significantly different; F pr.= F probability; LSD (0.05) =least significant difference at 5% level of significance; ns= non-significant difference; SE= standard error; and CV= coefficient of variation.

3.3 Effects of the fertilizer blends on maize grain yield

The findings of the study on the effects of the fertilizer blends on maize grain yield indicated significant differences in Mitundu, Kasiya, and Nanthenje, while a non-significant difference was recorded in Mpingu. The mean separation results showed that in Mitundu, Alpha blend (6.77 t ha^{-1}), Mwininthaka (6.64 t ha^{-1}) and National blend (6.62 t ha^{-1}) were effective than the Control which did not produce any maize (0 t ha^{-1}) whereas in Nanthenje, Alpha blend (11.17 t ha^{-1}), Mwininthaka (8.57 t ha^{-1}) and National blend (8.45 t ha^{-1}) were also more effective than the Control (1.31 t ha^{-1}). In Kasiya, Alpha blend (6.09 t ha^{-1}), Mwininthaka (7.41 t ha^{-1}) and National blend (7.02 t ha^{-1}) were more effective than the Control (3.18 t ha^{-1}), whereas in Mpingu, Alpha blend (8.30 t ha^{-1}), Mwininthaka (7.58 t ha^{-1}), National blend (8.65 t ha^{-1}) and Control (6.15 t ha^{-1}) were all equally effective. Table 2 presents a summary of maize grain yield as a result of the fertilizer blends at the four research sites.

Table 2. Maize grain yield as a result of the different fertilizer blends

Fertilizer Treatments	Maize Grain Yield (t ha^{-1})			
	Mitundu	Nanthenje	Mpingu	Kasiya
Alpha blend	6.77^{a}	11.17^{a}	8.30^{a}	6.09^{a}
Mwininthaka blend	6.64^{a}	8.57^{a}	7.58^{a}	7.41^{a}
National blend	6.62^{a}	8.45^{a}	8.65^{a}	7.02^{a}
Control	0.0^{b}	1.31^{b}	6.15^{a}	3.18^{b}
F pr.	1632.33	24.16	1.25	44.80
LSD (0.05)	0.00	3.38	3.89^{ns}	2.17
SE	0.03	0.86	0.99	0.29
CV %	2.34	16.53	18.32	6.81

Means not connected by the same letter in the same column are significantly different; F pr.= F probability; LSD (0.05) =least significant difference at 5% level of significance; ns= non-significant difference; SE= standard error; and CV= coefficient of variation.

3.4 Economic viability of the fertilizer blends on maize production

Since maize requires N in large amounts, it is often most cost-effective to target maize with a concentrated N fertilizer. The current fertilizer recommendations in Malawi are N-based, and standard recommendations of 69 kg ha^{-1} or 92 kg ha^{-1} of N have been used for maize production since the 1990s, though recent research shows that application rates ranging from 200 kg ha^{-1} are more effective in increasing maize yield (Waddington et al., 2015). For this study, the 3 N-based fertilizer blends (National, Alpha, and Mwininthaka) were compared for cost-effectiveness in maize production at the selected research sites. The results (Tables 3-6) indicated minimal differences in profitability margin percentages between the fertilizer blends in all the research sites.

The results for Mitundu, as shown in Table 3, indicated that the Alpha blend (33.7%) was the most cost-effective, followed by the National blend (32.1%), and then the Mwininthaka blend (31.6%).

Table 3. Economic viability of the fertilizer blends in Mitundu

Fertilizer	Qty per ha (50$_{kg}$ bags)	Unit Price ($)	Total Cost ($/ha)	Maize Yield (kg/ha)	Farmgate Price ($/ha)	Total Income ($)	Profitability (%)
Alpha blend	8	117.1	936.6	2,770	0.51	1,412.7	33.7
National blend	8	114.2	913.6	2,640	0.51	1,346.4	32.1
Mwininthaka blend	8	114.2	913.6	2,620	0.51	1,336.2	31.6

The results in Nanthenje indicated that the Alpha blend (83.6%) was the most cost-effective, followed by the

Mwininthaka blend (79.1%) and then the National blend (78.8%). Table 4 below summarizes the study findings.

Table 4. Economic viability of the fertilizer blends in Nanthenje

Fertilizer	Qty per ha (50_{kg} bags)	Unit Price ($)	Total Cost ($/ha)	Maize Yield (kg/ha)	Farmgate Price ($/ha)	Total Income ($)	Profitability (%)
Alpha blend	8	117.1	936.6	11,170	0.51	5,696.7	83.6
Mwininthaka blend	8	114.2	913.6	8,570	0.51	4,370.7	79.1
National blend	8	114.2	913.6	8,450	0.51	4,309.5	78.8

The results in Mpingu, presented in Table 5, indicated that the National blend (79.3%) was the most cost-effective, followed by the Alpha blend (77.9%) and finally the Mwininthaka blend (76.4%).

Table 5. Economic viability of the fertilizer blends in Mpingu

Fertilizer	Qty per ha (50_{kg} bags)	Unit Price ($)	Total Cost ($/ha)	Maize Yield (kg/ha)	Farmgate Price ($/ha)	Total Income ($)	Profitability (%)
National blend	8	114.2	913.6	8,650	0.51	4,411.5	79.3
Alpha blend	8	117.1	936.6	8,300	0.51	4,233.0	77.9
Mwininthaka blend	8	114.2	913.6	7,580	0.51	3,865.8	76.4

Finally, the results in Kasiya were as presented in Table 6. The Mwininthaka blend (75.8%) was the most cost-effective, followed by the National blend (74.5%), and finally the Alpha blend (69.8%).

Table 6. Economic viability of the fertilizer blends in Kasiya

Fertilizer	Qty per ha (50_{kg} bags)	Unit Price ($)	Total Cost ($/ha)	Maize Yield (kg/ha)	Farmgate Price ($/ha)	Total Income ($)	Profitability (%)
Mwininthaka Blend	8	114.2	913.6	7,410	0.51	3,779.1	75.8
National blend	8	114.2	913.6	7,020	0.51	3,580.2	74.5
Alpha blend	8	117.1	936.6	6,090	0.51	3,105.9	69.8

4. Discussion

The maize crop requires fertilizer in large amounts to achieve maximum yields. Nitrogen (N) fertilizer is considered one of the most important catalysts for the growth and grain yield of hybrid maize (Adhikari, 2021). Average maize yields in Malawi are around 1.2 MT ha^{-1}, which is lower than the average for Africa, 1.8 MT ha^{-1}, and is also considered to be far below the average potential (Abate et al., 2017; Mango et al., 2018). Scarcity of various and alternative fertilizer blends for maize production in Malawi has emerged as one of the enormous challenges limiting farmers from achieving optimum maize yields in recent years. The results of this study revealed significant differences between the fertilizer blends and the control, while no significant differences existed between the national standardized recommendation and the newly developed local fertilizer blends in affecting both the number of maize cobs and grain yield. The study further revealed that there were minimal site-specific variations in profit margins between the fertilizer blends at the four research sites in Lilongwe.

The effect of the site on maize production may be due to local environmental conditions such as temperature, rainfall, and soils (Mthambala et al., 2022). However, in this study, the considered factor, rainfall received at the research sites during the 2024-2025 farming season, was highly favourable for maize production (571 mm to 900 mm) at all the sites and contributed positively to maize yield. The research site that received the lowest rainfall was Kasiya (571 mm), yet it was within the required rainfall for maize production (450 mm to 600 mm). The findings were concordant with a study by Njira et al. (2017) who reported a similar rainfall pattern within the required range for maize production during their study period in Lilongwe.

The effect of the various fertilizer blends on the number of maize cobs was significantly different between fertilizer blends and the control at all sites except at Mpingu, a scenario which may be explained by the soil fertility status of the Mpingu site. This is because even where no fertilizer was applied, the site produced maize cobs within the same range as the plots where fertilizer blends were applied. Hence, the Mpingu site may have had nitrogen levels similar to the levels where the nitrogen fertilizer blends were applied (200 N ha^{-1}). The results were consistent with findings of a study by Adhikari et al. (2021) who reported that the highest N level of fertilizer treatments (220 N ha^{-1}) produced the highest number of maize cobs, cob length, and grain yield in their field trials.

The effect of the different fertilizer blends on maize grain yield was also significantly different between the fertilizer blends and the control at all sites except at Mpingu, a scenario which may again be explained by the good soil fertility status of the Mpingu research site. This is because even where no fertilizer was applied, the site produced grain yield in the same range as the plots where balanced nutrient levels, especially N, P, and K, were applied through the fertilizer treatments. These results concurred with the findings of a study by Adediran and Banjoko (2003), where it was generally observed that maize fails to produce good grain in plots without adequate nutrients.

The economic viability analysis of the various fertilizer blends in maize production revealed minimal variations in profitability margins between the fertilizer blends. The Alpha blend was the most economical or cost-effective fertilizer, having outperformed the National and Mwininthaka blends at two sites (Mitundu and Nanthenje), while the National and Mwininthaka blends were economical or cost-effective at one site each (Kasiya and Mpingu, respectively). This may be explained by the differences in nutrient compositions and current prices of the various fertilizer blends. The Alpha blend had a more well-balanced composition of the plant-required macronutrients than the National and Mwininthaka blends. The differences in prices were due to the cost of production, as the National blend is imported whole, while the Alpha and Mwininthaka blends are blended locally following importation of different raw materials, and this also translated to comparatively different maize production costs. The results corresponded with findings of a study by Kalawole (2009), who observed a reflection of the fact that there is a positive relationship between grain yield improvement and economic viability in maize production.

4.1 Implications for policy and practice

There is a need for all stakeholders in Malawi, including Government, Organizations, Institutions, and Private entities, to jointly increase efforts in exploring various local fertilizer blends as part of the broad soil health initiatives. The country, where the number one economic mainstay is agriculture, continues to grapple with fertilizer scarcity and rising prices of the commodity, exacerbated by extreme forex shortages for fertilizer imports.

5. Conclusion

From the study findings, it can generally be concluded that the local fertilizer blends Alpha and Mwininthaka are also effective in maize production systems. This is because the results indicated that, while significant differences existed when compared to the control, no statistically significant differences existed between the three blends, Alpha, Mwininthaka, and National fertilizers. Based on the economic viability analysis, it can also be concluded that the Alpha blend is more cost-effective than the Mwininthaka and National blends. Therefore, in the wake of fertilizer scarcity, rising costs, forex scarcity, and soil degradation, which results in dwindling maize production, any of the three fertilizer blends can be used to replenish soil nutrients required for maize production in Lilongwe, Malawi, with the Alpha blend more likely to make the farming enterprise more profitable in most areas.

6. Recommendations

1. There is a need to strengthen collaborative soil health research, extension, and innovation.
2. Create a more conducive environment for investment in local fertilizer blending and manufacturing.
3. Increase financing for locally tested agricultural innovations.
4. Expand extension innovation outreach on alternative local fertilizer options among farmers.

7. Limitations of the Study

The study has a spatial limitation, having been conducted in selected areas of Lilongwe District, central Malawi.

Declarations

Ethical approval: The study involved no human or animal participants.

Consent to participate: Consent was not applicable.

Consent for publication: The Meridian Group, through the Farm Services Unit (FSU), authorized publication as part of their private-sector research, extension, and innovation drive in the agricultural sector.

Availability of data and materials: The research supporting data and materials can be accessed upon formal request and approval by the Meridian Farm Services Unit.

Competing interests: The author declares that there are no competing interests.

Funding: The study was conducted as part of Meridian Group's day-to-day operations. No external funding was received.

Authors' contributions: The author conceptualized, ran data analysis, and drafted the study manuscript.

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