INFLUENCE OF SIMULTANEOUS INFESTATIONS OF *PROSTEPHANUS TRUNCATUS* AND *SITOPHILUS ZEAMAIS* ON THE REPRODUCTIVE PERFORMANCE AND MAIZE DAMAGE

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ABSTRACT

This study examined the combined effect of Prostephanus truncatus *and* Sitophilus zeamais *infestations on their reproductive performance and on the damage they cause to maize variety ZM 621 with 12.5% moisture content. The specific objective was to determine the number of the insect pests at* F_1 *and* F_2 *and the grain weight losses caused by the simultaneous pests' infestations of shelled maize in the search for a control strategy. The results showed a change in adult insect numbers from* F_1 *to* F_2*. During single infestation the change in* P. truncatus *was 47.54% while in simultaneous infestations it was 41.66%. The change in* S. zeamais *was 31.25% and 18.60% during single and simultaneous infestations respectively. The t-test indicated significant differences in the percentage change of adult insect numbers between single and simultaneous infestations at* $P< 0.01$*. Further, the grain weight loss in simultaneous infestations was 28.53% while in single infestation* P. truncatus *and* S. zeamais *caused loss of 26.40% and 6.21% respectively. The Kruskal-Wallis test showed a significant difference in weight losses among the infestation types at* $P < 0.01$*. The* P. truncatus *and* S. zeamais *numbers were positively correlated with the grain weight losses at* $P < 0.05$*. It was concluded that simultaneous infestations greatly reduced the reproductive performance of* S. zeamais *up to* F_2 *while that of* P. truncatus *was less affected. These findings thus contribute to the components of Integrated Pest Management (IPM).*

INTRODUCTION

In maize storage systems in Tanzania the newly introduced and most dangerous pest of maize, *Prostephanus truncatus* (Horn) (Coleoptera:Bostrichidae) is often associated with other insect pests especially the cosmopolitan *Sitophilus zeamais* (Motsch.) (Coleoptera:Curculionidae). Both are primary pests of maize, the most important cereal crop grown in this country. The thrust of this laboratory study was to investigate the numbers of adult insects produced at F_1 and F_2 as well as the maize weight losses as a basis for determining the insects' reproductive performance and damage levels during single and simultaneous infestations of shelled maize. The results may have implications on the design of the stored pests control strategies. Current control methods for stored insect pests of maize include applications of chemical pesticides which are expensive and environmentally hazardous. There is therefore a need to synergize control strategies available in an effort to reduce chemical applications in the context of developing Integrated Pest Management (IPM).

IPM is a system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic damage (Hill 1987, van Emden 1999). It is reported by Southwood and Henderson (2000) that information about animal populations is sought for a variety of purposes including pest management since it guides the application of control measures after the assessments of incidences and or damage levels. Thus a laboratory ecosystem is worthy studying as the results give the understanding and prediction of what could happen in natural situations.

P. truncatus and *S. zeamais* are primary pests attacking whole grains whose moisture content may be as low as 10.5% (Golob and Hanks 1990, Meikle 1998) resulting in severe damage and hence great weight losses in stored maize. Both insects can infest standing maize in the field once the crop has attained maturity and is drying in the field, early before harvesting (Hodges 1994, de Pury 1968). The insects are known to complete development over a wide range of temperatures, 27^0C to 32^0C and between 70% and 80% relative humidity conditions (Hodges 1986, Throne 1994). The developmental period for both insects is about 30 days (Howard 1984). Both adults and larvae feed on the maize grains since they all have biting and chewing mouthparts. In this study the adult, being the final stage in the life cycles of the two insect pests, is opted for in the assessment of both the amount of damage and egg oviposition.

The intrinsic rate of increase of *P. truncatus* is reported by Cowley *et al.* (1980) to be Lambda 1.399 at optimum conditions on shelled maize grains and that this apparently low rate may reflect a feature of interspecific competition with more fecund storage pests like *S. zeamais*. It is therefore important to examine the interaction of *S. zeamais* and *P. truncatus* from this point of view. As noted by Chapman and Reiss (2002) organisms differ in their ability to compete with each other and hence varying impacts of one species on another. Regarding interspecific associations, Krebs (1978), Southwood and Henderson (2000), Weimerskirch *et al.* (2003) observe that these can cause changes in reproduction since the effects of increasing intensity of competition among adult insects decreases fecundity or rate of reproduction after some generations.

MATERIALS AND METHODS

Maize samples

An experimental maize variety ZM 621, was selected for the investigation of the reproduction of *P. truncatus* and *S. zeamais* and for the determination of the damage caused to the maize in terms of weight loss. The grains are dent due to the starchy endosperm which extends to the apex of the grains. Shelled maize grains were used since they are recommended to smallholder farmers as it has been proved that they are less damaged by the serious pest, *P. truncatus* compared to maize on cobs thus a component in the IPM (Golob and Hanks 1990). The samples, free of infestation were equilibrated for four weeks at favourable conditions of temperature and humidity (29 ± 2^o C and R.H. of 70% - 80%).

Rearing of the insect pests

Initial insect stocks of *P. truncatus* and *S. zeamais* were obtained from cultures at Ilonga Agricultural Research Centre, Morogoro region. Adult insects were kept in glass jars and raised on maize variety Staha, a susceptible variety and not used in the testing (Rugumamu 2000). For massive production of the insects, *S. zeamais* were reared on shelled maize while *P. truncatus* were reared on maize on the cobs (Hodges 1986, Kossou et al. 1992).

Aging, sexing and conditioning *P. truncatus* and *S. zeamais*

Adults were removed from the jars after two weeks - this was after egg oviposition. Then the jars were left undisturbed and emerging adults were collected for seven days. These are parent insects aged 1 to 7 days and were sexed according to Shires and McCarthy (1976) and Kossou et al. (1992). The parents were conditioned to ZM 621 by infesting eight 60 g replicates with 18 adults i.e. the ratio of F : M = 2 : 1 (Dobie 1974). In the case of simultaneous infestations the number of parents of each species was halved. The set-ups were maintained at favourable conditions for 7 days. The R.H. was maintained using Calcium chloride solution

(Solomon 1957). Experiments were then carried out for both single and simultaneous infestations to assess (i) *P. truncatus* and *S. zeamais* numbers at F_1 and F_2 (ii) weight losses of the maize after the insects' attack.

Assessment of F_1 and F_2 *P. truncatus* and *S. zeamais* numbers

Six replicates of fresh 60 g maize grains and the parent insects which were then between 7 and 14 days old were set. For both F_1 and F_2, the experimental design fell into the following sets: (i) single infestations of maize grains by parents, *P. truncatus* and *S. zeamais;* (ii) simultaneous infestations of maize grains by both insects (iii) controls comprised of only maize grains without insects. Each replicate was contained in a 130 x 60 mm glass bottle. The insects were confined in the bottles by perforated Aluminium foils to allow adequate ventilation and the moisture content of the maize to equilibrate with the set conditions in incubators. After ten days the parents were removed from the test samples which were then undisturbed for 7 days. They were then inspected daily for emergence of F_1 adults that were removed and numbers recorded. The exercise continued until no any adult was emerging. In the separate set-ups for the second filial generation, F_1 adults were left to mature, mate and oviposit in the maize samples for two weeks and the F_2 adults were then removed and recorded as they emerged.

Assessment of weight losses of maize

Each sample replicate was sieved using a 4 mm aperture sieve to remove the created maize dust/flour, insect frass and larval/pupal exuviae. The samples were then weighed to determine weight losses of the maize at both F_1 and F_2. Moisture contents of the controls were measured before and after the experiments according to Pixton (1982). The actual weight losses of the maize grains due to insects' attack and damage were calculated after the application of the correction factor of percentage weight changes derived from the controls. This activity was carried out in both single and simultaneous infestation set-ups.

Data analysis

The t- test was carried out to compare changes in numbers of *P. truncatus* and *S. zeamais* at F_1 and F_2 during single and simultaneous infestations of shelled maize. Analysis of variance by the Kruskal-Wallis test was performed on the weight losses due to the insect infestations among the infestation types at both F_1 and F_2 followed by Dunn's multiple comparison test. The analyses were performed according to Gomez and Gomez (1984), Fowler and Cohen (1999) using Instat software package.

RESULTS

Numbers of *P. truncatus* at F_1 and F_2 in the maize grains

The mean numbers of F_1 *P. truncatus* emerging from the maize samples during single infestation was 122 ±1.155 while in simultaneous infestation it was 60 ± 0.930. The mean number of *P. truncatus* at F_2 was 180 ± 0.930 and 85 ± 1.155 in single and simultaneous infestations respectively. During single infestations the mean percentage changes of numbers were greater than during simultaneous infestations (Table 1). The t test indicated a significant difference between the percentage change in numbers of the insects from F_1 to F_2 in single and simultaneous infestations, $t_{0.01\ (2),\ 10} = 28.157$.

Numbers of *S. zeamais* at F_1 and F_2 in the maize grains

The mean number of *S. zeamais* was 160 ± 0.894 and 86 ± 1.366 at F_1 in single and simultaneous infestations respectively. At F_2 the adult insects were 210 ± 1.317 in single and 102 ± 1.155 in simultaneous infestations. During single infestations the percentage change in *S. zeamais* numbers increased greatly from F_1 to F_2 while in simultaneous infestations it was relatively small (Table 1). The t test showed a significant difference in the percentage changes of insect numbers from F_1 to F_2

between single and simultaneous infestations ($t_{0.01\,(2),\,10}$ = 52.746).

Table 1: Mean number of insect pest species and percentage change in adult numbers from F_1 to F_2 in single and simultaneous infestations

Insect spps	Infestation type	Number of adults		% change
		F_1	F_2	
P. truncatus	Single	122 ± 1.155	180 ± 0.930	47.54 ± 0.119
	Simultaneous	60 ± 0.930	85 ± 1.155	41.66 ± 0.179
S. zeamais	Single	160 ± 0.894	210 ± 1.317	31.25 ± 0.194
	Simultaneous	86 ± 1.366	102 ± 1.155	18.60 ± 0.133

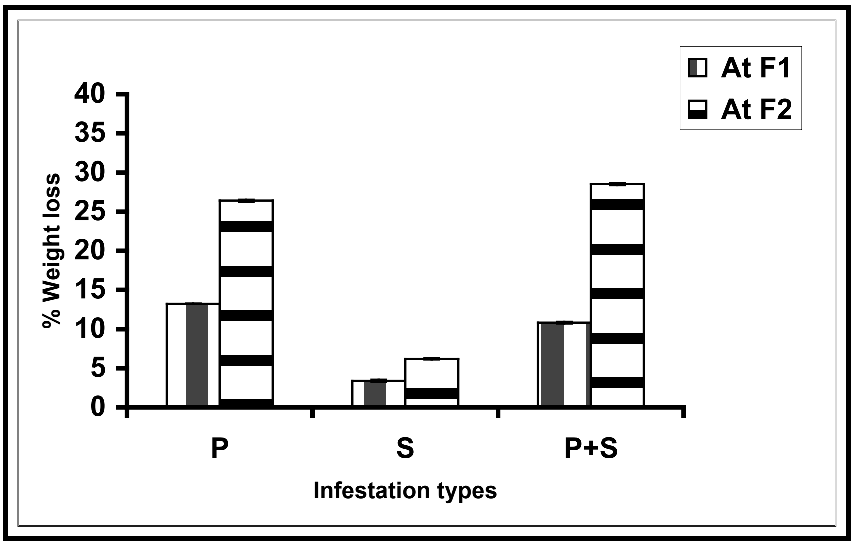

Figure 1: Maize weight losses caused by *P. truncatus* and *S. zeamais* in two infestation types

Weight loss of the maize caused by *P. truncatus* and *S. zeamais* at F_1 and F_2

The maize grains lost different amounts of weight after F_1 and F_2 *P. truncatus* have emerged. At F_1 and F_2 in single infestations the mean weight losses were 13.21 ±0.040% and 26.40 ± 0.120% respectively (Fig. 1). The mean weight losses of the maize caused by *S. zeamais* was 3.40 ± 0.133% at F_1 and at F_2 the loss was 6.21 ± 0.082% during single infestations. At F_1 and F_2 the maize grains lost 10.81 ± 0.106% and 28.53 ± 0.133% respectively during simultaneous infestations. Analysis of variance by the Kruskal-Wallis test indicated a significant difference among the types of infestations, χ^2 = 15.174, P < 0.01, 5 at F_1 and χ^2 = 15.205, P < 0.01, 5 at F_2. Multiple comparisons indicated significant differences between means of the types of infestations at P < 0.05. It was observed, however, that the amount of weight loss is less in simultaneous infestation at F_1 in relation to loss in single infestation of *P. truncatus* but greater than that in single infestations of *S. zeamais*. Numbers of *P. truncatus* and *S. zeamais* were positively correlated with weight losses, r = 0.914 and 0.827 (P<0.05) respectively.

DISCUSSION

The laboratory results of insect pests, *P. truncatus* and *S. zeamais* both in single and simultaneous infestations of maize exhibit different levels of reproductive performance and varying weight losses caused to maize. It was observed that the numbers of F_1 *P. truncatus* were fewer than *S. zeamais* in all the tests. The effect of simultaneous infestations of the two insect pests was detected at the F_2 generation.

The reproductive performance of *P. truncatus* and *S. zeamais*

The percentage change of the numbers of the two insects from F_1 to F_2 in both single and simultaneous infestations showed differing reproductive performance. In single infestations each insect exhibited relatively higher mean percentage change of numbers from F_1 to F_2 while during simultaneous infestations; *S. zeamais* decreased greatly but the reproduction of *P. truncatus* was less affected. The results reveal therefore, that during simultaneous infestations the two insect pests have a comparatively lower performance compared to single infestation. Krebs (1978) emphasized that in many laboratory experiments a species can do well when raised alone but can be driven to even extinction when raised in competition with another species. It was further found out that *S. zeamais* produced more F_1 individuals than *P. truncatus* during single infestations. This therefore supports the revelation by Cowley *et al*. (1980) that the intrinsic rate of increase of *S. zeamais* is greater than that of *P. truncatus*. However, the reproductive performance of *S. zeamais* was more affected than that of *P. truncatus* in simultaneous infestations.

The above observations could probably be due to inadequate food supply at the insect pest vicinity. It was pointed out by Weimerskirch et al. (2003) that for most animals, the only way to obtain resources is by expending energy while foraging and that the ability of individuals to adjust energy expenditure is likely to influence fitness and hence it fecundity. Further, *S. zeamais* females could no longer locate adequate favourable sites to deposit their eggs or may be even the larvae could not develop outside the grain since most grain contents were eaten up by the serious pest, *P. truncatus* save for the damaged grain sheaths (Hodges 1986). Such a condition could not favour the reproductive performance of *S. zeamais* but affected *P. truncatus* only slightly up to the F_2 generation.

According to Bell and Watters (1982), Meikle et al. (1998), *P. truncatus and S. zeamais* exhibit different egg deposition behaviour and this could probably explain their varying performance. It is reported that *P. truncatus* females deposit their eggs inside the grains and also could deposit them in the created flour and frass tunnels and at the bottom of the container. Further, the larvae of *P. truncatus* are also able to develop in compacted flour after making narrow tunnels against which they could support themselves and push their mandibles into the forward end of the tunnel for effective chewing. On the other hand, *S. zeamais* females deposit their eggs only inside the grain and particularly in the endosperm other than in the germ or germ-endosperm interface and larvae development is only completed inside the grain (Dobie 1974, Urrelo and Wright 1989). The survival of *S. zeamais* is dependent on its ability to locate an appropriate site in the kernel to lay an egg and any misplacement could result in retarded growth and development or even death of the larvae (Urrelo and Wright (1989).

Oviposition in insects is a dynamic process in which individual females respond to variation in host quality. This observation is supported by Aluja *et al.* (2001) who points out that a female reproductive performance is regarded as an important determinant of ovipositional dynamics and whatever affects oviposition affects reproductive output in turn. In some instances insect species stop maturing oocytes when deprived of a favourable deposition site and this affects performance because ovipositing females are time limited (Fitt 1986).

Furthermore, van Emden (1999) reports that there are different responses to the crowding effect in individuals of different species. The cited responses include the stimulation of restlessness of individuals resulting in, among other things, a reduced fecundity or an arrest in reproduction. The findings of this study could be supported among other things, the above stated responses.

Maize Damage caused by *P. truncatus* and *S. zeamais*

The maize damage reflected by weight loss of the grains caused by the two insect pests at F_1 was such that most loss was caused by *P. truncatus* while *S. zeamais* caused the least. This could probably be explained by two factors, namely, feeding behaviour and type of the mouthparts of the insect pests. With respect to feeding behaviour, of *P. truncatus* both the larvae and adults eat voraciously creating a lot of dust and frass while it is more the larvae of *S. zeamais* who do much of the feeding inside the grains than the adult (Shires 1980; Dobie 1988). This behaviour illustrates the economic importance of *P. truncatus* with respect to maize storage and therefore *P. truncatus* is classified as a serious pest.

In this study *P. truncatus* caused much weight loss at both F_1 and F_2 in relation to the estimated acceptable levels while losses caused by *S. zeamais* were lower than 9% at F_2. So far little effort has been made to apply the threshold concept to stored grain prior to Economic Injury Level (EIL). McFarlane (1988), for instance, estimated a level of approximately 3% weight loss while Henckes (1992) estimated the maximum weight loss accepted by the farmers to be about 9%.

Regarding the mouthparts, the mandibles of both larvae and adult *P. truncatus* are so adapted to effectively chew and grind maize grains while in the case of adult *S. zeamais* mandibles on the prognathous type of head orientation are comparatively less adapted for grinding. A decrease in weight loss in simultaneous infestation reflected a negative effect on the dual performance of *S. zeamais.* The results show that, of the two pests, *P. truncatus* caused greater weight loss of maize in single infestations at F_1 and F_2 and hence in simultaneous infestations. Chapman (1982) noted that the insect morphology relates to its behaviour. It is in this context that the relationship of insect mouthparts and maize damage is highlighted.

CONCLUSION AND RECOMMENDATIONS

The effects of simultaneous infestations of *P. truncatus* and *S. zeamais* were indicated by the percentage changes of insect numbers from F_1 to F_2. *S. zeamais* was more negatively affected than *P. truncatus*. It could therefore be deduced that there is a differential decrease in the reproductive performance of the two insect pests. Further the weight loss varies when maize grains are attacked by different numbers of P. *truncatus* and S. *zeamais*. Following from this, it could be inferred that the amount of maize weight loss corresponds with the numbers of a particular insect pest.

Furthermore, the results reveal that knowledge about the varying insect reproduction and shelled maize grain losses sheds light to the influence of simultaneous infestations. This could contribute in the design of control strategies of these pests which normally infest maize simultaneously. These findings therefore indicate that when P. *truncatus* and S. *zeamais* are simultaneously infesting shelled maize there is an increase in time before the onset of economic thresholds in terms of insect numbers and weight losses is reached. Such a situation therefore, delays the EIL that calls for chemical pesticides applications. It is this important quality of the insects' interactions that reduces the pests' populations to allow minimum application of hazardous chemical pesticides to stored maize. Practically, these results are of relevance to the control of P. *truncatus* and S. *zeamais* species. Using Farm Field Schools (FFS), this knowledge could be effectively utilized to combat stored insect pests of maize as a component in the IPM approach. Further, future research would centre on changes in the population composition of the immature stages of the insect pests, as these close correlate to the survivorship of adults and hence to the damage of grains.

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