African Crop Science Conference Proceedings, Vol. 7. pp. 1465-1473
Printed in Uganda.
ISSN 1023-070X/2005 $ 4.00

Management of soil fertility in western Kenya: Experience working with smallholder farmers

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Abstract Crop yields in sub-Saharan Africa are low and unsustainable, reflecting prolonged food insecurity in the region. In Western Kenya, maize (staple) yields at small scale farm level rarely exceed 0.5 t/ ha/ season. These low yields are largely explained in terms of droughts and depleted nutrients in soils, among other reasons. Thus the farmland soils in Western Kenya, mainly the acrisols (utisols) and ferralsols (oxisols) are highly weathered, with widespread N and P deficiencies. Agricultural-based research during colonial rule focused studies on-station. Whereas the findings from such research provided the basic concepts underlying constraints, they had limited applicability at on-farm level, plagued with the main problem of variability among farming communities, agro-ecosystems, including soils. To this end the donor/ partner community stressed the need to conduct applied research including the delivery of extension and outreach messages to smallholder farmers. We therefore appreciated this sentiment and received the Rockefeller Foundation, TSBF-CIAT and KARI-ARF funding to install soil fertility based research on small farms in Western Kenya. Our team approach, including graduate students, consisted of initial problem (poor soils) identification through surveys and soil testing, followed by site selection and the farmer's involvement throughout the research period. We formulated and tested the effectiveness of low cost products such as phosphate rocks. Overall, we found farmers' knowledge and participation vital in our experimentation. Farmers observed striking responses to inputs and realized economic benefits accruing from the use of these inputs. However, in spite of these illustrations, socio-economic factors and the farmer's priorities will continue to dictate the targeted adoption of soil fertility management technologies in many African countries. We discuss general aspects of research-extension/ NGO-farmer interactions towards enhanced collaboration.

Key words: Food insecurity, infertile soils, on-farm trials, technology adoption, socio-economic problems

Résumé Les rendements de plantes en Afrique Sub-Saharienne sont faibles et non durables reflétant l'insécurité alimentaire prolongée dans la région. Dans l'Ouest du Kenya, le maïs (rabougri) produit à l'échelle du petit fermier rarement une quantité excèdent 0,5 t/ha/saison. Ces faibles rendements sont largement expliqués en termes de sècheresses et l'épuisement des nutriments des sols parmi entre autres raisons. Ainsi les sols des terres de ferme dans l'Ouest du Kenya, principalement les acrisols (utisols) et ferrasols (oxisols) sont hautement dépendant de la météo, avec déficiences en N et P rependues. La recherche basée sur l'agriculture durant le règne colonial avait focalisé les études sur les stations. Alors que les résultats à partir des telles recherches avaient fournis les concepts de base des contraintes prioritaires, ils avaient une applicabilité limitée au niveau de la ferme, accablés par le problème principal de variabilité entre les communautés des fermiers, les agro - écosystèmes, incluant les sols. A cette fin les donateurs / la communauté partenaire avaient souligné le besoin de conduire des recherches appliquées incluant la livraison des services des agronomes (d'extension) et des messages aux domiciles des petits fermiers. Nous avions alors apprécié ce sentiment et reçu la fondation Rockefeller, les fonds TSBF-CIAT et KARI-ARF pour installer la recherche basée sur la fertilité du sol sur les petites fermes dans l'Ouest de Kenya. L'approche de notre équipe, comprenant des étudiants d'après graduat, consistée à l'identification du problème initial (pauvres sols) à travers des enquêtes et les essais de sol, suivie par la sélection du site et l'implication des fermiers pendant la période de recherche. Nous avions formulé et testé l'efficacité des produits moins coûteux tels que les roches de phosphate. De façon Générale, nous avions trouvé les connaissances et la participation des fermiers vitales dans nos expériences. Les fermiers avaient observé les réponses frappantes aux intrants et avaient réalisé des bénéfices économiques provenant de l'usage des ces intrants. Cependant, malgré ces illustrations, les facteurs socio – économiques et les priorités des fermiers continueront à dicter l'adoption des technologies de fertilité de sol visée dans beaucoup des pays Africains. Nous discutons les aspects généraux de la recherche – extension / les interactions ONG – fermier vers une collaboration améliorée.

Mots clés: Insécurité alimentaire, sols infertiles, essais sur ferme, adoption de technologie, problèmes socio économiques

Introduction

In sub-Saharan Africa, the bleak constraint of food insecurity may be managed if smallhold farming communities accept to practice simple and economically viable technologies that have been recommended from long-term research efforts. Such recommendations include: the cultivation of diversified crops with improved genotypes, restoration of fertility of soils, disease and pest control and overall improved cultural practices. Research in agriculture in most African countries has undergone transitional phases. Thus in the early stages, mainly during the colonial rule, the research activities consisted of problem identification and finding possible solutions related to improved production. For example, in plant nutrition studies, pot tests carried out on-station were used from 1950s to diagnose nutrient deficiencies on major East African cropland soils (Birch, 1955; Chenery, 1956; Butters, 1961).

In the results transfer phase, there have been wide variations in the applicability and acceptability of findings recommended on-station. These variations are mainly explained by the fact that most small scale farmers do not practice the recommended improved crop production packages or technologies. Results are also specific to agroecozones. For example, in western Kenya, maize (staple) yields are commonly below 0.5 t/ha/season (Nekesa *et al*; 1999), against the potential yield (on-station) of 6 – 8 t/ha, obtained when a good seedbed, followed by the early planting of hybrid seed, together with 60 kg N plus 26 kg P/ha fertilizer application are done, along with improved cultural practices (Allan *et al;* 1972). Citing soil fertility studies on-station, there have been negative maize and sorghum responses to fertilizers applied in Kenya and Uganda (Okalebo, 2000); while on the other hand, a high maize yield of 8 t/ha has been found at Chepkoilel Campus, Moi University, on the control treatment receiving no fertilizer inputs (Kifuko, 2002).

These scenario are partly explained in terms of the long-term effects of fertilizer (particularly phosphate) applied to fields at the experimental stations; but this negative result of inputs is deceptive at on-farm level; where soils are generally nutrient depleted (Woomer *et al*; 2003a).

From yet another phase, from about 1980 to date, changes in research direction have taken place worldwide. The developing countries have in particular received donor/partner funding to support the costs of their research agenda, whereby the overall emphasis is to promote technology adoption through empowering the smallhold farmer to learn and participate on practical aspects related to increased and sustained agricultural production. To this end, we report our experiences working with farmers on soil fertility restoration based-research in western Kenya, the region with over 0.5 million hectares of poor, highly weathered and nutrient leached soils, mainly the acrisols and ferralsols (Woomer and Muchena, 1996).

Our approach consisted of conducting diagnostic surveys to identify/confirm limiting nutrients, followed by pot and field tests to study nutrient responses, including economic analysis of farm operations and crop yields to establish profits and losses as these govern the adoption issue. We trained graduate students and valued the farmer's knowledge and involved him throughout our experimentation. In this paper we highlight our experiences from both positive and negative findings which may be useful for future vital farmer's cooperation towards food security and poverty alleviation.

Study approach

Diagnostic tasks and farmer contacts. In our smallholder farm studies, we strongly believe that the farmer is the end-user of results or recommendations and that low and unsustained crop yields on-farm are dependent on a wide range of constraints. Therefore some forms of diagnostic studies are necessary to establish, obtain the magnitudes of constraints and prioritize the problems. Suggestions to solve the problems are then made. Thus to initiate our on-farm studies in western Kenya, from 19990s to-date, we first visited the District Agricultural Officers (DAOs) and their Divisional staff, including some NGOs in the region (Table 2). During these visits the purposes of our research studies were explained and discussed. Permission (administrative) was then given to conduct research in the pertinent district/division. Both extension and NGOs staff led on farm visits and site/farm selection.

To identify and prioritize production constraints, graduate students in various agricultural disciplines prepared brief questionnaires and used these to find answers from farmers on specific problems (Omare, 1998; Makokha *et al;* 1999). During the same farm visits, surface (0 – 15 cm) soils were taken separately from both high and low productivity portions in field identified by each farmer.

The soils were processed and analyzed in the laboratory to detect their nutrient levels and possible deficiencies prior to field experimentation (Okalebo *et al;* 2002).

Selected field experiments with farmers. Farmers in sub-Saharan Africa, including those of western Kenya, argue that they cannot afford the imported fertilizers because of their high and ever increasing prices (e.g. Sanchez *et al;* 1997). With this sentiment in mind, we have had variations in our soil fertility field studies.

But towards technology affordability and hence adoption, we have emphasized the use of low cost and effective local phosphate rocks: Minjingu phosphate rock (MPR) from Tanzania and Busumbu phosphate rock (BPR) from Uganda, where the two rocks are applied either directly or in combination with on-farm available low cost organics (crop residues, manures, composts), shrubs on hedges (tithonia diversifolia or lantana camara) or industrial wastes (pyrethrum residue). We are also examining the liming effect of phosphate rock and evaluating the performance of soil fertility management technologies on maize-legume intercropping system which is widely used in western Kenya. But all in all, we target site and technology specificity-based recommendations which have been lacking in many soil fertility studies.

Specific experiments

Testing of the PREP-PAC soil amelioration package. The composition and effectiveness of PREP-PAC on maize-legume intercrops in acid soils of western Kenya are rather widely known (Nekesa *et al;* 1999; Obura *et al;* 2001; Woomer *et al;* 2003b; Okalebo *et al;* 2005). Nonetheless, the reader is reminded that PREP-PAC, developed by Moi University, Eldoret, Kenya, consists of 2 kg of MPR (25 – 30% P_2O_5), 0.2 kg urea, Rhizobial (Biofix) inoculant with its component lime pellets and gum Arabic adhesive, 120 g food grain legume seed and instructions for use, written in English, Kiswahili and other local languages. One package is for use within 25 m^2 area of fertility depleted patches. We highlight in this paper the diversified effectiveness of the package over a range of legumes intercropped with maize in two staggered maize and legume rows, the MBILI system (Tungani *et al.*, 2002) at Nyabeda, Siaya, Kenya. The crop yield and economic data are presented in this paper.

Towards enhanced solubility and hence availability of P from phosphate rocks. The main hypothesis in this experiment is that the incorporation of low cost organics with phosphate rock into soils will enhance the solubility of the rock material through acidifying effect of the decomposing organic materials; this will eventually increase the release and availability of P for crop uptake and yield. Organic materials with varying quality (maize stover, tithonia, lantana camara, sugar bagasse, pyrethrum waste and manure) at 1 and 2 t/ha each, were incorporated into soils with each of the two different phosphate rocks above (MPR and BPR) at 40 and 60 kg P/ha, the rates considered affordable (Waigwa *et al;* 2003; Kifuko, 2003, Thuita *et al;* 2004). Maize-soybean-common bean intercrops were planted in the staggered two row MBILI system (above) on the acid (pH<5.5) and low available P (<5 mg P/kg) soils of Nyabeda Siaya, Kenya on-farm site. Changes in pH and P availability in soils were monitored throughout crop growth, including measurements of yield, N and P uptakes.

The liming effect of Minjingu Phosphate Rock (MPR). Most studies with MPR in East Africa have highlighted the direct and residual effects of the P component on crop yields (Mnkeni *et al;* 1991; Nekesa *et al;* 1999; Obura *et al;* 2001, Ndungu, 2003). It is however recognized that MPR contains about 38% CaO, the lime component. The effect of this separate liming component in this phosphate rock (and others) is not well documented in the East African region with widely distributed acid soils. This experiment therefore, also planted at the low soil pH and low P soils at Nyabeda (above), sought to delineate the P and liming effects of MPR. Inclusion of diammonium phosphate (DAP) isolated the effects of P, while agricultural lime (20% CaO) from Koru, Kisumu, Kenya, separated the effects of lime, thereby portraying the combined and separate effects of P and lime. The test crops were maize and beans intercropped under the MBILI system. Measurements included: changes in soil pH and available P in acid soils, crop yields, N and P uptakes (Nekesa *et al;* 2004).

Evaluation of soil fertility management technologies in western Kenya (Best-Bets). This trial, started from 2002 to date, (Woomer *et al.*,2003a) observes the existence of a wide range of technologies with diversified use of organic and inorganic materials to restore the fertility of nutrient depleted soils across western Kenya. Nonetheless, the technologies in place have rarely been compared side by side. Hence, from the collaborative effort (Table 3), eight soil fertility management technologies were compared in each farm across 140 smallholder farms (replicates) in seven districts of western Kenya. The soils (Table 3) have diverse characteristics. In addition to this, the climatic differences across districts or farms, do suggest site specific differences on the effectiveness of materials. The farmers are empowered to plant and manage their own trials. In the later part of the study (2004 and 2005) they will select their own best bet technologies for comparison and possible adoption. It is however important to emphasize here that the trials are installed according to the recommendations of each technology.

Results and discussion

Diagnostic studies. In the surveys across farms by Omare (1998) and Makokha *et al* (1999), it is clear that the majority of farmers in western Kenya do not apply fertilizers to their soils to increase crop production. Most of them had not heard about the existence of MPR probably as a result of an earlier misconception that his material was ineffective. This depends on the type(s) of soils where the material was tested and other unknown factors.

To this end, the Government Extension agents appeared 'reserved' to comment on MPR. But, on the basis of our positive findings, many retailers of agricultural inputs are now willing to sell the material (Mwaura, 2002).

The soil test data of surface (0 – 15 cm) soils from the 'good' and 'poor' crop productivity areas within and across farms in several districts in western Kenya, confirm the accuracy and importance of farmer's knowledge on evaluation of the fertility of his land. Thus, there are higher levels of total C and N and available P in the good portions of the land (perhaps due to some applications of nutrient inputs), compared to poor portions as indicated by the farmer himself (Table 1). Such farmers' knowledge should not be ignored in research endeavours. There is also an indication of soil pH reduction in poor portions of land, reflecting possible increased Al and Fe availability and hence enhanced P fixation in soils (J. Kamau and J. R. Okalebo, unpublished results).

Soil characteristics across western Kenya, year 2002. In Table 2 we present some soil characteristics across a much wider section of western Kenya. The surface (0 – 20 cm) soils were sampled randomly across each field for each farm and composite soils taken for laboratory analysis, prior to installation of the Best-Bets soil fertility management option experiment (iv) above. The data (Table 2) show the generally low pH, available P and organic matter (C and N) levels in soils (Okalebo *et al;* 2002), suggesting the need for major nutrient inputs in these soils. There are also wide differences in soil properties across districts, implying different fertility management strategies.

Diversifying the use of PREP-PAC, towards technology adoption. As indicated above, PREP-PAC targets the replenishment of depleted N and P nutrients as evidenced by poor crop growth with low yields in patches that are common on smallhold farms, particularly in western Kenya. Initial field tests with PREP-PAC across farms in western Kenya and in Uganda, compared the performance of this package on maize-bean or soybean intercrops whereby the legumes were planted between maize rows, the so-called the conventional intercropping system. But in an endeavour to diversity the applicability of PREP-PAC, from 2003 short rains to 2004 long rains, we planted a range of commonly grown grain food legumes in the region, with or without PREP-PAC applications (Table 3). All legume species were intercropped with maize using the improved staggered two maize and two legume rows, the MBILI system, reported to increase the yields of both crops, particularly through increased light radiation penetration to the legume (Tungani *et al.*, 2002). Table 3 presents the grain yields of maize and legume intercrops at the low P (<5 mg P/kg Olsen P) and acid (pH<5.5) soils of Nyabeda, Siaya site, in long rains in 2004. There was a significant

Table 1. Selected properties of surface (0 – 15 cm) soils from smallholder farms taken from good and poor fields in western Kenya.

District	pH (H_2O)		Total N (%)		Olsen P (mg/kg)	
	Poor area	Good area	Poor area	Good area	Poor area	Good area
Vihiga	5.20	5.63	0.16	0.25	1.2	2.0
Siaya	5.10	5.52	0.10	0.26	1.1	1.9
Bungoma	6.00	6.10	0.13	0.20	1.1	2.2
Means	5.43	5.75	0.13	0.24	1.1	2.0

Source: Survey by J. W. Kamau and J. R. Okalebo, June 2000.
Note: The good and poor crop productivity areas were identified by the farmers themselves in each field.

Table 2. Some properties of surface (0 – 20 cm) soils from Best-Bets experiment in western Kenya, year 2002.

NGO and District	Soil parameter			
	pH (H_2O)	% C	% N	Bicarbonate P (mg P/kg)
SACRED Africa, Bungoma	5.54	1.37	0.18	4.8
SACRED Africa, Teso	5.76	0.67	0.09	6.4
CARE (Kenya), Homa Bay	6.79	2.29	0.43	19.8
Resource Projects (Kenya), Vihiga	4.84	1.23	0.16	3.3
EAT, Trans Nzoia	5.26	2.01	0.27	3.5
ARDAP, Busia	5.13	1.00	0.27	4.0
SCODP, Siaya	4.82	1.67	0.18	3.6

Source: Moi University, Department of Soil Science Laboratory.
NB: The results are means of 20 farms from each district or NGO.

Table 3. Maize and legume yields (t/ha) from MBILI intercropping system on the control and PREP-PAC treatments at Nyabeda, Siaya on-farm site, first rains 2004.

Maize-legume	Maize grain			Legume grain		
	Control	PREP-PAC	% increase	Control	PREP-PAC	% increase
Maize-bambara nuts	0.64	1.47	130	0.43	0.44	2
Maize-dry beans	0.44	1.17	166	0.41	0.69	68
Maize-soybeans	0.55	1.14	107	0.1	0.25	127
Maize-yellow grams	0.51	1.14	124	0.13	0.23	177
Maize-cowpeas	0.29	1.29	45	0.15	0.34	127
Maize-groundnuts	0.31	0.90	190	0.43	0.44	2
Maize-dolicos (lablab)	0.51	1.07	110	nd	nd	nd
Means	(0.46)	(1.17)	(167)	0.28)	0.400	(67)

Note: nd = grain yields of dolicos unavailable due to logistics associated with hiring of labour to harvest this legume (dolicos) at irregular maturity periods compared to others.
Source: Ruto *et al.*, 2004.

($p \leq 0.05$) effect of PREP-PAC on grain yield increases, particularly those of maize.

There is also an influence of legume intercrops on crop yields whereby the maize yields on the control treatment (with no PREP-PAC) range between 290 and 640 kg/ha from maize-cowpea and maize-bambara nuts intercrops respectively.

Promising legumes in the PREP-PAC input under MBILI intercropping system appear to be cowpeas, common beans, ground and bambara nuts (Table 3). There are positive returns to investment (data not shown) from these legume-maize and PREP-PAC combinations (Ruto *et al;* 2004). More on-farm PREP-PAC diversification studies are suggested towards technology adoption challenge.

Enhancing the solubility of Minjingu (MPR) and Busumbu (BPR) and hence P availability through organic resource incorporation in soils. This experiment examined the performance of maize-soybean MBILI intercrop when organic materials commonly available (Table 4) with different qualities (Thuita, 2004) and quantities applied at 1 and 2 t/ha each, were incorporated into soils together with MPR and BPR at 40 kg P/ha each in the first rains 2004 at the depleted soil fertility Nyabeda, Siaya on-farm site above. All field experiments conducted at this site in 2004 were planted in different farms within Nyabeda area. Maize yields (Table 4) in this phosphate rock (PR) solubilization experiment in 2004 first rains ranged from 0.18 to 3.70 t/ha and were significantly ($p \leq 0.05$) increased by treatments applied, above the no inputs (control) treatments. There was Striga weed infestation particularly on malnourished control plots, which reduced yields even below the 0.50 t/ha on-farm level reported by Nekesa *et al* (1999). Maize seed planted was Western WH 502.

The highest 3.70 t/ha maize yield occurred from soluble Triplesuperphosphate (TSP) addition at 40 kg P/ha, and this yield figure is attributed to solubility of TSP', particularly at the early (7 weeks after planting) stages of maize growth (Thuita *et al;* 2004). Thus TSP out yielded BPR by a factor of nearly two. Higher MPR yields compared to BPR likely resulted from higher solubility of MPR as shown by differences in the bicarbonate extractable P levels (Olsen P) in soils about 1 to 2 months after planting the trials (Thuita *et al;* 2004) and also in a separate finding by Ngoze (2000). Both tithonia and lantana camara, associated with biomass transfer soil fertility restoration technology, gave consistently high maize yields when incorporated/combined with the PRs into soils.

Soybean grain yields (0.23 to 1.10 t/ha) under maize intercrop, were also significantly ($p \leq 0.05$) increased as a result of PRs and organics combined incorporation into soils. Again, the soluble TSP gave the highest soybean yield whereas the least soluble BPR with low quality maize stover combination gave the lowest yield (Table 4). Overall, MPR was superior to BPR as revealed in terms of agronomic effectiveness, whereby BPR and MPR were respectively found to be 46 and 75% as effective as TSP

Table 4. Maize and soybean grain yields (t/ha) from incorporation of phosphate rocks (PRs) with organics at Nyabeda, Siaya, first rains 2004.

Treatment	Maize	Soybeans	Total
Control	0.18	0.33	0.51
BPR with: Lantana camara tops	1.70	0.32	2.02
Maize stover	1.95	0.23	2.18
Pyrethrum waste	1.30	0.43	1.73
Tithonia diversifolia tops	1.82	0.36	2.18
BPR with organics means	(1.69)	(0.33)	(2.02)
MPR with: Lantana camara tops	3.07	0.72	3.79
Maize stover	2.36	0.73	3.09
Pyrethrum waste	2.48	0.78	3.26
Tithonia diversifolia tops	3.18	0.68	3.86
MPR with organics means	(2.77)	(0.73)	(3.50)
Farmyard manure at 2 t/ha	1.14	0.55	1.69
TSP at 40 kg P/ha	3.70	1.11	4.81
Overall means	(2.08)	(0.57)	(2.65)
SED	0.76	0.05	-
LSD (P = 0.05)	1.54	0.10	-

Source: Thuita *et al* (2004).
BPR = Busumbu phosphate rock from Mbale, Uganda, 5 – 12% total P.
MPR = Minjingu phosphate rock from Arusha, Tanzania, 11 – 13% total P.
TSP = Triplesuperphosphate.
N.B: Means of 1 and 2 t/ha organics are given.

in terms of maize grain yields. But with regard to soybean grain yield, BPR and MPR were 30 and 66% as effective as TSP respectively.

The liming effect of Minjingu phosphate rock (MPR) on maize-bean intercrop yields. In this experiment we tested the direct and combined effects of P and CaO contained in MPR through individual and combined application of DAP and agricultural lime from Koru, Kisumu, Kenya. Heavy doses of P (0 – 180 kg P/ha) as DAP or MPR and lime at (0 – 0.6/ha agricultural lime as MPR), with nitrogen at 160 kg N/ha, the amount of N in DAP at the highest 180 kg P/ha rate, significantly ($p \leq 0.05$) increased maize grain yields (0.48 to 6.24 t/ha) in the first rains 2004 at Nyabeda (Table 5). Positive crop yield responses from the combinations of P and lime have been reported in Ghana by Rowell (1994). On acid soils of Chehe, Kenya, higher tea yields have been obtained from 22 kg P/ha MPR compared to when 44 kg/ha P in DAP was added (Kanyanjua *et al.*, 2002). This observation appears to support the positive effect of combined P and lime addition from MPR compared to P alone as DAP, the finding of this present study (Table 5). Bean grain yield (0.28 to 0.93 t/ha) was also significantly ($p \leq 0.05$) raised from DAP, MPR and lime incorporated into infertile soils of Nyabeda in the first rains 2004 (Table 5). The higher bean yield of 0.93 t/ha from MRP, compared to that of 0.86 t/ha from DAP with lime combination at the highest P and lime levels, suggests the favourable and economical use of MPR having both P and liming effects, compared to DAP requiring additional lime input to produce yields equivalent to those of MPR in acid soils of western Kenya. Additional labour is needed to incorporate lime with DAP into soils.

On-farm evaluation of soil fertility management technologies in western Kenya (Best-Bets). As indicated earlier on, this experiment involved collaboration among stakeholders: the researchers, NGOs and small scale farmers across 7 districts and 140 farms in western Kenya from 2002 to date (Table 2). The experiment provided a rare opportunity to compare side-by-side, the performance of eight soil fertility management options below within and across farms. The farmers managed the trials and participated on technology evaluation, the prerequisite for technology adoption. The materials used and their rates of application, varied with each technology:

Table 5. Maize and bean grain yield (t/ha) from MBILI intercrop, from DAP, MPR and agricultural lime applications at Nyabeda, Siaya, Kenya, first rains 2004.

Treatment	Maize yield		Bean yield	
	Grain	% increase	Grain	% increase
Control	0.48	-	0.28	-
Lime	2.54	429	0.62	121
DAP	4.93	927	0.71	1.54
DAP + Lime	6.24	1200	0.86	207
MPR	5.67	1081	0.93	232
Means	(3.97)	(909)	(0.68)	(179)
SE	0.34	-	0.04	-

Source: Nekesa *et al.* (2004).
Means of 3 levels of each material application are given.

Table 6. Yields (t/ha) of maize-legumes from soil fertility managements (Best Bets) in western Kenya during two cropping seasons of 2002.

Management/technology	Long rains		Short rains		Cumulative (Ksh.)	
	Maize yield	Legume yield	Maize yield	Legume yield	Maize yield	Legume yield
No inputs (control)	1.95	0.19	0.51	0.14	14515	12036
Farmers' practice	2.64	0.22	1.00	0.19	25375	10987
Fortified compost	2.40	0.22	0.92	0.13	18895	13651
Mineral fertilizer (FURP)	2.72	0.24	1.10	0.150	24584	13238
PREP—PAC package	2.78	0.24	1.20	0.18	26185	13336
MBILI package	2.43	0.36	1.26	0.24	20811	25378
Crotalaria fallow[1]	2.06	0.21	n.c.	0.16	14515	9258
Lablab relay	2.03	n.c.	0.88	0.14	15412	10388
LSD 0.05 (a)	0.27	0.04	0.27	0.04	551	4150

[1]Management was intended to produce next season residual benefits. (a) LSD allows for yield comparison between management and season. n.c. shows no yield from the management as no cropping for the component was made in the season in question.
Source Woomer *et al;* 2003a.

(i) The absolute control, simulating the resource poor farmer with no nutrient inputs
(ii) Farmers' own practice where any form of manure, compost or inorganic fertilizer is applied at varying rates (estimated at 15 kg N + 17 kg P/ha as DAP in Bungoma but 4 t/ha manure/ compost in some districts).
(iii) Organic farming community treatment, with biogenic Minjingu PR fortified wheat straw or maize stover developed at Moi University, Kenya, applied at 2 t/ha (44 N + 8.5 kg P/ha).
(iv) PREP-PAC package as above; this is an input of 100 kg/ha P + 40 kg N/ha urea + Biofix, the Moi University package.
(v) Mineral fertilizer, the KARI – FURP (1994) treatment consisting of 75 kg N/ha CAN or urea + 26 kg P/ha TSP or DAP.
(vi) Mineral fertilizer for MBILI package above, with inputs of 31 kg N + 20 kg P/ha (DAP at planting but CAN as a topdressing).
(vii) ICRAF's maize-bean-crotalaria short fallow intercropping system designed to supply upto 200 kg N/ha from the biological nitrogen fixation (BNF) process, fixed by crotalaria, through legume biomass incorporation and nutrient deep root capture.
(viii) Legume cover crop maize cropping, with Dolicos Lablab incorporated into soils supplying mainly N. No other external inputs were applied to the fallow and lablab relay crops.

The soil properties of farms are summarized in Table 2 and the experimental procedures are summarized by Woomer *et al*. (2003a). But being on-farm trials, some failure (23%) in recovery of yield data existed. That is, yield data for crops from first nutrient inputs in the first rains and second rains 2002 (residual effects) were obtained in 107 farms (Table 6). The overall performance of intercropping management showed better performance from four technologies out yielding the no inputs management. The PREP-PAC package produced the highest yields (t/ha/yr) and MBILI produced the greatest annual net return (Ksh./ha/yr). This positive effect of MBILI economically is mainly due to its maize-groundnut intercrop. Groundnut is usually sold for about twice the price of beans. But overall, performance of technologies varied with sites (data not shown).

The research-extension/ngo-farmer interactions towards technology development and adoption. In the developing countries and from the case on-farm studies presented in this paper, many soil fertility management practices have generated positive crop responses and attractive returns to input investments. However, there is widespread slow to non-adoption of technologies.

Reasons for this rather negative attitude are multiple, but include the following:

i) In the third world countries, the structural adjustment and reform programmes from the 1990s have in a way benefited the middle man who sets the prices of farm produce. In most cases these prices are low for smallhold producer. Prices of inputs are generally high and increasing, making the inputs unaffordable; if not, these are applied below the recommended rates, or not applied at all.

ii) Reforms in a way have also influenced the accessibility of the formal Government extension services in that the farmer is expected to approach the extension agent and pay for services. Therefore extension messages are likely to percolate to able farmers thereby slowing down the adoption rates.

iii) Many farmers tend to adhere to specific practices or cultures of no change. For example, in the granary' districts in Kenya, Trans Nzoia and Uasin Gishu, there is a DAP and maize hybrid H 614 D culture. New messages on enhanced agricultural production are not readily received. This makes it rather difficult to implement the new or specific effective fertilizer or maize cultivar recommendations and adoption.

iv) Farmers have their own priorities. Most of them would rather buy food, pay school fees for their children and settle medical bills, rather than buy agricultural inputs.

v) The practices of handouts from donor communities in particular, including international organizations, does not expose many farmers to the need or reality of cost-sharing for acquisition of inputs. In some projects farmers are compensated for low yields on control treatment yields. Labour payments are also hiked well above the usual government rates. Projects with low funding, e.g. from Government Institutions, Universities, find it hard to hire labour.

vi) Many farming communities in rural areas are misinformed about the nature of research to be conducted at their farmlands. They therefore, believe that their land will be sold; the soils sampled from their fields may be containing gold which they will lose; all crop harvests will be taken away at maturity and that fertilizers will make their soils hungry etc. This is probably related to poor selection of farmers by Extension/ NGO staff for new research in that specific farmers are ear-marked by these agents. Hence the residual effects of fertilizers from previous projects certainly affect the results of new experiments just like most on-station situations cited in this paper.

vii) Training of farmers is inadequate in most areas. This is evidenced from one of the Field days recently hosted by Moi University – SCODP collaborative RUFORUM Project at Sega, Siaya.

Farmers asked:

Why do researchers introduce new maize varieties every year?

Why do termites feed on healthy maize plants receiving fertilizers or manures, but not on poor crops on control plots (Nekesa *et al*., 2005).

Shall we ever afford fertilizers?

Experimentation on-farm has other drawbacks such as:

The cows, goats and rodents feeding on experimental plots

Humans stealing produce before yield measurements are taken

Farmers harvesting and mixing harvests from specific plots/treatments and even consuming the produce before the experimenters visit the farms for harvesting their crops.

Researchers on the other hand tend to ignore the usual farmers' practices. Example, to save on labour, farmers almost always broadcast seed instead of row planting, particularly the small finger millet seed. It is advisable to build on farmers' practices. Above all, extension/outreach messages need simplification or the use of a language understood by the farmers.

Acknowledgement

We are grateful to the following for funding the training, on-farm and related research activities: The Rockefeller Foundation FORUM and Food Security Programmes, The KARI's Agricultural Research Fund (ARF) for making fortified compost and TSBF-CIAT. We extend our appreciation to the following graduate students whose contributions are highlighted in this paper: Musa Omare, M. O. Makokha, P. A. Obura, P. Nekesa, F. Mwaura, M. Waigwa- Musyoka, M. N. Kifuko, K. W. Ndungu, H. Mwaura, C. K. Kainyu, John Kamau, M. Thuita, A. O. Nekesa and S. Ngoze. We extend our gratitude to Marynancy W. for typing this paper. Finally we say thank you to the Vice Chancellor, Moi University for permission to attend this Conference and to present research results.

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