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POTENTIAL OF PASTURE LEGUMES IN LOW-EXTERNAL-INPUT AND SUSTAINABLE AGRICULTURE (LEISA). 2. FARMER ADAPTATION OF STARTER TECHNOLOGY BY FARMER RESEARCH GROUPS IN LUAPULA PROVINCE, ZAMBIA

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SUMMARY

The participatory approach of Farmer Research Groups (FRGs) was used in Farmer Adaptation of Starter Technology (FAST) with small-scale farmers in Luapula Province, Zambia. The introduction of a starter technology proved to be a suitable method to induce self-help initiatives with farmers. Their first move in FAST related to the improvement of food security and income generation by the cultivation and marketing of new maize (*Zea mays*) varieties in wetlands during the dry and early rainy seasons. By informal on-farm seed multiplication the expenditure on external agricultural inputs was reduced. The technical aspects of the starter technology began with the integration of pasture legumes as a pioneer crop for green manuring purposes in maize production. In this respect, FRGs developed individual risk-aversion strategies to ensure early planting of the maize with the onset of the rains. The groups made adaptations such as biomass transfer, intercropping and crop rotations in order to integrate pasture legumes into current cropping systems for green manuring purposes.

INTRODUCTION

As part of its mandate in the Low-External-Input and Sustainable Agriculture (LEISA) sub-component within the Luapula Livelihood and Food Security Programme (LLFSP) in the north of Zambia, co-ordinated on-station and on-farm trial programmes were carried out by the Farming Systems Research Team, Luapula Province (FSRT-LP). LEISA was understood as a concept to induce the development of technical options whereby small-scale farmers could reduce expenditure on external inputs. Emphasis was laid on new options for maize (*Zea mays*) production through the introduction of new varieties and the application of green manure from pasture legumes as supplements to mineral fertilization. To achieve a high degree of farmer participation, LEISA co-operated with Farmer Research Groups (FRGs), which had been constituted in conjunction with the Participatory Extension and Adaptive Research (PEAR) approach introduced by

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LLFSP. Findings from on-station research were presented by Steinmaier and Ngoliya (2001) and the results from the Farmer Adaptation of Starter Technology (FAST) are presented in this paper.

MATERIALS AND METHODS

Farmer research groups

FRGs operate on a permanent basis and are self-sustaining. The basic philosophy of the approach is to empower farmers to analyse their farming situations, to identify and prioritize their agricultural problems, to seek solutions by integrating their indigenous knowledge and skills but also to formulate and present demands to agricultural extension and research institutions. This means that the mandate of FRGs in LEISA includes conducting field trials, promoting active participation of farmers in the development of research agenda, evaluating trial activities and disseminating new findings to fellow farmers. A FRG is an umbrella group at camp level. A camp comprises several villages and is the smallest operational and institutional unit in the agricultural extension system in Zambia. FRGs consist of farmer-representatives of different community groups from all villages of the respective camps. On-farm activities undertaken by FRGs include regular meetings for information exchange, planning and harvest assessments as well as implementation of trial and demonstration programmes, monitoring and evaluation at field days.

Operational areas

Within the on-farm research programmes, LEISA operated with FRGs in 15 pilot areas that had been identified by LLFSP as being representative of the whole range of farming and livelihood systems prevalent in the Luapula Province (MAFF and FINNIDA, 1994).

Starter technology

In order to respond to the agricultural problems identified together with farmers, the concept of a starter technology was developed. Experiences and findings from recent and current on-station investigations in Zambia were included. The idea behind this concept was that farmers should have the choice of either adopting the starter technology as it had been designed, or adapting it according to their farming environments and needs. The concept was discussed with all FRGs. In separate meetings the farmers made their decisions on who – whether the individual or the group – should carry out the trial, and where it should be located.

The concerns and components of a starter technology implemented together with FRGs during the rainy season of 1995–96 are described in Table 1. A pioneer pasture legume crop for green manuring purposes was sown in the early rainy season. In the middle of the rainy season and two weeks after the incorporation of the pioneer crop biomass into the soil, a food crop was planted on the same field.

Table 1. The conceptual set-up of the LEISA starter technology

Concern	Purpose	Species	Character
Improved soil fertility management and reduced costs on mineral fertilizer	Green manure	*Crotalaria zanzibarica*	Atmospheric N-fixing pasture legume; easy to establish; fast growing; easy to harvest
Reduced costs on seed and enhanced access to seed	Food and seed production	*Zea mays* cv MMV 400	Staple crop in Luapula Province; short maturation period; open pollination; white colour of grain and meal; reasonable performance at low fertilizer levels

For this field experiment a complete block design with two fertilizer treatments and two replications was chosen. The plot sizes were 5×8 m. On two out of four plots a pioneer crop of sunn hemp (*Crotalaria zanzibarica*) was sown with the first rains in October-November 1995 and was ploughed under in early- to mid-January 1996. Farmers were recommended to broadcast the sunn hemp seed in the manner normally used in finger millet (*Eleusine coracana*) cultivation because broadcasting is less labour-intensive than planting in lines. The seed rate was 30 kg ha^{-1}. Two weeks after the incorporation of the sunn hemp biomass, an early-maturing and open-pollinating maize variety MMV 400 was sown on all four plots. No recommendations were given on land preparation for maize but, in the Luapula Province, farmers usually plant maize in ridges to minimize the risk of water-logging in this high-rainfall area. The plant spacings were 90 cm between rows and 25 cm within rows with two seeds per station. This resulted in a seed rate of 20 kg ha^{-1}. To both treatments – with and without green manure – mineral fertilizer was applied at 100 kg ha^{-1} compound D (D) plus 50 kg ha^{-1} ammonium nitrate (AN). The fertilizer rates were less than half the rates recommended for maize production by the agricultural extension services in Luapula Province.

Statistical analysis

In addition to the independent-samples t-Test procedure, descriptive statistics were used to explore the data. All statistical procedures were carried out at Mansa Technology Assessment Site (TAS) using the SPSS for Windows™ statistical software package for personal computers.

RESULTS

Rainy season 1995–96

Starter technology trials. In the 1995–96 rainy season, 12 FRGs conducted 14 trials of the starter technology. At Mwenda and Mubende, two trials each were carried out. Figure 1 shows that maize grain yields showed a significant response to green manure application. The mean relative green manure effect was +36.5% while

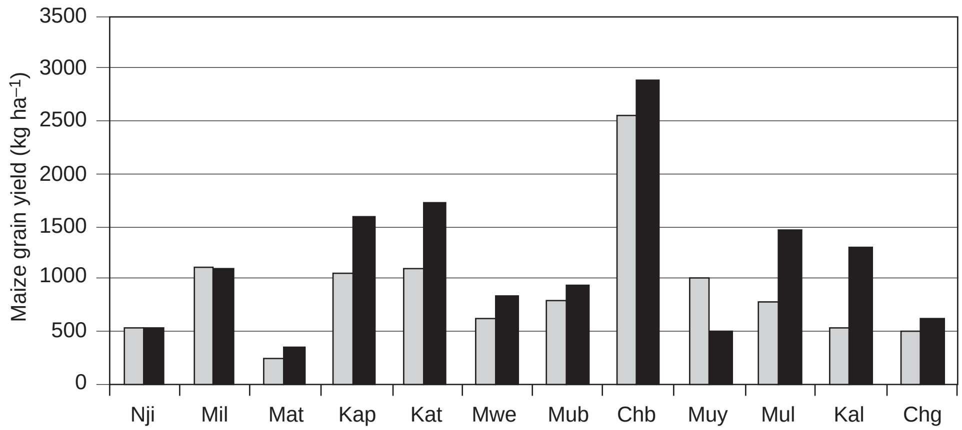

Fig. 1. Results from starter technology on-farm trials conducted by FRGs on early maturing and open-pollinating maize MMV 400 at low mineral fertilizer input in combination with *Crotalaria zanzibarica* incorporated as green manure during the rainy season of 1995–96. Participating FRGs: Njipi (Nji), Milambo (Mil), Matanda (Mat), Kapalala (Kap), Katuta (Kat), Mwenda (Mwe), Mubende (Mub), Chibote (Chb), Muyembe (Muy), Mulwe (Mul), Kalembwe (Kal), Chienge (Chg). Maize grain yield (kg ha^{-1}) without green manure (■) and with green manure (■) application.

extreme values were +138.8 and −40.2%. In a departure from the trial design, some farmers did not apply mineral fertilizer to those plots where green manure was incorporated, for example at Njipi. In other instances as in Muyembe, they put the mineral fertilizer assigned for two plots on only one plot. In those cases, therefore, the sunn hemp had to compete with either no added mineral fertilizer or double the recommended application rates and this resulted in negative relative green manure effects (−40.2%). Inadequate weeding – only once per season – caused generally low maize grain yields.

At FRG field days, farmers judged in favour of *Crotalaria zanzibarica* as a green manure because of their assessments of the resultant maize crop stand: a more vigorous growth habit, taller plants, more intense green colour and larger numbers of cobs per plant. Positive reactions from farmers were also noted regarding the early-maturing characteristic, the white colour and the sweet taste of MMV 400.

Wetland cultivation of maize. The introduction of the starter technology resulted in further demand for seed of MMV 400 by some FRGs and by individual farmers in the neighbourhood of the operational areas who wanted to test the new maize variety on wetlands (dambos). Thus, for the dry season of 1996, seed packages (0.4 kg) for assessment plots (10 × 20 m) were provided by FSRT-LP. Farmers were advised to cultivate the MMV 400 variety in isolation from their local maize varieties to avoid cross-pollination.

FRGs from 34 locations at Kazembe, Muyembe and Chibote in Kawambwa District reported some good potential of MMV 400 for dambo cultivation. At zero fertilization, the mean grain yield reached 1745 kg ha^{-1}, ranging from 212 to

3816 kg ha^{-1}. Results from 27 locations at Lubunda dambo, an area adjoining Mulwe FRG in Mwense District, showed a mean grain yield of 2449 kg ha^{-1} without added mineral fertilizer. Here the highest grain yield was 4800 kg ha^{-1} and the lowest 1080 kg ha^{-1}.

Rainy season 1996–97

Further assessments of the starter technology by FRGs. As a result of the 1995–96 rainy season activities, the FRGs stated that the starter technology should be tested more widely and in different environments. They drew attention also to the fact that only those farmers who lived within walking distance of the trials could attend field days. It was suggested, therefore that the starter technology be tested by more farmers in more than one village within a FRG area. Thus, a repetition of the starter technology at a larger number of locations was initiated by FSRT-LP for the rainy season of 1996–97. In response to farmers' interest in open-pollinating and early-maturing maize, a new variety named 'Pool 16' was included in the trial design. While MMV 400 takes about 110 d to mature, Pool 16 can be harvested in about 95 d. The fertilizer rate chosen was 100 kg D ha^{-1} basal dressing plus 100 kg AN ha^{-1} top dressing. This is half the rate recommended by the agricultural extension service in Luapula Province but is the most common fertilizer rate used by those Luapula small-scale farmers that can afford to buy mineral fertilizer. Replications were planted on 63 farms. The number of trials carried out within each FRG depended on the interest and labour capacity of the relevant farmers. It varied as follows: Chibote (1), Chienge (6), Kalembwe (7), Kapalala (2), Katuta (2), Kazembe (8), Matanda (5), Milambo (1), Miponda (1), Mubende (4), Mulwe (9), Muyembe (10), Mwenda (5) and Njipi (2). The results from these trials are presented in Figure 2.

Across all farms the incorporation of *Crotalaria zanzibarica* significantly increased the grain yields of Pool 16. The mean relative green manuring effect was +61.7% and ranged between +385.7 and −95.7%. In Chibote, no fertilizer was applied on either plot. This resulted in a very low maize grain yield for the treatment without green manure. In Mwenda the trials were affected by a dry-spell in March 1997 and farmers observed that the maize plants on the plots with green manure suffered less from water constraints than did those without green manure. In some trials in Chienge and Kalembwe, *Crotalaria zanzibarica* established itself very quickly. At the time of incorporation in January it was already overgrown at a height of about 1.8 m and the decomposing bulky green manure biomass harmed the young maize plants through microbiological nutrient competition. For the same reason, negative relative green manure effects occurred in some Matanda trials where farmers had not waited the recommended two weeks between the incorporation of the sunn hemp and the planting of Pool 16.

Increased interest in pasture legumes. As a result of the introduction of the starter technology, farmers' interest in *Crotalaria zanzibarica* increased. In FRG meetings members stated that they recognized the positive impact of green manure but that access to seed remained a problem because only a few of the intended assessment

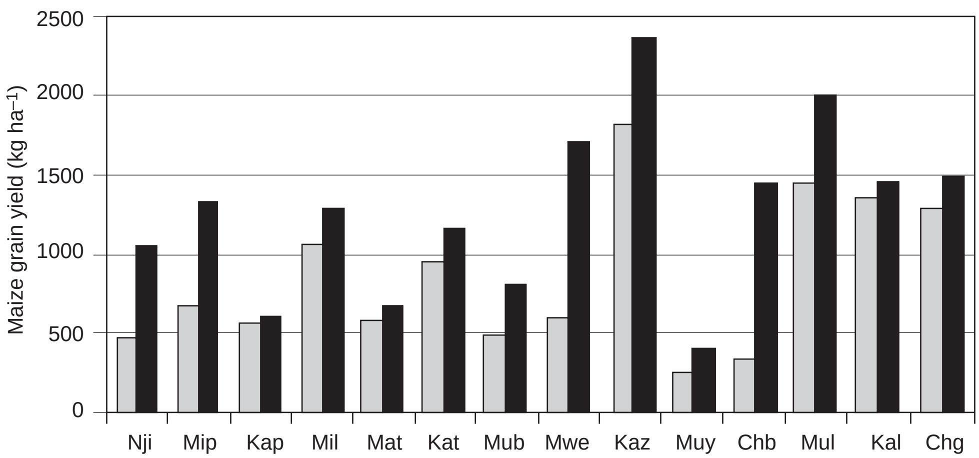

Fig. 2. Results from verified starter technology on-farm trials conducted by FRGs on early maturing and open-pollinating maize Pool 16 at low mineral fertilizer input in combination with *Crotalaria zanzibarica* incorporated as green manure during the rainy season of 1996–97. Participating FRGs: Njipi (Nji), Miponda (Mip), Kapalala (Kap), Milambo (Mil), Matanda (Mat), Katuta (Kat), Mubende (Mub), Mwenda (Mwe), Kazembe (Kaz), Muyembe (Muy), Chibote (Chb), Mulwe (Mul), Kalembwe (Kal), Chienge (Chg). Maize grain yield (kg ha^{-1}) without green manure (■) and with green manure (■) application.

plots had been planted and harvested by FRGs during the 1995–96 season. In addition, they discussed whether other pasture legume species could improve soil fertility. As a result, in addition to *Crotalaria zanzibarica* velvet bean (*Mucuna pruriens* cv NIRS 16) was included in FRG on-farm programmes for assessment and seed multiplication purposes in 1996–97. Velvet bean was chosen because the crop establishes very quickly and had shown a strong weed-suppressing characteristic in an on-station trial carried out by FSRT-LP at Mansa TAS (Steinmaier and Ngoliya, 2001). The planting of *Crotalaria zanzibarica* was recommended as described above for the starter technology. The plots were 10 × 10 m, and the seed rate was 15 kg ha^{-1}. Velvet bean seed packages suitable for 10 × 10 m plots (seed rate equivalent to 65 kg ha^{-1}) were distributed to interested farmers. The recommendations for planting were as follows: Line planting at 4 cm depth with one seed per station at a spacing of 90 cm between rows and 30 cm within rows.

Results from 31 *Crotalaria zanzibarica* plots indicated a mean yield of 531 kg ha^{-1} with a range of 1500 to 100 kg ha^{-1}. In harvest assessment meetings farmers assigned the low yields to late planting. They stated that establishing *Crotalaria zanzibarica*, and seed multiplication in general, was not problematic and could be handled easily. FRGs were slightly more excited by the performance of velvet bean compared with *Crotalaria zanzibarica*, especially with the former's extremely vigorous and creeping growth habit. Velvet bean mean yield across 46 locations was 1290 kg ha^{-1} and ranged from 6500 to 100 kg ha^{-1}. Farmers appreciated the good pod formation with velvet bean and explained that low yields in some cases were due to the delayed harvest which allowed seed losses from popping pods.

Table 2. Farmer initiative in FAST

Adaptation	Description
1-season pasture legume pioneer crop cultivation	Upland: introduced and verified starter technology including additional pasture legume species as pioneer crops, e.g. velevt beans. Dambo: use of pasture legume species as pioneer crops with various exotic and indigenous vegetables.
1-season pasture legume intercropping	Upland: intercropping and incorporation of pasture legume species between plant rows of local, open-pollinating or hybrid maize varieties.
1-season cut and carry pasture legume biomass transfer	Upland: cut and carry of pasture legume biomass from lots established in close neighbourhood to the food crop fields. Option a: incorporation at time of ridge making before the planting of the food crop. Option b: incorporation along the ridges after the establishment of the food crop.
1-season cut and carry tree legume biomass transfer	Upland: cut and carry of tree legume biomass (leaves) of various species like *Tephrosia vogeli*, *Caliandra calothyrsus*, *Cassia spectabilis*, *Cajanus cajan* from lots established in close neighbourhood to the food crop field.
2-season pasture legume crop rotation	Upland: use of pasture legume species as rotation crop with maize and other food crops. Dambo: use of pasture legume species as rotation crop with maize and various exotic and indigenous vegetables.

FRG initiatives. After the rainy season of 1996–97, FRG initiatives resulted in the design of various adaptations of the starter technology. These are described in Table 2. In addition to the integration of velvet bean as an optional pioneer crop, farmers decided to apply green manure to indigenous vegetables on wetlands. From their experience of intercropping maize with pasture legumes, they regarded green manuring as applicable not only to early-maturing but also to late-maturing maize varieties. The flexibility exhibited in extending green manuring to late-maturing food crops should also be applied in FRG plans regarding two-year rotations of pasture legumes and food crops either on uplands or on wetlands. The system of producing and importing the green manure biomass from outside the field (cut-and-carry) was outlined for both pasture and tree legume species.

DISCUSSION

Rainy season 1995–96

First initiatives by farmers to adapt the starter technology to their production conditions and needs related to food security and income generation. The early-maturing and open-pollinating maize variety MMV 400 was tested regarding its suitability for dambo cultivation. In the Luapula Province, dambo cultivation is understood to have potential for producing food during the six-month dry season from May to October. Starting in early November, maize produced during that period is sold mostly as green maize. Green maize is consumed as either boiled or roasted cobs. The taste, colour and early-maturing characteristic of MMV 400

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were the determining factors for farmers to start this initiative. The short maturation time of the variety allows delivery to the markets of the first green maize of the season and hence has competitive advantages in achieving higher sale prices and greater income. In general, farmers confirmed a good market for MMV 400. According to them, customers favour this variety because it remains soft after roasting whereas local maize and hybrid maize varieties become hard. Furthermore, because of its short maturation period farmers considered MMV 400 ideal for dambo cultivation. Limited water supply and cold temperatures in some dambos allow only a short period of favourable growing conditions for maize. In this context, the new variety can be grown in different types of dambos and at the same time creates increased flexibility with regard to planting dates. Consequently, the interest and demand for adequate seed of open-pollinating and early-maturing varieties increased. While farmers started with on-farm seed multiplication of MMV 400, on-station investigations by FSRT-LP on further open-pollinating and early-maturing maize varieties continued.

Rainy season 1996–97

In the second year of on-farm experimentation, farmers took account of the soil fertility-related aspects of the starter technology. After repeating the starter technology in 1996–97 on a greater number of sites, farmers' confidence in the impact of *Crotalaria zanzibarica* as a green manuring crop increased. There is a strong indication that farmer acceptance of, and confidence in, a new technology is positively related to the success of trials conducted on sites in their close farm neighbourhood. In this respect on-farm research should envisage as many trial replications as affordable, especially when it comes to the assessment of technically oriented trials. In contrast, farmers reacted less conservatively to the introduction of the new maize varieties. Here the adoption or rejection processes took less time to decide.

In most FRGs, farmers were convinced of the positive impact of green manure on maize yields but not of when and how it was applied within the starter technology. FRGs, therefore, developed new ideas and initiatives on how to integrate pasture legumes into their cropping systems. Among several adaptations outlined by FRGs, a two-year crop rotation was seen as an adequate alternative. The reason why farmers opted in favour of crop rotation is that with the starter technology the pioneer crop plus the food crop had to be squeezed into one rainy season and this involved too great a pressure with respect to land preparation and planting, twice per season. In January, the incorporation of the pasture legume biomass competed with other duties such as the planting of cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*) or the weeding of crops sown earlier on. Also, the late planting of maize meant a risk in terms of water availability towards the end of the rainy season. In discussions with FRGs it was explained that planting maize as early as possible after the start of the rains is part of the farmers' risk aversion strategy. In addition, this early planting of maize ensures a harvest of green maize around early February. Farmers indicated this to be the most critical period in the year in terms of food supply and, in this respect, they appreciated particularly the early-maturing maize varieties MMV 400 and Pool 16. With reference to the situation in which rains might start late, the new varieties were assigned a high rain-security status (Kapalala FRG), as the maize would be able to mature within a shortened rainy season. Asked which they preferred of MMV 400 and Pool 16, farmers were slightly more in favour of the former due to its larger cob size, a potential selection criterion for future plant breeding programmes. Other criteria that should be investigated are the sweet taste and white colour favoured by farmers during FRGs harvest field days.

Although the LLFSP focused on small-scale farmers as being a special category of farming households, these cannot be regarded as a homogenous group. Especially in terms of cropping area and labour force, there are big differences with implications for the introduction of farming technologies. For those farmers with a scarcity of arable land, the two-year crop rotation for green manuring purposes was not regarded as being applicable to their farming conditions since there would be one year without food production. In this respect, and deviating from the starter technology, some of the FRGs favoured intercropping where both the green manure crop and the main crop (for example maize) are sown at the same time. The green manure crop is sown between the maize rows and is incorporated into the soil after reaching a certain height, while the maize continues growing. Efficient use of the limited arable land is the reason behind the cut-and-carry system. In this regard and depending on the availability of labour, some farmers considered the labour aspect to be the most limiting factor. It was noticed in FRG meetings that farmers assessed more critically the labour implications for the starter technology than for their indigenous cropping systems. Adaptations related to crop rotation, intercropping and cut-and-carry cropping systems correspond fully or partially with indigenous cropping systems applied by farmers in Luapula Province. In this regard the innovative aspect lies in the integration of pasture and tree legumes into these indigenous systems.

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