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Original article

UNLOCKING MAIZE CROP PRODUCTIVITY THROUGH IMPROVED MANAGEMENT PRACTICES IN NORTHERN TANZANIA

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ABSTRACT

Addressing the problem of low crop productivity and food insecurity can be accelerated through community-centered implementation of good agricultural management practices. This study was conducted in Babati, Northern Tanzania. The objective of the study was to determine nitrogen (N) and phosphorus (P) application requirements for maize, and demonstrate economically viable best bet yield-improving management technologies under three ecozones namely; 'low elevation low rainfall', 'medium elevation high rainfall' and 'medium elevation low rainfall' ecozone. Two sets of trials were conducted: N (0, 45, 90, 120 and 150 kg ha^{-1}) and P (0, 15, 30, 40 kg ha^{-1}) response trials in 16 representative fields in three seasons of 2013/14, 2014/205 and 2015/16 and; demonstrations trials in 8 farmer-selected fields in 2015/16 season. Combined N and P application increased maize yields by 32 to 62% over single nutrient applications. In the medium elevation low rainfall ecozone, 60-86% yield response to nitrogen was observed. Largely, modest applications of 50 kg N ha^{-1} and 20 kg P ha^{-1} resulted in profitable (marginal rate of return (MRR) of 2.4 to 3.0) yield increases of up to 214% over the farmers practice (unfertilized), varying with variety and ecozone. The source of P (DAP or Minjingu Mazao) had little influence on maize productivity except under low altitude low rainfall where Minjingu Mazao is unprofitable. Farmer rankings and agronomic indices showed new maize hybrids namely Meru H513, Meru H515 and SC627 as priority across the ecozones; Mams H913 is suitable mainly in medium elevation low rainfall ecozone. The conclusion is that use of new maize hybrids and appropriate rates of locally available N and P nutrient sources can bridge existing yield gaps and reduce food insecurity. Technologies from community-driven research in development are easily adopted by a large number of farmers and could result in a quick, yet lasting productivity gains.

Key words: Phosphorus sources, ecozones, profitability, farmer preferences, innovation

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INTRODUCTION

To achieve food security, increasing crop yield per unit area, production intensification through soil fertility management and appropriate varieties under good agronomic practices is needed [1, 2]. Current production practices with low inputs lead to nutrient mining and resultant land degradation [3]. African countries have committed to accelerated growth of agriculture and addressing soil fertility together with availability of appropriate crop varieties for different agro-ecozones across sub-Saharan Africa (SSA) [1, 3]. Technologies to transform agriculture are available and some view the poor agricultural performance as a problem of process, and call for multi-stakeholder approaches such as Integrated Agricultural Research for Development (IAR4D) and innovation platforms [4].

Positive response of crops to soil fertility improving technologies including fertilizer application is widely demonstrated in SSA, but adoption has not always been high, resulting in call for innovation systems approaches [4, 5, 6, 7, 8]. In some places of SSA, fertilizer use is not common and efforts to promote its utilization are based on blanket recommendations developed for other areas. In the Babati district of Northern Tanzania, very low fertilizer use by only three percent of farming households has been reported [9]. Accelerating technology uptake and reversing low productivity is realized while working in partnership with relevant stakeholders in a process that allows joint interaction, learning and consequently addressing emerging concerns [4]. Achieving higher productivity per unit area is an important aspect of intensification designed to overcome low productivity of extensive systems that are commonly used by majority of farmers. The current average smallholder farm maize productivity of about two tons ha^{-1} compared to potential yield of above 7.5 t ha^{-1} in Babati and elsewhere require that farmers put more land under cultivation to achieve food security as well as meeting their basic needs [9]. This expansion leads to land degradation following conversion of natural vegetation to agricultural land [10] and retaining smallholder farmers in a cyclical poverty loop from a damaged natural resource base. This situation can be reversed using the available technologies within a multi-stakeholder innovation systems approach. This is because increased production is critical in SSA where yield gaps are high compared to other regions of the world [11]. Considering the existing food production scenario, raising yields to 50% of attainable yield will be a huge gain [12].

Nitrogen and phosphorus remain the most limiting nutrients to crop productivity in Babati, a common phenomenon in SSA [9, 13]. Options for nitrogen management through nitrogen fixation and application of inorganic fertilizers have been widely studied [11, 14]. Low maize productivity despite extensive intercropping with pigeon peas in Babati indicates low N fixation rates or inadequate P in the soil coupled with poor agronomic practices [9]. Farmers have options of using either external P blends such as DAP, or blends from locally available natural phosphate deposits. The need for evaluating both fertilizers was identified since suitability of the Minjingu-based P sources is influenced by moisture availability, with low performance relative to DAP under moisture stress [12, 15].

The use of good seed is a critical component of yield improvement package. Although a high majority (81%) of farmers in Babati appreciate the use of improved seeds, challenges such as climate variability and maize lethal necrosis disease call for a wider basket of options with crop varieties that farmers can choose from [9]. Farmers' perception and feedback to scientists and seed producers/suppliers on variety performance are important in scaling of yield improving technological packages. Feed the Future (FtF) zones of influence in Tanzania represent seven clusters of recommendation domains for scaling identified in Babati, providing a huge opportunity for impact at national level with best performing technologies [16].

Efforts to increase crop productivity within the framework of integrated agricultural research for development approach through FtF (program of Africa RISING) identified three objectives that this study sought to pursue. The objectives are to: 1) determine N and P application requirements for maize in Babati, 2) together with key stakeholders, demonstrate economically viable best bet yield-improving management technologies under different ecozones, and 3) identify new production challenges from the view-point of the farmers and provide recommendations for addressing them in future research. These address the key sustainable intensification indicators of productivity, economic and social domains. The integration of social and biophysical aspects is important to ensure technological adoption by farmers due to considerations of their production environment.

MATERIALS AND METHODS

This study was undertaken in the Babati district of Northern Tanzania, characterized with a sharp gradient of altitude due to its location at the western part of the Great Rift Valley. A detailed characterization of the district had been conducted at the initiation of the Africa RISING project of the FtF initiative in this location [9]. Following that characterization, production challenges were identified and supported by farmers' concerns at village-level feedback meetings during the 2012/13 season. In 2014, a newly initiated Babati Integrated Agricultural Research for Development (IAR4D) platform called JUMBA brought together seed and fertilizer companies, farmer representatives from project villages, researchers and agro-dealers to identify, discuss and address the production and marketing challenges.

Based on the identified challenges, two sets of on-farm trials were conducted where both cases were researcher-designed and farmer-managed. The first set of experiment was nutrient (N and P) response trials conducted in 16 farmer fields during the three cropping seasons between 2013/14-2015/16 in three ecozones of Babati. The 16 farmers' identification was done at farmers' meetings at the village-level based on criteria provided by researchers (such as representation of villages, ease of access for field monitoring, farmer willingness to host trial including performing weeding, uniformity of field for an experiment). This first set of trials involved five rates of N application (0, 45, 90, 120 and 150 kg N ha^{-1}) and four rates of P (0, 15, 30 and 40 kg P ha^{-1}) and a control treatment where no nutrients were applied (the control represents farmers' practice with limited amount of applied manure, about 3.5t ha^{-1}). In each field, the experimental design was a completely randomized block design with three replications. Plot sizes were 10 m by 10 m in all fields. SeedCo variety (SC627), a hybrid commonly grown by farmers in Babati, was used in this set of trials. At the end of every season, results of preliminary analysis were discussed with farmers and other stakeholders during annual feedback meetings.

The second set of trials were demonstrations of best-bet practices where nutrient application rates were informed by initial results of the nutrient response trials. A treatment with modest (rounded off) application rates of N (50 kg ha^{-1}) and P (20 kg ha^{-1}) was identified as best-bet practice and was further placed in demonstration trials for farmer evaluation. These were conducted in eight farmer fields during the 2015/16 cropping season, and included the best-bet practice in comparison with unfertilized control. Minjingu Mazao (supplied by Minjingu fertilizer company) contains 10% N and 9% P while DAP fertilizer has 18% N and 20% P. Nitrogen not supplied by the P source was applied as Urea fertilizer. The selected treatments were demonstrated under four improved maize varieties; Mams H913, Meru H513, Meru H515 and NATA H105 [Table 1]. The 'Meru Agro Seed' and 'AMINATA Quality Seed' companies provided the seed required every year for the experiments. The demonstrations included six fields in 'low elevation low rainfall' ecozone, one field in 'medium elevation high rainfall' and one field in 'medium elevation low rainfall' ecozone.

Land preparation followed common farmer practices of using oxen-drawn plough. Maize was planted at a spacing of 90 cm by 25 cm and intercropped with a late maturing pigeon pea variety. Weeding was done twice, at V6 and V12 stages (that is at six and twelve well developed leaves, respectively), using hand hoes while pest management, essentially stem-borer control was by the application of bulldock.

Phosphorus from the respective sources was basal applied at planting (in planting holes) while nitrogen was applied in two equal splits, before weeding at V6 and at V12 stages through banding. Harvesting, done manually at harvest maturity, was carried out in two subplots of 3 m by 3 m plots for each variety and fertilizer combination for the non-replicated demonstration trials, and within 3 m by 3 m net plots for on-site replicated nutrient response trials. All the maize plants in the subplots were cut, ears separated from stovers and each component weighed. A sub-sample of five ears was selected to ensure it represented the sizes and the moisture content of all the cobs. These were oven-dried for 48 hours at 60ºC and dry weights of maize cores, ear and grain were measured, using a Mettler Toledo Electronic balance (0.01 g precision).

At the commencement of the experiment, four soil sampling points were randomly selected using Y sampling method and initial soil nutrient content assessed at 0-20 cm depth. The parameters assessed were soil organic carbon (SOC), total N and extractable P using Mehlich 3 extraction procedure and pH (1:1 soil: H_2O). Soils of the three eco-zones have moderate pH while medium elevation high rainfall eco-zone is deficient of extractable P. Results of the initial soil nutrient content and other locational characteristics are provided in Table 2.

For both sets of trials, leaf chlorophyll concentrations were measured in one farmer field in "Medium elevation high rainfall ecozone" using a Minolta SPAD 502 plus meter. The

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SPAD values provide an estimate of the leaf N status for decision making on timing and application quantities of N. For the "Medium elevation low rainfall ecozone", leaf chlorophyll measurements were recorded for one field within the nutrient response trial. The measurements were taken in all treatments of N response during V12 growth stage and, in each plot, measurements were an average of 10 ear leaves (10 plants).

Farmer technology assessment was conducted within the demonstrations in selected villages of Sabilo, Ayamango and Orngadida facilitated by trained district level agriculture extension staff. The process involved farmers separated in sub-groups of men, women and youths walking through masked labeled plots that did not reveal actual fertilizer treatments and under different varieties. Each group recorded the key characteristics of each fertilizer and variety combination. Farmers reported back their findings to their peers who were segregated as men and women groups. This was followed by group discussions and a ranking of the fertilizers and varieties by each group. Determination of future farmer research and development needs and potential solutions to increase agricultural productivity was based on focused group discussions with 26 (23% women) participating farmers and village extension staff from each of the ecozones. Participants listed the needs, followed by a ranking based on priority. For each of the needs, potential solutions were also identified.

Based on the exchange rate of the Tanzanian Shilling to the United States Dollar (US$), an economic analysis of the technologies used in the study was performed. The economic analysis was based on a participatory process with farmers in each ecozone providing the farm gate prices, which were US$ 32.2 per 50 kg bag of urea and DAP, US$ 16.1 per bag of Minjingu Mazao, US$ 2.3 for fertilizer transport of up to three 50 kg bags, US$ 6.8 cost of fertilizer application at planting and Urea top-dressing ha^{-1}, US$ 7.9 for harvesting t^{-1}, US$ 10 for threshing and bagging t^{-1}. Maize stover is sold at an average price of US$ 0.46 t^{-1}. To account for researchers' influence including penalty on small plot sizes used in yield determination, grain and stover yields were adjusted downwards by 15% [15, 18]. For outputs (price of maize = US$ 18.4 per 100 kg bag).

Data analysis

Data derived from fertilizer response trials was analyzed using one-way Analysis of variance in GenStat software 14th edition. The effect of fertilizers was analyzed per individual ecozones and cropping seasons. Replicates were nested within farms and grain yield used as variate of the model. Data for four fields during the 2014-15 cropping season were not used since there was crop failure, due to drought. There were three trial fields in both 'low elevation low rainfall' and 'medium elevation high rainfall' ecozones and six fields in the 'medium elevation low rainfall' ecozone included in the analysis. Mixed effects model was also used for statistical analyses using lme4 package in the R statistical software (R 3.2.4 version) to analyze data from the demonstration trials. For this, DAP and Minjingu Mazao fertilizers were considered as replications nested within farms in the analysis, since their performance was similar. For the medium elevation ecozones, varieties were also considered as replications since no major performance differences was observed.

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Dominance analysis was done to identify the fertilizer options that have more costs that vary yet less net benefits than other options [5]. For the non-dominated options, marginal rate of return was calculated as the ratio of the additional benefits and costs of using any of the fertilizer options over the control.

RESULTS AND DISCUSSION

Effect of fertilizer application on maize grain yield

Maize grain yield performance was variable in the three eco-zones and over the two seasons of assessment. Treatments tested had a significant effect on maize yields ($P<0.05$). Fertilizer use resulted in yield gains ranging from 17% to 66% relative to farmer practice where manure as the only nutrient source was applied in 2016 (Table 3). These gains were statistically significant ($P<0.05$) in most cases. In the low elevation - low rainfall ecozone, there is no response to N without application of P; that is both N and P limited yields. Here, combined application of N and P increased yields by 41% and 35% in the 2014 and 2016 seasons, respectively, over treatments where either nutrient was omitted. For the medium elevation ecozones, only N and not P limited yields especially in 2014 season. The application of N of at least 45 kg ha^{-1} in these medium elevation ecozones increased yields by 41-96% in the 2014 season and 12-117% in the 2016 season depending on quantity of nutrient applied. Although 2016 yields under the medium elevation -high rainfall ecozone were not statistically different, the zero N treatment still had the lowest yields relative to treatments with N. These results show that medium elevation eco-zone require application of N of at least 45 kg ha^{-1} while the low elevation low rainfall ecozone requires also P of at least 15 kg ha^{-1} for increased yields but the actual benefits will vary by season.

The role of fertilizers in increasing productivity as demonstrated in our study is also evident elsewhere [19, 20, 21]. In our study, the differences in P play a huge role in influencing productivity than the difference in rainfall of 80mm between Medium elevation –high and low rainfall sites. While application of manure under farmer management is important in improving crop yields [9], further application of fertilizers can raise the productivity and bridge the yield gap in these systems.

Increased yield with both DAP and Minjingu Mazao in all ecozones is interesting, especially because the effect of Minjingu-based fertilizers such as Minjingu Mazao on crop yield under moisture stress is a subject of debate [15]. Moisture stress early in the season was associated with a short crop stand relative to DAP but final yields were similar.

Effect of fertilizer application on leaf chlorophyll

The status of leaf N, based on SPAD readings, was low for the treatments without N application (0 N) relative to the other treatments (Figure 2a). Besides, SPAD measurements were consistent with yield results where any amount of nitrogen applied increased SPAD readings over the control in both the medium elevation high rainfall ecozone and the medium elevation low rainfall ecozone (Figure 2b).

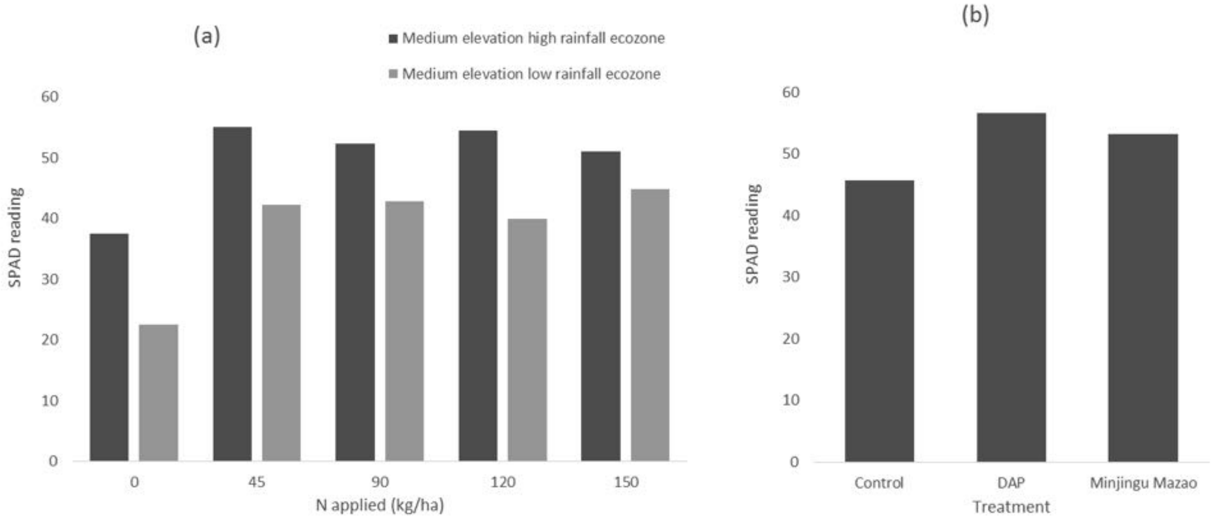

Figure 2: **SPAD measurements under different N fertilizer treatments in two ecozones of Babati; each bar represented the average of 10 ear leaves within a plot**

The profitability trend mirrors that of leaf chlorophyll readings that were also not different with successive N amounts beyond the 45 kg N ha^{-1}. This demonstrates the potential to utilize SPAD meters as diagnostic tools to inform nitrogen application across sites and within seasons. In this study and except under fertilizer subsidy, N and P application at low rates is recommended, with exception of the medium elevation low rainfall ecozone, where the need for P is yet to be demonstrated.

Effect of varieties and P sources on maize productivity

Except for Mams H913, there was a significant ($P<0.05$) positive effect of fertilizer application on the tested varieties used in the demonstration trials (from 75 to 135% yield increase over the control treatment; Figure 3). The highest maize grain yield under the improved practice were observed with Meru H513, Meru H515 and SC627. In Ayamango, men ranked Minjingu Mazao to be superior than DAP while women ranked them vice versa (data not shown). In a second village (Orngadida) within the same ecozone, DAP applied to SC627 was ranked superior to Minjingu Mazao by both men and women. However, with Meru H513, women preferred Minjingu Mazao to DAP while men preferred DAP to Minjingu Mazao, indicating the equal performance of these two fertilizers.

The debate of using Minjingu only in ecozones classified as moist is challenged by climate change since such environments are now experiencing increased climate variability including periods of moisture stress. While yields are significantly higher in the medium than low elevation ecozone, yields under low rainfall sites of medium elevation ecozone are the same as sites considered to be of high rainfall within this ecozone. The medium altitude low rainfall ecozone had good soils limited only in N.

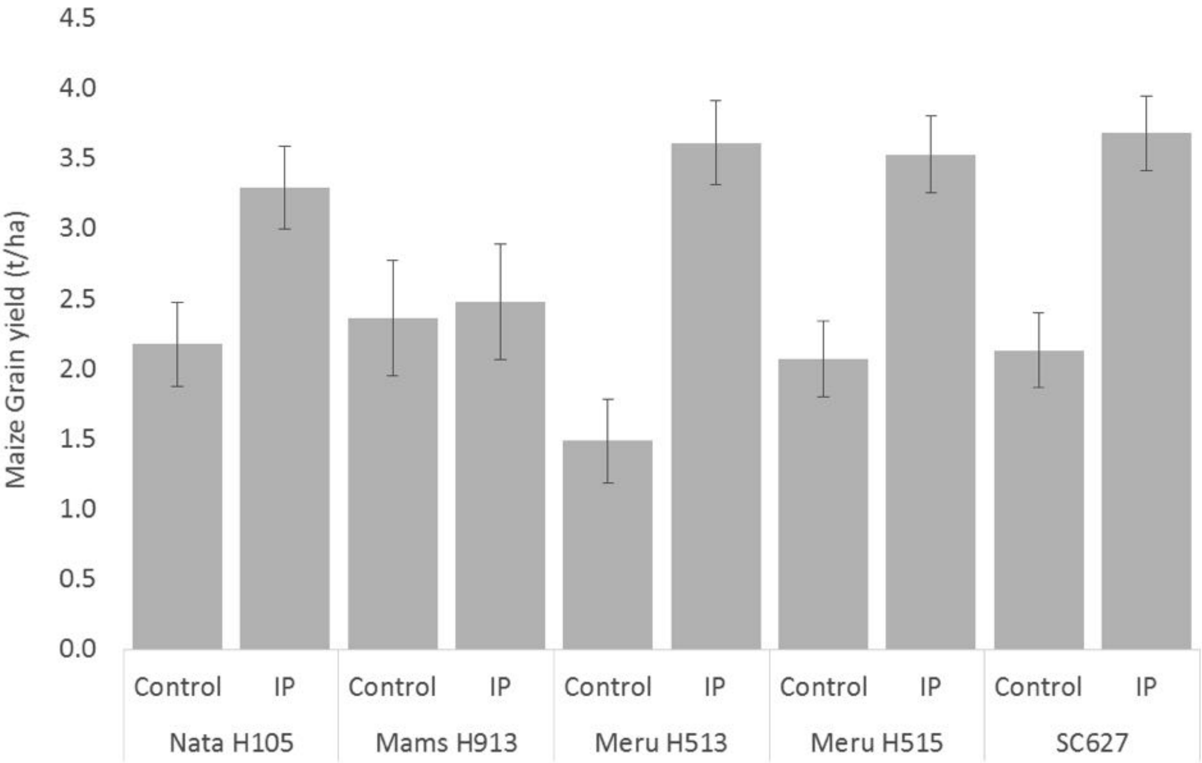

Figure 3: Maize grain yield observed under different varieties and treatments in demonstrations in Low altitude low rainfall agro-ecozone. Error bars are 95% confidence limits of mean. IP= "improved practice"

Responses to fertilizer (DAP and Minjingu Mazao) were on average 188% in the low rainfall, and 214% in the high rainfall sites (Figure 4). A joint technology ranking by men and women in the low rainfall site, under DAP, showed performance differences of varieties in the descending order Meru H513>SC627>Mams H913 >Meru H515. Under Minjingu Mazao, a different order was observed, that is, Meru H515>Meru H513>Mams H913 > SC627. This indicates farmer inability to differentiate performance of the different varieties that all produced high yield in these two ecozone.

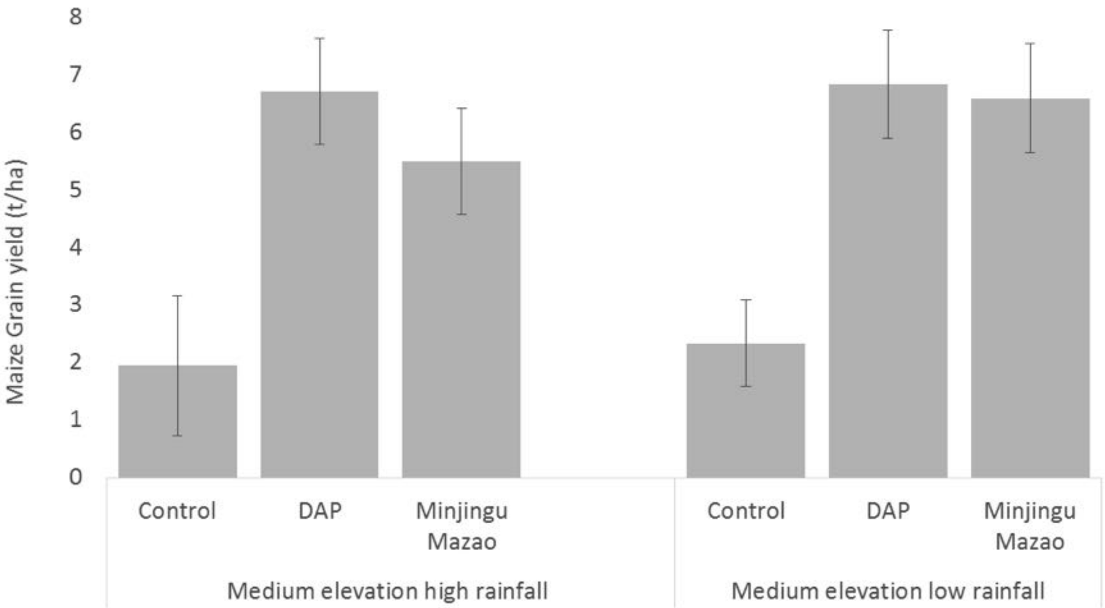

Figure 4: Maize grain yields observed under control and improved practices in demonstrations in medium elevation ecozones; error bars are 95% confidence limits

Although hybrids are generally categorized based on ecologies, their response in different environments determine where each hybrid type is best suited for higher performance [22]. Mams H913 is unsuitable for low elevation - low rainfall ecozone and is best targeted to the medium altitude. Among the varieties tested in this study, Meru and SeedCo (SC 627) will still perform well in low or high elevations indicating they are stable varieties.

Maize variety ranking by gender

Variety ranking, done separately by men and women was consistent with the final harvest data but with some noticeable gender differences (Table 4). The differences in variety ranking are associated with preferences such as number of ears, sizes of cob and grain by either gender. In Ayamango village men ranked Meru H515 and SC627 similarly, followed by Meru H513. Contrary to men, women ranked Meru HB513 first, followed by Meru H515 and then SC 627. Meru H513 has leaf architecture that allows increased light penetration and air circulation benefiting the commonly intercropped pigeon pea, unlike SC627 and Meru H515 that shadow the intercrop. However, Meru H513 does not close the ear completely and may result in increased Aflatoxin infestation when moisture gets into the cob.

Economic benefits of fertilizer application

Economic analyses of the improved practice and unfertilized control show both Minjingu Mazao and DAP as highly profitable in medium elevation agro-ecozones attracting a marginal rate of return of 2.4 to 3.0 (Table 5). At the prevailing input market prices, application of these fertilizers was unprofitable in the low elevation low rainfall due to poor response by Mams H913 and the overall low yield in this ecozone influenced by drought. Both DAP and Minjingu Mazao are profitable considering their half prices offered in the subsidy program (except Minjingu Mazao in the low altitude low rainfall ecozone). Economic analyses of the individual nutrients N and P based on the nutrient response trials showed N application at 45 kg ha^{-1} is profitable and attractive for adoption by farmers in all ecozones (MRR of 1.8, 2.2 and 3.0 in Low altitude low rainfall, Medium elevation high rainfall ecozone and Medium elevation low rainfall ecozone, respectively; data not shown). All other N application rates except 90 kg /ha (MRR=2.0) in the Medium elevation low rainfall ecozone attracts a low MRR of less than two. Application of P alone attracted a low MRR of 1.8 in the low altitude low rainfall and 1.4 in the Medium elevation high rainfall ecozone when applied at 15 kg/ha, with all other cases having MRR<one. Using prices available within the subsidy program for DAP and urea, N application was profitable (MRR 2.0 –5.0) at all application rates and in all ecozones while P application was profitable only for 15 kg P ha^{-1} in the Low altitude low rainfall (MRR=3.0) and Medium elevation high rainfall ecozones, (MRR=2.5).

Despite the non-statistical differences in yield due to P source, the extra US$ 120-210/ha obtained with DAP relative to Minjingu Mazao is attractive enough for the DAP investment. For acidic soils, Minjingu which has a liming effect is preferred [23]. In the moderate pH soils where liming is not needed, P source should be guided by relative prices of the fertilizers, seasonal weather forecasts and by ratio of cations in the soil [9, 24].

Factors contributing to low agricultural productivity

Focused group discussions identified and ranked problems contributing to low agricultural productivity in the following order: (1) Drought due to unreliable rains, poor rainfall distribution, and early cessation, 2) Low/lack of knowledge on improved crop husbandry practices, 3) High costs for inputs 4) Low soil fertility, 5) Pests and diseases and 6) Low availability of labour.

In the participatory technology assessment, the almost similar yields yet interchanged ranking of Meru H513, Meru H515 and SC627 maize seeds by both genders indicate likely differences in preferences and high competitiveness between the three varieties. Prioritization of drought by farmers as the first concern in production resonates with researcher experiences during the period.

Uptake of the demonstrated technologies has the potential for huge impact at the national level. Considering that the cultivated land constitutes 37% of 83000 km^2 of the seven recommendation domains of FtF focus region in Tanzania, a modest yield increase of one t ha^{-1} per season translates to additional 3 million tons in the national food basket annually, a 565m US$ worth of food [16]. Achieving this requires partnerships with relevant development partners to integrate good agricultural practices in their outreach work. Following capacity enhancement, the ministry of agriculture staff can implement demonstrations of varieties and fertilizer use on their own and conduct field days to reach out to more farmers as is the case in Babati. To absorb the increased productivity, Selian Agricultural research institute is actively linking farmers to markets and E-soko awareness and utilization whose utility has increased among farmers. Testing and demonstrating technologies within a multi-stakeholder engagement approach catalyses ownership and emerging knowledge gaps are addressed and fears arrayed through the wide expertise presented. Including policy makers ensures that appropriate policies can be put in place in order to remove institutional barriers to delivery and uptake of agricultural technologies.

CONCLUSION

Combined applications of modest amounts of P at 20 kg ha^{-1} and nitrogen at 50 kg ha^{-1} are adequate to increase maize productivity, by at least 32%, in most ecozones studied. Minjingu fertilizers and DAP are highly profitable in medium elevation agro-ecozones but more work is needed to improve profitability of Minjingu Mazao in the low elevation low rainfall ecozones. To maximize on the economic benefits, farmer decision on P sources need to be guided by information regarding relative fertilizer prices.

The utilization of new improved varieties such as Meru 513, Meru 515, Nata H105 and Mams H913 within the suitable ecozones and their promotion alongside the traditional varieties has potential to enhance productivity and response to fertilizers, and acceptability by farmers.

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Table 1: Improved maize varieties used in the study and their unique attributes

Name of Variety	**Year of release**	**Elevation (m)**	**Maturity**	**Yield Potential (t ha^{-1})**	**Special attributes**
Meru H513	2013	800-1500	Intermediate	8.5 - 10	Drought and Low N tolerance
Meru H515	2013	800-1500	Intermediate	7 - 10	Drought tolerance
Mams H913	2013	800-1500	Intermediate	8.5-10	Quality Protein Maize-enhanced lysine and Tryptophan
NATA H105	2013	<1600	Early to intermediate	9	General adaptability
SC627	2001	Intermediate range	Intermediate	7-9	General adaptability

Table 2: Locational characteristics of the studied eco-zones in Babati, Northern Tanzania

Ecozone	Villages	Elevation (m.a.s.l)	Rainfall (mean annual in mm)	Lat	Long	SOC (%)	Total N (%)	pH	P (ppm)
low elevation low rainfall	Hallu, Ayamango and Orngadida	1233	769	-4.29	35.89	1.68	0.13	7.68	26.21
medium elevation high rainfall	Seloto	1644	845	-4.24	35.49	1.77	0.11	5.94	10.36
medium elevation low rainfall	Sabilo	1648	763	-4.34	35.47	1.57	0.11	6.93	49.4

Lat= latitude; Long=Longitude; SOC=Soil organic carbon; P=phosphorus

Table 3: Maize yield (t ha^{-1}) observed under different rates of N and P during the long rains of the 2014 and 2016 seasons in three eco-zones of Babati

Treatments	Low elevation-low rainfall	Medium elevation - low rainfall	Medium elevation - high rainfall	Low elevation -low rainfall	Medium elevation - low rainfall	Medium elevation - high rainfall
		2014			2016	
0N 40P 60K	2.6b	3.2d	2.4c	3.7ab	2.3c	2.5bc
45N 40P 60K	3.5a	4.7bc	4.1ab	4.5a	4.7ab	2.8b
90N 40P 60K	3.8a	4.9abc	4.4a	5.0a	5.0ab	3.0b
120N 0P 60K	2.2b	4.9abc	3.3b	4.7a	5.1ab	2.7bc
120N 15P 60K	3.5a	5.3ab	4.1ab	4.6a	4.1b	3.0bc
120N 30P 60K	3.5a	4.9abc	3.8ab	4.3a	4.6ab	3.9a
120N 40P 60K	3.7a	4.5c	4.7a	4.8a	4.9ab	3.0b
150N 40P 60K	3.4a	5.4a	4.7a	5.7a	5.6a	2.7b
Farmer Practice				1.9b	2.5c	2.0c
LSD	0.76	0.67	0.90	2.07	1.06	0.78

LSD=least significant difference. Values followed by the same letter within a column are not significantly different (P<0.05)

Table 4: Ranking of technologies by men (m) and women (w) based on maize varieties, and basal fertilizers in Ayamango village

Seed type	Characteristics (+DAP)	Rank	Characteristics (+Minjingu Mazao)	Rank
Meru H513	Two cobs per plant, Good in sifting, low weight (m)	3 (m)	Two cobs in some (m)	3 (m)
	Large cobs, big tall plants, grains sunken (w)	1 (w)	Tall plants, long and slightly thin cobs, sweet when roasted (w)	3 (w)
Meru H515	Big stovers, cobs well closed on top, one cob per plant, good for roasting, high weight, filled grains (m)	1 (m)	Big cobs, big grains, no pests, tall plant, little biomass (m)	2 (m)
	More flour, breaks when sifting, closed tops, small cobs, good for sifting (w)	2 (w)	Big cobs, with closed tops, sweet when roasted, two cobs per plant (w)	1 (w)
SC 627	Small cobs, open tops, some plants without cobs, high weight (m)	2 (m)	Big cobs, two cobs per plant, small grains, few plants, cobs well closed, large grains, high biomass (m)	1 (m)
	Thin cobs (w)	3 (w)	Thin cobs, cob tops well closed, tall plants, high biomass (w)	2 (w)

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Table 5: Results of partial economic analyses of effects of fertilizer application in different ecozones in Babati

	Low altitude low rainfall			**Medium altitude high rainfall**			**Medium altitude low rainfall**		
	Control	**DAP**	**MM**	**Control**	**DAP**	**MM**	**Control**	**DAP**	**MM**
Gross benefit ($\$$ ha^{-1})	327.2	620.8	503.7	310.9	1077.0	878.5	375.8	1096.7	1059.8
Total variable cost ($\$$ ha^{-1})	33.6	241.5 (161.9)	229.5 (150.0)	32.7	290.0 (210.5)	269.6 (190.0)	35.7	281.8 (202.2)	278.0 (198.5)
Net benefit ($\$$ ha^{-1})	293.6	379.3 (458.9)	274.2 (353.7)	278.2	786.9 (866.5)	609.0 (688.5)	340.1	815.0 (894.5)	781.8 (861.3)
Marginal rate of return		1.4 (2.3)	0.9 (1.5)		3.0 (4.3)	2.4 (3.6)		3.0 (4.3)	2.8 (4.2)

MM=Minjingu Mazao. Value in bracket are based on subsidy prices of DAP and Urea sold at half of market price

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