CHAPTER 8

Damage to storage roots by insect pests

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8.1 Background

Damage to sweetpotato storage roots by insect pests, even when it occurs before harvest, can be considered a post-harvest problem as it reduces both the nutritional and economic value of the storage roots and can reduce shelf-life.

The most important insect pest of sweetpotato storage roots worldwide is the sweetpotato weevil (*Cylas* spp., Coleoptera: Apionidae). In certain areas of East Africa, the so-called rough weevil (*Blosyrus* spp.), which damages the surface of the root, is also starting to gain economic importance.

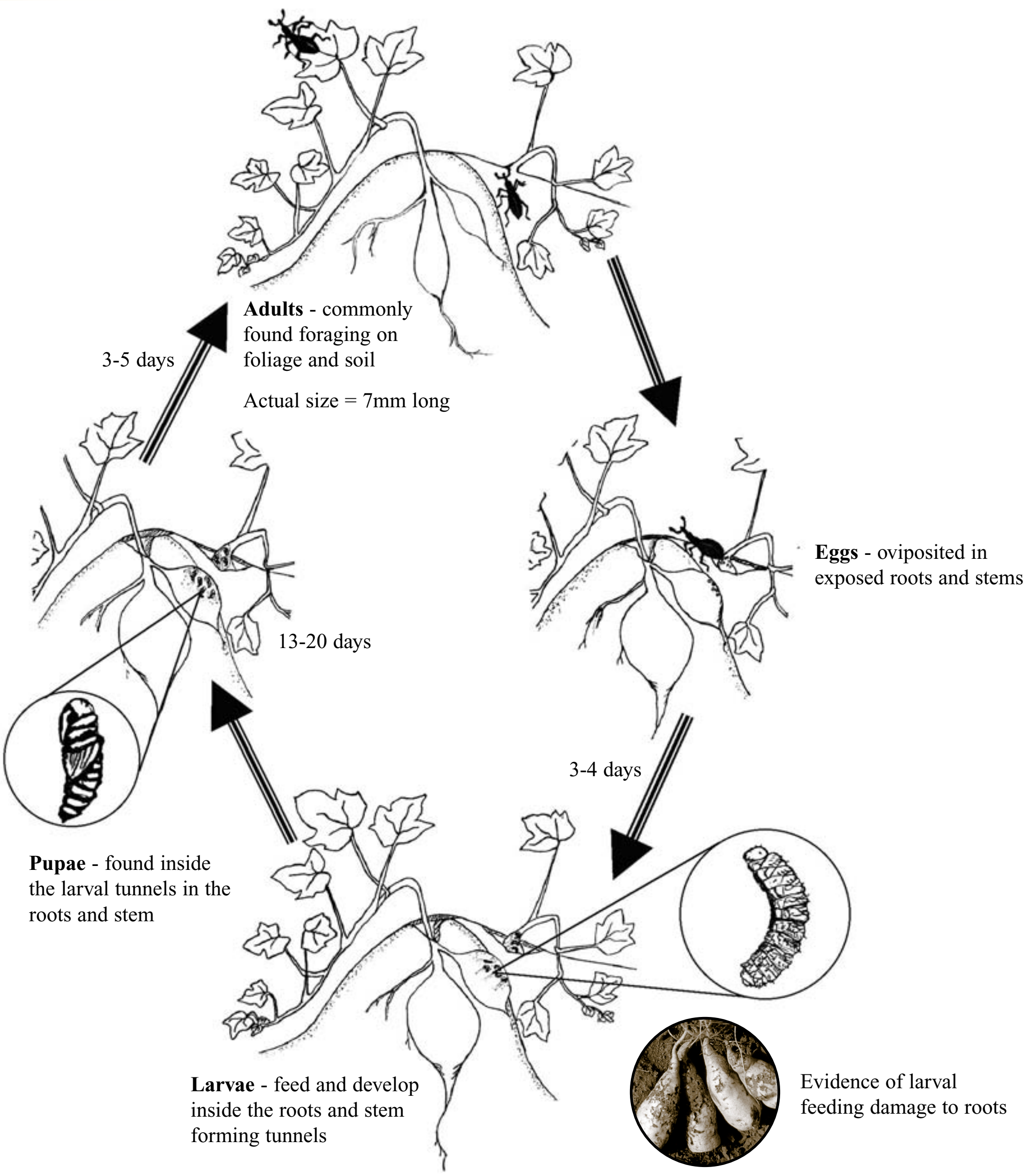
8.1.1 Sweetpotato weevils (*Cylas* spp.)

Sweetpotato weevils constitute a major constraint to sweetpotato production and utilization worldwide (Villareal, 1982; Sutherland, 1986; Chalfant *et al.*, 1990; Lenne, 1991). Yield losses as high as 60–97% have been reported (Ho, 1970; Subramanian *et al.*, 1977; Mullen, 1984; Jansson *et al.*, 1987; Smit, 1997). Even low levels of infestation can reduce root quality and marketable yield because the plants produce unpalatable terpenoids in response to weevil feeding (Akazawa *et al.*, 1960; Uritani *et al.*, 1975) and consumers will pay only reduced prices for roots damaged by *Cylas* spp. (Ndunguru *et al.*, 1998).

Sweetpotato weevils are a particularly serious problem under dry conditions, because the insects, which cannot dig, can reach roots more easily through cracks that appear in the soil as it dries out. In much of East

Africa, the sweetpotato crop matures after the end of the rains, and root bulking, which has a tendency to shift the soil, often exposes roots providing easy access for *Cylas* spp. It is for this reason that during the dry season, unlike cassava, sweetpotato roots cannot be stored in-ground for any significant period of time. Given the perishability of the root once it has been harvested, this critically limits the potential of the crop as a secure food supply. Initial surveys of root quality in the markets of Tanzania have shown that, at certain times of the year, 15–20% of roots that are sent to the market may be spoiled by infestation (Kapinga *et al.,* 1997). This is an underestimation of the total levels of loss, since farmers usually leave infested roots in the field.

There are a number of species of sweetpotato weevil; *Cylas puncticollis* and *C. bruneus* are the most prevalent species in East Africa, while *C. formicarius* is the most abundant in North and South America and the Far East. The female sweetpotato weevil lays eggs singly in cavities excavated in either the vines or exposed/easily accessible roots (Figure 8.1). The developing larvae tunnel while feeding inside the vine or root and are the most destructive stage. Pupation takes place within the larval tunnels and adults emerge after a few days. Plants may wilt or even die as a result of extensive stem damage, and damage to the vascular system can reduce the size and number of storage roots. While external damage to roots can affect their quality and value, internal damage can lead to complete loss. As sweetpotato weevils fly infrequently and generally only for short distances (Chalfant *et al.*, 1990), newly planted fields are most likely to be infested through planting material, immigrating *Cylas* spp. weevils from neighbouring fields or alternative host plants (Sutherland, 1986), or survivors in crop debris from a preceding crop (Talekar, 1987).



Source: Adapted by T.E. Stathers, NRI, UK from original artwork by W. Temu, MATI Mwanza, Tanzania.

Figure 8.1 Lifecycle of *Cylas puncticollis* and its association with sweetpotato plants

8.1.2 Selecting cultivars for resistance/ tolerance to root insect infestation

Several attempts have been made to breed for resistance to *Cylas* spp. The most likely resistance mechanisms include: escape via deep rooting (as weevils can only burrow short distances); or early maturity (enabling farmers to harvest roots before the onset of the dry season and the subsequent increase in *Cylas* spp. populations); or non-preference related to the chemical composition of the roots of different cultivars. However, the rate of success in breeding for non-preference has been slow, leading some breeders to conclude that an adequate source of resistance may not exist within the sweetpotato germplasm. Nevertheless, there are numerous reports of variation among varieties in susceptibility to weevil attack. Among East African germplasm, for example, one cultivar, which is particularly popular throughout the region (known as SPN/0 in Tanzania and Tanzania in Uganda), appears to be highly susceptible compared to other less popular varieties (S. C. Jeremiah, personal communication). There is no evidence of cultivar differences in susceptibility to attack by the rough weevil.

It has been standard practice to assess insect damage to roots as part of the yield trials conducted within breeding programmes throughout East Africa. In practice, the data obtained have not provided consistent information on cultivars. This is probably because the timing of trials, with harvests at the start of the dry season, is arranged to avoid weevil infestation. Studies have shown that where weevil infestation is either low or very high, cultivar differences cannot be observed (Stathers *et al.,* in press a). This is illustrated in Table 8.1, which summarizes the results of nine trials conducted in Tanzania and Uganda in 1997/98. Significant cultivar effects could be seen in all cases, except those where infestation was very high, or low. Despite this, observations on insect infestation during yield trials may be useful in picking out any varieties with particularly high susceptibility and is, therefore, recommended.

A recent study has been carried out as a collaborative venture between the Tanzanian National Root and Tuber Crops Programme (TNRTCP), National Agricultural Research Organization (NARO), Natural Resources Institute (NRI) and the International Potato Center (CIP) with the following objectives:

- to determine the extent to which sweetpotato cultivars presently available in East Africa differ in their susceptibility to field infestation by *Cylas* spp.
- to examine the factors that determine the susceptibility of sweetpotato cultivars to this pest
- subsequently, to use the above information to establish strategies for selection of suitable cultivars for East Africa with reduced susceptibility.

Some of the results obtained are presented here, while further details can be found in Stathers *et al*. (1999, in press a, b). The main purpose of this chapter is to present the methods used to assess levels of insect damage.

8.2 Methods

8.2.1 Assessment of storage root damage by *Cylas* spp.

Within a breeding programme, methods for measurement of insect infestation need to be simple and rapid. Two methods are described here. A non-destructive scoring system relies on scoring each root

Table 8.1 Percentage yield without *Cylas* spp. infestation and significance of cultivar effects for trials conducted in Tanzania and Uganda in 1997 and 1998

Trial			Percentage clean marketable yield (by weight)	
			Overall mean	Cultivar effect *P* value
Ukiriguru 1997			53.5%	*
Ukiriguru 1998			71.1%	**
Kibaha 1997			95.1%	n.s.
Kibaha 1998			14.4%	n.s.
Serere 1997	Season 1	4 months	66.8%	+
Serere 1997	Season 1	6 months	77.7%	***
Serere 1997	Season 2	4 months	99.5%	***
Serere 1997	Season 2	6 months	89.8%	+
Serere 1998			85.3%	***

+ $P<0.1$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

At Serere, percentage clean total yield was measured.

for visible signs of infestation. A second method is more precise and measures the extent of damage by cutting the roots into clean and infested portions. *Cylas* spp. are cryptic, i.e. they spend much of their lifecycle inside the storage root or vine, so that some damage may not be visible from the outside. Precise assessment of insect numbers and damage, therefore, requires the storage root to be carefully taken apart. However, this is very time consuming. We present data, however, that show that the scoring method relates well with destructive methods of measurement, and is of practical use in breeding programmes.

8.2.2 Non-destructive damage scoring

Following harvest, roots are separated into those of marketable size (in Tanzania this typically includes roots with a root diameter >25 mm), and those which are unmarketable (root diameter <25 mm). Only marketable roots are assessed for weevil damage. However, as the criteria for determining whether roots are marketable or not differs between countries, these categories will need to be adjusted as appropriate in individual countries.

Roots are separated into different categories depending on the percentage of the external surface showing infestation (Figure 8.2). The damage within each plot is expressed as the weighted mean (Table 8.2).

Figure 8.2 Sweetpotato roots sorted by *Cylas* spp. infestation category

8.2.3 Measurement of percentage infested portion of roots by cutting

For this assessment, marketable roots are separated into infested and non-infested (clean) groups. The infested portion of the infested roots is removed by cutting to separate the clean and infested parts (Figures 8.3 and 8.4). This provides three parts of the harvest:

- completely clean (non-infested) roots, which are suitable for marketing
- clean parts of infested roots (edible) which can be used by the household, but will not keep for long
- infested portions of roots that are useless for most purposes.

This is the more time consuming of the methods, but we believe that it provides the most accurate representation of the way the sweetpotato harvest is used by farmers.

8.2.4 Comparison of the two methods of measurement

The two methods of assessment are compared in Figure 8.5. Data from two trials with very different levels of infestation are included.

The two methods produced strongly related values (Figure 8.5), but the degree of scatter is also quite high. This is an indication of the degree to which roots without much external signs of damage often have greater internal damage as a result of burrowing and feeding by developing *Cylas* spp. larvae. Thus, we have confidence in the non-destructive damage scoring method as an approximation of levels of infestation, but believe that for detailed studies where extra effort is justified, the destructive method (infested portion of roots by cutting) is more appropriate.

8.2.5 Assessment of storage root damage by other insect pests

Where roots are to be assessed for damage by pests other than *Cylas* spp., for example, *Blosyrus* (Figure 8.6), it is easy to use a scoring system similar to that used for *Cylas* spp. (see Table 8.2).

Table 8.2 Example of scoring method calculation

	Percentage damage seen on root surface							
	Number of roots in each damage category							
	1 (0%)	2 (1–10%)	3 (11–25%)	4 (26–50%)	5 (51–75%)	6 (>75%)	Calculation	Weighted mean score
SPN/0 Rep1	4	5	8	2	0	0	= ((1*4)+(2*5)+(3*8)+(4*2)) /(4+5+8+2)	2.42

Figure 8.3 Removal of *Cylas* spp. infested portion of root

Figure 8.4 Cut sweetpotato roots showing edible and *Cylas* spp. infested portion of roots

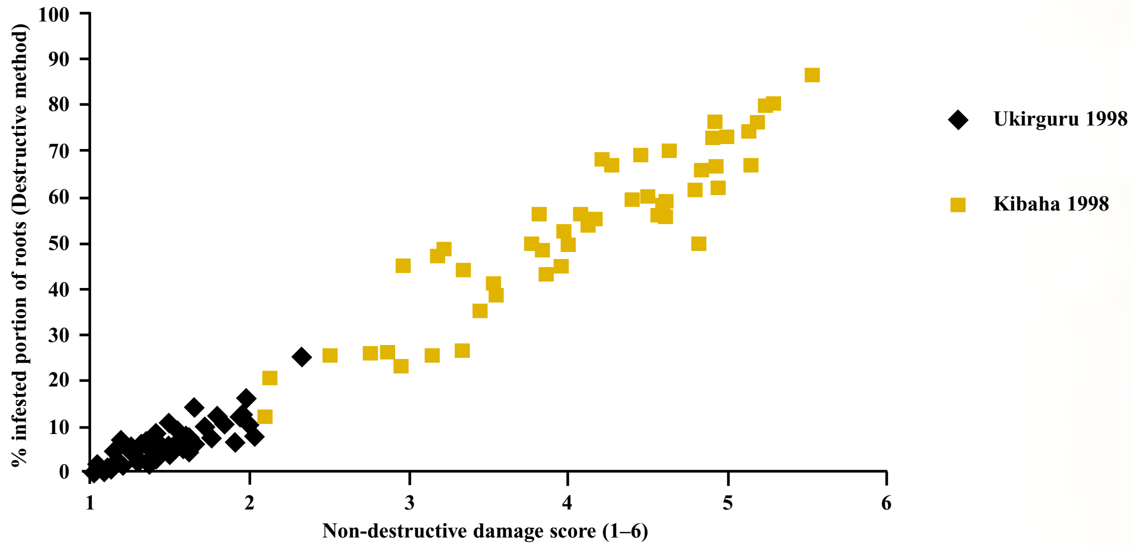


Figure 8.5 A comparison of two methods for assessing damage by *Cylas* spp. during sweetpotato trials at Kibaha and Ukiriguru, Tanzania in 1998

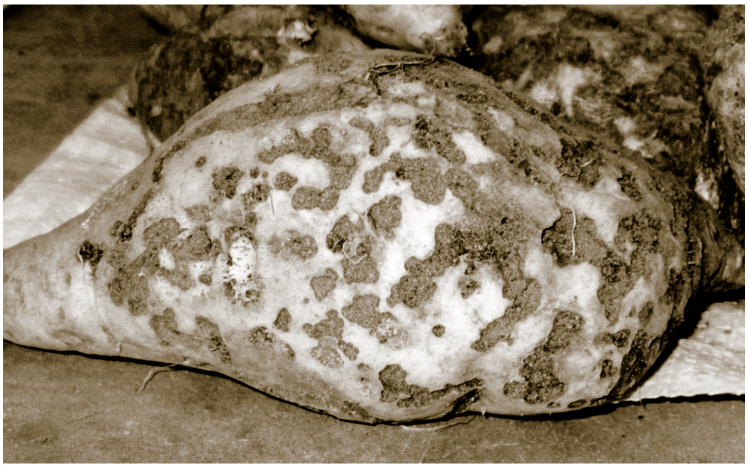


Figure 8.6 **Surface damage caused by the rough sweetpotato weevil *Blosyrus* spp.**

8.3 Results and discussion

Using the methods of damage assessment described above, trials were conducted at two sites in Tanzania (Lake Zone Agricultural Research and Development Institute (LZARDI), Ukiriguru and the Sugarcane Institute, Kibaha) and one site in Uganda (Serere Agricultural and Animal Production Research Institute) to assess a range of cultivars for their susceptibility to infestation by *Cylas* spp. In Tanzania, natural levels of *Cylas* spp. infestation were supplemented by artificial infestation (full details are given in Stathers *et al.,* in press a).

There was a notable range in both yield and infestation levels between cultivars within trials. An ANOVA established that the cultivar effect on infestation levels (percentage of clean marketable yield) was significant to less than 10% in all but two trials (see Table 8.1), which had the highest and lowest percentage clean marketable yield, respectively. The results for LZARDI, Ukiriguru are illustrated in Figure 8.7.

The consistency of cultivar behaviour between seasons (i.e. genotype effect) is indicated by correlating infestation levels (clean marketable yield and percentage clean marketable yield) for the two seasons considered for each site (Table 8.3). Significant correlations were obtained for Ukiriguru and Serere, but not for Kibaha, where (as mentioned above) extreme levels of infestation were recorded.

Four cultivars, Mwanamonde, Budagala, Sinia and SPN/0, were included in the trials at both Kibaha and Ukiriguru. A degree of consistency was seen; at both sites, Budagala and Mwanamonde were less susceptible than Sinia and SPN/0 (Figure 8.8).

These results indicate that significant and reasonably consistent differences in susceptibility to *Cylas* spp. exist among East African sweetpotato germplasm. In order to determine what factors might be associated with reduced infestation levels, we measured a wide range of plant characteristics. Attempts to model infestation levels in terms of these characteristics produced the linear regression models given in Table 8.4.

These models indicate that most of the cultivar variation observed could be explained by relatively few characteristics: root yield (root number, root weight), foliage yield, crown diameter, soil cracking, exposed roots and shortest weevil distance. (Shortest weevil distance refers to the shortest distance from soil surface to root. Details of measurement are given in

Table 8.3 **Correlations for cultivar clean (marketable) yield and percentage clean (marketable) yield between years at three locations**

		Correlation coefficient (R)	
	Number of cultivars	Clean (marketable) yield	Percentage clean (marketable) yield
Ukiriguru 1998 vs. Ukiriguru 1997	16	0.57 *	0.67 **
Kibaha 1998 vs. Kibaha 1997	10	n.s.	n.s.
Serere 1998 vs. Serere 1997 (at 6 m.a.p)	21	n.s.	0.49*

* *P*<0.05, ** *P*<0.01, n.s. = not significant.

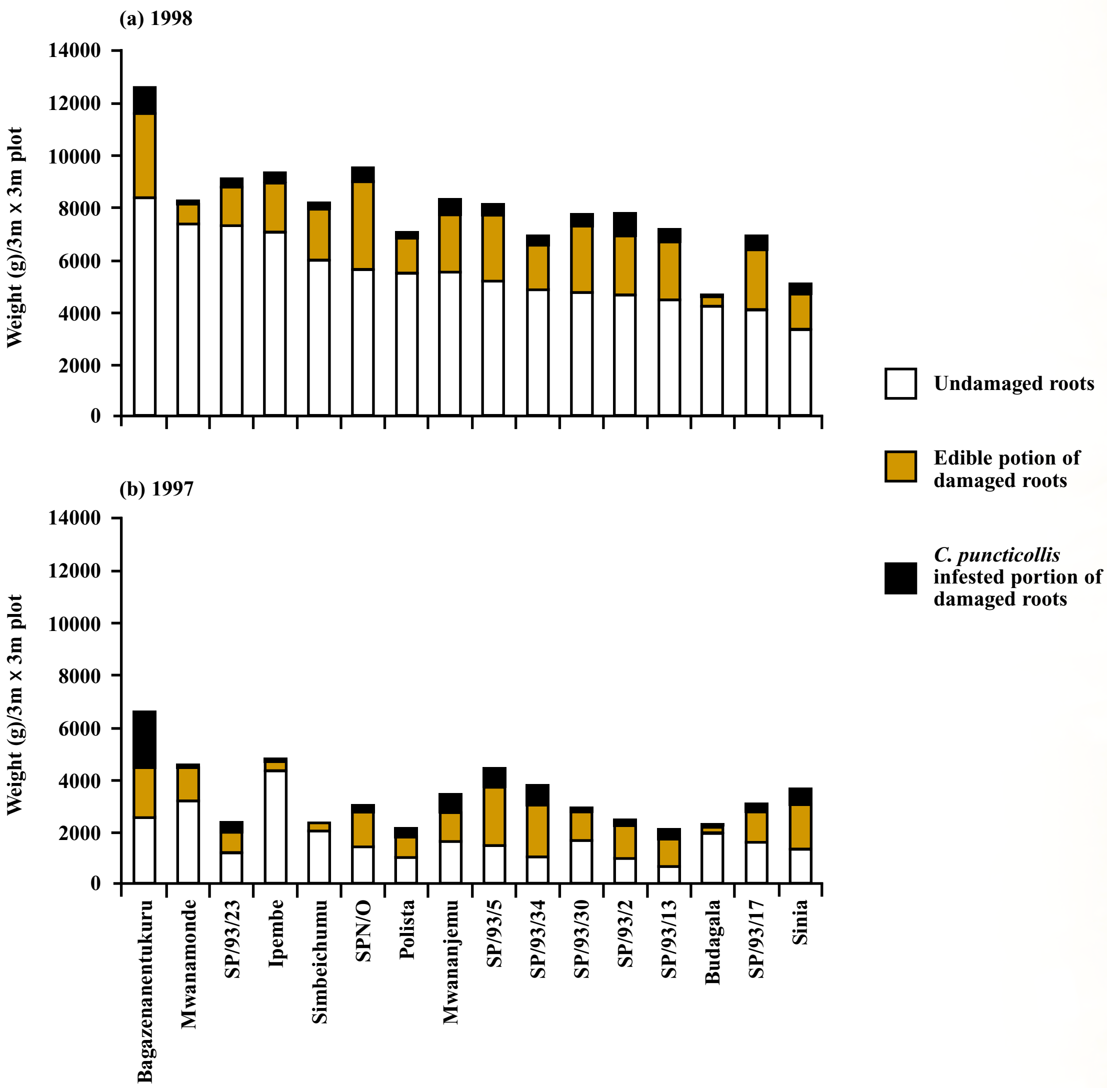


Figure 8.7 Comparison of *Cylas puncticollis* damage on the mean marketable yield of 16 sweetpotato cultivars at Ukiriguru, Tanzania in (a) 1998 (n = 5), and (b) 1997 (n = 4). Damage assessment was carried out by cutting (see section 7.2.3)

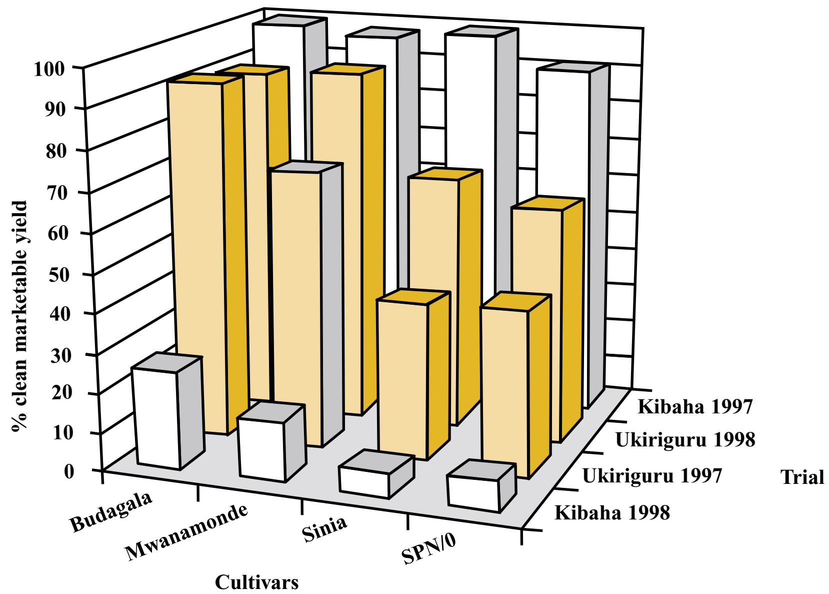


Figure 8.8 Percentage clean yield for four key sweetpotato cultivars in trials at Ukiriguru and Kibaha in 1997 and 1998

Table 8.4 Models of *Cylas* spp. infestation in terms of plant characteristics

Location and season of trial	Percentage clean yield*		Percentage infested portion of roots **		Non-destructive damage score ***	
	Model	**var.**	**Model**	**var.**	**Model**	**var.**
Ukiriguru 1997	60.0+5.0FW-0.6R	69 (29)	5.9-1.1FW+0.2R	29 (24)	1.5-0.06FW+0.008R	57 (26)
Ukiriguru 1998	94.0+0.6FW-1.6ER 0.4SC	88	1.6 0.2FW+0.4ER+0.07SC	68	1.2-0.02FW+0.02ER+0.007SC	74
Kibaha 1997	No meaningful models could be constructed					
Kibaha 1998	No meaningful model could be constructed		30.4-2.4FW+7.8RW+4.7ER	88 (46)	3.1-0.2FW+0.4RW+0.2ER	75 (49)
Serere 1997	97.4-0.9RW	30	No meaningful model could be constructed		ND	
Serere 1998	23.0+7.5SWD+ 4.5CD-0.9RW	70 (37)	25.7-2.3SWD-1.8CD+0.1RW	74 (25)	ND	

FW = foliage weight (t/ha); RW = root weight (t/ha); R = root number (/ha); ER = percentage of plants with exposed roots; SC = percentage of plants with soil cracks; SWD = shortest weevil distance (cm); CD = crown diameter (mm); ND = no data.

var. = percentage variance accounted for by model. Where models include a root yield term (R or RW), the variance accounted for by this term alone is given in brackets.

* Percentage clean yield refers to weight of roots completely clear of infestation.

** For measurement of percentage of infested portions, roots were cut and separated into clean and infested portions as described in section 8.2.3.

*** Non-destructive damage score as described in section 8.2.2.

Stathers *et al.,* in press a.) It is not unexpected that higher root yield is associated with increased levels of infestation, but clearly this is not a useful relationship in the context of breeding for reduced susceptibility. Soil cracking, exposed roots and shortest weevil distance all relate to root architecture. In all but one location, we approximated root depth by measuring neck length. Although this was related to infestation levels in several trials, we could not find any strong models containing this parameter. 'Root neck length' measures the distance from the crown (soil level on plant stem) to the tip of the root when the harvested plant is held above ground. This measurement gives no indication of whether the roots have gone straight down into the soil or spread sideways (possibly close to the edge of the ridge) and, therefore, is not a realistic measurement of accessibility of roots to *Cylas* spp. The shortest distance to the root is a much more time consuming method, but future fieldwork studying cultivar differences in *Cylas* spp. infestation levels would benefit from using this more accurate indicator of how accessible roots are to the infesting *Cylas* spp. weevils.

In several models, high foliage weight was associated with reduced levels of infestation. This suggests it might be advantageous to select for cultivars that have increased foliage or whose foliage persists longer into the dry season. Increased foliage cover may maintain moisture in the soil and prevent the formation of soil cracks, or make them less accessible to weevils. In addition to maintenance of soil moisture, two alternative hypotheses are firstly, that *Cylas* spp. damage to the crown may reduce foliage growth (a significant negative correlation was observed between foliage yield and external damage to crowns), or secondly, that there may be complex links between *Cylas* spp. feeding behaviour and oviposition, or foliage and predatory insect numbers.

Although the results are not presented here, laboratory experiments were conducted at all three sites to determine if the harvested storage roots of sweetpotato cultivars differed in their acceptability to *C. puncticollis* or if any root antibiosis (toxicity) towards *C. puncticollis* existed (for details see Stathers *et al.,* in press b). For all experiments, cultivar effects on the number of new adults emerging were significant to at least 10% and in most cases were much more significant. At Ukiriguru and Kibaha, the results showed reasonable consistency between years and, of the four cultivars used at both sites, fewer *C. puncticollis* adults emerged from roots of Sinia and Budagala than from SPN/0 and Mwanamonde on all occasions. A relationship between laboratory experiments and crown damage by *Cylas* spp. in the field suggests that cultivar differences in attraction/deterrence for *Cylas* spp. exist. However, correlations between adult emergence in laboratory experiments and field infestation levels were generally not strong. Although this indicates that cultivar selection by laboratory experiments is not a useful strategy for reducing field infestation, there may be potential for using such techniques to select cultivars that are resistant to attack during long-term storage.

8.4 Conclusions and implications

Two methods for assessing cultivars for susceptibility to *Cylas* spp. infestation have been introduced. The best strategies for assessing cultivars may differ by location. In countries where sweetpotatoes are grown almost exclusively for marketing, roots infested by *Cylas* spp. have virtually no economic value. In contrast, in many developing countries the clean portion of partially infested roots can act as a food source, either fresh if consumed immediately, or sliced and sun-dried. Comparison of the methods indicated no great difference in subsequent ranking of the cultivars. For detailed studies, the destructive measurement of the percentage of infested portion of roots is the most accurate representation of the way the sweetpotato harvest is used by farmers in East Africa. However, our data suggests that non-destructive damage scores can be used as a rapid approximation.

Although attempts to breed for resistance to *Cylas* spp. infestation have so far shown little success, results presented here on the differences among cultivars in East Africa, indicate the value of continuing to assess cultivars for their levels of susceptibility to the pest, as indeed most breeding programmes continue to do.

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