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POTENTIAL OF GRAIN LEGUME FALLOWS TO ADDRESS FOOD INSECURITY AND BOOST HOUSEHOLD INCOMES IN WESTERN KENYA

***1James K. Mutegi, 2Bashir A. Jama, 3Said Silim and 4Julia N. Ameru**

1International Plant Nutrition Institute (IPNI), sub-Saharan Program, c/o IFDC-East and Southern Africa Division, P.O. Box 30772-00100, Nairobi, Kenya
2Alliance for a Green Revolution in Africa, P.O. Box 66773, Westlands, Nairobi, Kenya
3International Centre for Research in the Semi Arid Tropics (ICRISAT), Nairobi, Kenya
4Kenya School of Government, P.O. Box 23030-00604, Lower Kabete, Nairobi, Kenya

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ABSTRACT

A pigeonpea fallow-maize crop rotation trial was carried out over a period of 4 seasons in western Kenya. The trial compared six high altitude long duration pigeonpea varieties i.e. ICEAP 00020, ICEAP 00040, ICEAP 00048, ICEAP 00053, ICP 9145 and ICP 13076 and a medium duration variety i.e. ICP 13211 for productivity, post fallow maize crop yield and financial returns indicators. Long duration pigeonpea varieties take 140-180 days to mature while medium duration varieties take >200 days to mature. Continuous maize cropping acted as a control. Depending on the variety, pigeonpea grain yield ranged between 1.3 and 1.9 t ha^{-1}. Post fallow maize grain yield from each of pigeonpea variety plot was approximately 3 fold higher than yield from continuous maize plots. The medium duration pigeonpea plots yielded significantly higher maize grain than the long duration (ICEAP 00053, ICEAP 00040) pigeonpea variety plots. Relative to the control, incremental returns to land were highest for medium duration pigeonpea fallow plots (619 USD ha^{-1}) and lowest for ICEAP 00040 fallow plots (305 USD ha^{-1}). We estimated that by selecting an appropriate pigeonpea variety for a fallow-maize rotation system, a household could produce sufficient food for consumption and remain with a surplus of approximately 2.8 tons for sale. For widespread adoption of pigeonpea based technologies in western Kenya, there is a need for policy improvement on issues related to improved seed production systems, cost of fertilizers, extension services, and market for the end products.

INTRODUCTION

Improved fallows are common low cost nutrient management technologies in eastern Africa (Buresh & Cooper, 1999). In improved fallows, fast growing N-fixing trees and shrubs are planted and managed as they rapidly enhance soil fertility, crop yields and provide wood for fuel and construction (Kwesiga & Coe, 1994; Sanchez, 1995). Additionally, through biomass retention they boost the soil organic matter and microbial diversity improving soil nutrient processing, soil structure and water holding capacity. Most of what is known about improved fallows emanates from long period of research with trees and shrubs and not on grain legumes although grain legume fallows are also common in the farms (Jama *et al.* 1998; Buresh & Cooper, 1999; Gathumbi *et al.* 2004). Grain legume fallows have the benefits of improving soil fertility while simultaneously producing consumable and marketable protein rich grains (Gathumbi *et al.* 2004) thus enhancing household food security and incomes. This makes them more attractive to the small holder farmers whose land is often too small to rationally allow for two or three seasons of no consumable/marketable output which characterizes tree fallows (Franzel *et al.,* 1998). Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one species that has demonstrated ability to improve soil health and improve yield of associated cereals while simultaneously yielding other consumable and marketable outputs like grain and fuelwood (Odeny, 2007). Across the entire Kenya, the area under pigeonpea rose from 156,492 in 1996 to 200,000 ha in 2005 and the popularity of pigeonpea is projected to continue growing (FAOSTAT, 2006) mainly driven by the high value of pigeonpea grain and its

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****Corresponding author: James K. Mutegi,***
International Plant Nutrition Institute (IPNI), sub-Saharan Program, c/o IFDC-East and Southern Africa Division, P.O. Box 30772-00100, Nairobi, Kenya

resilience to drought (Odeny, 2007). Besides, protein rich grains, pigeonpea fix up to 235 kg N ha^{-1} (Peoples et al., 1995) of which about 40 kg N ha^{-1} becomes available to rotated cereals (Nene, 1987). In a pigeonpea-cereal cropping system, this translates to savings of more than US$ 60 ha^{-1} that could have been used to purchase N fertilizers.

Western Kenya is one of the most populated regions in Kenya. In addition to being one of the poorest regions in Eastern Africa, the region has one of the highest HIV prevalence rates (about 15%) in the region. Food nutrition is therefore a crucial aspect of diet in this region but majority who live on < US$1 a day cannot afford to access nutritious food through markets (Nziguheba *et al*., 2010). For this type of region, legume crops play multiple roles; including provision of proteins (majority cannot afford animal protein), incomes from sale of high value grains, boosting production of associated cereals and hence food security and enhancing saving of money that is ordinarily spent on nitrogen fertilizers.

At present the average pigeonpea crop yield in western Kenya and other Kenyan regions is approximately 0.5 tons ha^{-1} relative to estimated potential of 2-3 tons ha^{-1} (FAOSTAT 2011). This yield gap has been associated with low quality seeds and inadequate P fertilization (Odeny, 2007). Further, there is very little if any data on post- fallow effect of pigeonpea on maize crop yield. Against this backdrop the main objectives of this study were: (i) to compare the effect of different pigeonpea variety improved fallows on maize grain yield and, (ii) to evaluate the potential contribution of pigeonpea-maize rotations on household food security and incomes. A secondary objective was to review the policy requirements for widespread uptake of successful pigeonpea-based technologies in Kenya.

MATERIALS AND METHODS

Site description

The present study was conducted for four seasons in two experimental farms located in Nyabeda and Khwisero divisions of western Kenya with one year of legume fallow, followed by 2 seasons of maize crop. The Nyabeda site lies at approximately 0.080'N latitude, 34.240'E longitude and is about 1300 m above the sea level while the Khwisero site lies at approximately 0.080'N latitude, 34.330E longitude and is about 1450 m above the sea level. In general, these sites fall within the Lake Victoria basin and highlands of East and Central Africa. The long-term monthly average temperature is 19.5°C with a maximum of 29°C and a minimum of 14°C. The soils are mainly Isohyperthemic Kandiudulfic Eutrudox, with the following soil properties in the top 15 cm: air-dried pH (1:2.5 soil water suspension) = 5.1, organic C = 15 g kg $^{-1}$, bicarbonate EDTA extractable P = 2 mg kg^{-1}, clay = 46% and sand = 26%. The region has a subsistence-level, mixed crop livestock farming system. The major crops of smallholder farmers are maize (mostly unimproved varieties) and beans (*Phaseolus vulgaris* L.), while the cattle are mostly unimproved breeds of Zebu (*Bos indicus*). Land pressure is high, with a population estimated at about 12 million, or about 30% of the total population of Kenya (GoK, 2009). Most farms are smallholder, with an average of 0.25 ha. Notwithstanding the small farms, leaving land fallow for 2 to 4 seasons is a common practice among farmers in the region, in order to improve soil fertility and crop yields (Kiwia *et al*., 2009; Jama *et al*., 2008). Although there has yet to be a definitive count of improved fallow users in western Kenya, by 2004 the users were estimated to be somewhere between 10,000 and 20,000 households per year (Place et al. 2004). Grain legume fallows are favored over legume tree fallows, due to their ability to produce consumable/ marketable grains during the fallow phase (Gathumbi *et al.,* 2004). In this respect, pigeonpea fallows are amongst the most popular grain legume fallows but very few quantitative studies have evaluated the benefits of integrating them into the maize production systems. Khwisero site had very high pigeonpea infestation by *Coccus alpius* pest. As, the pest infestations implied limited or low biomass yield, we opted to use this site to study the role of pests in pigeonpea production.

Experimental layout and management

The trials were established during the long rains cropping season in March 2007. A completely randomized block design consisting of seven pigeonpea varieties replicated four times was used in each site. The pigeonpea seed varieties evaluated were: ICEAP 00020, ICEAP 00040, ICEAP 00048, ICEAP 00053, ICP 9145 and ICP 13076 as long duration varieties and ICP 13211 as a medium duration variety (hereafter referred to as medium duration or MD). The medium-duration pigeopea varieties take 150–200 days to mature while the long-duration varieties take more than 220 days to mature (Mergeai *et al.,* 2001). The seeds we used in this trial were pure high quality seeds bred and tested by ICRISAT. Pigeonpea seeds were inoculated as per the ICRISAT recommendations and directly seeded in rows with intra- and inter-row spacing of 0.75 x 0.75 m. The test plot sizes were 5 x 4 m with a distance of 1 m separating them. Litter fall was collected continuously by use of 0.25 m^2 litter traps during the plant growth and recorded after oven drying to a constant weight. Final biomass was harvested concurrently with grain harvesting. The harvested biomass was separated into stems, branches and foliage (leaves and pods). Fresh weight for each plant part was determined at harvest and sub-samples used for dry weight determination. Nitrogen in the fallow biomass was determined by use of acid digestion method (Okalebo *et al.,* 2002).

We used these biomass N values to estimate the amount of N recycled through incorporation of foliage into the soil. Following pigeonpea fallow harvest, plots were tilled; foliage biomass (leaves + litter + pods) incorporated and fertilized with triple super phosphate (TSP) fertilizer at the recommended rate of 50 kg P ha^{-1}. They were then planted with maize (hybrid 513 variety) at a plant density of 53,000 plants ha^{-1} (the local agricultural extension recommendation rate) for two consecutive seasons. For the control plots maize (hybrid 513 variety) was planted for all the four seasons with 50 kg P ha-^{1} per season but with no biomass or N application. This was done to facilitate determination of the effect of pigeonpea biomass N on post fallow maize crop yield. Maize yield was assessed from a net harvest area of 12 m^2. After harvest maize was separated into cobs, grains and stover and each of these parts weighed to determine the fresh weight. Sub-sample moisture was determined by use of a moisture meter and the resulting moisture used for calculation of maize grain yield at 15.5% moisture content. Failure of pigeonpea varieties at the Khwisero site prompted an insect pest assessment in November 2007. These surveys were meant to determine the severity of pest infestation and consequently determine the most tolerant varieties for this region. The severity of infestation was expressed as the percentage of plants affected by pests.

Financial Analysis

Financial benefits were estimated by comparing the results from fallow plots with those of continuous maize cropping system hereafter referred to as the control. Costs and benefits of each variety were compared by use of partial budgeting procedures (CIMMYT, 1988). The extra costs of fallows relative to continuous cropping were: pigeonpea seed cost, cost of labor for establishing and harvesting pigeonpea and labor for preparation of firewood; extra benefits on the other hand included: pigeonpea fuelwood, pigeonpea grains, and post fallow increment in maize yield (Table 1). The values for these costs and benefits were obtained through a market survey in the region. Only pigeonpea wood with a diameter of > 2 cm up to a maximum of 2 Mg ha^{-1} per year was valued, because as shown by Jama *et al.* (2008), there is no formal market value for fuelwood and farmers typically give some wood to neighbors and friends for free. Swinkels et al. (1997) valued only 1 Mg ha^{-1} of wood from 3-10 Mg ha^{-1} of sesbania fallow wood while Jama *et al.* (1998) valued only 3 Mg ha^{-1} out of 21 Mg ha^{-1} of sesbania fallow wood in western Kenya. Labor requirements for various farm operations during the study were obtained from field observations.

Table 1. Values used for cost-benefit analysis, with U.S. dollar (USD) Kenyan shilling exchange rate estimated at 1:80

Data	Value
Inputs costs	
Maize seed rate, kg ha^{-1}	32.00
Hybrid maize seed, USD kg^{-1}	0.54
Pigeonpea seed, USD kg^{-1}	0.63
Triple super phosphate, kg ha^{-1}	250.00
Triple super phosphate, USD kg^{-1}	0.84
Transport of TSP to the home stead, USD kg^{-1}	0.012
Opportunity cost of capital per annum	20%
Labor cost	
Labor cost, USD labor-d^{-1}	2.5
Triple super phosphate application, USD ha^{-1}	50.00
Maize yield-dependent operations, labor-d ha^{-1}§	16.00
Pigeonpea yield-dependent operations, labor-d ha^{-1}§§	12.00
Pigeonpea harvest and firewood preparation labor-d ha^{-1}¶	25.00
Products	
Farm gate maize grain price, USD kg^{-1}	0.35
Farm gate pigeonpea grain price, USD kg^{-1}	0.50
Pigeonpea wood price; diameter > 2 cm, USD kg^{-1}	0.04
Maximum firewood valued, Mg dry wt ha^{-1}	2.00

For all the pigeonpea varieties, the seed costs were similar; 1 kg of pigeonpea seeds = 7000 seeds (Amadalo et al., 2003); § Includes yield-dependent field harvest operations, transport of cobs to homestead, and shelling of maize grain; §§ Includes yield-dependent field harvest operations, transport to homestead, and threshing of pigeonpea grain; ¶ Labor for pigeonpea harvest and fuelwood preparation assumes only 2.0 Mg ha^{-1} of wood is valued

Since during the first season pigeonpea in the fallow and maize in the control plots were planted at the same time, the labor cost for pigeonpea establishment was assumed to offset maize planting costs in the control plots for that season. All the inputs and outputs of different pigeonpea plots and the control were recorded in each of the four seasons and converted to monetary value using their 2007 market prices. The values were discounted at 10% per season (20% per year). The discount rate as commonly used in projects and investments reflects a farmer's preference to receive benefits as early as possible and postpone costs (Hoekstra 1985; Swinkels *et al.,* 1997). All monetary values were converted to US dollars at average dollar: Kenyan shilling exchange rate operational during the trial period (1 USD = 80 Kenyan shillings).

The dominance analysis procedures outlined in the CIMMYT (1988) were used to select potentially profitable pigeonpea varieties. The purpose of dominance analysis is to simplify subsequent calculations by ignoring inferior treatments. All treatments are first listed in order of increasing total variable costs. Any treatment with net benefits less than or equal to those of a treatment with lower cost is considered to be dominated (i.e., inferior). Dominated treatments are omitted from subsequent steps in the marginal analysis. The non-dominated treatments were ranked from the lowest to the highest cost treatment. For each pair of ranked treatments, a percent marginal rate of return (MRR) was calculated. The MRR between any pair of non-dominated treatments denotes the return per unit of investment. Thus, a MRR of 100% implies a return of 1 dollar on every dollar invested.

Data analysis

Biomass, grain yield and nutrient datasets were analyzed by GenStat for windows software (version 13, Rothamsted Experimental Station) (GenStat, 2009) and means separated by Duncan's multiple range test procedures. We used regression analysis to evaluate the hypothesized relationship between fallow biomass and maize crop yields. Unless otherwise stated values were considered statistically significant when P levels were either equal to or less than 0.05.

RESULTS AND DISCUSSION

Biomass yield and its implications at the farm and household level

Pigeonpea fallows produced an average of between 8.5 and 16.1 Mg ha^{-1} total aboveground biomass annually (Table 2). Most of the fallow biomass was wood which represented about 60% of the total biomass. Mugo, (1999) established that approximately 80% of the farmers in western Kenya face fuelwood scarcity and as a result use cow dung and crop residues for cooking and heating. This limits manure allocation to farms exacerbating the problem of land degradation; leading to reduced land productivity. Based on estimated household fuelwood need of 8.6 kg fuel wood/day (Mugo, 1999; Jama *et al.,* 2008), we computed the length of time annual fuelwood yield from a hectare of pigeonpea fallow would last a typical western Kenya household as between 1.7 and 2.9 years (Table 2).

On average, foliage biomass ranged between 2.0 and 5.3 Mg ha^{-1} and represented only 28% of the total aboveground biomass. This was the proportion of fallow aboveground biomass that was returned to the soil for purposes of soil fertility enhancement. These pigeonpea foliage biomass values are lower than those reported in western Kenya (Niang *et al.,* 2002) for 12 months old *T. vogelii* (8.2 Mg ha^{-1}) and *S. sesban* (7.4 Mg ha^{-1}) fallows. This suggests a possibility for lower nutrient cycling by pigeonpea relative to non-grain producing leguminous fallows but as will be shown later in this paper,

Table 2. Pigeonpea biomass, grain production and the duration post fallow fuel wood can last a typical household in western Kenya

Variety	Foliage yield (Leaves + litter fall + pods)	Wood yield	Grain yield	Total aboveground biomass yield	Household fuelwood consumption duration (years)
	………………………………	……Mg ha^{-1}	………………		
ICEAP 00020	4.1abc	8.4a	1.4b	13.8ab	2.7
ICEAP 00040	2.0c	5.2a	1.3b	8.5b	1.7
ICEAP 00048	5.3a	9.0a	1.7ab	16.0a	2.9
ICEAP 00053	2.0c	5.7a	1.5ab	9.3b	1.8
ICP 13076	2.8bc	7.1a	1.9a	11.8ab	2.3
ICP 9145	4.3ab	7.7a	1.7ab	13.7ab	2.4
*MD	3.7abc	7.1a	1.4b	12.2ab	2.3

*MDM-Medium duration variety

the benefits associated with observed 1.3-1.9 Mg ha^{-1} of grains could overcome this limitation. The N cycled to maize through foliage incorporation ranged between 75-203 kg N ha^{-1} (Table 3). Cycled N was significantly higher for ICEAP 00048 and ICP 9145 than ICEAP 00053 and ICEAP 00040 ($P<0.05$). The amount of N cycled by ICEAP 0048, ICP 9145, ICEAP 00020, medium duration material and ICP 13076 was statistically similar ($P<0.05$). The quantities of N removed through wood ranged between 37 and 65 kg N ha^{-1}. Thus about one third of the N in standing pigeonpea biomass was exported from the soil-plant system. Use of pigeonpea wood as fuelwood reduced the need for use of cow dung as a source of fuel energy. This implies that under pigeonpea fallow system more cow dung is available for use on farm as manure instead of being used for cooking and heating. In addition to the effect of fallow biomass on soil, the retained manure boosts soil quality further through improvement of soil organic matter.

Table 3. Nitrogen yield from 12 months old pigeopea fallows in Nyabeda

Treatment	Foliage	Wood	Total
	--------------------	N yield (kg ha^{-1})	--------------------
ICEAP 00020	156abc	60.3a	217ab
ICEAP 00040	75c	37.3a	112c
ICEAP 00048	203a	65.1a	268a
ICEAP 00053	77c	41.2a	118c
ICP 13076	105bc	51.2a	156b
ICP 9145	163ab	55.7a	218ab
*MD	142abc	50.8a	193abc

*MDM-Medium duration variety

Relationship between maize grain yield and pigeonpea fallows

Post-fallow maize grain yield from each of the seven pigeonpea variety plots was more than 3 fold higher than those from continuous maize plots (control) (Table 4). Summed across the 4 seasons (fallow + post fallow period) the medium duration pigeonpea fallow plots produced significantly higher maize grain than ICEAP 00053 and ICEAP 00040 pigeonpea varieties. Although not significantly different, maize yield from medium duration plots were somewhat higher than yields from ICEAP 00048, ICP 9145, ICP 13076 and ICEAP 00020. The relationship between the amount of foliage returned to the soil and maize yield (Figure 1) was linear and positive ($r = 0.77$), and so was that of the amount of foliage N and maize yield ($r = 0.74$). In cause-effect terms, this implies that those pigeonpea fallows that produced more foliage added more nutrients to the soil led to better maize grain yields in such plots relative to those for fallows that produced less biomass.

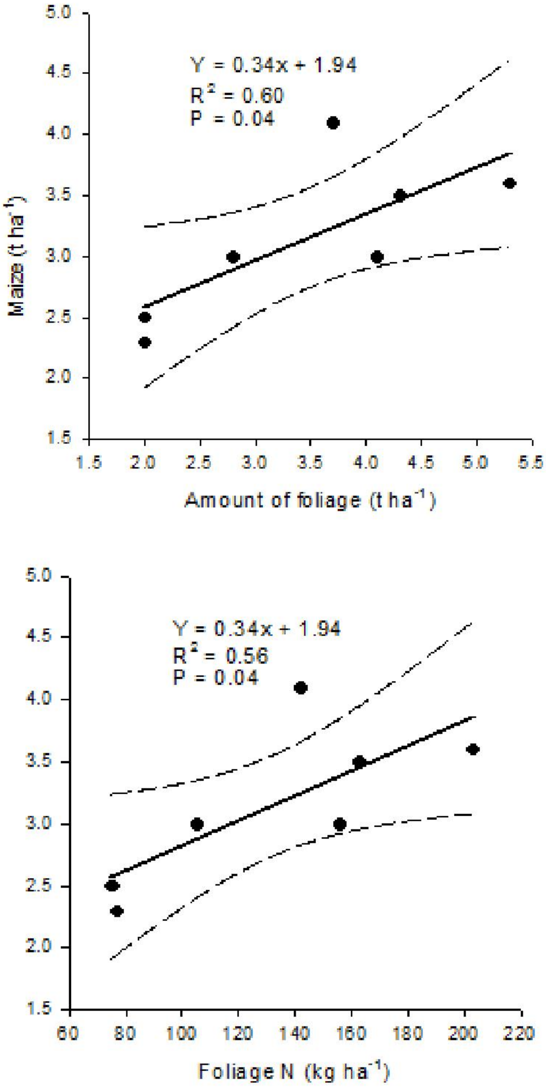

Figure 1. Relationship between pigeonpea foliage and foliage N with maize grain yield. Dotted lines represent the 95% confidence interval for regression line

The averaged cumulative yield in the pigeonpea plots ranged between 6 and 9.6 tons/ha while total maize crop yield from the control was about 5 tons/ha. This implies that inspite of four seasons of maize harvest for the control against 2 seasons for pigeonpea fallow plots, the cumulative maize grain yields from fallow plots exceeded yields from the control plots highlighting the role of soil N deficiency in limiting maize crop yield in western Kenya.

Table 4. Maize grain yield during the pigeonpea post fallow seasons

Treatment	Post fallow season 1	Post fallow season 2	Total
Control	1.1a	1.2a	2.3a
ICEAP 00053	3.6b	3.0b	6.6b
ICEAP 00040	3.6b	3.1b	6.7b
ICEAP 0020	4.3c	3.6c	8.0c
ICP 13076	4.4c	3.4bc	7.8bc
ICP 9145	4.8d	3.7c	8.6d
ICEAP 00048	5.0d	3.7c	8.8de
MD	5.5e	4.1d	9.6e

MD-Medium duration variety; Means followed by different letters are significantly different. Yield values coinciding to fallow phase for the control have been omitted from this table but used in economic analysis

Pest infestation as a challenge to pigeonpea production

Several insect pests are associated with pigeonpea. Insects such as flower thrips *(Megalurothrips Spp*), blister beetles *(Mylabris Spp*), pod sucking bugs (*Clavigralla Spp*), and pod borers (*Helicorverpa Spp*) are important pests that significantly reduce pigeopea yield (Minja *et al.* 2000). Leaf hoppers (*Empoasca Spp*) and some defoliator larvae were abundant in Khwisero during the experimental period. The most prevalent and damaging pests were coccids (*Coccus alpinus* De Lotto) from the family Coccidae. ICEAP 00048 and ICEAP 9145 tolerated Coccus *alpinus* infestations better than other varieties (Figure 2). Coccus infestation led to total destruction (100%) of ICEAP 00040 and medium duration variety in this site. As indicated by Odeny (2007), chemical control of these pests is expensive and often unaffordable by poor smallholder farmers. Therefore in addition to other challenges, pests are a key threat to sustainability of pigeonpea- based production systems.

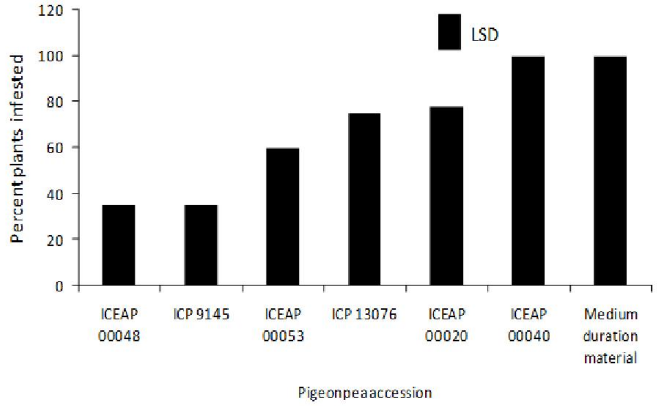

Figure 2. Percent pigeonpea plant infested with coccids (*Coccus alpius)* at Khwisero, western Kenya. Error bar represents LSD

Returns to factors of production

Net returns to land and labor for pigeonpea fallows relative to the control were consistently positive (Table 5). Among the fallows, returns to land were high for the medium duration material, ICEAP 00048, ICP 9145 and ICP 13076 and low for ICEAP 00040. Similarly return to labor was highest for medium duration variety, ICP 13076, ICP 9145 and ICEAP 00048 and low for the ICEAP 00040. This implies that the return to factors of production were lowest for the ICEAP 0040, suggesting that in households where these factors are limiting, it is more rational for farmers to ignore ICEAP 0040 in preference to other varieties.

Dominance analysis suggested that 6 of the pigeonpea fallow varieties, i.e; medium duration material, ICP 9145, ICEAP 13076, ICEAP 00053, ICEAP 00048, ICEAP 00020 would be profitable while ICEAP 00040 would not be profitable relative to the control. The marginal rate of return analysis of non-dominated fallows (ranked in the order of increasing variable costs) demonstrated that a change from the lowest cost ICEAP 00020 to higher cost ICP 13076 would produce the highest returns per every dollar invested ($20 per every $1 invested) (Table 6). These huge differences in return were directly linked to the huge differences in crop yields (both pigeonpea and maize grain) inspite of lesser variable cost of production. So for very slight differences in cost the differences in value of output were significantly higher.

Table 6. Marginal cost and returns from non-dominated pigeonpea improved fallows in Nyabeda

Treatment	Marginal cost (US $ ha^{-1})	Marginal benefit (US $ ha^{-1})	Return per US $
ICEAP 00053	31.5	313.1	9.9
ICEAP 00020	9.6	101.0	10.5
ICEAP 13076	6.0	119.9	20.0
ICP 9145	6.0	51.6	8.6
ICEAP 00048	0.7	6.4	9.1
*MD	4.6	27.2	5.9

* MDM-medium duration variety

Potential impact of pigeonpea on food security and foreign exchange earning

Over the 4 seasons of this trial, cumulative yields from pigeonpea fallow plots totaled to an average of between 1.3-1.9 t ha^{-1} for pigeonpea and 6 to 10 t ha^{-1} for maize. Total edible grain (pigeonpea + maize) yield from pigeonpea fallow plots therefore ranged between 7 and 12 t ha^{-1}. As the average arable household farm holding under food crops in western Kenya is estimated at 0.25 ha (Jama *et al.,* 2008), through

Table 5. Effects of pigeonpea improved fallows on added net benefits/ returns to land and returns to labor for the entire study period in Nyabeda, western Kenya

Treatment	Gross added benefits ($ ha^{-1})	Total added cost ($ ha^{-1})	Returns to land over control (US $ ha^{-1})	Returns to labor over control (US $ work days^{-1})
ICEAP 00020	455.3	41.1	414.1	5.7
ICEAP 00040	337.1	32.4	304.8	5.2
ICEAP 00048	645.8	53.8	592.0	6.9
ICEAP 00053	344.6	31.5	313.1	5.6
ICEAP 13076	581.2	47.1	534.0	7.2
ICP 9145	638.7	53.1	585.6	6.9
*MD	677.	58.4	619.2	6.7

*MD-Medium duration variety; pp-pigeonpea; Total added cost = Capital + labor costs adoption of pigeonpea fallow-maize rotation, a typical household could produce about 5 tons of food (maize + pigeonpea) in 4 seasons which is higher by about 3.5 tons/ha relative to yields that would be recovered were the households to continue with continuous maize cropping in the same region. By use of estimate of 1 ton as amount of food required to feed a household of 5.5 persons/yr (see, Denning *et al.,* 2009), we estimate that through inclusion of appropriate varieties of pigeonpea in maize cropping systems as improved fallows a household of 7 would produce sufficient food for consumption and remain with a surplus of about 2.8 tons. Conservative estimates by use of market value of US$ 300 for a ton of maize (Ariga *et al.,* 2010) and US$ 400 for a ton of pigeon pea (Shiferaw *et al.,* 2008) showed that such surplus could boost household income by >US$ 900. Through scenario analysis, Kristjanson *et al.* (2004) demonstrated that if food surpluses are maintained and linked to markets they could act as a pathway for permanent escape from poverty and food insecurity in western Kenya.

Like for any other developing country, foreign currency is crucial for Kenyan economy. The Kenyan pigeonpea export market has continued to grow over the last two decades owing to the attractive international market in India and other Asian countries (Odeny, 2007, Rusike and Dimes, 2004). Presently over 60% of pigeonpea produced in East Africa is exported to these Asian countries, at a value of between US$ 500 and 600 per ton (Fintrac, 2012). This value is between 1.5 and 2 fold higher than the value of a ton of maize whose average market value both locally and abroad is lower than US$ 350 per ton (Ariga *et al.,* 2010). Established across more than 30,000 hectares of land in western Kenya that is appropriate for such practices, the foreign currency earnings by Kenya from pigeonpea would be in excess of US$ 18 million. As western Kenya is classified as one of the poorest regions in Kenya, such improved incomes are crucial for enhancing access to quality food, education, medical services and boosting household wealth.

Important areas for policy interventions

Although integration of superior varieties of pigeonpea in maize-fallow systems has a high potential for boosting livelihoods; the success of such interventions can only be possible in an environment with appropriate agricultural policies (Shiferaw *et al.,* 2008). The constitution of Kenya 2010 devolved the agricultural functions to the county (regional) level bringing agricultural services closer to where they are required. This constitution created 47 counties with a capacity to make regional specific agricultural policies. This is crucial for identifying region specific variations in soil fertility, physical and biological characteristics, nutrient deficiencies and climatic conditions and matching such variations with procurement and delivery of the most appropriate seeds, fertilizers and other soil amendments (e.g inoculants and lime) at an appropriate time. In particular, the key policy issues for boosting adoption and returns from pigeon pea-maize cropping system in western and other favorable parts of Kenya are:

Improve farmer access to appropriate inputs- Due to continued cultivation with limited soil nutrient replenishment, western Kenya soils are highly depleted of most important nutrients (Titonell et al., 2008). These nutrients especially P and K must be supplied from external sources like commercial fertilizers. Short supply of P to pigeonpea may decrease nitrogenase activity and ATP concentration in nodules limiting plants ability to fix adequate N (Adu-Gyamfi *et al.,* 1990; Ogata *et al.,* 1998). Even with optimal fertilizer application, about 30% of crop yield is a function of the genetic potential of planted seeds. But due to high poverty levels over 30% of western Kenya farmers plant uncertified seeds with either lower than recommended or no fertilizer application. As a result the crop yields rarely exceed 1 ton/ha for maize and 0.5 tons for legumes against the regional potential of 7 tons/ha and 2.5 tons/ha for maize and legumes respectively (Ngome *et al.,* 2013).

This has been associated with farmers' inability to access adequate fertilizers and certified seeds as a result of either in availability and in ability to afford (Shiferaw *et al.,* 2008; Ariga *et al.,* 2010). The government should develop policies that improve access to appropriate fertilizers and quality seeds. This can be done through support of widespread distribution of agro input stockists, input financing and legume breeding programs. Traditionally fertilizer has been sold in packages of 50 kg, which are either un affordable or in appropriate to most of western Kenya farmers who own less 0.25 ha of land (Swinkels *et al.,* 1997). Repackaging of fertilizers into smaller packets is increasingly taking place, but this is sometimes associated with fertilizer adulteration and counterfeit products. Often, farmers also buy low quality seeds presented as certified seeds. The Kenyan government could handle this by boosting the capacity of Kenya Bureau of Standards (KBS) and the Kenya Plant Health Inspectorate Services (KEPHIS) to investigate and restrict sale of sub standard or adulterated farm inputs. To be more effective, such investigations should be backed by appropriate constitutional acts and educational programs to build farmer awareness of substandard products.

Improve extension services- In order to be successful, access to fertilizers and seeds must be accompanied with appropriate agronomic practices. Legume based technologies require complex interventions like, fertilizer application and inoculation for which farmers require support. However like with many other African countries the extension worker-farmer ratio in western Kenya is significantly lower than the recommended 1:400 ratio. The contact between farmers and extension workers is therefore limited, limiting farmers' access to knowledge. In Kenya the training of agricultural graduates reduced by more than 100% in the 1990s due to reduced funding of agricultural training institutions and reduced employment rates for agricultural graduates. The number of originally recruited agricultural workers has also been diminishing due to retirements, death and movement to more lucrative career opportunities. There is therefore a need for better investment in extension services. In short run innovative extension methods like mobile phones, radios, videos and TVs can be embraced but ultimately more personnel will be required to support the technology.

Provide farmers with risk management tools- Crop failure is common in western and surrounding regions in Kenya. This has most often been associated with droughts, which have become common lately owing to climate change. Other causes of crop failure are pests and diseases as this study has shown in the case of Nyabeda. Apart from the pigeonpea pests, striga affects over 50% of farms in western Kenya and it is associated with annual cereal crop yield losses of up to 30%. Significant volumes of grain are also lost after harvest. The losses may be in terms of grain quality (aflatoxin contamination) or quantity (volume shrinkage or deterioration of condition). According to the African Postharvest Losses Information System (APHLIS), post harvest losses in Kenyan highlands and other regions in Eastern and Southern Africa alone are estimated at US$1.6 billion per year, or about 13.5% of the total value of grain production (US$11 billion). The government should therefore enact policies that buffer farmers from such risk. Such policies could include: support and promotion of weather forecasting programs, promotion of water management programs, weather indexed crop insurance schemes, provision of affordable pesticides and herbicides, post harvest seed handling training programs and development of effective seed storage facilities.

Link farmers to output market-Assurance of sustained profit is key to widespread adoption of high yielding pigeonpea varieties and therefore better yields of pigeopea and associated crops. Although Fintrac, (2012) shows that the demand for pigeonpea grains is higher than the supply and prices in international market surpass US$ 500 per ton, farmers access to such remunerative markets is limited (Shiferaw *et al.,* 2008). As a result, most farmers sell their produce immediately after harvest at less than US$ 300 per ton to exploitative middlemen denying them a chance to improve their household food security and wealth through market returns. This implies a need for better investment in market research, market information systems and value addition in addition to development of partnerships with key players in pigeonpea agronomy, breeding and marketing to map the demand and match it with the production/supply.

Regional integration- Although it is widely recognized that intra-regional trade could play a significant role in accelerating economic growth, reducing poverty and enhancing food and energy security in Africa, the continent continues to trade little with itself and with other continents. As a result improved crop varieties, farm input supplies and agricultural commodities do not flow freely across borders leading to duplication of research efforts, food wastage in some countries/regions concurrently with famine in others (UNECA, 2010). This is largely attributed to existing barriers (both tariff and non-tariff) to the free movement of goods and services across countries. Improved regional trading policies will be crucial for enhancing food security and improving profitability of agricultural activities.

Conclusions

We observed higher financial returns from pigeonpea fallows in comparison to continuous maize cropping. Among the pigeonpea varieties evaluated, the medium duration was the most economically attractive fallow owing to higher marginal rate of return and high returns to both land and labor. On the other hand, ICEAP 00040 was the least attractive as a result of low returns to land and labor. Despite the promising results of these fallows in Nyabeda, pigeonpea fallows could not withstand pest infestation in Khwisero. This implies that for pigeonpea fallows to survive in Khwisero either costs related to pest control have to be incurred or pest resistant varieties have to adopted. By selecting an appropriate pigeonpea variety for a fallow-maize rotation system, a household could produce sufficient food for consumption and remain with a surplus of approximately 2.8 tons for sale. For widespread adoption of pigeonpea based technologies in western Kenya, there is a need for policy improvement on issues related to extension sevices, improved seed production systems, input costs, risk management tools, and market for the end products.

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