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THE NATURAL CONTROL OF HEARTWATER VECTORS

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ABSTRACT

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Socio-economic factors and environmental considerations have increasingly encouraged the search for methods of tick control other than acaricidal treatment. Biological control management regimes have, so far, not proved to be sound replacements for acaricides.

The major natural control methods employed successfully at present are host resistance and pasture management. The former has been extensively studied and utilized in a one-host-tick situation, and its potential specificity for the *Amblyomma* species is discussed. Pasture management in the form of tick-resistant plants and habitat modification affecting vector ecology and viability is discussed, as is host availability.

Parasites and predators affecting tick populations are gleaned over with the accent on predacious birds (*Buphagus* species) which may play a limited role in integrated control programmes.

Reference is made to the possibilities of genetic manipulation, problems accompanying the implementation of sterile male techniques, and hybrid sterility.

In conclusion, a plea is made to ensure a thorough understanding of target vector ecology before any control measures are employed. This should be preferably from an integrated point of view rather than from a standpoint of unilateral reliance.

INTRODUCTION

Natural or biological control is almost always presented as the antithesis of chemical control. Scientists have been encouraged to research the use of natural or biological methods of control for varying reasons. The main drive has been socio-economic and environmental pressures resulting from the alternative, namely, the use of toxic and increasingly expensive chemicals. The emergence of resistance to acaricides by ticks (Nolan, 1981; Baker, 1982) and its genetic basis (Stone, 1981; Lourens, 1979), has also given impetus to both the search for alternative tick control methods and new pesticides. Estimates of the cost of discovering and developing a new pesticide have been placed at $65 M (US), excluding capital investment (Fisher, 1983). This cost is subsequently shared by producers who have to manage their industry on an economic basis. The producer, however, can only institute proven methods to ensure the survival of the animal before being able to invest in its productivity.

The effectiveness and desirability of intensive dipping to control tick-borne diseases, and its cost effectiveness, have been debated for some time (Howell, De Vos, Bezuidenhout, Potgieter & Barrowman, 1981; Sutherst, 1981; Norval, 1982; Spickett, 1982). An alternate policy of strategic tick control has evolved (Bigalke, 1980; Norval, 1981a; Norval, 1981b; De Vos & Potgieter, 1982) based on host resistance, integrated with strategic dipping practices to suit the local conditions. In no instance has complete reliance on natural control methods evolved. With both intensive and strategic control the main advantages and disadvantages listed (Anon, 1983), refer to production and capital outlay respectively. This again asserts the economic basis upon which all methods of control are finally judged.

In general, research on natural control has revolved around 3 main biological entities influencing the fluctuation of tick populations.

- Vegetation and microclimate
- Host factors
- Direct effects, including parasites, pathogens, predators and genetics

Research on influencing these factors to adversely affect tick numbers continues with a lesser or greater measure of success. This article highlights this, with particular reference to heartwater vectors.

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VEGETATION AND MICROCLIMATE

Amblyomma species are generally dependent on specific ecological needs (Theiler, 1962) which are obtained in microclimatic conditions conducive to the viability of their developmental stages.

Habitat modification

Veld burning has been used in a very haphazard manner as a means of disrupting the microclimate and with very little success to date. It is generally thought (Theiler, 1959, 1969) that burning does not destroy the developing stages but rather increases exposure which shortens developmental periods. Traditional winter burning does not coincide with *Amblyomma hebraeum* seasonal activity periods of questing stages (Norval, 1977), and this combined with the fact that agronomists do not advise winter burning, has made veld burning an unsuccessful biological control measure (Galun, 1978).

Habitat modification in the form of bush clearing (Theiler, 1959) seems to hold promise for those species which are ecologically dependent on tall grass and tree shade, i.e. *A. hebraeum* (Norval, 1977), *Amblyomma americanum* (Barnard, 1981), and *Amblyomma cajennense* (Smith, 1975). In marginal zones where the tick has a tenuous foothold, *A. hebraeum* infestation has disappeared through a combination of pyrethroid dipping and bush substitution with kikuyu pasture (Spickett, unpublished observation, 1985). Smith (1975) clearly illustrated the susceptibility of *A. cajennense* to a reduction in grass length and its dependence on tree shade. Bush clearance has also been attempted as an aid in reducing *A. americanum* populations (Hair & Howell, 1970). In general, though, the execution of these measures has not been on a scientific basis and their success has not been quantitatively assessed.

The introduction of tick-resistant grasses has had some attention in the literature. This research has been aimed more at investigating the tick repellent properties than on large scale assessments of the effects on tick populations.

Defence mechanisms of plants that could be utilized for tick control fall into 3 main categories, i.e. plants with hooked trichomes forming a barrier to ticks such as *Desmodium* (Levin, 1973); plants with chemical defence mechanisms, and plants with glandular trichomes. Plant species exhibiting potential as tick deterrents are *Melinis minutiflora* (molasses grass), *Pennisetum cynodon* (gambo grass) (Thompson, Roa & Romero, 1978) and certain *Stylosanthes* species (Sutherst, Jones & Schnitzerling, 1982).

The *Stylosanthes* species are probably the most effective, possessing glandular trichomes which form viscous secretions incorporating volatile chemicals toxic to tick larvae. A major research programme is currently planned to evaluate, under field conditions, the efficacy of *Stylosanthes viscosa* and *Stylosanthes scabra* in the control of *Boophilus microplus* in Australia (Sutherst & Wilson, 1986). The value of *Stylosanthes* as a direct control measure for *Amblyomma* is debatable, as large nymphal and adult stages are not affected. Their incorporation in an integrated biological system would not only decrease the number of *Amblyomma* ticks but would increase the nutritive value of the pasture.

HOST FACTORS

Host availability

The availability of domestic hosts on a local scale (stocking rate) is a function of management and should be adjusted according to available resources. On a host population scale, however, most heartwater vectors are among those tick species which are able to exploit the ecological imbalance caused by agricultural practice. Because the main vectors possess the ability to utilize the increasing number and variety of domestic animals present (including a large range of small mammals and ungulates) these ticks have the potential to assume pest status in their numbers, their associated direct damage and in the transmission of disease (Norval, 1979). The current practice of stocking wild animals on farms could further increase the host source for the ticks. Other hosts such as kudu, impala and birds present in the environment could, for instance, contribute towards the nymphal *A. hebraeum* burdens on cattle (Horak, 1982).

Attempts at removing the domestic hosts for varying periods of time (pasture spelling) have met with some success in a one-host-tick environment within integrated control systems (Wilkinson, 1957). The large host range of *A. hebraeum*, *Amblyomma variegatum* (Theiler, 1962) and *A. americanum* (Clymer, Howell & Hair, 1970), however, precludes this as an efficient control measure for any of the important heartwater vectors.

Host favourability

The existence of certain cattle breeds more resistant to tick infestation than others has long been recognized (Johnston & Bancroft, 1918; Kelley, 1932; Bonsma, 1944). Later workers established the heritability of this resistance (Seifert, 1971; Hewetson, 1972) and effective strategies for the control of the one-host-tick *B. microplus* have evolved (Powell & Reid, 1982; Norton, Sutherst & Maywald, 1983). Utech, Wharton & Kerr (1978) determined tick resistance to be directly proportional to the amount of Zebu genes present in a herd and Seifert (1971) and Bennett & Wharton (1986) showed heritability to be higher in Zebu cattle. Bonsma (1981) propagated superior resistance to *A. hebraeum* of Zebu crossbred cattle over British breeds. Garris, Stacey, Hair & McNew (1979) showed that under field conditions, fewer larvae, nymphae and adults of *A. americamum* engorged on purebred Brahman than on Hereford cattle, and this confirmed laboratory findings by Strother, Burns & Smart (1974). Spickett (unpublished data, 1986) found indigenous Nguni cattle consistently carried less *A. hebraeum* engorged females than Bonsmara or Hereford animals and that the direct damage associated with *A. hebraeum* bites was also lower.

The use of tick-resistant cattle to control heartwater through population control of the vectors will probably never be sufficiently effective on its own. Further research, however, needs to be conducted on integrating this principle with acaricidal control, taking into account such factors as the preservation of immunity through threshold vector numbers, disease manifestation and the possible resistance to tick-borne diseases by *Bos indicus* breeds and their crosses (Bonsma, 1944; Van der Merwe, 1979).

Host vaccination

Following on research into the effect of host resistance to ticks, workers have identified the actual mechanisms involved (Wikel, 1981; Askenase, Bagnall & Worms, 1982; Brown & Askenase, 1983) and have isolated and characterized the antigens inducing host immune resistance (Willadsen, Williams, Roberts & Kerr, 1978; McGowan, Barker, Homer, McNew & Holscher, 1981).

The feasibility of artificially immunizing cattle against ticks by using various crude antigen extracts was demonstrated by the successful stimulation of acquired resistance in *B. microplus* (Willadsen *et al.*, 1978), and, significantly, also in the 3-host-ticks, *A. americanum* (Brown, Shapiro & Askenase, 1984) and *Dermacentor variabilis* (Ackerman, Floyd & Sonenshine, 1980). Currently the use of hidden tick antigens (midgut) is being employed to successfully vaccinate cattle against *B. microplus* (Johnston, Kemp & Pearson, 1986).

Research into the isolation of specific antigens and consequent vaccination against heartwater vectors should be given priority, especially when the possibilities for the production of large quantities of antigens by molecular cloning techniques (Gamble & Zarlenga, 1986) are considered. Another promising area of research in vaccination against ticks is aposymbiosis. Nogge (1980) succeeded in drastically reducing the longevity and fecundity of tsetse flies by eliminating their symbiots after intake of antisymbiot antibodies during feeding.

These vector control principles, however, are not aimed at eradication but at containing tick populations to low numbers, and disease transmission to a stable situation, with implications of vaccination against disease in marginal zones.

DIRECT EFFECTS

Parasites and pathogens

Five species of hymenopterous parasites have been described infesting 20 species of ticks (Oliver, 1964; Cole, 1965). Only 1 species, however, has been reported parasitizing an *Amblyomma*, i.e. *Amblyomma tholloni*, on the Ivory Coast (Graf, 1979).

Several attempts at utilizing these parasites to control tick populations, notably *D. variabilis* in 1928 and in 1932 (Smith & Cole, 1943) and *Dermacentor andersoni* from 1927–1933 (Cooley & Kohls, 1934), were unsuccessful. The fecundities of parasites and pathogens appear to be too low to effectively control high numbers of ticks during periods of seasonal incidence (Sutherst, Wharton & Utech, 1978).

Pathogens have as yet not been used successfully against ticks. *Bacillus thuringiensis* has been shown to be highly lethal to ticks (Fiedler, 1969) but the means of establishing a concurrent infestation in tick populations is, as yet, lacking.

Predators

Predation of ticks by various animals, reptiles, birds and insects is a process constantly occurring in nature. Probably the only predation of any significance for tick control is that of the oxpecker birds, *Buphagus erythrorhynchus* and *Buphagus africanus africanus* in Africa. Bezuidenhout & Stutterheim (1980) evaluated biological control of ticks by *B. erythrorhynchus*, concluding that they could play a significant role on free-living animals. They reported indiscriminate feeding on larvae and nymphae but a reluctance to feed on *A. hebraeum* adults specifically. Stutterheim, Bezuidenhout & Elliot (in press) have subsequently shown *B. a. africanus* to have a higher feed capacity and the ability to utilize larger tick species, especially *A. hebraeum*, probably due to their larger beak and overall size. They also showed *B. erythrorhynchus* to have a preference for *A. hebraeum* nymphae and *Boophilus decoloratus* adults.

The effect of these predators on tick populations in the environment is almost impossible to evaluate, but they may be of immense value on wild animals with a probable limited role in integrated control programmes.

Genetics

The use of sterile males as a form of pest control is strongly supported, no doubt due to the success of the screw-worm eradication campaign in the southern United States of America (Bushland, 1971).

Research on this technique applicable to tick control has been advocated by Whitehead (1969) and tentatively attempted for *Amblyomma* as a result of suitable biological factors. Females of *Amblyomma* species require the presence of sexually mature males before attaching to a host, parthenogenesis apparently does not occur, and males remain on the host for a considerable period of time during which multiple matings take place (Gladney & Drummond, 1970; Gladney, 1971; Norval, 1974; Norval & Capitini, 1974). These factors have suggested various *Amblyomma* species as likely candidates for sterile male control (Drummond, Medley & Graham, 1966; Graham, Drummond & Hoffman, 1968). It has been shown that *A. variegatum* males are sterilized by irradiation dosages of less than 8 krad (Buethner, 1975), that egg batches of *A. americanum* fertilized by males irradiation dosages of less than 8 krad (Beuthner, 1975), Oliver, 1975) and that *A. hebraeum* males are sterilized by 8 krad (Spickett, 1978). In the case of *A. hebraeum*, application of the technique was found unacceptable to producers because of the potential direct damage associated with the tick at a suggested infestation rate of 10:1 as recommended by the Cattle Tick Control Commission Inquiry (Anon., 1973). One principle of sterile male control, that the released individuals must not be harmful to man and animals (Lindquist, 1963), cannot be fulfilled. In an African context, another principle, i.e. that the species to be controlled must have a comparatively small population, obviously presents extreme problems. No field application of the technique with any tick species could be found in the literature.

The use of hybrid sterility, should this phenomenon exist within the genus *Amblyomma*, will be subjected to the same restrictions as the sterile male technique. In addition, hybrid zones between species as with *A. hebraeum* and *A. variegatum* in Africa, are a result of a balance in favourability between biological and environmental factors (Sutherst, 1987). Any change in these factors could favour one of the species, leading subsequently to encroachment by the other. Any species specific control strategy would have to consider the relative heartwater transmission abilities of the tick species involved.

SUMMARY AND FUTURE PROSPECTS

Despite the great amount of ecological data available on ticks, their hosts, and tick-borne diseases, and the fact that ecological, geographical and genetic factors can and do play a role in containing tick populations, it continues to be difficult to implement specific procedures. They are often complicated by the variety of factors involved, and, in addition, the cost-effectiveness of biological procedures in a production environment are under suspicion and will remain so until proven otherwise. Certain aspects discussed may be of value on a local scale where ecological factors permit their implementation, but a broader view of *integrated parasite control* is necessary. In this regard, the extension of integrated practices, combined with both disease and vector vaccination, through the development of recombinant DNA vaccines, offer stimulating scope for future research.

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