Farmers' information on sweet potato production and millipede infestation in north-eastern Uganda. I. Associations between spatial and temporal crop diversity and the level of pest infestation

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Abstract

Farmers in five districts of north-eastern Uganda were interviewed to generate information on sweet potato production and constraints, with emphasis on damage by millipedes. Participatory rural appraisal methodology was used to interview 148 farmers. The peak period of planting sweet potato was from the end of May till the beginning of July in order to produce dried form food (amukeke) for storage in the dry season, which sets in around November. Vine cuttings were usually planted on mounds and weeding was mostly done only once. Osukut, Araka Red and Araka White were the most popular varieties. Many respondents obtained planting material from volunteer plants. Separation of plots over time and in space was often not practised. Sweet potato crop rotations were diverse. Millet, groundnut and maize were commonly grown after sweet potato. Cassava, sweet potato, groundnut and maize are host crops for millipedes and were often grown in succession. Millipede incidences were not statistically different for the three agro-ecological zones of north-eastern Uganda, but depended on the frequency of millipede hosts (including sweet potato) in the crop rotations. Groundnut planted after sweet potato had high levels of millipede attack. Millipede incidence was often associated with the incidence of weevils. The results of this inventory show that most farmers consider millipedes as a pest of sweet potato and other major food and cash crops, but that many farmers lack the knowledge to control them.

Additional keywords: crop rotation, Diplopoda, farmer variety, host crop, *Ipomoea batatas*, participatory rural appraisal, planting material, spatial diversity.

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lamk) ranks fifth among the world's most important crops (Anon., 2002) and is important in all countries of eastern Africa. It is mostly grown as a subsistence crop by resource-poor farmers in a non-seed carbohydrate staple food system (Smit, 1997). In Uganda it is a major staple food, along with banana, cassava and Irish potato, often in combination with beans (kidney beans or another grain legume) (Ewell & Mutuura, 1994; Smit, 1997). It is cultivated in all agro-ecological zones and performs well in marginal soils (Bashaasha *et al.*, 1995; Smit, 1997). Sweet potato is high in carbohydrates and vitamin A and is crucial during the harsh dry periods when people depend on the crop to combat hunger (Anon., 1998).

In Uganda during the early 1990s, the production of cassava declined due to Cassava Mosaic Virus, and the production of banana dropped because of the Sigatoka disease and banana weevil infestation (Bashaasha *et al.*, 1995). So food supply was inadequate, often resulting in famine and dependence on relief aid for survival. Meanwhile, sweet potato established itself in the food system in meeting the people's nutritional requirements, and for covering recurrent household expenses (Scott & Ewell, 1992; Scott *et al.*, 1999). For example, many farmers in Kumi District grow sweet potato as a cash crop for commercial markets and are the main suppliers for the market of Kampala (Abidin, 2004). Income from sales of sweet potato also helped many farmers in their efforts to re-stock cattle herds in areas where stealing of cattle had taken place during the period of civil unrest (Bakema *et al.*, 1994).

Currently, Uganda is the largest producer of sweet potato in Africa (Anon., 2002). However, compared with Uganda's 4.4 t ha^{-1}, the yields of neighbouring countries are higher (Anon, 2002). This strongly suggests that there are constraints that require to be overcome urgently if the production of the crop is to increase, especially in north-eastern Uganda.

Farmers in north-eastern Uganda are poor (Anon., 1994; 1999) and inputs in sweet potato, such as fertilizers and pesticides, cannot be afforded. In a previous study only farmers in the village Aukot (Soroti District; Sub-county Gweri) were reported to apply pesticides or inorganic fertilizers (Abidin, 2004). Moreover, pesticides and inorganic fertilizers are not always available at the trading centres, or are only accessible for those who own transportation means.

Farmers in Uganda consider insect pests the most important production constraint in sweet potato (Smit, 1997; Abidin, 2004). They believe that the sweet potato weevils (*Cylas brunneus* and *C. puncticollis,* Coleoptera: Curculionidae) and the caterpillars of the sweet potato butterfly (*Acraea acerata,* Lepidoptera: Nymphalidae) are the main culprits (Bashaasha *et al.*, 1995; Smit, 1997). Also rats are important. Serious damage by millipedes (Diplopoda) was suggested by Abidin (2004). There is inadequate information at present about the identity, biology, ecology, behaviour, damage and possible control strategies of millipedes in Uganda and eastern Africa as a whole.

We are carrying out research to develop an appropriate integrated pest management package, with emphasis on millipedes, to minimize yield losses, particularly for the resource-poor farmers in north-eastern Uganda.

This paper analyses the results of farmers' interviews aimed at establishing the relative importance of the millipede problem in sweet potato production. A companion paper describes the indigenous control strategies in sweet potato production (Ebregt *et al*., 2004).

Materials and methods

Interviews were conducted in Soroti, Kumi, Katakwi, Kaberamaido and Lira, the main sweet potato growing districts in north-eastern Uganda. According to reports received from farmers and agricultural extension agents, millipede problems in these regions were significant. Farmers' knowledge of general agronomic practices and pest management with emphasis on millipedes was assessed through participatory rural appraisal (Nabasa *et al*., 1995; Anon., 1996).

Details on interview sites, methodology, data collection and processing are described in this paper.

Description of interview area

One hundred and forty eight farmers in 32 sub-counties were interviewed between 19 April 2001 and 7 April 2002. For the location of the households interviewed and the agro-ecological zones as classified by Wortmann & Eledu (1999) see Figure 1. This classification shows that farms where interviews took place were located in the Northern Moist Farmlands (Lira and Kaberamaido Districts), the North-central Farm-Bush Lands with sandy soils (Soroti and Katakwi Districts), and the Southern and Eastern Lake Kyoga Basin (Kumi District). The rainfall pattern has been described by Bakema *et al*. (1994) as bimodal. It is characterized by a long rainy season from March to June, which makes it possible to grow all major crops. A shorter rainy season follows from August to November but is less reliable, so that crop failure is quite common in this period. The maximum air temperatures for the three agro-ecological zones are more or less the same (above 30 °C), but rainfall distribution varies. In Lira, Kaberamaido and Soroti Districts annual rainfall is between 1000 and 1500 mm, in Katakwi District between 850 and 1500, whereas in Kumi District it is over 1500 mm (Rabwoogo, 1997).

Soil texture in the three agro-ecological zones varies from sandy loam to clay loam (Aniku, 2001). The proportion of land used for the cultivation of sweet potato varies from 1 to 5% in the first two zones. In the Southern and Eastern Lake Kyoga Basin this figure is between 5 and 15%. In the eastern part of this agro-ecological zone the proportion of land under sweet potato may even reach up to 35%. In the three zones, groundnut, millet, sorghum and cassava are the predominant crops (Bashaasha *et al.*, 1995; Mwanga *et al*., 2001). In the three agro-ecological zones a number of broad valley bottoms occur with grassland communities consisting of *Echinochloa* and *Sorghastrum*, which are seasonally water-logged (Aluma, 2001). As the soils in these valley bottoms contain moisture during the dry season, farmers establish sweet potato nurseries in these swampy grasslands (Smit, 1997).

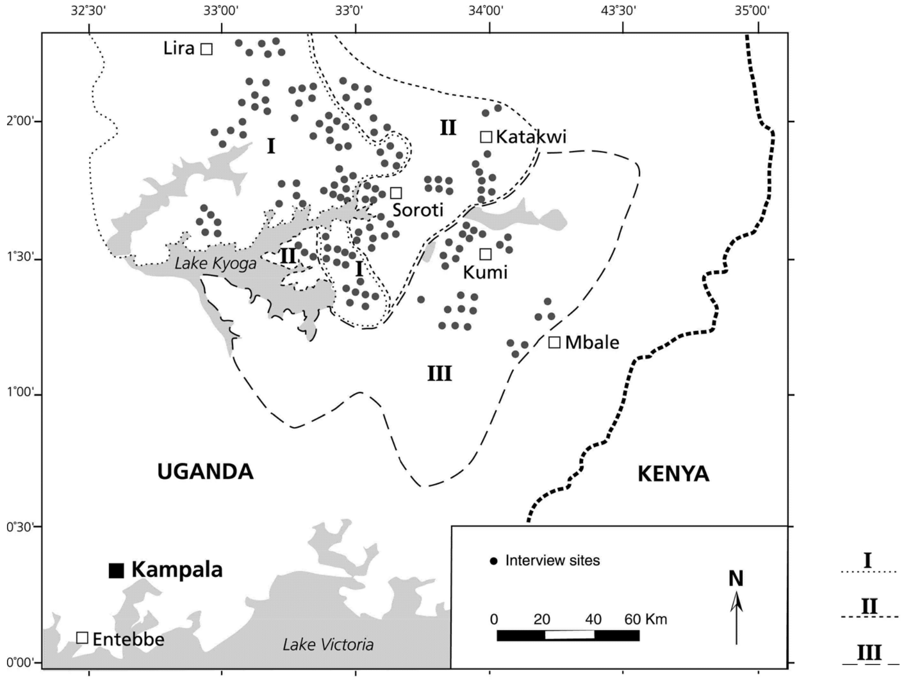

Figure 1. Map of north-eastern Uganda with location of the 3 agro-ecological zones (AEZ) and the households (black dots) where farmers were interviewed.
.... = Northern Moist Farmlands (AEZ I);
- - - - - = Northern Central Farm-Bush Lands with sandy soils (AEZ II);
– – – = Southern and Eastern Lake Kyoga Basin (AEZ III).

Interview methodology

With the assistance from extension workers and leading farmers, between five and nine sub-counties were selected per district. A preliminary survey was done to obtain information on the number of farmers in the area. Based on this information the number of interviews per sub-county was determined. Water bodies like swamps and streams were often the natural boundaries between the sub-counties and their presence might affect millipede dispersal as these insects cannot cross water.

A standard questionnaire – partly structured and partly open – for individual interviews was designed and administered. The following topics were targeted: (1) general sweet potato agronomic practices, (2) common sweet potato varieties and sources of planting material, (3) spatial dispersal of sweet potato plots, (4) type of cropping systems and sweet potato frequencies, and (5) crops not favoured after sweet potato.

Direct field observations in the presence of the farmers interviewed were made too, and interviewees were encouraged to give information freely. Farmers' crop management methods were noted. Each interview took about 1 hour and 45 minutes.

Data collection and processing

Answers from the respondents of different areas were tabled and analysed. Questions on preference for varieties and for origin of planting material included a rating. The rating was based on the preference of the most common sweet potato varieties and sources of planting material. The score decreased with decreasing preference, i.e., a score of 4 represented the first choice of farmers, a score of 3 the second, a score of 2 the third, and a score of 1 the last choice of farmers. Next, for each district, the overall score for each variable was calculated by using the formula $\Sigma\, n_i s_i \;/\; n_t$, where n_i is the number of farmers who gave score s_i and n_t is the total number of farmers interviewed.

Genstat (Anon., 1997) was used for general analysis of variance, the Kruskal-Wallis test, and matrix correlation. General analysis of variance was used to test the ranking of sweet potato varieties and source of planting material. The Kruskal-Wallis test was used to analyse the millipede and weevil incidences reported by farmers in sweet potato cropping systems, related to the three agro-ecological zones in north-eastern Uganda. The frequencies of sweet potato in the rotations were generated from the cropping systems mentioned by the respondents. Graphs were used to relate the incidences of millipedes and weevils to the interval between two sweet potato crops in the crop rotations across the agro-ecological zones. Relations were quantified using matrix correlation. Correlation coefficients (R^2) $\geq$ 0.25 (number of respondents in these cases 145) were considered statistically significant.

Results and discussion

General agronomic practices

Area and soils under production

Detailed information on the minimum and maximum area under sweet potato per farmer in each district is presented in Table 1.

The farmers interviewed did not apply inorganic fertilizers or available organic manure produced by their animals, and did not hesitate to grow sweet potato on less fertile, sometimes even nutrient-depleted soils. Sweet potato is known as a crop that can still do reasonably well on less fertile soils (Gibbon & Pain, 1985). Growing sweet potato on poor soils is typical for resource-poor farmers in low-input agricultural systems. However, the respondents of Lira District mostly grew their crops on loam, which generally is fertile (Table 2).

Seedbed management

In swamp areas ridges are used for nurseries, while in upland areas mounds are preferred. According to the respondents' information, ridges would enhance burrowing by rats. In the research area the number of vine cuttings planted per mound varied between 2 and 4 (Table 3), confirming earlier findings by Abidin (2004). The respondents indicated that the number of cuttings planted per mound depends on factors

Table 1. Land area per farmer under sweet potato in 5 districts of north-eastern Uganda.
n = number of farmers.

District	n	Area		
		Minimum	Maximum	Mean
		(ha)		
Soroti	43	0.10	2.02	0.43
Kumi	28	0.20	1.62	0.59
Katakwi	24	0.10	2.02	0.57
Kaberamaido	23	0.20	0.81	0.39
Lira	30	0.10	1.01	0.39

Table 2. Soil texture of the farms in north-eastern Uganda (by district).

District	Soil texture			No. of farms not recorded
	Loam	Sandy loam	Clay	
Soroti	8	26	4	5
Kumi	3	18	1	6
Katakwi	3	18	0	3
Kabaramaido	15	5	0	3
Lira	21	6	0	3

Table 3. Number of sweet potato vines per mound in 5 districts of north-eastern Uganda.
n = number of respondents.

District	n	Vines per mound		
		Minimum	Maximum	Mean
Soroti	38	2	4	2.5
Kumi	28	2	4	3.7
Katakwi	24	2	4	3.4
Kaberamaido	23	2	4	2.5
Lira	30	2	4	2.9

like soil fertility, availability and maturity of the vines, survival expectations, marketability and home consumption.

Weeding

Weeding is normally done one month after planting, sometimes followed by a second weeding a month later. However, the farmers interviewed underlined their experience that the vines may break if pushed aside during this second weeding. This is caused by sweet potato weevil larvae that attack the stem base causing it to swell, crack and break. To avoid this problem, many farmers do not weed a second time, hence their fields will look neglected, as noted by Smit (1997). During the process of weeding, the mound will be carefully loosened and earthed up with surrounding soil to allow water to penetrate, resulting in larger storage roots. As this earthing up of mounds also has a weed control effect and weeding close to the stem basis can disturb the storage root development, a second weeding is not really recommended by farmers. This was also reported by Abidin (2004). According to earlier research by Smit (1997), this cultivation practice could prevent sweet potato weevils from having easy access to the storage roots. On the other hand, millipedes now find a suitable environment to live in, although the respondents indicated that millipedes generally do not affect the roots until 5 months after planting. The farmers nevertheless did report weevil damage in non-mature storage roots, especially during a dry spell, confirming observations by Smit (1997).

Common varieties planted

The number of varieties reported in the study area ranged from 18 in Katakwi District to 36 in Lira District. According to farmers' information, Osukut was the most popular variety, followed – with the exception of Lira District – by Araka Red and Araka White. Osukut is an old farmer variety in the region (Smit, 1997; Abidin, 2004). The respondents in Kumi District significantly favoured Osukut, a variety wanted above all other varieties by the market in Kampala. Detailed information on varieties is presented in Table 4.

Most respondents preferred to plant a mixture of varieties, mostly based on yield performance, maturity, culinary values and tolerance to pests. According to Smit (1997) and Abidin (2004), this strategy evens out the risk of any failure and farmers have access to varieties with different useful characteristics.

Early maturing and late maturing varieties

In the interviews, the 148 respondents mentioned a total of 60 different varieties grown on their farms. Twenty-five of them were planted because they were early maturing. Nine varieties were reported to be late maturing. Also Abidin (2004) listed a number of early maturing and late maturing varieties reported by farmers in this region.

By planting early maturing varieties, farmers can harvest before the end of the growing season, and in that way can escape the risk of drought and consequently the damaging effect of weevils, which enter the soil through cracks. Farmers stated that when harvesting of sweet potato was delayed too much, millipedes affected the storage

Table 4. Some characteristics and mean scores[1] for importance of sweet potato varieties in 5 districts of north-eastern Uganda. n = number of farmers.

Variety	Characteristics	District				
		Soroti (n = 43)	Kumi (n = 28)	Katakwi (n = 24)	Kaberamaido (n = 23)	Lira (n = 30)
Osukut	Early maturing, good yield, sweet, good marketability.	2.3a[2]	3.6a	2.3a	1.3a	1.1b
Araka Red	Early maturing, good yield, tolerant to *Cylas* spp.	2.3a	1.5b	2.3a	1.8a	1.2b
Araka White	Early maturing, good yield.	2.3a	1.2b	2.6a	1.7a	1.3b
Lira Lira	Early maturing, good yield.	none[3]	none	none	1.5a	2.5a
Ateseke	Good yield.	1.3b	none	1.4b	1.7a	none
Igang Amalayan	Early maturing, good yield.	none	1.3b	1.6b	none	none
Latest	Early maturing, good yield, sweet.	1.3b	none	none	2.1a	1.4b
Osapat	Good yield.	none	1.4b	none	none	none
Ekampala	Good yield.	none	1.5b	none	none	none
Tedo Oloo Keren	Good yield, tolerant to *Cylas* spp.	none	none	none	none	1.4b
Odupa	Tolerant to *Cylas* spp.	none	none	1.3b	none	none
F-value		< 0.001	< 0.001	< 0.001	0.242	< 0.001
LSD[4]		0.5	0.5	0.7	0.7	0.5

[1] Scores on a scale of 1–4 (1 = not relevant; 4 = highly relevant). Data based on scores and numbers of respondents only.

[2] Mean scores in the same column, followed by a common letter are not statistically different ($P > 0.05$).

[3] none = no sample of this variety was found.

[4] LSD = least significant difference ($P > 0.05$).

roots, especially if the roots were stored 'in-ground on the plants' during the dry season and harvesting was done at the first rains of the new growing season. Farmers indicated that late maturing varieties were drought tolerant and could be stored 'in-ground on the plants' during the dry season. In general the crop was stored 'in-ground on the plants' a bit longer, but by the end of February most of the crop was harvested.

Table 5. Mean scores[1] of sources of sweet potato planting material for farmers in 5 districts in north-eastern Uganda. n = number of farmers.

Source of planting material	District					Across districts
	Soroti (n = 43)	Kumi (n = 28)	Katakwi (n = 24)	Kabaramaido (n = 23)	Lira (n = 30)	
Buying	1.7b[2]	2.3ab	1.7b	1.1c	1.3c	1.6b
Neighbours	1.6b	1.5cd	1.3bc	2.0b	2.3b	1.8b
Home nurseries	1.7b	2.6a	2.6a	1.2c	1.1c	1.8b
Swamp nurseries	1.6b	1.2d	1.3bc	1.1c	1.3c	1.3bc
Vines	1.1c	1.1d	1.0c	1.0c	1.0c	1.0c
Volunteers	2.8a	1.9bc	3.1a	3.4a	3.2a	2.9a
F-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
LSD[3]	0.5	0.6	0.7	0.5	0.7	0.6

[1] Scores on a scale of 1–4 (1 = not relevant; 4 = highly relevant). Data based on scores and number of respondents only.

[2] Means in the same column, followed by a common letter are not statistically different (P > 0.05).

[3] LSD = least significant difference (P = 0.05).

Sources of planting material and planting time

The sources of planting material across the districts, in order of importance, were (1) volunteer plants from previous gardens, (2) home nurseries, (3) neighbours, (4) sellers, and (5) swamp nurseries, with only the contrast between volunteer plants and the other categories being statistically significant (Table 5). With the exception of Kumi District and to some extent of Katakwi District, the use of planting material obtained from volunteer plants was often dominant (31 respondents; n = 148), especially in Kaberamaido District (43%). This corresponds with data obtained from other areas in Uganda (Gibbon & Pain, 1985; Ewell & Mutuura, 1994). With volunteers most farmers have access to their own favourite varieties. However, they can only plant if enough volunteer plants have established, which is about 6 weeks after the start of the first rains.

In order to secure enough planting material, farmers often combine a number of sources. The respondents indicated that they often supplement their planting material from volunteer plants with vine cuttings obtained from their nurseries and/or from their neighbours. The category ‘buying vines’ often correlated positively with the category ‘from neighbours’.

Table 6 shows that planting took place from March to mid August, with a peak period from the end of May to the beginning of July. Most planting started about 2 months after the start of the growing season, after crops with a low evaporative

Table 6. Planting calendar for sweet potato in north-eastern Uganda (by agro-ecological zone (AEZ) and district). n = number of farmers.

Agro-ecological zone[1]/ District	n	Month of planting										No. of plots	No. of plantings per year (%)		
		March	April	May	June	July	Aug	Sept	Oct	Nov	Dec		1	2	3
AEZ I															
Soroti	18	5	6	1	6	3	4	0	1	0	0	26	56	44	0
Kaberamaido	23	2	3	9	8	8	6	1	1	0	0	38	48	43	9
Lira	30	2	9	6	9	4	2	3	3	1	1	40	70	27	3
Total AEZ I	71	9	18	16	23	15	12	4	5	1	1	104	59	37	4
AEZ II															
Soroti	25	2	6	8	4	5	4	1	0	0	0	30	56	44	0
Katakwi	24	1	5	10	8	5	3	1	2	0	1	36	63	35	2
Total AEZ II	49	3	11	18	12	10	7	2	2	0	1	66	59	37	4
AEZ III															
Kumi	28	10	2	12	9	6	3	1	1	1	1	46	50	39	11
Total AEZ I–III	148	22	31	46	44	31	22	7	8	2	3	216	57	37	6

[1] AEZ I = Northern Moist Farmlands; AEZ II = Northern Central Farm-Bush Lands with sandy soils; AEZ III = Southern and Eastern Lake Kyoga Basin.

demand, such as groundnut, had been planted. As long as the soil was moist enough for ridging or preparing mounds and for crop establishment, planting continued till October. However, many respondents said to prefer to plant in the first rainy season, as the rains of the second season are unreliable.

Farmers who are eager to plant in March–April for reasons of food security or to get a good price on the market, consider obtaining planting material at that time as a constraint (Abidin, 2004). Another constraint of planting early was considered the risk of losing planting material due to millipede activity.

To be able to plant at the onset of the first rains, farmers have to maintain a nursery during the dry season or obtain vine cuttings from neighbours' nurseries. About 15% of the respondents in Soroti, Kumi and Katakwi Districts have nurseries. For Kaberamaido and Lira Districts this figure is much lower, as farmers in these districts are less commercially orientated and obtain their planting material mainly from volunteer plants and neighbours.

Swamp nurseries score slightly but not statistically lower than home nurseries. The probable reason is that during the dry season many farmers drive their animals into the lower areas, where they can wander around and survive on the little available vegetation. The lush green vegetation of the sweet potato would be grazed off if the nursery is not well fenced. Ewell & Mutuura (1994) and Smit (1997) stated that there is a tendency to establish nurseries near the homesteads, because of the increasing animal pressure due to re-stocking.

During our field observations we noticed that home nurseries, which also function to supplement the families' scanty diet during the dry season, harbour relatively high populations of millipedes. This may be explained by the fact that such nurseries are often kept in shady environments (for example under a mango tree), by the role such nurseries play as a permanent food supply and by their relatively long lifetime (often more than two years).

Distance between fields

Table 7 lists farmers' statements on leaving a distance between sweet potato fields. In a number of cases few farmers maintained a reasonable distance between sweet potato fields. The most common reason for separating fields is to avoid pests, mainly weevils and millipedes (10 respondents). However, a large number of the farmers responding to this issue (116 out of 144) did not have any problem with establishing a new plot adjacent to a previous or existing one.

Infestation of sweet potato by soil pests like weevils, mostly originates from neighbouring fields, as sweet potato can be found in the field year-round. For that reason it has been suggested that spatial separation of fields or physical barriers (Smit, 1997) combined with cultivation practices like re-hilling of the mounds (Anon., 2000), could result in reduced pest infestation. However, the effects of such control strategies on millipedes need to be verified.

Life cycle and behaviour of weevils and millipedes

As biological information is essential to understand pest incidence, and for developing

Table 7. Farmers' statements on distances they leave between separate sweet potato fields in 5 districts of north-eastern Uganda. n = number of respondents.

District	n	Distance between fields (m)					No problem planting next to previous/other sweet potato field(s)
		0–10	10–25	25–50	> 50	Any	
Soroti	42	14	3	5	12	8	34
Kumi	28	14	1	2	10	1	25
Katakwi	24	13	1	3	7	0	22
Kabera-maido	20	6	0	1	7	6	16
Lira[1]							
– Bar and Amach	13	0	1	0	12	0	2
– Other	17	7	1	0	3	6	17
Total	144	54	7	11	51	21	116

[1] Bar and Amach are subdistricts.

control strategies, a short paragraph is included with a description of the life cycle and the behaviour of millipedes and weevils.

Millipedes

Millipedes are normally regarded as saprophytes, living in the soil or surface litter. They burrow through the soil and litter or penetrate underneath surface objects using the force of their legs. At night many become active on the soil surface (Marshall & Williams, 1977). The majority of millipedes eat dead plant material and fragments of organic matter. Some eat living plant parts but these usually consist of soft and easily digestible material such as young shoots, fine roots and groundnut pods (Hopkin & Read, 1992).

Eggs with large yolks are usually laid in a nest of earth (Marshall & Williams, 1977). After hatching, the minute larvae with only three pairs of legs shed their skins, acquiring more legs and more body rings after each moult. They take more than a year to reach the full size of the adult millipede. Because of their vulnerability during moulting (about three weeks in all), most millipedes seek refuge in specially constructed cells where they shed their exoskeleton (Lawrence, 1984; Hopkin & Read, 1992).

Weevils

Adult weevils are often found on the leaves, in the stem bases or in the storage roots. Eggs are laid in hollows on the stems, after which the larvae tunnel the stems downwards, causing thickening and cracking of the affected parts. Pupation takes place in the stems. When storage roots are exposed to the soil surface, weevils can lay their eggs directly into the roots. The larvae tunnel their way through the storage roots.

Debris is deposited in the tunnels. The roots respond by producing toxic terpenes, which render storage roots unpalatable. Weevils usually appear in the fields at the time when the storage roots start to develop. As planting is done during the whole growing season, populations can build up easily and the damage can be tremendous, especially during dry spells (Ames *et al*., 1997; Smit, 1997).

Sweet potato and crop rotation

Types of cropping systems and cropping sequences

Table 8 lists the main rotation systems in the three agro-ecological zones of north-eastern Uganda. The cropping systems in these zones of the research area are diverse. Rotations vary among and even within households, depending on their requirements and priorities, as Bashaasha *et al*. (1995) noted before in other districts of Uganda. Table 9 shows that, averaged over the 3 agro-ecological zones, sweet potato most often was followed by millet (85 respondents out of 148) or groundnut (30 respondents out of 148). Also maize was grown after sweet potato, but this was, with one exception, only reported in the Northern Moist Farmlands (12 respondents out of 71). Detailed information is presented in Table 9. Also minor crops, such as sunflower, soya bean, kidney bean or another grain legume, sesame and cassava were grown after sweet

Table 8. Scheme of most common sweet potato crop rotations and the normal sweet potato frequencies (years) in the 3 agro-ecological zones (AEZ) of north-eastern Uganda.

AEZ I: Northern Moist Farmlands	Frequency
1. Sweet potato→millet→sorghum→any other crop(s) (predominantly cassava/fallow)	1 : 3
2. Sweet potato→millet→cassava/fallow→any other crop(s)	1 : 5
3. Sweet potato→millet→any other crop(s)→cassava/fallow	1 : 4
4. Sweet potato→groundnut→any other crop(s)	1 : 3
5. Sweet potato→maize→any other crop(s) (predominantly cassava/fallow)	1 : 5
AEZ II: Northern Central Farm-Bush Lands with sandy soils	
1. Sweet potato→millet→sorghum→any other crop(s)	1 : 3
2. Sweet potato→millet→cowpea→any other crop(s) (predominantly cassava/ fallow)	1 : 4
3. Sweet potato→millet→groundnut→any other crop(s) (predominantly cassava/fallow)	1 : 5
4. Sweet potato→millet→cassava/fallow→any other crops(s)	1 : 4
5. Sweet potato→groundnut→any other crop(s) (predominantly cassava→fallow)	1 : 4
AEZ III: Southern and Eastern Lake Kyoga Basin	
1. Sweet potato→millet→groundnut→predominantly cassava	1 : 4
2. Sweet potato→millet→cowpea→any other crop(s) (predominantly cassava)	1 : 3
3. Sweet potato→millet→any other crop(s)→cassava/fallow	1 : 4
4. Sweet potato→groundnut→any other cop(s) (predominantly cassava/fallow)	1 : 3

Table 9. Number of farmers planting millet, groundnut or maize after sweet potato in north-eastern Uganda, by agro-ecological zone (AEZ) and district. n = number of farmers.

Agro-ecological zone[1]/ District	n	Crop following sweet potato			
		Millet	Groundnut	Maize	Other
AEZ I					
Soroti	18	8	6	0	4
Kaberamaido	23	15	7	1	0
Lira	30	11	0	11	8
Total AEZ I	71	34	13	12	12
AEZ II					
Soroti	25	15	6	0	4
Katakwi	24	19	3	0	2
Total AEZ II	49	34	9	0	6
AEZ III					
Kumi	28	17	8	1	2
Total AEZ I–III	148	85	30	13	20

[1] See Table 6.

potato. Occasionally sweet potato was followed by a fallow period.

As for crops preceding sweet potato, in the Northern Moist Farmlands (71 respondents), 50% of the respondents grew sweet potato following a 'resting period' of 1 to 3 years under cassava or fallow. Also sorghum, millet and maize were often the preceding crop (15, 8, 5%, respectively). Beans (kidney bean or other grain legumes), sesame and groundnut scored around 5% each. In the Northern Central Farm-Bush Lands with sandy soils (49 respondents) the major preceding crops were cassava (28%), which usually lasted 2 years, groundnut (17%), the cereals sorghum (8%) and millet (7%), and sesame (8%). In this zone also sorghum or groundnut was grown before sweet potato and sometimes maize or leguminous crops preceded it (data not shown). In the Southern and Eastern Lake Kyoga Basin the preceding crops were cassava (39%), groundnut (3%), millet (10%) or sorghum (7%). In the group of 'sweet potato-groundnut' rotations sometimes also cowpea and green gram were grown before sweet potato.

Comparing the above results on the 'after-crop' with the findings of Bashaasha *et al.* (1995), it is remarkable that these authors do not mention groundnut at all, whereas our respondents often cultivated it after sweet potato.

It is striking that no respondents from Lira District grew groundnut after sweet potato (Tabel 9). The reason mentioned by the farmers was that millipedes affect groundnut during germination and pod development. The farmers in Katakwi District were of the same opinion.

Many of the farmers interviewed grew sweet potato after a 1-year fallow period or left the field under cassava, as this crop is also considered by the farmers as a 'resting crop', after which they burned the vines. In both cases the soil will recover little of its lost fertility. Cassava is well known for its potential to draw on the last resources of the soil. The short burning period leaves little organic material to decompose. Nutrients are lost due to leaching and some, particularly N and S, are easily lost to the atmosphere (Ames *et al.*, 1997). This suggests that the farmers' perception of the role of cassava and fallow in north-eastern Uganda will add to the depletion of the soil in that area. The increasing population pressure will intensify land use and so adds to the non-sustainability of the traditional cropping system.

Crops not planted after sweet potato

Table 10 presents a list of crops that are not favoured by farmers for being grown after sweet potato, especially in the Northern Moist Farmlands. Across the three agro-ecological zones, groundnut and to a lesser extent cassava, are the most important ones that together with beans (kidney bean or other grain legumes) are host plants of millipedes and other pests.

Table 10 shows that 20% of the reactions (n = 206) reflected a ban on groundnut after sweet potato. The main reasons for this were the damaging effects of millipedes on the germinating seeds and young pods (44% and 32% of the reactions, respectively) (Table 11). Also for southern and western Africa millipedes have been reported to damage groundnut (Wightman & Wightman, 1994; Umeh *et al.*, 1999).

Farmers preferred millet after sweet potato above groundnut. They claimed that millipedes caused damage in both groundnut and sweet potato but not in millet. So farmers wanted to discontinue the population build-up of millipedes. Furthermore, the sweet potato crop can suppress weed development because of its excellent soil cover.

In the Northern Moist Farmlands 24% of the respondents grew sorghum after millet in the rotation after sweet potato. After harvesting, the farmers often leave the crop residues of sorghum in the field. Sorghum has been reported to contain cyanogenic glycosides and large amounts of silicates (Van Genderen *et al.*, 1997), which may deter soil pests. Indirectly, this cultivation practice could play a role in controlling the millipede population.

The army ant is another important culprit, although not mentioned by respondents of Lira District (Table 11). For example, in Katakwi District, the incidence of damage by millipedes and army ants in groundnut and sweet potato was high and for that reason only few respondents of this district grew groundnut after sweet potato or sweet potato after groundnut.

Indifference of choice of groundnut after sweet potato

Out of the 106 reactions concerning millipedes in groundnut, 48% (altogether 59 respondents) stated that they would grow groundnut after sweet potato in spite of their awareness and concern about the damaging effect of millipedes on groundnut (Table 12).

Table 10. Crops not favoured after sweet potato in north-eastern Uganda (by agro-ecological zone (AEZ) and district). n = number of reactions.

Agro-ecological zone	n	Indifferent	Crop									
			Groundnut	Millet	Cassava	Maize	Cowpea	Bambara groundnut	Sesame	Sorghum	Beans[2]	Other
AEZ I												
Soroti		14	4	0	1	1	1	0	0	0	0	0
Kaberamaido		18	6	1	1	0	0	1	0	0	1	1[3]
Lira		28	3	5	8	1	0	0	5	3	4	0
Total AEZ I	107	60	13	6	10	2	1	1	5	3	5	1
AEZ II												
Soroti		22	6	0	1	0	1	0	0	0	0	1[4]
Katakwi		11	17	0	0	0	0	0	0	1	0	0
Total AEZ II	60	33	23	0	1	0	1	0	0	1	0	1
AEZ III												
Kumi	39	29	6	0	3	0	1	0	0	0	0	0
Total AEZ I–III	206[5]	122	42	6	14	2	3	1	5	4	5	2

[1] See Table 6.
[2] Mixture of kidney bean and other grain legumes.
[3] Pigeon pea.
[4] Tomato.
[5] Total of 206 reactions given by the 148 farmers.

Table 11. Reasons (absolute numbers; percentages in parentheses) for excluding groundnut after sweet potato in 3 agro-ecological zones (AEZ) in north-eastern Uganda. n = number of respondents.

Agro-ecological zone[1]	n	Reason					No damage
		Millipedes during:		Army ants	Volunteers	Vegetative growth	
		Germination	Pod set				
AEZ I	13	11	6	3	2	1	1
AEZ II	23	18	14	7	0	0	0
AEZ III	6	2	3	2	1	0	0
Total	42[2]	31(44)	23(32)	12(17)	3(4)	1(1)	1(1)

[1] See Table 6.
[2] A total of 71 reactions were given by the 42 respondents.

Table 12. Indifference in choice of growing groundnut after sweet potato in 3 agro-ecological zones (AEZ) in north-eastern Uganda. n = number of reactions.

Agro-ecological zone[1]	n	Awareness of millipede damage, but farmer still grows groundnut	No awareness of millipede damage in groundnut	No damage in groundnut by millipedes	Awareness of damage by army ants
AEZ I	60	34	6	17	3
AEZ II	33	19	4	6	4
AEZ III	29	6	13	1	9
Total	122	59	23	24	16
%	100	48	19	20	13

[1] See Table 6.

Why cassava and other crops are not favoured after sweet potato

Reasons mentioned by the farmers for not planting cassava after sweet potato were its lush vegetative growth, poor germination and low yield, whereas some reactions pointed out millipedes as the reason (Table 13). The respondents claimed that millipedes affect the sprouting planting material, especially when planted at the beginning of the early rains, with poor growth or vigour of young plants as a result. They also reported that if cassava is harvested late, for example after 2 years, millipedes affect its

Table 13. Reasons given by farmers in north-eastern Uganda for excluding cassava, sesame, millet, beans, cowpea, sorghum and maize as crops following sweet potato. n = number of reactions.

Reason	n	Crops following sweet potato						
		Cassava	Sesame	Millet	Beans[1]	Cowpea	Sorghum	Maize
Lush vegetative growth	12	2	3	1	2	2	2	
Poor germination	6	3	1	2				
Low yield	7	3		3				1
Volunteers	2					2		
Heavy feeder	1						1	
Spear grass	1	1						
Striga	1							1
Millipedes	7	3	1		3			
Other pests	1				1			
Total	38	12	5	6	6	4	3	2

[1] Mixture of kidney bean and other grain legumes.

roots. Millipede damage in cassava has also been reported in India (Alagesan & Ganga, 1989), South Africa (Govender *et al.*, 1996) and Colombia (E.E. Carey, personal communication).

Table 13 shows that millipedes damaged germinating beans (kidney bean and other grain legumes). This was especially the case in Lira District, again at the start of the first rains. It was also reported that finger millet did not germinate well after sweet potato. The farmers believed that this was caused by the poor soil structure after harvesting the storage roots. However, another cause might have contributed to the poor germination. For instance, Peterson *et al.* (1999) found that sweet potato has an allelopathic effect, inhibiting the germination of proso millet.

The interval between two subsequent sweet potato crops

Generally, the interval between two subsequent sweet potato crops in the cropping systems across the three agro-ecological zones varied from 1 to 7 years. As sweet potato becomes increasingly important, only few farmers maintained a long interval. Millipede incidence did not differ statistically between the agro-ecological zones ($P = 0.396$). However, a highly significant statistical difference was noted for the millipede incidence across the crop rotations. The same was true for the weevil incidence (Table 14).

Figure 2 shows the relationship between scores for relevance of weevil and millipede infestation and the interval between two subsequent sweet potato crops. Millipede incidence was significantly correlated ($R^2 = 0.4225$; n = 65) with weevil incidence.

Table 14. Average scores[1] by farmers of millipede and weevil incidence in sweet potato cropping systems in north-eastern Uganda, by agro-ecological zone[2] (AEZ). n = number of respondents.

Length of rotation[3]	AEZ I (n = 68)		AEZ II (n = 49)		AEZ III (n = 28)		Across AEZ's	
(years)	Millipedes	Weevils	Millipedes	Weevils	Millipedes	Weevils	Millipedes	Weevils
2	1.0	3.0	1.0	2.0	3.0	3.0	1.7	2.7
3	1.5	2.8	1.6	2.9	2.1	2.3	1.7	2.7
4	1.5	2.2	1.7	2.6	1.4	2.4	1.5	2.4
5	1.0	2.4	1.5	2.9	1.0	2.4	1.3	2.8
6	0.9	2.4	1.8	3.0	1.5	3.0	1.2	2.8
7	1.5	2.5	1.0	3.0	0	0	0.8	1.8
8	1.5	3.0	2.0	2.0	0	0	1.2	1.7
Mean[4]	1.3	2.6	1.5	2.6	1.3	2.0		

1 Scores on a scale of 1–4 (1 = not relevant, 4 = highly relevant).
2 See Table 6.
3 Number of years in a complete sequence of crops in a rotation with sweet potato.
4 The differences between means across crop rotations are statistically highly significant ($P < 0.001$); P-value (Kruskal-Wallis test) is 0.396 for millipedes and 0.897 for weevils. The means for millipedes and for weevils across AEZ's are not statistically different.

In the Southern and Eastern Lake Kyoga Basin the patterns of weevil and millipede incidences were slightly different, but this was not the case in the other two agro-ecological zones. In the former zone, weevil incidence showed a stable fluctuation up to an interval of 6 years, after which it decreased. However, in the case of millipedes, the incidence decreased with increasing interval. In the other two agro-ecological zones (Northern Central Farm-Bush Lands with sandy soils and Northern Moist Farmlands) the incidences remained more or less constant.

According to the farmers interviewed, the root damage caused by millipedes followed on the damage caused by weevils. This suggests that these pests could enhance each other's entry and damage. During the dry season, when roots are kept 'in-ground on the plants', weevils are most active in the storage roots, and consequently can inflict a lot of damage. With the onset of the first rains, millipedes – attracted by the damaged storage roots – leave their hiding places. This mutual effect could also imply that control measures applied to one group of pests would affect the other one as well.

Concluding remarks

This inventory showed sweet potato to be important in the cropping systems in north-eastern Uganda. Most farmers regarded millipedes as pests of sweet potato and other

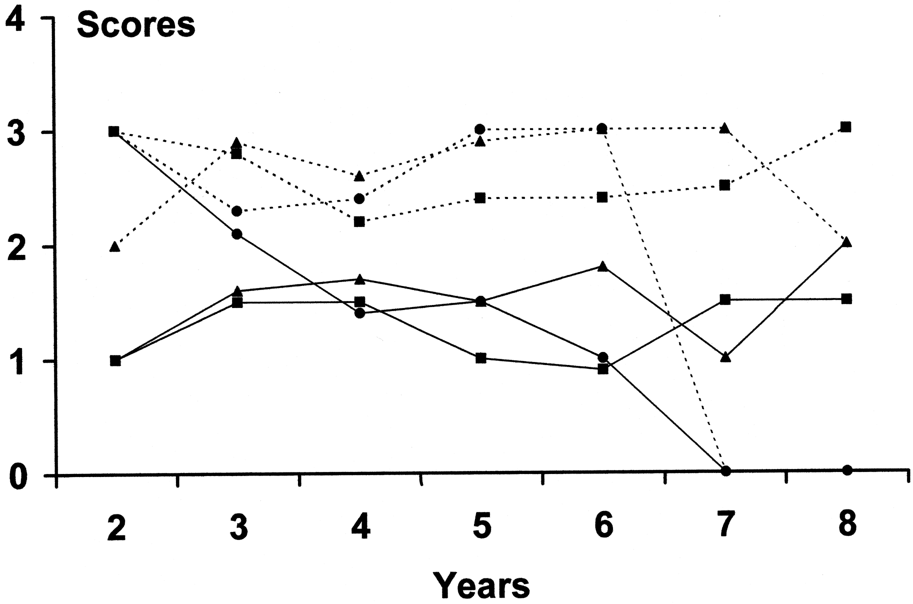

Figure 2. Relationship between scores for relevance of weevil (interrupted lines) and millipede (solid lines) infestation and interval between subsequent sweet potato crops. ● = AEZ I; ▲ = AEZ II; ■ = AEZ III. For explanation see Figure 1.

major food and cash crops. Effects of millipedes were often confounded and confused with those of other soil pests, like the sweet potato weevils. While some farmers had ideas of how to reduce pest damage in their crops, such as separating the fields, others lacked that knowledge. Methods to manage millipedes should be designed that are based on the local cropping system.

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