A REVIEW OF YIELD LOSSES AND DAMAGE CAUSED BY MAIZE STEMBORERS IN EASTERN, CENTRAL AND SOUTHERN AFRICA

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INTRODUCTION

Maize, Zea mays, is one of the most important staple cereal crops in the developing world. In 1977 the area under maize cultivation in Africa was 17 per cent of the world's total and the grain produced accounted only for 7 per cent (FAO, 14). In eastern, central and southern Africa, maize is an important source of carbohydrate for the majority of the people. Maize is important as livestock feed in the form of grain or silage. In Kenya about 40,000 hectares of land are under maize cultivation in the Coast Province (46) while 1.5 million hectares were put to maize cultivation in 1985 and 1.6 tonnes of maize were realised from the southern highland regions of Rukway, Mbeya, Iringa and Ruvuma (11,20). In Malawi maize is grown in the Northern, Central and Southern Provinces (Munthali, 1987). In Mozambique, Maputo and Gaza Provinces in the South of the country are the major maize growing areas (10). In Zimbabwe, most of the maize is grown in Agro-ecological Region I, receiving an annual rainfall in excess of 1000 mm and Region II with an annual rainfall ranging from 600 to 750mm over four months (47). In 1981 the Commercial Agricultural Sector produced 997,000 tonnes of maize while the Communal Sector (resource-poor sector) produced 100,000 tonnes (Department of Agricultural Extension and Technical Services Report, Unpublished). The maize yields from the resource-poor farmers' fields are generally very low owing to damage caused by insects, diseases, nemotodes, weeds, birds and rodents. Maize yield losses of 30 per cent are generally regarded as normal (14).

Among insect pests of maize, the lepidopterous stemborers constitute an economically important group with various species belonging to the families Noctuidae and Pyralidae (18,22,13,34,17,44,45,31,27,5,41). Stemborers occur regularly in a maize crop causing damage varying from low intensity to high according to prevalent environmental conditions. Stemborers are thought to be one of the major constraints to maize production in eastern, central and southern Africa. The maize stalkborer (Busseola fusca Fuller), spotted stemborer (Chilo partellus Swin), pink stemborer (Sesamia calamistis Hmps) and the sugarcane stemborer Eldana saccharina Wlk) are widely distributed and destructive. However, the relative importance of these stemborers with respect to maize yield reduction is variable depending on prevalent agro-ecological conditions. For example S. calamistis and E. saccharina appear to be economically important in relation to yield loss in Kenya while they are insignificant in Zimbabwe. Current research activities in eastern, central and southern Africa, with regard to the interaction between maize and stemborers seems to be directed towards the acquisition of knowledge on stemborer migration, timely insecticidal application, cultural measures, bio-control agents, use of sex pheromones, resistant maize varieties and integrated stemborer management without adequate generation of information essential to the implementation of control measures. For example, it is a prerequisite that economic damage, economic levels and economic thresholds be determined in order to develop an integrated pest management (IPM) programme. Clearly this demands the collating of comprehensive data in relation to maize yield losses ascribed to stemborers. Yield losses due to stemborers are very difficult to assess precisely owing to the number of stemborer species involved, different damage symptoms, different stages of maize development attacked and the confusing presence of other pests including diseases and nematodes. These factors make separate determination of the effect of stemborers a very difficult task (12). To date very little maize yield loss studies have been conducted in eastern, central and southern Africa. However, some studies have been conducted in East Africa, Zimbabwe and South Africa by such investigators as Ingram (1958), Rose (1962), Walker (1960, 1965, 1977) and Van Rensburg et al, 1988. Investigators of maize yield loss have confined their studies to research stations without carrying out concurrent research activities on farms, especially those of resource-poor farmers. Since objective data for thorough on-farm yield loss assessment due to stemborers is lacking, the objective of this paper is to review the stemborer-yield relationship using published and unpublished work in the region under review.

DISTRIBUTION AND BIOLOGY

Maize stalkborer (Noctuidae: Busseola fusca Fuller)

The maize stalkborer is generally considered the most widespread and destructive of all insects attacking maize in eastern, central and southern Africa (27,31,3,5). B. fusca is indigenous to Africa and prefers maize as a host although it is capable of causing serious losses to grain-sorghum. It is the dominant maize stemborer at high elevations (26). In Tanzania, B. fusca is reported to be the major pest at 400 meters above sea level (20) although this altitude is considered too low for this stemborer to be the dominant species attacking maize. However, this author has observed high infestations of the maize stalkborer on maize and sorghum in a small area at low elevation in Zimbabwe where low infestations would be expected. The cause in Tanzania and Zimbabwe is a clear indication of the capability of B. fusca to adapt itself to low-lying and warmer areas. The distribution of the maize stalkborer is depicted in Tables 1 and 2. B. fusca has two generations per year but in some seasons a third generation may occur depending on the prevailing agro-ecological conditions and the presence of suitable host plants. At the onset of the dry season, second generation larvae enter into diapause in tunnels at the bases of maize stalks to await pupation later with the arrival of rains. Moths emerge three weeks after the commencement of pupation and lay eggs on the bases of leaf sheaths. Eggs hatch within a week and the newly hatched larvae migrate to feed on tender leaves in the funnel prior to entering into the stem. Observations in southern Africa are that the larvae have a tendency to penetrate the underground part of the stem as the weather becomes colder. The assumption is therefore that the minimum daily temperature in the bases of maize stalks is higher than on the soil surface and is favourable to the survival of the pest.

Spotted Stemborer (Pyralidae: Chilo Partellus)

The spotted stemborer (C. partellus) is not indigenous to Africa but invaded the continent from India (23). Its presence in South Africa was recorded in 1958 (38). Although it causes severe losses to maize, C. partellus prefers sorghum as a host plant. In eastern, central and southern Africa, the spotted stemborer appears to be confined to medium and low elevations. However, this pest is becoming an important borer of maize at high elevations in South Africa. Revington (26) reported the recording of C. partellus attacking maize in 1958 in warmer areas of Transvaal. Quite recently C. partellus has been reported to be a threat to maize at high elevations in eastern and northern Transvaal and north-west Free State suggesting that it is adapting to cold environmental conditions very rapidly (26). The distribution of this pest in the region under review is shown in Tables 1 and 2. C. partellus has three or more generations; especially where maize is grown throughout the year. The spotted stemborer is known to complete its life cycle in 30 to 40 days (1, 15). It has a short life cycle probably as an adaptation to the conditions prevalent in its environment.

Pink Stemborer (Pyralidae: Sesamia calamistis)

This stemborer species is most prevalent at medium and low elevations as shown in Table 2. In the region under review very little research work has been conducted with respect to its pest status. Female moths lay eggs between the base of the leaf sheath and the main stem. Larvae hatching within 7 days work their way into the stem close to the oviposition site. Larval development takes 6 to 10 weeks in the stem and culminates in pupation lasting about 14 days prior to moth emergence.

Sugarcane Stemborer (Pyralidae: Eldana saccharina)

This pyralid is an important pest of sugarcane. Although it is known to attack maize, its impact on yield is not known. Newly hatched larvae feed on leaves and penetrate the stem when they are fully grown. Larval development lasts for 3 to 8 weeks and pupation takes about 7 to 14 days.

Table 1: Lepidopterous Stemborers of Maize, Sorghum, other hosts and their Distribution in East Africa (Modified after Seshu Reddy, 1984)

STEMBORER		HOST PLANTS	DISTRIBUTION
Common Name	**Scientific name**	**Host Plants**	**Country**
Maize Stalkborer	Busseola fusca Fuller	Maize Sorghum Pearl Millet Sugarcane Several grasses	Kenya Tanzania Uganda
	Busseola segata Bowden	Maize Sorghum Finger Millet Sugarcane Many grasses	Tanzania Uganda
African pink stalkborer	Sesamia botanephaga Tams and Bowden	Maize Rice Finger Millet Sugarcane Several grasses	Tanzania Uganda
	Sesamia calamistis Hampson	Maize Sorghum Pearl Millet Finger Millet Rice Sugarcane Many grasses	Kenya

Table 1: Lepidopterous Stemborers of Maize, Sorghum, other hosts and their Distribution in East Africa (Modified after Seshu Reddy, 1984) (cont'd)

STEMBORER		HOST PLANTS	DISTRIBUTION
Common Name	Scientific name	Host Plants	Country
	Sesamia Penniseti Tams and Bowden	Maize Sorghum Pearl Millet Sugarcane	Uganda
Sorghum Stemborer	Chilo partellus (swinhoe)	Maize Sorghum Finger millet Rice	Uganda Kenya
		Wheat Sugarcane Wild species of Sorghum Many grasses	Tanzania
Sugarcane stemborer	Eldana saccharina Walker	Sorghum Maize Pearl Millet Finger Millet Sugarcane Rice, Cassava	Uganda Kenya Tanzania

Table 2: Distribution of Lepidopterous Stemborers of Maize and Sorghum in Southern Africa

Stemborer		Distribution		Elevation (m) & Percentage Relative Abundance*		
Common Name	Scientific Name	Country	Economic Importance Rank**	High > 900	Medium 700-900	Low < 700
Maize stalkborer	*Busseola fusca* (Noctuidae)	Botswana	2	90	18	10
		Lesotho	1			
		Malawi	2			
		Mozambique	2			
		South Africa	2			
		Swaziland	1			
		Zimbabwe	2			
Spotted stemborer	*Chilo partellus* (Pyralidae)	Botswana	1			
		Malawi	1			
		Mozambique	1	5	40	70
		South Africa	1	(South Africa)		
		Swaziland	2			
		Zimbabwe	1			
Pink stemborer	*Sesamia calamistis* (Noctuidae)	Malawi	3			
		Mozambique	3	5	40	10
		South Africa	3			
		Zimbabwe	3			
Sugarcane stemborer	*Eldana saccharina* (Pyralidae)	Mozambique	4	0	2	10
		South Africa	4			
		Swaziland	4			
		Zimbabwe	4			

* Information arising from a preliminary investigation conducted by the author during the 1985/86 cropping season.

** 1 = high Economic Importance. 4 = low Economic Importance

DAMAGE SYMPTOMS

The damage symptoms caused by the maize stemberers (B. fusca, C. partellus and E. saccharina, are essentially the same (2).

At about 10 to 15 days after crop emergence the first generation eggs are oviposited on young plants. Young plants are thought to be more attractive to ovipositing females and hence are more susceptible to larval attack than old plants. Larvae feeding on leaves cause elongated 'windows' and 'shot-holes' and may result in the reduction of the photosynthetic tissue area when infestations are very heavy. However, it is often observed that the rate of infestation is less for the first generation than the subsequent generations. During a growing season, stemborer generations overlap with the consequence that the pest is continually causing damage to newly developed sheaths and young leaves. Leaf-feeding continues until the larvae have reached the second or third instar stage when they penetrate into the stem (39).

Stem penetration by larvae occurs from about 8 to 15 days after hatching. The point of larval entry into the stem varies and very important in relation to the position of the apical meristem and the damage symptom caused by the pest. When larval entry into the stem occurs after floral initiation and the apial meristem has moved up to a position far removed from entry point, the damage symptoms observed are shot holes, elengated windows, entry holes and stem is at the apical meristem, meristematic tissue is destroyed with the consequent formation of a 'deadheart' symptom in which the apical meristem loses its dominance. When this occurs, the lateral meristemetic tissues become active and the affected maize plants may produce suckers. In the absence of deadheart formation, stemtunnelling activity continues and stems may become weak. In the event of a wind of high velocity blowing, the affected stems may break at the points of weakness. If the larvae penetrate the stems prior to peduncle elongation, tissues of the closely packed internodes below the apical meristem are destroyed and the plants may become stunted.

Stemtunnelling occuring at the same time as tne peduncle is elongating may lead to the destruction of vascular bundles and grain filling may be interrupted (21). If stemtunnelling is confined to the pith and the vascular bundles are not damaged grain development will be normal. If stem or peduncle breakage due to damage by stemborers occurs after physiological maturity is attained then the reduction in yield will be minimal. Sometimes pith decay occurs as a result of larval tunnelling activity and the phloem and xylem vessels become damaged with the consequent malformation of grain. Accordingly neat stemtunning confined to the piths of maize stems in the absence of deadhearts, stembreakage and cob rotting may not be correlated with yield loss (36).

YIELD LOSS AND CONTROL

The current information on stemborer infestation levels, injury to crops, and the consequential maize yield loss in eastern, central and southern Africa is inadequate as it fails to build up the necessary foundation for stemborer management in the field. Information available in the region under review is attributed to work in East Africa, Zimbabwe and South Africa conducted by Ingram (1958), Walker (1960, 1965, 1977), Rose (1962) and Van Rensburge et al, (1988). These investigators concentrated on maize yield losses resulting from primary damage (leaf-feeding, deadheart formation and larval biomass per stem) without assessing the extent of injury of secondary damage (larval feeding activity in the stem) in relation to grain yield loss. Apart from information generated by these workers, yield loss estimates have been very subjective rather than being objective. Where attempts to quantify maize yield reduction due to stemborers were made, studies have been confined to research stations without concurrent on-farm activities.

In making decisions on what control measure to take, information on the relation between the rate of stemborer infestation and yield must either be available or generated (45).

The rate of infestation is measured as percentage number of plants attacked, degree of leaf-feeding, number of deadhearts, internodes attacked, stembreakage, eggs, larvae and pupae per maize plant. This quantitative assessment is important in the establishment of economic thresholds of infestation for purposes of mapping out control strategies, conduction of surveys on maize yield losses on the basis of infestation levels, prediction of losses from infestation from infestation intensity and evaluation of maize genotypes for resistance to stemborers in maize breeding activities (7). The concepts of economic injury and economic threshold constitute a good foundation in decision making because they integrate both biology and economics (32,35,25,33,4,28).

Larvae play an important role in the spreading of micro-organisms either directly as carriers or indirectly by boring into maize stems and cobs. This larval feeding activity facilitates the entry of micro-organisms into plants (37). The second generation larvae are often associated with cobrot disease *Fusarium moniliforme*. According attention ought to be paid to the interaction between stemborers and pathogens like *Fusarium* in relation to yield loss.

In the region under review there are reports of stemborer infestations ranging from 14% with a yield loss of only 9.8% (6) to 49% infestation with a yield loss of 37% in untreated plots (42). In 1957 Swaine recorded 22% damage plants in untreated lands and harvested 83% more grain from uninfected plants than infected plants. Borrow (9) working on maize genotypes resistant to stemborers reported that yield potentionals vary under pest attack with reduction in yield ranging from 38% to 100%. He found yield to be significantly correlated with leaf damage and even higher correlation with the degree of stemtunnelling. Table 3 shows percentage estimates of stemborer infestations and maize yield loss in countries of estatern, central and southern Africa. This clearly shows no relationship between the degree of stemborer infestation and maize yield loss.

Table 3: Estimates of Stemborer Infestation Levels and Maize Yield Loss

Country	Area	Infestation (%)	Yield Loss (%)
Kenya[1]	Late Maturity Zone: Kisii Kitale	10 - 33	2 - 30
	Coast Maize Composite Zone: South Coast Mtwapa Kilifi	33	25 - 75
	Early Maturity Maize Zone:	Very serious (No estimate)	No estimate
Tanzania[2]	Central	No estimate	44
	Western	No estimate	14
	South	No estimate	48
	Coastal	No estimate	11
Malawi[3]	Northern Region: Mzuzu	5	No estimate
	Central Region: Dedza	20 (9 larvae/ plant)	No estimate
	Zomba	25	No estimate
	Thondwe	48 (4 larvae/ plant	No estimate
	Chikwawa (Shire Valley)	17 (4 larvae/ plant	No estimate
Mozambique[4]	Maputo and Gaza Provinces	70 - 80 (Cobs infested: larvae/plant)	No estimate
Zimbabwe[5]	Natural Region I	40	
	Natural Region II	50	
	Natural Region III	40	10 - 43
	Natural Region IV	30	
	Natural Region V	30	
South Africa[6]	Eastern Transvaal: Malelane Komatipoort	80	50

1 Mailu, Waiyaki and Nyamasyo (1987).
2 Duerden (1953), Swaine (1957), Kabisa and Luhusa (1975).
3 Munthali (1987).
4 Berger (1981).
5 Wally (1967) and Page et al (1985).
6 Revington (1986).

Stemborer infestations on cereal crops cause the most severe damage during the early stages of development unless there is a high degree of peduncle boring for example at a later stage. Results of investigations conducted by Sharma and Sharma in India and the author of this paper in Zimbabwe favour the protection of cereal crops during the early stages of development because it is more beneficial in relation to yield loss reduction than when pesticides are applied at their later stages. Since two or more stemborer generations may occur on the same cereal crop, it is reasonable to assume that first generation larvae are more important than second generation larvae in reducing yield (28). However, second generation larvae are equally important in reducing yield in late planted maize crops and therefore late planting should be avoided as much as possible in order to minimise cob damage attributable to second generation larvae. Larvae are often observed in the funnels of young maize and sorghum crops about a week after hatching or artificial infestation and it is during this period that they are vulnerable to funnel applied pesticides. However, once they have penetrated the stems, control becomes extremely difficult unless a systemic pesticide has been applied at planting. Therefore chemical control measures should be applied either at planting or some time during the early stages of development. In breeding for resistance to stemborer attack, it is important to pay particular attention to the vulnerable early stages of crop development.

Different crop genotypes show variation in their reaction response to stemborer attack (9). The variations in crop genotype response to stemborer attack are reflected in the extent to which crop yields are reduced. Although little or no work on yield loss assessment has been conducted in the region, indications are that with ageing the toughness of leaves and stems of cereal crop increases, crop susceptibility to stemborer attack decreases and yield loss decreases (19,8,16,1,28,30).

CONCLUDING REMARKS

In conclusion, I would like to make the following recommendations in relation to maize yield losses attributable to stemborers:

1. The available information on yield losses in the farmers' fields is based on visual estimates with very few objective estimates in some countries. Therefore, more objective estimates should be made.

2. Surveys on stemborer species on the farmers' fields should be conducted using standardised procedures that will permit repeatability and comparison of data across locations.

3. There is need to conduct loss assessment trials at specific location using the following methodologies:

   - Protected and unprotected trials
   - Artificial infestation
   - Paired plant analyses of infected and uninfected plants.

   This should be conducted both at stations and farmers' fields.

4. The relationships between borer infestation and actual yield losses, amount of protection, and cost should be worked out.

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