# Diversity and seasonality of Chrysomelidae (Coleoptera) on kenaf, *Hibiscus cannabinus* Linnaeus (Malvaceae), in South Africa, with special reference to preference indices of *Podagrica testacea* (Chapuis) (Alticinae).

by

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# ABSTRACT

Kenaf (*Hibiscus cannabinus* L.) is being developed as a new fibre crop in South Africa and its potential in this regard has been under investigation since 2000. Kenaf is a short-day, annual, herbaceous plant. It belongs to the Malvaceae, a plant family notable for both its economic and horticultural importance. The kenaf stalk consists of two types of fibre, an outer 'bast' and an inner 'core', thereby making it a multi-purpose crop, with a variety of applications, for example, paper, building materials, adsorbents, textiles, livestock feed.

Monitoring of all arthropods associated with kenaf was conducted at different trial-site localities throughout South Africa and leaf beetles (Chrysomelidae) were recorded as the most abundant phytophagous insect group. The aim of this study was, to first of all, determine the diversity of Chrysomelidae feeding on kenaf. In this regard, a total of 20 species was sampled during the study period. This data was analysed, and preference indices with regard to season, cultivar or cultivation method were determined for the most abundant species. The flea beetle, *Podagrica testacea* (Chapuis) (Alticinae), proved to be the most abundant and wide spread species, also causing the most damage by skeletonizing the leaves of the plants, characteristically resulting in a 'shot-hole' appearance. This species occurred in high densities at four of the six locations (*i.e.* Winterton (western KwaZulu-Natal), Rustenburg (Northwest Province), Addo (Eastern Cape Province) and Makhathini (northern KwaZulu-Natal)) where kenaf trials were planted.

The entomopathogen, *Beauveria bassiana* Balsamo (Vuillemin), was tested as a biopesticide on *P. testacea* flea beetles sampled at the Winterton (KwaZulu-Natal) site. Results obtained were inconclusive suggesting that the specific formulation used was not successful in controlling these specific flea beetles.

Because of the close relationships that exist between plant diseases and insects, the possibility exist that leaf beetles, *P. testacea* and *Monolepta cruciata* Guérin-Méneville occurring on kenaf were acting as possible plant disease vectors, was investigated. Beetles from Winterton were incubated and a total of twelve different fungal species were isolated from these specimens, of which *Alternaria* spp., *Fusarium spp.* en *Penicillium* spp. were the most abundant.

World-wide defoliation of kenaf plants by insect herbivores has serious consequences in terms of its successful cultivation. Selective artificial defoliation as a partial insect control mechanism has some potential. It implies removing leaves of the plant, thereby excluding the insects on the basis that their food source is no longer abundantly available. Artificial defoliation trials in this study did not demonstrate this, but rather contributed towards an understanding of the level of impact that simulated beetle herbivory exerts on kenaf yield. Overall the impact of Chrysomelidae in the agricultural environments covered by this study has demonstrated that they are prominent role-players with regard to phytophagy and disease transmission. Therefore, these beetles contribute to the wide variety of factors that should be considered and evaluated to justify the ultimate goal of successfully establishing a viable and sustainable fibre industry for South Africa.

Future recommendations for the successful cultivation of kenaf in South Africa would be to invest in a resistant cultivar breeding program, for cultivars particularly suited to South African conditions. Accompanying this would have to be an understanding of the array of anthropocentric activities in the agroenvironment and their influence on the status of pests, crop cultivar and density, and environmental variables, and to what extent, all of these would contribute to the justification and scope of a pest management program.

Kenaf, fibre, *Podagrica testacea*, Alticinae, disease transmission, entomopathogen, *Beauveria bassiana*, artificial defoliation.

# SAMEVATTING


Kenaf (*Hibiscus cannabinus* L.) word sedert 2000 as 'n potensiële nuwe veselgewas vir Suid-Afrika ontwikkel. Kenaf is 'n kortdag, eenjarige, kruidagtige plant. Dit behoort aan die plantfamilie Malvaceae, wat veral vir hul ekonomiese en tuinboukundige belang bekend is. Die kenaf stam bestaan uit twee tipes vesel, die buitenste 'bas' vesel en die binneste 'kern' vesel, hierdie einskap gee aanleiding tot 'n wye verskeidenheid van produkte waarvoor die plant aangewend kan word. Dit sluit in produkte soos, papier, boumateriaal, tekstiele, absorbeer middels asook voer vir diere.

Monitering van alle geleedpotiges wat met kenaf geassosieer is, is by verskillende proefperseel lokaliteite dwarsdeur Suid-Afrika uitgevoer en blaarkewers (Chrysomelidae) was die volopste fitofage insekgroep wat aangeteken is. Die doel van hierdie studie was, eerstens, om die verskeidenheid van Chrysomelidae wat op kenaf voed, te bepaal. In hierdie konteks is 'n totaal van 20 verskillende spesies vervolgens tydens die studietydperk versamel. Hierdie data is toe geanaliseer, en voorkeur indekse wat seisoen, kultivar of bewerkingspraktyk betref van die volopste spesie is vasgestel. In hierdie verband is die vlooi kewer, *Podagrica testacea* (Chapuis) (Alticinae), as die volopste en mees wydverspreide spesie uitgewys, en het dit ook die meeste vreetskade aan die plant veroorsaak, naamlik 'n kenmerkende 'hael-skade'-tipe voorkoms. Hierdie spesie het by vier van die ses lokaliteite (*d.i.* Winterton (westelike Kwazulu-Natal), Rustenburg (Noordwes Provinsie), Addo (Oos Kaap Provinsie) en Makhathini (noordelike Kwa-Zulu Natal)) waar kenaf proewe geplant is, voorgekom.

Die entomopatogeen, *Beauveria bassiana* Balsamo (Vuillemin), is as 'n biologiese beheeragent teen *P. testacea* (Chapuis) vlooikewer eksemplare, wat by die Winterton (KwaZulu-Natal) perseel versamel is, getoets. Resultate wat verkry is was nie oortuigend nie en dui moontlik daarop dat die formulasie wat

hier gebruik is nie suksesvol sal wees in die beheer van hierdie spesifieke vlooikewer spesie nie.
Met die noue assosiasie wat tussen plantsiektes en insekte bestaan, is die moontlikheid dat *P. testacea* en *Monolepta cruciata* blaarkewers wat op kenaf voorkom, om as vektore van plantsiektes op te tree, ondersoek. Kewers vanaf Winterton is geïnkubeer en ‘n totaal van 12 fungus spesies is van hierdie eksemplare geïsoleer, waarvan *Alternaria* spp., *Fusarium* spp. en *Penicillium* spp., die volopste was.

Die ontblaring van kenaf plante wat deur insekherbivore veroorsaak word, het orals in die wêreld ernstige probleme tot gevolg. Daar bestaan ‘n geringe moontlikheid dat selektiewe, kunsmatige ontblaring, as ‘n meganisme wat gedeeltelike insekbeheer kan bewerkstellig, gebruik kan word. Dit berus op die beginsel dat die verwydering van blaarmassa kan lei tot die onbeskikbaarheid van genoegsame voedsel vir die insek. Onder die omstandighede kon die kunsmatige ontblarings proewe in hierdie studie nie hierdie moontlikheid demonstreer nie, maar het dit eerder bygedra tot ‘n begrip van die impaksvlak van gesimuleerde kewer herbivorie op kenaf opbrengs. In die geheel het die impak van Chrysomelidae op die landbou omgewings van hierdie studie gedemonstreer dat hulle vername rolspelers is wat fitofagie en siekteoordrag betref. As sulks dra hierdie kewers by tot die wye verskeidenhed van belangrike faktore wat in ag geneem en ge-evalueer moet word om die suksesvolle ontwikkeling en vestiging van kenaf as ‘n nuwe kommersiële gewas in Suid-Afrika te regverdig.

Verdere aanbevelings vir die suksesvolle verbouing van kenaf in Suid-Afrika, sluit ‘n daadwerklike belegging in ‘n weerstandbiedende teelprogram vir kultivars, wat aan die spesifieke Suid - Afrikaanse toestande voldoen, in. Gepaardgaande hiermee sou ‘n begrip van die verskeidenheid van mensgedrewe aksies in die agro-omgewing wees, en daarmee saam ‘n bepaling van hul invloed op

plaagstatus, gewaskultivar en digtheid, en omgewingsveranderlikes, en in welke mate dit alles bydra tot die regverdiging en omvang van ‘n plaagbestuur program.

Kenaf, vesel, *Podagrica testacea*, Alticinae, siekteoordrag, entomopatogeen, *Beauveria bassiana*, kunsmatige ontblaring.

# CHAPTER 1

## LEAF BEETLES (CHRYSOMELIDAE) AND THEIR ROLE AS PHYTOPHAGES AND DISEASE TRANSMITTERS IN AGROECOSYSTEMS

# LEAF BEETLES (CHRYSOMELIDAE) AND THEIR ROLE AS PHYTOPHAGES AND DISEASE TRANSMITTERS IN AGROECOSYSTEMS

## 1.1 INTRODUCTION

Defoliation of a crop by any organism, such as foliar pathogen attack, insect herbivory, or rabbit grazing, results in decreased crop canopy. Decreased canopy allows more light to reach understory weed plants, resulting in more weed growth. Damage to the root system caused by nematodes, insects, or pathogens, results in decreased root function and plant growth. Damage to the canopy or root system results in less water and nutrients being used by the crop; thus, more water and nutrients are available for the weeds, again resulting in more weed growth. This represents the expression of an interaction wherein higher level consumers determine how well producers are growing (Norris *et al.*, 2003).

Insects and plants interact on a wide variety of levels within the plant population habitat. Of all the feeding niches in agroecosystems, leaf feeding is almost the most common (Barbosa, 1998) and therefore also the most common point of attack by insect pests.

Chrysomelidae species discussed, as classified by Seeno & Wilcox (1982) was chosen to give a broad overview of die diversity of families that impact crops in this order.

## 1.2 LEAF BEETLES AS PEST ORGANISMS

According to Odum (1997), we should think of a ‘weed’ or even a ‘pest’ not so much as an undesirable species that should be wiped of the face of the earth, but rather as a species that is in the wrong place at the wrong time. This remark gives rise to the notion that in an ecological sense, in natural systems there, are no such entities as pests and the term ‘pest’ is anthropocentric and perceived and defined differently by diverse segments of the human population. Thus, in the absence of humans, all organisms are just part of an ecosystem (Norris *et al.*, 2003).

A different angle to this debate would be that pest species could be regarded as those naturally occurring species which by reason of their biology are preadapted to exploit new man-made ecosystems (Hodkinson & Hughes, 1982). For example, in its natural habitat in western USA, the Colorado potato beetle, *Leptinotarsa decemlineata* (Chrysomelidae: Chrysomelinae), feeds at relatively low density on wild members of the plant family Solanaceae. The transition to pest status occurred when man began planting a highly acceptable food source, potatoes, on a large scale, thereby creating large areas of favourable habitat (Hodkinson & Hughes, 1982).

Most agricultural crops can be classified as non-apparent species growing at high densities, thereby providing a monoculture of plants with an even age structure. In such low-diversity systems the chance of locating a host plant, and parameters favouring reproduction of the pest organism, is greatly increased (Hodkinson & Hughes, 1982).

Therefore, phytophagous arthropods are of vital importance in sustainable agriculture. The Chrysomelidae, or leaf beetles, constitute a vast family of phytophagous beetles (Skaife, 1979). Being a diverse family, they consequently have many different plant utilising strategies. This ability to utilise a host plant in many different ways, and at different growth stages, results in an even more injurious situation for the plant. In cases where the host plant provides a niche for both the adult and larvae of the insect, a double damage impact is caused, which could result in immense damage indices in the long run.

### 1.2.1 Chrysomelidae as defoliators

The ingestion of plant cytoplasm or tissue represents an energy gain by the pest and an energy loss by the plant. For example, the consumption of leaves results in reduced photosynthetic area, which then results in yield loss (Norris *et al.*, 2003). The adults and larvae of Chrysomelidae are phytophagous and feed principally on flowers and foliage. Some larvae feed freely on foliage; some are leaf miners; some feed on roots; and others bore in stems. Members of this family are serious pests of cultivated plants (Borror *et al*., 1992). Selected examples of crop pests within the different subfamilies of Chrysomelidae follow below.

### 1.2.1.1 Alticinae

a) *Argopistes* spp.

The Olive beetles, *A. oleae* Bryant, *A. sexvittatus* Bryant and *A. capensis* Bryant, are pests of the European olive, *Olea europea* (Oleaceae), in South Africa. The adults feed on the leaves and produce small feeding holes that may coalesce. Young leaves that are attacked develop into abnormal shapes, and the adult beetles may also feed on and severely damage olive fruits. The larvae mine between the upper and lower leaf surfaces and produce tunnels that increase in size as the larvae grow (Annecke & Moran, 1982).

b) *Chaetocnema confinis* Crotch

Originally this species comes from North America, but it has spread to tropical America, Africa, Asia and the Pacific. It is evident that the distribution of *C. confinis* is wider than documented. Primary hosts of *C. confinis* are members of the plant family Convolvulaceae *e.g*. sweet potato (*Ipomoea batatas*). Larvae of the Sweet potato leaf beetle feed within the plants roots and can attack the collar, the area between the stem and the root. Leaves which have been attacked display long narrow grooves, especially on the upper surface along the veins. When these channels are numerous, the leaf may wilt and turn brown and the plant may die or be badly stunted (Metcalf & Flint, 1939).

c) *Phyllotreta cruciferae* (Goeze) and *Phyllotreta striolata* (Fabricius)

The Crucifer flea beetle *P. cruciferae* and the Striped flea beetle *P. striolata* are major pests of canola (Brassicaceae: *Brassica napus*). Canola is an important oilseed crop in the northern Great Plains of the United States and Canada. Most economic damage occurs when the flea beetles feed on cotyledons and the first true leaves during the first two weeks after emergence. Leaf tissue of the cotyledons dies around adult feeding sites, producing a shot-hole appearance and necrosis (Knodel & Olson, 2002). Attack by flea beetles reduces the leaf area available for photosynthesis and disrupts transpiration, which can lead to wilting and death of the seedlings, especially under dry conditions. Seedlings are killed when the shoot apex is completely severed by flea beetle feeding. Although some seedlings may recover from flea beetle attack, affected plants can show reduced biomass, delayed maturity, and stunting in their later developmental stages, which affects both seed yield and quality (Dosdall *et al*., 1998).

d) *Psylliodes chrysocephala* Linnaeus

*Psylliodes chrysocephala* , is a pest of most Brassica seed crops. The Cabbage stem flea beetle is found in Europe, North Africa, Asia and Canada and with the expansion of rape (*Brassica napus* var. *napus*) growing in the United Kingdom, it extended its range both northwards and westwards and is now found in most areas where rape is grown (Winfield,1992).

The adults chew holes in the leaves and the larvae usually mine the lower petioles, moving from ageing to healthy tissue, but will move to the stem and destroy the growing point if larval numbers are high. Severe larval attack can distort the plant and cause the epidermis to peel, leading to the death of the plant (Williams & Carden, 1961).

### 1.2.1.2 Chrysomelinae

a) *Chrysomela scripta* Fabricius

The Cottonwood leaf beetle, *C. scripta*, is a major defoliator in young *Populus* plantations (Salicales: Salicaceae) in the United States. *Chrysomela scripta* feeding can have a variety of effects, including seedling deformation, terminal damage and mortality. Multiple defoliation events can have significant effects on tree growth over time, and stresses on the trees early in the rotation may result in considerable losses in later growing seasons (Coyle *et al.*, 2002).

b) *Entomoscelis americana* Brown

The Red turnip beetle, *E. americana*, is an oligophagous leaf beetle which feeds on plants in the family Brassicaceae and is a pest of rape crops (*Brassica campestris* L. and *B. napus* L.) in the Prairie provinces and British Columbia (Canada). The larvae feed on the cotyledons and first true leaves of seedlings of volunteer rape and commercial mustards (*Brassica juncea* (L.) Coss and *B. hirta* Moench) and also on cruciferous weeds. If the supply of these plants is not adequate in a particular field, the larvae and (or) adults will invade new rape fields and may cause sufficient damage to seedling rape plants over a wide range (Gerber & Obadofin, 1981).

c) *Leptinotarsa decemlineata* Say

The Colorado potato beetle, *L. decemlineata*, is one of the most economically damaging insect pests of potato (*Solanum tuberosum* L.) world-wide (Hare, 1990; Hawthorne, 2003). *Leptinotarsa decemlineata* originated in south-western North America where it utilized a variety of solanaceous species. In the first half of the $19^{th}$ century, its host range expanded to include potato, which was grown east of the Rocky Mountains, as the western USA became settled. By the late

19th century, their distribution continued eastwards throughout North America and by the early 20th century it had eventually spread into Europe and Asia (Hsiao, 1981). *Leptinotarsa decemlineata* adults and larvae indirectly reduce potato tuber yields by devouring foliage. If plants become entirely defoliated prior to tuber initiation, total crop loss will result. The adults also feed on the tubers of host plants in addition to the leaves, stems and growing points. *Leptinotarsa decemlineata* attack various cultivated Solanaceae, including tomatoes (*Lycopersicon esculentum*) and aubergines (*Solanum melongena*), as well as wild Solanaceous plants, which are usually widely distributed and can act as a reservoir for infestation (Schalk & Stoner, 1979).

d) *Mesoplatys ochroptera* Stål

The Sesbania beetle, *M. ochroptera*, has recently become a serious pest of *Sesbania sesban* in agroforestry in Ethiopia, Kenya, Malawi and Zambia. *Mesoplatys ochroptera* has so far been reported only from eastern and southern Africa. *Sesbania* species (Fabaceae) are a valuable plant resource in tropical agriculture. The larvae cause damage by feeding on the foliage, growth tips, flower buds, petioles and the bark of the stem. The adults feed on portions of leaf tissue from the middle or margins of leaflets (Sileshi *et al*., 2003)

e) *Zygogramma bicolorata* Pallister

The Parthenium leaf beetle, *Z. bicolorata*, is originally known from Mexico and was released as a biological control agent for the weed *Parthenium hysterophorus* in Australia in 1980. However, three years later, the beetle changed primary hosts to annual ragweed, *Ambrosia artemisifolia*. Other hosts include sunflower (*Helianthus annuus* L.) and jasmine (*Jasminum grandiflorum*). The larvae of this leaf beetle are voracious feeders, first attacking the terminal and axillary buds and later the leaf blades. In Australia adults and larvae defoliate *Parthenium* hosts completely, and they prefer younger leaves to senescent leaves of their *Parthenium* hosts. In India, adults feed on the leaves of sunflower seedlings, preferring the first true leaves and retarding the growth of the plant at the vegetative stage (Chakravarthy & Bhat, 1994).

f) *Zygogramma exclamationis* (Fabricius)

The sunflower beetle, *Z. exclamationis*, is the major defoliating pest of sunflower (*H. anuus*) in the northern plains of the United States and Canada. Both the adult and larval stages consume leaf tissue and when beetle populations are high, damage can result in yield loss (Charlet & Knodel, 2003).

**1.2.1.3 Criocerinae**

a) *Oulema erythrodera* (Lacordaire)

The Grain slug, *O. erythrodera*, may be found on cereals in South Africa from about June onwards. The grain slug damages leaves by feeding between the veins and giving the leaves a white-striped appearance (Annecke & Moran, 1982).

b) *Lema bilineata* (Germar)

The Tobacco slug, *L. bilineata*, is damaging to tobacco, *Nicotiana tabacum* (Solanaceae) in South Africa. The larvae cause the actual damage by feeding superficially on the undersurface without penetrating the leaf, the damage showing on the upper surface as irregular pale green marks and blotches. Later the larvae penetrate the leaf, leaving holes, and when abundant they sometimes virtually destroy the leaf (Annecke & Moran, 1982).

c) *Oulema melanopus* (Linnaeus)

The Cereal leaf beetle, *O. melanopus*, is an important pest of wheat, *Triticum aestivum* L.; oats, *Avena sativa* L.; and barley, *Hordeum vulgare* L. Native to Europe, this insect was accidentally introduced to the United States around 1950. Adults fly from overwintering sites to small grain fields after the first warm days of spring. Larvae skeletonize leaves by feeding from the tip of the blade to the base, consuming the chlorophyl containing mesophyl cells, but leaving the lower epidermis intact. In heavy infestations, when seen from a distance, the plants, appear to be frost damaged, the result of larval feeding that causes whitening of the leaf tips. Adult damage can be distinguished by the leaf being completely chewed through, creating narrow slits on the dorsal surface (Buntin *et al*., 2004).

d) *Lema trilinea* (White)

Larvae of the Gooseberry beetle, *L. trilinea*, feed on the foliage of gooseberries (*Physalis peruvianum*) and some other solanaceous plants, such as ‘stinkblaar’ (*Datura* species) and wild tobacco (*Nicotiana glauca*) (Annecke & Moran, 1982).

**1.2.1.4 Eumolpinae**

a) *Syagrus rugifrons* Baly

In South Africa larvae of the Black cotton beetle, *S. rugifrons*, feed on the roots or often ring-bark cotton plants, *Gosypium hirsutum* (Malvaceae) from November to January. When cotton seedlings emerge above the soil surface, overwintering adults exploit them and may cause considerable damage by feeding on the foliage (Annecke & Moran, 1982).

### 1.2.1.5 Galerucinae

a) *Acalymma vittatum* (Fabricius)

The Striped cucumber beetle, *A. vittatum*, is known from the USA, east of the Rocky Mountains and from south-western Canada and Northern Mexico. Adults of over-wintering, striped cucumber beetles, move into cucurbit fields as the seedlings are just cracking through the soil. Beetles prefer to feed on the cotyledons of cucurbits and thereby kill small plants. Feeding damage to the stem, true leaves and flowers also occurs. Fruit of other Curcubitaceae hosts, usually pumpkin (*Cucurbita moschata*) and watermelon (*Citrullus lanatus*), can also be scarred as the outer rind is fed upon. When eggs oviposited in the soil next to the base of the plants hatch, the larvae feed on the roots and stem of the plant (York, 1992). Feeding by adults or larvae when plants are small can stunt or kill plants (Crop Protection Compendium, 2001; Bellows & Diver, 2002).

b) *Cerotoma arcuata* (Oliver)

*Cerotoma arcuata* (Olivier) is a polyphagous pest of legumes, including soyabean, *Glycine max* (L.), kidney bean *Phaseolus vulgaris* (L.) and cowpeas, *Vigna unguiculata* (L.), which are considered important protein sources for humans and domestic animals, especially in Third World countries. Larvae of *Cerotoma* species feed on roots and nitrifying nodules, thereby reducing nitrogen fixation up to 45%. As adults, beetles consume cotyledons, leaves and reproductive organs, which can cause significant yield losses (Nava & Parra, 2003).

c) *Cerotoma trifurcata* (Forster)

The Bean leaf beetle, *C. trifurcata*, is a native species in North America and is common in the eastern half of the USA. It is generally found wherever soyabeans, *G. max* (L.), are grown, making this species one of the most widespread insect pests of the crop. Where soyabean is not grown, *C. trifucata* is commonly seen in gardens and on some leguminous woody ornamentals. Plants parts fed upon by larvae include roots, root hairs and nodules, with a preference for nodules. Nodule feeding is of particular interest because of the importance of nitrogen fixation to soyabean yield. Defoliation by adults is recognisable as small round holes between major leaflet veins. Pod injury occurs as leaves mature and beetles turn to feeding on younger tissues of the pod. They feed only on the pod surface, consuming tissue down to the endocarp, which directly encloses the seed, leaving round scars (Newsom *et al*., 1978; Crop Protection Compendium, 2001).

d) *Diabrotica balteata* LeConte

The Banded cucumber beetle, *D. balteata*, can be a major polyphagous crop pest. As larvae they feed on roots and tubers exclusively, reducing plant vigour, growth rate and fruit set, as well as market value, by leaving large unsightly holes in root crops, such as sweet potatoes (*I. batatas*) (Schalk & Jones, 1985). As adults *D. balteata* can seriously damage cucurbit crops in the seedling stage by entirely consuming the bitter cotyledons. From the southern USA, through Mexico and Central America, *D. balteata* has the potential to reach economic injury levels on maize (*Zea mays*) and sweet potatoes (Krysan, 1986).

Lettuce, *Lactuca sativa* L. (Asteraceae), is one of the most important vegetable crops cultivated in the United States in terms of quantities produced and consumed. As a cultivated crop, lettuce also serves as food to many insects pests including the banded cucumber beetle, *D. balteata*. Foliar feeding by *D. balteata* causes problems in the commercial production of lettuce, such as decreasing the photosynthetic capacity of the leaves, introducing frass to the heads, and opening the plants to pathogenic infection (Haung *et al*., 2002).

e) *Diabrotica speciosa* (Germar)

*Diabrotica speciosa*, is a highly polyphagous species as an adult. In South America, it is a common and problematic species. Its known host range includes maize (*Z. mays*), wheat (*T. aestivum*), groundnut (*A. hypogaea*), soyabeans (*G. max*) and potato (*S. tuberosum*). The larval damage resulting from root feeding can cause the death of the host when the host is small, but the larvae will usually only induce stunted growth in host plants, due to a reduction in nutrient uptake. In maize, attack on young plants produces a typical condition known as 'goose neck', in which the plant exhibits stunted growth, reduced vigour, and the first few internodes of the plant grow in a bent way, sometimes to such an extent that the plant actually lies on the ground. The adults cause defoliation and general feeding damage to leaves, flowers and fruit. In maize, they cause a serial reduction of the number of ripening kernels from the tip of the ear to the base, due to their feeding on the tassels, which prevents pollination (Krysan, 1986; Crop Protection Compendium, 2001).

f) *Diabrotica virgifera virgifera* LeConte

The Western corn rootworm, *Diabrotica virgifera virgifera* Leconte, is a serious insect pest of maize, *Z. mays* L., in the United States Corn Belt region (Meinke *et al.*, 1998; Losey *et al.*, 2003). The western corn rootworm tends to be found in maize fields throughout its life-cycle and may move locally from more mature to less mature maize. This considerable interfield movement occurs in areas where season length and cultural practices result in the presence of maize at varying maturities (Beckler *et al*., 2004). Newly-hatched larvae feed primarily on root hairs and outer tissues of the roots. As the larvae mature and their food requirements increase, they burrow into roots. Larval damage is usually most severe after the secondary root system is well established and brace roots are developing. Root tips appear brown and are often tunnelled into and chewed back to the base of the plant. Larvae may be found tunnelling in larger roots and occasionally in the plant crown. Larvae may burrow through plants near the base, causing stunting or death of the growing point and frequently causing tillering. Larval feeding can continue into maize brace roots and onto lower leaf sheaths. As root feeding starts shortly after plant emergence, early symptoms are expressed as drought or nutrient deficiencies. Plant lodging occurs later in plant development. Sites of larval damage are often pathways for infection by disease pathogens, resulting in root rots (Krysan, 1986). In contrast, adult rootworms cause only limited damage, although in some severe cases, silk feeding by adults reduces corn yield by adversely affecting pollination (Zhou *et al*., 2003).

g) *Diabrotica undecimpunctata* Mannerheim

In North and Central America, adults of the Spotted cucumber beetle, *D. undecimpunctata*, damage various vegetable and flower crops, especially cucurbits. Adult beetles cause the most noticeable damage by feeding on flowers, leaves and fruits. This includes feeding holes in the leaves, and scars on the crown, stems and fruits. Attacked fruits have a characteristic pinhole appearance that can reduce their market value. In groundnut, (*A. hypogaea*), the larvae bore into underground pods and feed on the kernels. They prefer young pods, but will often attack the tips of shoots or pegs and kill them before the pods develop. Occasionally, when pods are scarce, they attack the stems. Fungi and bacteria may enter injured pods and cause decay. In maize (*Z. mays*) larval feeding symptoms are very much the same as with the western corn rootworm, *D. virgifera virgifera* (Krysan, 1986; Crop Protection Compendium, 2001).

h) *Pseudapophylia smaragdipennis (*Jacoby)

The Sandveld grain worm, *P. smaragdipennis*, is an insect pest of the ‘winter cereals’, *i.e.* wheat (*T. aestivum*), oats (*A. sativa*), barley (*H. vulgare*) and rye (*Secale cereale*) planted in South Africa. Damage to cereals is caused by the larvae boring into the subterranean portion of the stems. The adults emerge from September to mid-October and congregate on ‘stinkkruid’, *Pentzia globifera*, on which oviposition also takes place. The eggs hatch only after the first winter rains and the development is thus synchronised with growth of the cereal crops (Annecke & Moran, 1982).

i) *Xanthogaleruca luteola* (Müller)

The Elm leaf beetle, *X. luteola*, was accidentally introduced into the United States in the 1830’s, but is now present in North America almost everywhere that elms are planted. Elm leaf beetles overwinter as adults in sheltered places, and emerge in spring to feed on the elm foliage for one to two weeks before starting to oviposit. The larvae, which are the most damaging stage, skeletonize the leaves. Heavy infestations can cause leaves to drop and completely defoliate a tree. The preferred host trees are English elms (*Ulmus procera* Salisbury) and, to a lesser extent, Siberian elms (*Ulmus pumila* L.), followed by American elms (*Ulmus americana* L.) and Chinese elms (*Ulmus parvifolia* Marsham) (Lawson & Dahlsten, 2003).

### 1.2.2 Chrysomelidae as disease vectors

A large number of different groups of insects have been shown to act as vectors for an equally wide range of animal and plant disease-causing pathogens. The ability of an insect vector to transport a pathogen from one host to another is of prime importance, and the amount of vector movement can have a great influence on disease dynamics and spatial distribution (Speight *et al*., 1999).

Many pathogens, especially viruses, fastidious bacteria, and phytoplasmas, require an arthropod, nematode or fungus to carry the inoculum from one plant to another and thus transmit the disease. Pathogens vectored by arthropods are an extremely significant problem, and are often the most serious impediment to increasing crop yields (Norris *et al*., 2003). The importance of insects as vectors of fungal plant pathogens has often been underestimated (Kluth *et al*., 2002). Selected examples of Chrysomelidae species that transmit diseases to crops follow below.

#### 1.2.2.1 Alticinae

a) *Chaetocnema pulicaria* Melsheimer

Stewart's bacterial wilt is an important disease of sweet corn (*Z. mays*) in the central and eastern United States. The disease has tremendous economic implications in both the seed and sweet corn industries in the Corn Belt (Esker *et al.*, 2004). The disease is caused by the bacterial pathogen, *Erwinia stewartii* (Smith) Dye, and is vectored almost exclusively by the Corn flea beetle, *C. pulicaria* (Kuhar *et al*., 2002; Michener *et al*., 2002). The bacteria overwinter in the gut of adult *C. pulicaria* and in the spring the beetles infest early plantings of corn and transmit the pathogen to the plant by feeding and defecating on the leaves. Secondary infection and spread of the disease occurs as beetles feed on infected plants and disperse throughout the field. Once a plant is infected, bacteria multiply in the vascular tissue, restricting the flow of nutrients and water. Symptoms of infection include yellow to brown stripes or streaks with wavy or irregular margins on the leaves and stalks. Stems clogged with the multiplying bacteria show a typical discoloration when cut in cross section. Seedlings that survive early infections remain stunted, tassel prematurely, and frequently produce unmarketable ears. Severe infections may result in the death of the plant. Disease severity depends on growth stage of the corn plant at the time of infection, resistance or susceptibility of the plant hybrid, and the abundance of the inoculum. Climatic conditions after inoculation can also affect disease severity. Warm temperatures encourage faster symptom development and movement of the bacteria through the plant and arid conditions impact plant growth and health, which in turn, can affect severity (Kuhar *et al*., 2002).

#### 1.2.2.2 Galerucinae

a) *Acalymma vittatum* (Fabricius)

Besides the damage that both adults and larvae of the Striped cucumber beetle, *A. vittatum*, cause to the foliage, roots and stem of plants from the family Brassicaceae, the beetles also transmit bacterial wilt (Brust, 1997). Overwintering beetles become active in the Midwest USA in early spring. The beetles are thought to harbour the bacteria *Erwinia traceiphila* in their gut (Clayton, 1927). When they begin to feed and congregate on plants, they spread the bacteria onto the leaves via their faeces. The bacteria are then able to penetrate the vascular bundle of the plant through the feeding wounds of the beetles. Beetles are also responsible for the transmission of Cucumber mosaic cucumovirus (Doolittle & Walker, 1925; Clayton, 1927), Cowpea mosaic comovirus (Jansen & Staples, 1971) and Pumpkin mosaic virus (Squash mosaic comovirus) (Stoner, 1964).

b) *Cerotoma trifurcata* (Forster)

The Bean leaf beetle, *C. trifurcata*, is the vector for bean pod mottle virus (BPMV). This beetle is common on soyabean, *G. max*, in the North Central United States, and in central Iowa. The Bean leaf beetle overwinters as an adult, primarily in wooded areas. In early spring the beetles leave their overwintering sites and move to feed on naturally occurring legumes and alfalfa. One native legume, *Desmodium canadense* (L.), has been identified as a naturally occurring host of BPMV and Bean leaf beetles are known to feed on this species. As soon as soyabean seedlings emerge, beetles move to them and begin feeding, thereby transmitting the virus (Krell *et al*., 2004). The disease causes mottling of soyabean leaves and severe strains of the virus may cause puckering and distortion of the leaves in the upper canopy. Stems of infected plants may remain green after the pods have matured and plants may also retain the leaf petioles after the leaf blades have abscised (known as 'green stem'). In addition to causing harvesting problems, BPMV can lower seed quality and yield (Levine *et al.,* 2002).

## 1.3 LEAF BEETLES AS BIOLOGICAL CONTROL AGENTS

Phytophagous insects and phytoparasitic fungi have been used the world over in the fight against imported weeds in their adopted countries (Jolivet, 1998). Selected examples of Chrysomelidae species that act as biological control agents follow below.

### 1.3.1 Alticinae

a) *Longitarsus columbicus columbicus* Harold

The introduced ornamental plant, *Lantana camara* L. (Verbenaceae), is one of South Africa's worst invasive weeds. It has been the target of a biological control programme here for the past four decades. Although several natural enemies have become established, the level of control is considered unsatisfactory, and a number of new potential biological control agents are being evaluated. The flea beetle, *L. columbicus columbicus* Harold, is considered to be highly destructive, attacking the roots of lantana, a niche largely ignored by biological control scientists in the past. The adults feed on the leaves and oviposit in the leaf litter near the soil surface. The larvae burrow into the soil, where they feed externally on the secondary rootlets. This root-feeding flea beetle may be able to supplement damage inflicted by the suite of agents already established on lantana. *Longitarsus columbicus columbicus* and other root-feeding flea beetles constitute a specialised guild that has not been represented in the biological control programme against *L. camara* world-wide (Baars, 2001).

b) *Longitarsus flavicornis* (Stephens)

The Ragwort flea beetle, *L. flavicornis*, was introduced into Australia from Annonay, France, in 1979 as a biological control agent for ragwort. Ragwort, *Senecio jacobaea* (Asteraceae), is a serious pasture weed of high-rainfall, temperate regions in Australia. It is toxic to livestock. The larvae of *L. flavicornis* live below ground, feeding predominantly on the root crown and roots of ragwort plants. High larval densities on ragwort rosettes can ultimately result in plant death (Potter *et al*., 2004).

c) *Aphthona abdominalis* (Duftschmid)

Leafy spurge, *Euphorbia esula* L. (Euphorbiaceae) is an introduced perennial weed of Euro-Asiatic origin that infests about one million hectares in the United States and Canada, mainly in pastures, ranges and non-cropland areas. Leafy spurge is a serious weed problem because of its toxicity to livestock and man. Among the natural enemies associated with leafy spurge, the flea beetle *A. abdominalis*, was selected as a candidate for the biological control of leafy spurge in North America, since the larvae cause severe damage to the roots, underground shoots, and root buds of its host plant, and the adults feed on the aerial portions of the plant. This kind of damage severely stresses leafy spurge and prevents the growth of new stems, thus reducing the spread of the plant and the production of seed (Fornasari & Pecora, 1994). Since 1978 five flea beetle species, *A. cyparissiae* (Koch), *A. flava* Guillebeaume, *A. nigriscutis* Foudras, *A. czwalinae* Weise, and *A. lacertosa* (Rosenhauer) have been released to control *E. esula* in Canada (Kalischuk *et al*., 2004)

### 1.3.2 Cassidinae

a) *Gratiana spadicea* (Klug)

*Gratiana spadicea*, a leaf-feeding Tortoise beetle, native to South America, has been released in South Africa for the biological control of *Solanum sisymbriifolium* Lamarck (Solanaceae). *Solanum sisymbriifolium* Lamarck (wild tomato, sticky nightshade) is a shrubby weed native to South America, where it is associated with short term disturbances such as ploughed fields, roadsides, wastelands, landfills, and crops. The plant has accidentally been introduced into several countries and become invasive in some. In South Africa *S. sisymbriifolium* has been considered to be an invasive weed since the early 1900's. Increasing invasions of croplands, limited pressure from native herbivores, and the failure of chemical and mechanical control methods in South Africa resulted in the initiation of a biological control program against *S. sisymbriifolium* in 1989. Both larvae and adults are leaf feeders, and when they occur in high densities, can cause partial or total defoliation of plants (Schachter-Broide *et al*., 2003).

### 1.3.3 Chrysomelinae

a) *Zygogramma bicolorata* Pallister

The Parthenium leaf beetle, *Zygogramma bicolorata* Pallister, is a biological control agent of parthenium weed, *Parthenium hysterophorus* L., (Asteraceae: Heliantheae) in Australia and India (Withers, 1998).

### 1.3.4 Criocerinae

a) *Crioceris* sp.

The Bridal creeper (*Asparagus asparagoides* (L.) W. Wight; Asparagaceae), is native to southern Africa and was introduced into Australia, as an ornamental plant, in the 1800's. It has subsequently invaded large tracts of land in southern Western Australia, South Australia, Victoria, and southern and central New South Wales and is currently regarded as one of the most serious environmental weeds in the region. It threatens the conservation value of many areas, since it can completely dominate the understory, and has the potential to affect the regeneration of native species and alter the composition and structure of the plant community (Witt & Edwards, 2001). A biological control project was initiated in 1990, and several potential agents were identified in the Western Cape Province, South Africa. The leaf beetle, *Crioceris* sp. (Coleoptera: Chrysomelidae), was brought into quarantine in Perth during 1998. Approval for its release was given in May 2002. The adults and larvae feed exclusively on the plant's young, expanding tissues resulting in reduced plant vigor (Batchelor & Woodburn, 2003)

### 1.3.5 Galerucinae

a) *Galerucella calmariensis* L

Purple loosestrife, *Lythrum salicaria* L. (Myrtiflorae: Lythraceae), is a European herbaceous perennial that was introduced into North America in the early 1800's. During the early 1990's, several natural enemies of *L. salicaria* were identified in Europe. Six species, including *G. calmariensis* and *Galerucella pusilla* (Duftschmidt) were selected for a biological control program and approved for release in the United States (Wiebe & Obrycki, 2004). Purple loosestrife is well adapted to invasion of disturbed sites, and following establishment, can form dense and highly persistent stands in wetlands and other moist habitats (Kaufman & Landis, 2000). Larval feeding in the shoot tips of these plants destroys the apical meristems and results in stunted plants and delay or prevention of flowering. Defoliation and destruction of stem tissue results in desiccation of the shoots (Landis *et al*., 2003).

## 1.4 DISCUSSION

At the first glance the effect of a chewing insect, such as a chrysomelid beetle, on a plant might appear simple, *i.e.*, there is an immediate, measurable loss of leaf area and an equivalent drop in the plant's photosynthetic capacity. The relationship between leaf damage and plant productivity is, however, far more complex and depends on several interrelated factors (Hodkinson & Hughes, 1982). The effect of insect phytophagy on a particular plant is never just a simple give and take interaction.

Many plant species contribute to the total primary production of diverse natural ecosystems and each species has its own group of associated insect herbivores. If, therefore, one particular plant species were to suffer heavy losses to insect feeding, the effect on the primary production of the ecosystem would be small. In contrast, in a monoculture, there would be drastic effects on overall productivity (Hodkinson & Hughes, 1982).

Management of pests (including weeds) through the use of biological control agents seeks to replace chemical control, thereby neutralizing its detrimental effect on environmental and human health. As such, any successful biological control agent, such as the leaf beetle species mentioned above and known to fulfil this role, is an economic, environmental and ecological asset worthy of further discussion. Although there are relatively few documented cases of damage to non-target plants in weed biological control, the introduction of phytophagous biological control agents may have unanticipated effects on non-target species. For instance, some phytophagous insects may become habituated on a host plant as a result of a previous experience, regardless of whether this species is the most appropriate for development (Schachter-Broide *et al.*, 2003). Extreme care should be taken to avoid such occurrences. The failure of biological control agents to establish in the field has been the subject of much discussion. The appropriateness of the host plant, environmental conditions, parasitism or predation, and release methods used have all been proposed as possible reasons that some agents have not established (Day & McAndrew, 2002). The most important rule is to ensure that the introduced plant or animal species is not detrimental to useful indigenous species (Jolivet, 1998). Establishing a successful biological control program is dependent on so many factors influencing the situation and it is therefore essential to obtain as much information as possible beforehand. During the preliminary studies prior to the introduction of a phytophage, the particular species must be imported free from all its natural enemies. Its selectivity has to be studied to determine that it is harmless to the cultivated plants in the region, and it must be determined if it can adapt to the new habitat (Jolivet, 1998). Unexpected factors, such as biotic interference by natural enemies, should not be left unanticipated. For example, in Iowa, predators may be limiting *Galerucella* species to densities below the levels required for biological control of purple loosestrife (*L. salicaria*) (Wiebe & Obrycki, 2004). Biological control has been identified as the only sustainable mechanism to prevent the spread of invasive weed species and the re-invasion of cleared areas in the long term (Olckers, 1999).

Defoliating insects have varying impacts on tree growth, often depending on the timing, duration and intensity of defoliation. However, plants have several ways of coping with defoliation, including nutrient reallocation, altering leaf size or structure, or delaying senescence. Plants can exhibit positive or negative responses depending on the extent of defoliation. They can also often withstand short periods of intense defoliation. However, repeated defoliation may have negative impacts on plant growth, defence and reproduction (Coyle *et al.*, 2002).

Overall, the impact of Chrysomelidae in natural and agricultural environments has demonstrated that they are superior role-players with regard to phytophagy, disease transmission and biological control. The ecological interaction network in which leaf beetles find themselves is intricate, calling for holistic ('whole system') analysis methodologies to comprehend their functionality within an ecosystem. Habitat manipulation (such as with agroecosystem establishment), topography, local distribution and abundance of natural host plants, are all factors that influence the population dynamics and community structure of leaf beetles and other phytophagous insect groups. Further refining of these entities by considering host plant patch size, host plant density, whether host plants grow in monoculture or polyculture, trophic specificity and patterns of seasonal occurrence, brings a new awareness. There is a common denominator in that all relate strongly to the way Chrysomelidae live and how crop hosts are cultivated, whether in agriculture and/or forestry. This implies that crops and crop cultivation will be strongly influenced by the trophic activity of leaf beetles.

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# CHAPTER 2

## KENAF IN PERSPECTIVE: PAST TO PRESENT

# KENAF IN PERSPECTIVE: PAST TO PRESENT

## 2.1 HISTORY OF KENAF

The name kenaf is of Persian origin, and describes the plant *Hibiscus cannabinus* L. According to Dempsey (1975), there are around 129 world-wide names that have been given to this plant. In India the common name is mesta, in Bombay, deccan hemp, in Egypt and northern Africa it is variously called til, teel, or teal; in South Africa, stokroos ("wild stok rose") and in West Africa it is known as dah, gambo and rama, to name but a few.
Kenaf is a short-day, annual, herbaceous plant. It belongs to the Malvaceae, a plant family notable for both its economic and horticultural importance. The genus *Hibiscus* is widespread, comprising some 200 annual and perennial species (Dempsey, 1975). Kenaf is closely related to cotton (*Gossypium hirsutum*), okra (*H. esculentum*), hibiscus (*H. hibiscum*) and hollyhock (*Althaea rosea*) (Dempsey, 1975).

Most authors agree that the origin of kenaf is Africa, where several forms of the species are found growing widely in many countries. According to Murdock (1959) and Meints & Smith (2003), kenaf may have been domesticated as early as 4000 BC in the Sudan region. Brown and Massey (1929) mention native kenaf growth on the upper White Nile and provinces of the Anglo-Egyptian Sudan, where the local inhabitants made use of the plant. The plant grows in all the countries of east and central Africa; in the lower fertile parts of Ethiopia; in Eritrea and in Somaliland (Haarer, 1952). Indigenous wild stock rose were found occurring in large numbers in the Transvaal and Natal, extending northwards to central Africa (Verdoorn & Collett, 1947; McGregor, 1952). It is been said that kenaf is the most widely cultivated fibre plant, next to cotton, in the open savanna country from Senegal to Nigeria on the west coast of Africa (Dalziel, 1948). Hooker (1875), in Dempsey (1975) stated that kenaf was cultivated both as a crop and a hedge plant throughout India, after being introduced from Africa. Kenaf was cultivated both as a crop and a hedge plant in Bombay, the central provinces, and Madras. Coarse sackcloth was often made from the fibre, although its chief use was for ropes and twine. According to Dunstan (1903) kenaf fibre also first entered the London market in 1901-1902 under the name of Bimlipatam jute.

During 1920-25, the USSR began an extensive program for fibre crops research which included kenaf. By 1935, kenaf was grown widely in the Soviet Union, with 14 800 ha under cultivation. In 1935, kenaf was introduced to Mainland China from the USSR (Dempsey, 1975). By 1958-59 Mainland China was the largest producer of kenaf fibre in the world (Kirby, 1963).

Prior to World War II little was known about kenaf outside of Asia. In the Western Hemisphere an intensive research program on kenaf was initiated in the USA by the US Department of Agriculture and other government agencies, such as the Cooperative Fibre Commission in 1942, as a joint study by American and Cuban technicians. This work resulted in the development of new, high-yielding, disease resistant varieties (Dempsey, 1975).

Also in 1942, when jute supplies were curtailed, many countries began research studies on substitute fibres. Kenaf received by far the greatest attention because of its greater adaptability and ease of handling than allied fibre crops (Clark *et al*., 1962; Wing, 1967). The crop has less intensive labour requirements, is cheaper to produce, may be grown on a wide range of soils under varied climate conditions, and is not necessarily competitive with food crops. Yet, in terms of the latter, it produces a higher cash income than most farm crops. While kenaf is somewhat coarser than jute, it has greater tensile strength, is lighter in colour, and has greater resistance to moisture (Tommy-Martin, 1964).

In 1960 kenaf and hemp were selected as the most promising non-wood fibre alternative for pulp and paper production from among 500 crop species by the Agricultural Research Service (ARS) of the United States Department of Agriculture. During the following two decades an extensive research program was undertaken in the USA into the field production and the paper making characteristics of kenaf. Continued research resulted in the development of high yielding, anthracnose resistant varieties. Today, research and development continues, primarily in Texas, Oklahoma, Mississippi and South-eastern USA, with emphasis on development for newsprint manufacture (LeMahieu *et al*., 1991; Wood, 1998).

Research on kenaf in Australia started in 1972, with research trials initiated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The first trials were grown in the Ord River Irrigation Area. The research was also directed towards the production of paper products from kenaf. Further work was conducted in the Burdekin River Irrigation Area of north Queensland by the Queensland Department of Primary Industries during the late 1970's so too in the "Top End" of the Northern Territory (NT) by the NT Department of Primary Industry and Fisheries during the late 1980's (Wood, 1998).

According to Rymsza (1999) kenaf is being grown and pulped in Spain and also investigated for further development. In Japan, a higher level of kenaf use and awareness has also been created. Nearly half of the paper companies use or have used kenaf in some of their products.

## 2.2 APPLICATION OF KENAF

The stalk of the kenaf plant consists of two distinct fibre types. The outer fibre is known as "bast" and comprises roughly 40% of the stalk's dry weight. The refined bast fibres are similar to softwood fibres used to make paper. The whiter, inner fibre is known as the”core” and comprises 60% of the stalk’s dry weight. These fibres are comparable to hardwood tree fibres (Dempsey, 1975; Johnson, 2001). The kenaf fibres, bast and core, can be pulped as a whole stalk or separated and pulped individually (Webber & Bledsoe, 2002a).

For the last 3000 years kenaf has been used as a cordage crop to produce twine, rope, and sackcloth. Since the 1950’s kenaf has been shown to be an excellent source of cellulose fibres for a wide range of paper products *e.g.* newsprint, bond paper, and corrugated liner board, requiring less energy and chemical processing than standard wood sources. More recent research and development work in the 1990’s has demonstrated the plant’s suitability for use in building materials *e.g.* particle boards of various densities and thicknesses, and for fire and insect resistance. Also as an adsorbent, for textiles, livestock feed, and fibres in both new and recycled injected, molded and extruded plastics. Kenaf also has application for products such as charcoal, non-woven matting in the automotive industry, potting soil and animal bedding (Webber & Bledsoe, 2002a; Morrison *et al*., 1999).

The kenaf plant is remarkably versatile as a multi purpose crop, providing a variety of applications to the industry and probably serves as the best example of a crop with multiple value-added properties. Primarily kenaf is only considered a fibre crop, but the entire plant, stalk including core and bark and the leaves can be used as a livestock feed. According to Webber & Bledsoe (2002a) kenaf can be ensilaged effectively, and it has satisfactory digestibility with a high percentage of digestible protein. Kenaf meal is also used as a supplement in a rice ration for sheep, comparing favourably with a ration containing alfalfa meal.

Kenaf’s absorption and retention properties have been incorporated into industrial socks, pillows, brooms, and floor sweeps for managing and handling industrial wastes. Another use for kenaf core may be as a cleanup material in biological remediation and as a bulking agent for sewage sludge compositing (Ramaswamy *et al*., 1999; Webber *et al*., 1999).

The latest and very important application for kenaf is in providing renewable raw materials in car production. Materials made of natural fibres represent a valuable alternative to synthetic varieties. They display excellent mechanical properties, are light in weight, but nevertheless stable. This conscious use of renewable resources in car production is just one of many ways to contribute to sustainable management and the conservation of resources. One such company that uses natural fibres and other organic products is the BMW Group®. In addition to supplying food, the cultivation of renewable raw materials has counted among the main tasks of the agricultural industry from time immemorial. Renewable materials are officially defined as "products derived from the agricultural and forestry sectors being used for other purposes than nutrition" (Anonymous, 2002).

## 2.3 KENAF IN THE WORLD

Although the literature indicates that kenaf's importance was proven through research, some countries believed that there would be enough trees available for fibre, and therefore did not invest heavily in this crop. According to Warner (2004) global demands for natural fibres are set to explode and those in the supply line are set to make an impact.

According to Wood (1998) kenaf is currently being grown and pulped in Thailand, China and the USA. Japan is one of the main importers of pulp from Thailand and China, and is producing a range of high quality writing papers. These papers are marketed as 'Ecological Papers' and are sold at a substantial premium over comparable wood-based papers. The Japanese pulp and paper industry currently produces only 0.04% of its pulp production of about 15 million tonnes from non-wood materials (Wood, 1998).

Kenaf is also one of the traditional fibre crops of the Indian sub-continent. Bangladesh, Thailand and China are established producers. Production by these countries is predominantly at the village level, by small lot holders, and is labour intensive with little or no mechanical or automated procedures (Anonymous, 2003b).

The bulk of the world's kenaf fibre production is in Asia, at a village level, using non-mechanised methods. Japan consumes the majority of its production. The United States of America produces limited broad acre production during their summer, which is all consumed internally. Although kenaf is well suited to Australian climatic conditions, there is no commercial production of kenaf and all the present production of fibre is for experimental purposes only (Anonymous, 2003b).

According to Sinclair (2001) the Sustainable Projects Development Group (Ltd.) (SPDG) of the Coach House Group in Cumbria, England, has identified Spain and South Africa as countries in which to grow and add value to kenaf. The reasons being that the current world supply chain of kenaf fibre is complex and fragmented. Since Spain is in Europe and in the Northern Hemisphere, and South Africa in the Southern Hemisphere, it is almost possible to achieve two crops a year. The commercial development of kenaf was initiated during 1998 in Spain. This was due to Spain's favourable climate and other factors, such as the existing agricultural infrastructure and previous kenaf research done during the EU Eurokenaf trials from 1992-1996, which made it the best possible choice in Europe (Sinclair, 2001, 2002).

Despite its commercial and environmental advantages, the kenaf paper industry is as yet undeveloped. As of August 1995, New Mexico's 'Vision Paper' was the only company commercially producing kenaf paper in the USA (Anonymous, 2003a).

## 2.4 KENAF IN SOUTH AFRICA

SPDG (Ltd.) has been exploring the possibilities of producing kenaf in the eastern and southern coastal areas of South Africa. Stemming from this, the commercial development of kenaf in South Africa was officially initiated in October 2000 (Anonymous, 2004a).

South Africa's warm climate makes it an ideal country in which to cultivate kenaf, especially the warmer Lowveld and areas in KwaZulu-Natal (KZN). The University of the Free State (UFS) and the Agricultural Research Council - Institute for Industrial Crops (ARC - IIC) have been involved in the research program for the commercial development of kenaf since May 2000. Initially research centred around one field trial planted at Rustenburg in the North West Province and small additional field plots that were planted at Bloemfontein in the Free State Province. All the plantings were monitored for insects, plant pathogens and nematode populations associated with kenaf. Five cultivars were planted, and the average yield obtained was 24.2 metric tonnes per hectare. One hundred and eleven days after planting (DAP) the plants had grown to an average height of 3.26 metres and yielded an average bast fibre percentage of 41.8%, with an average stem diameter of 2.33 cm. These results demonstrated that kenaf could be grown in South Africa (Sinclair, 2001).

During the next phase of development it was important to determine exactly where kenaf should be planted in the country. Consideration was given to the fact that kenaf must be grown within a 70 km radius of any processing facility, which in turn, must be in relatively close proximity of a harbour. This is essential, as kenaf will be exported to countries where it can be utilized and included in existing production lines, until further market development has taken place in South Africa.

The 2001/2002 season included the planting of a total of 10 kenaf cultivars in field trials at Rustenburg in the North West Province, Makhathini in KwaZulu-Natal, Addo in the Eastern Cape Province and at Bloemfontein in the Free State. This took place under irrigation and dryland conditions to conduct various observations and evaluations concerning crop development. Selected cultivars were also planted at different plant population densities and nitrogen levels. These trials provided a better understanding of the general production management practices of kenaf prior to commercial production in South Africa.

During the 2003/2004 season, a few farmers in the vicinity of Winterton in KwaZulu-Natal planted kenaf commercially, employing dryland and irrigated cultivation practices. An interested farming community, their willing participation in new developments, and the availability of farm land made the choice of Winterton as the first commercial development site for kenaf in South Africa, an easy one. Kenaf planted in this area of South Africa will primarily be for providing fibre for the automotive industry, thereby providing solutions for the new environmental protocols with which the industry has to comply. In line with this, top German and Japanese automotive manufacturers have increasingly been using natural recyclable fibres and materials, as replacement material biocomposites for glass-reinforced plastic materials, in the manufacture of car seats, door panels, boot trims, wheel arches and parcel shelves. The South African non-woven textiles manufacturer, Brits Automotive Systems®, entered into a joint-venture agreement with the Industrial Development Corporation of South Africa (Pty), Ltd. and SPDG of the United Kingdom to cultivate, process and produce end-products locally from natural raw-fibre materials. According to a market study undertaken by SPDG, the use of natural fibres is rising, due to strong international legislation. The SPDG chose South Africa for the establishment of a biocomposites project due to the excellent conditions for cultivating the crop in KZN. Brits Automotive Systems will process the raw material, manufacture the finished product and market it to the automotive industry using established channels. This project not only benefits the broader South African industry, but it also provides employment and development opportunities for rural entrepreneurs and the workforce in poor areas (Anonymous, 2004b).

According to Cockcroft (2001), the new ‘end of life’ vehicle (ELV) regulations imply that car manufactures can no longer be complacent about the life cycle of their product, since they are now responsible for the environmentally sound disposal of their creation. This creates great opportunities for industries looking for greener resources.

## 2.5 CONCLUSION

For six thousand years the long bark fibre strands of kenaf have been a valuable and important resource for use in cordage products. Although synthetic fibres now often reduce the use of the bark fibre strands in cordage material, the newer and more complete usefulness of the entire kenaf plant continues to make kenaf a crop of world-wide interest. The useful kenaf plant components include bark and core of the stalk, the leaves, and seeds. The combined attributes of these components *e.g.* bark fibre strands and bast fibres, the core material and individual core fibres, and leaf and oil chemistry, provide ample potential product diversity to continue use and development of this crop. Beyond the diverse new uses for kenaf, *i.e.* including its utilisation in paper products, building materials, absorbents, textiles, and livestock feed, the commercial success of kenaf has important potential economic and environmental benefits in the following areas: soil remediation, toxic waste cleanup, removal of oil spills on water, reduced chemical and energy use for paper production, better quality recycled paper, reduced soil erosion due to wind and water, replacement or reduced use of fibreglass in industrial products, and the increased use of recycled plastic (Webber & Bledsoe, 2002b).

Although all of this sounds as if this is the ultimate cash crop, there is always some degree of trial and error when a new crop is tested. Conti & Bin (2001) warn that the introduction of a crop into a new area sometimes results in a shift of indigenous herbivores, especially if polyphagous, from other crops or wild plants. Consequently novel insect-plant associations may become established. Having evolved separately, the introduced plant lacks natural defences against the new phytophages, therefore leaving a window of opportunity for these species to become serious pests.

Ultimately kenaf will be a suitable annual crop in a geographical area with the following prerequisites: (1) availability of a reliable irrigation source; (2) low pest populations; and (3) adequate market and transportation to the processing facility (McMillin *et al*., 1998).

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# CHAPTER 3

## INSECTS REPORTED ON KENAF

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## 3.1 INTRODUCTION

Developing a new crop tends to give rise to new opportunities in a recently created habitat. Interactions develop between the environment, the newly introduced host plant and the insects that become associated with it. Occasionally, some of these insect species may become pests, as was the case with flea beetles utilising newly introduced kenaf plants in South Africa. In all probability certain Chrysomelidae species initially occurred in low numbers, under natural conditions, at the kenaf trial locations. Some of these beetles fed on indigenous plant species, related to kenaf. As time progressed, within the monoculture setup, populations of these species became established under the optimal trophic conditions prevailing in the closed system. Ultimately this created a threat to kenaf cultivation. So although the kenaf plant, *Hibiscus cannabinus* L., is nothing new, newly planted monocultures of cultivars of this plant, create a new opportunity for insect- plant interaction to develop.

## 3.2 LITERATURE REVIEW

Since kenaf and cotton (*Gossypium hirsutum*) both belong to the plant family Malvaceae, they are both attacked by many of the same insect species, several of which are extremely serious pests to these crops. Tables 1 to 4 list the insects that Dempsey (1975) noted as being damaging to kenaf. These include the folowing which also occur on cotton: Spiny bollworm (Lepidoptera: *Earias sp.),* the Cotton bollworm (Lepidoptera: *Heliothis sp.),* Pink bollworm (Lepidoptera: *Pectinophora gossypiella* Saunders), and Cotton stainer (Hemiptera: *Dysdercus* sp.). From this information alone it would be a good precautionary step to never plant kenaf near cotton. This notion is confirmed by Green *et al.* (2003) who collected Spiny bollworm (*Earias* sp.) on the indigenous plants (*e.g. Hibiscus cannabinus*) and weeds on the Makhathini Flats (northern KwaZulu-Natal), surrounding cotton cultivations.

In a global context, other serious pests of kenaf are the European corn borer (Lepidoptera: *Pyrausta nubilis* Hubner) in Taiwan, the cosmopolitan Cotton aphid (Sternorrhyncha: Aphididae: *Aphis gossypii* Glover), and the Leaf-cutting ant (Hymenoptera: *Atta insularis* Guern.), which has been a serious pest in Cuba, El Salvador, and Brazil. The Spiral borer (Lepidoptera: *Agrilus acutus* (Thunberg) is a serious pest of kenaf in India (Dempsey, 1975).

A number of beetle species (Coleoptera) attack the leaves, stems, and roots of kenaf. Flea beetles (Coleoptera: Chrysomelidae: Alticinae) that attack kenaf are widespread and have been noted to take on epidemic proportions in several countries (Dempsey, 1964). Eldin & El-Amin (1981) indicated that the flea beetle *Podagrica puncticollis* Weise is of economic importance in Sudan. The pest is most destructive in the seedling stage. Five generations can be completed during the plant's growth cycle, depending on the weather conditions.

Cotton stainers (Hemiptera: *Dysdercus* spp.) are serious pests since their nymphs attack the seed crop. There are many species of cotton stainers and the family is widespread throughout the world. Several insects belonging to the suborders Auchenorrhyncha (Leafhoppers) and Sternorrhyncha, including, Mealy bugs, and Cotton aphids, attack kenaf. These insects are primarily sap-suckers that have been reported to sometimes cause severe injury to kenaf plants through leaf wilting and stunting, and eventual defoliation (Dempsey, 1975). Conti & Bin (2001) reported that the native Mirid bugs, *Lygus rugulipennis* Poppius and *L. pratensis* (L.), attacked kenaf in central Italy. Feeding by *Lygus* bugs damages the apical meristem, with consequent development of secondary stems and leaf tattering. Ultimately plant height is decreased and large lesions, with brown necrotic tissue, form on the main and secondary stems. This direct injury to the stem severely affects fibre yield.

## 3.3 PRESENT STUDY

Data on the insects that occur on kenaf in South Africa were obtained over two separate seasons. During the 2001-2002 season, 10 kenaf cultivars were planted at four localities (*i.e.* Bloemfontein (SE 2926Aa), Rustenburg (SE 2527Ca), Addo (SE 3325Da) and Makhathini (SE 2732Ac)) across South Africa. The 10 cultivars that were evaluated are Cuba 108, Tainung 2, Everglades 41, El Salvador, SF 459, Gregg, Dowling, Endora, Whitten and Everglades 71. These cultivars were planted at equal density, in small plots of less than one ha, at all four localities.

During the 2003-2004 season, nine cultivars were planted at two localities, *i.e.* Winterton (SE 2829Dc) and Nelspruit (SE 2530Bd). The nine cultivars were the same as listed above, with the Whitten cultivar omitted from the trials, due to its weak germination characteristics. Arthropods were sampled from these six different sites, with some of the sampling conducted more intensely at selected sites.

### 3.3.1 Material and methods

#### 3.3.1.1 Sampling methodology

Establishing a scouting technique for insects on kenaf proved problematic due to the height and density of the plants, hence the non-uniformity of techniques ultimately used between sites. However, at each specific site the particular technique used was the same throughout the survey, thus rendering each particular site's data comparable. Table 5 shows the scouting protocols followed at the different sites.

**Table1: Literature records of the Coleoptera diversity sampled on kenaf.**

| Common name | Latin name | Family | Reference | Country |
|---|---|---|---|---|
| Flea beetle | *Nistora gamella* Erichson | Chrysomelidae | Dempsey (1975) | Philippines |
| Flea beetle | *Chaetocnema* sp. | Chrysomelidae | Dempsey (1975) | Philippines |
| Flea beetle | *Podagrica javena* Motschulsky | Chrysomelidae | Dempsey (1975) | Java |
| Philippine boll weevil | *Amorpnoidea lata* Motschulsky | | Dempsey (1975) | Philippines |
| Flea beetle | *Podagrica bowringi* Baly | Chrysomelidae | Dempsey (1975) | India |
| Flea beetle | *Podagrica puncticollis* Weise | Chrysomelidae | Dempsey (1975)<br>Eldin & El-Amin (1981) | Sudan<br>Sudan |
| Flea beetle | *Podagrica* sp. | Chrysomelidae | Dempsey (1975) | Vietnam, Thailand, Indonesia, New Guinea |
| Flea beetle | *Podagrica sjostedti* Jacoby | Chrysomelidae | Dempsey (1975) | Nigeria, Uganda |
| Flea beetle | *Podagrica infirmia* Jacoby | Chrysomelidae | Dempsey (1975) | Nigeria |
| Flea beetle | *Podagrica* sp. | Chrysomelidae | Dempsey (1975) | Thailand |
| Flea beetle | *Nistora dilectra* | Chrysomelidae | Dempsey (1975) | Chad, Ivory Coast |
| Spiral borer | *Agrilus acutus* (Thunberg) | Buprestidae | Dempsey (1975) | India |
| Stem borer | *Hipposis lemniscata* (Fabricius) | Cerambycidae | Dempsey (1975) | USA |
| Ring pest | *Nupserha bicolor* Thos. ssp. *postbrunnae* Bruen | Cerambycidae | Dempsey (1975) | India |
| Stem borer | *Apion subangulirostre* Wagner | Apionidae | Dempsey (1975) | Central African Republic |
| Bark beetle | *Lagria villosa* Fabricius | Tenebrionidae | Dempsey (1975) | Nigeria |
| May beetle | *Anomala expansa* Bates | Scarabaeidae | Dempsey (1975) | Taiwan |
| Wireworm | *Melanotus communis* (Gyllenhal) | Elateridae | Dempsey (1975) | USA |

**Table 2: Literature records of the Lepidoptera diversity sampled on kenaf.**

| Common name | Latin name | Family | Reference | Country |
|---|---|---|---|---|
| Cotton bollworm | *Heliothis obsoleta* Fabricius | Noctuidae | Dempsey (1975) | Java |
| Cotton bollworm | *Heliothis zea* (Boddie) | Noctuidae | Dempsey (1975) | Nigeria, USA |
| Black cutworm | *Agrotis ypsilon* Rottemburg | Noctuidae | Dempsey (1975) | S. Vietnam |
| Granulate cutworm | *Feltia subterranea* (Fabricius) | Noctuidae | Dempsey (1975) | S. Vietnam |
| Southern armyworm | *Prodenia eradania* (Clemens) | Noctuidae | Dempsey (1975) | USA |
| Spiny bollworm | *Earias insulana* Boisduval | Noctuidae | Dempsey (1975)<br>Green *et al.*(2003) | Iran<br>Makhathini (KwaZulu-Natal) |
| Spiny bollworm | *Earias biplaga* | Noctuidae | Dempsey (1975)<br>Green (2003) | Nigeria<br>Makhathini (KwaZulu-Natal) |
| Pink bollworm | *Pectinophora malvella* Herrich-Schäffer | Gelechiidae | Dempsey (1975) | USSR |
| Pink bollworm | *Pectinophora gossypiella* (Saunders) | Gelechiidae | Dempsey (1975) | Brazil |
| Mallow caterpillar | *Anomis flava fibriago* (Stephens) | Phalaenidae | Dempsey (1975) | USA |
| Mallow caterpillar | *Anomis illitia* Guenée | Phalaenidae | Dempsey (1975) | USA |
| Mallow caterpillar | *Anomis erosa* (Hübner) | Phalaenidae | Dempsey (1975) | USA |
| Noctuid caterpillar | *Anomis flava flava* Fabricius | Noctuidae | Dempsey (1975), | Taiwan |
| European corn borer | *Pyrausta nubilis* (Hübner) | Pyralidae | Dempsey (1975) | Taiwan |

**Table 3: Literature records of the Hemiptera sampled on kenaf.**

| Common name | Latin name | Family | Reference | Country |
|---|---|---|---|---|
| Cotton stainer | *Dysdercus megalopygus* Breddin | Pyrrhocoridae | Dempsey (1975) | Philippines |
| Cotton stainer | *Dysdercus poecilis* (Herrich-Schäffer) | Pyrrhocoridae | Dempsey (1975) | Philippines |
| Cotton stainer | *Dysdercus rufficollis* DeGeer | Pyrrhocoridae | Dempsey (1975) | Surinam |
| Cotton stainer | *Dysdercus suturellus* ( Herrich-Schäffer) | Pyrrhocoridae | Dempsey (1975) | S. Vietnam |
| Cotton stainer | *Dysdercus cingulatus* Fabricius | Pyrrhocoridae | Dempsey (1975) | Malaysia |
| Stink bug | *Tectocoris lineola* Fabricius | Pentatomidae | Dempsey (1975) | Java |
| Stink bug | *Tectocoris diopthalmus* (Thunberg) | Pentatomidae | Dempsey (1975) | Philippines |
| Stink bug | *Nezara viridula* (L.) | Pentatomidae | Dempsey (1975) | USA |
| Stink bug | *Euschistus servus* (Say) | Pentatomidae | Dempsey (1975) | USA |
| Stink bug | *Euschistus ictericus* (L.) | Pentatomidae | Dempsey (1975) | USA |
| Chinch bug | *Lygaeus* sp. | Lygaeidae | Dempsey (1975) | Nigeria |
| Mirid bug | *Lygus rugulipennis* Poppius | Miridae | Conti & Bin (2001) | Italy |
| Mirid bug | *Lygus pratenis* L. | Miridae | Conti & Bin (2001) | Italy |

**Table 4: Literature records of the Auchenorrhyncha and Sternorrhyncha diversity sampled on kenaf.**

| Common name | Latin name | Family | Reference | Country |
|---|---|---|---|---|
| Leafhopper | *Empoasca flavescens* Fabricius | Cicadellidae | Dempsey (1975) | Java |
| Leafhopper | *Chlorita biguttula* Ishida | Issidae | Dempsey (1975) | Taiwan |
| Mealy bug | *Phaenococcus hirsutus* Green | Pseudococcidae | Dempsey (1975) | India |
| Cotton aphid | *Aphis gossypii* Glover | Aphididae | Dempsey (1975) | S. Vietnam |

The sampling protocols were as follows:

a) 25 plants were randomly selected per cultivation, and insects occurring on these plants were observed and noted. A reference list was compiled and insects were identified accordingly, and their abundance noted. When it became obvious that flea beetles were the dominant phytophagous insect, the focus shifted from overall occurrence of insects, to counting only flea beetles.

b) A 1m² block of plants was randomly selected per cultivation and from these plants the insects were beaten into a net. Insects collected were then transferred to plastic bags, labelled with the date and site details and killed by ethyl acetate fumes.

c) Sweep net sampling was conducted within the cultivation, using ± 20 sweeps along the vertical axis of the plants, from the bottom to the top. Insects collected in the sweep net were transferred to plastic bags, labelled with the date and site details and killed by ethyl acetate fumes.

**Table 5: Insect scouting protocols followed at the kenaf trial sites.**

| Locality | Cultivation | Scouting sessions | Scouting Techniques |
|---|---|---|---|
| **Bloemfontein** | Wetland | 7 | b |
| **Rustenburg** | Wetland | 4 | a |
| | Dryland | 6 | a |
| **Addo** | Wetland | 1 | b |
| **Makhathini** | Wetland | 1 | a |
| | Dryland | 1 | a |
| **Nelspruit** | Wetland | 1 | a |
| **Winterton** | Wetland | 1 | c |
| | Dryland | 1 | c |

Due to logistical constraints, most of the planting sites could only be visited once.

#### 3.3.1.2 Sorting methodology

Material was sorted at the laboratory. The plastic bags were cut open at the top, and the contents transferred to a white, rectangular plastic container. Specimens were removed with a soft pincette, and preserved in 70% ethanol in 10 ml glass vial bottles. Due to the sampling methods, employed leaves sometimes fell into the sweep net and couldn't be removed, due to the presence of flying insects. Small insects sticking to the leaves were carefully removed with a small brush.

#### 3.3.1.3 Identification methodology

A reference collection of dry pinned specimens was assembled and specimens were identified to at least family level, using a dissection microscope, and labelled accordingly. Specimens were also sent to specialists (see p. 64) for further identification.

### 3.3.2 Results and Discussion

At all the sites the incidence of plant-feeding species was high (Tables 6 - 11), indicating that the kenaf plants are under some or other form of insect feeding pressure, irrespective of locality. Insect trophic structure analyses of the Bloemfontein and Addo sites (Figures 1 & 2 respectively), indicate that phytophagous species dominate. Other often beneficial species were also present (*e.g.* Coleoptera: Coccinellidae and Neuroptera: Chrysopidae) and could play a role in keeping certain species, with pest potential, in check. Non-phytophagous insects that occurred at the different locations are listed in Appendix A.

All Chrysomelidae that were sampled at the sites are only listed in the tables, but will be discussed in detail in Chapter 4.

At the Bloemfontein site (Table 6), insects from the families Pentatomidae and Pyrrhocoridae pose a potential threat, due to them being sap-suckers on seed capsules and flower buds. However, not any real threat was noted at this site, maybe due to the plot size being very small and not really simulating commercial cultivation. The trophic structure (Figure 1) shows that beneficials are present at the site, but that phytophagous species are quantitatively dominant.

At the Addo site (Table 7) flea beetles, *Podagrica testacea* (Chapuis) (Chrysomelidae: Alticinae), were present in vast numbers causing the most damage. The basic trophic structure (Figure 2) indicates that the diversity of phytophagous insect species (*i.e.*14) was much lower than at the Bloemfontein site (*i.e.* 25). The difference between the number of phytophagous species and beneficial organisms was also much lower.

At the Rustenburg site (Table 8) only flea beetles, *P. testacea* (Chrysomelidae: Alticinae), and a *Dysdercus* sp. (Pyrrhocoridae) were present in large numbers throughout the growing season. Both are known to occur on Malvaceae. During the 2001-2002 season *P. testacea* was exceptionally destructive on all growth stages of kenaf at this site.

At the Makhathini site (Table 9) flea beetles, *P. testacea*, and cotton stainers, *Dysdercus* spp. (Pyrrhocoridae), were also present in large numbers during a sampling session late in the growing season. Other noteworthy records included *Maconellicoccus hirsutus* (Sternorrhyncha: Pseudococcidae) and large numbers of termites (Isoptera: Termitidae). The mealybug, *M. hirsutus* is a well-known pest on Malvaceae, whilst termites are destructive polyphagous stemchewers. As such, both these species are pests worthy of further monitoring and attention at this locality.

At the Nelspruit site (Table 10), the flea beetle, *P. testacea*, which was damaging at Winterton, Addo, Rustenburg and Makhathini, was absent. The kenaf trial site was surrounded by plantings of aromatic plants *e.g.* Rose geranium (*Pelargonium* sp.) and Lemongrass (*Cymbopogon* sp.), and it is speculated that these plants could have had some influence on the absence of certain phytophagous species on the kenaf. According to Simon *et al.*, (1984) geranium and lemongrass repel insects because of their citronella content.

At the Winterton sites (Table 11) the flea beetle species, *P. testacea* was present in large numbers. This species proved to be extremely damaging to the foliage of the plants in this area. Other phytophagous insects were also present, but their numbers were very low during the sampling period and they apparently did not pose any real threat. Figure 3 shows the trophic structure for insects collected from the Winterton site. This indicates that the species diversity is dominated by the phytophagous functional group, but that beneficial species are also present.

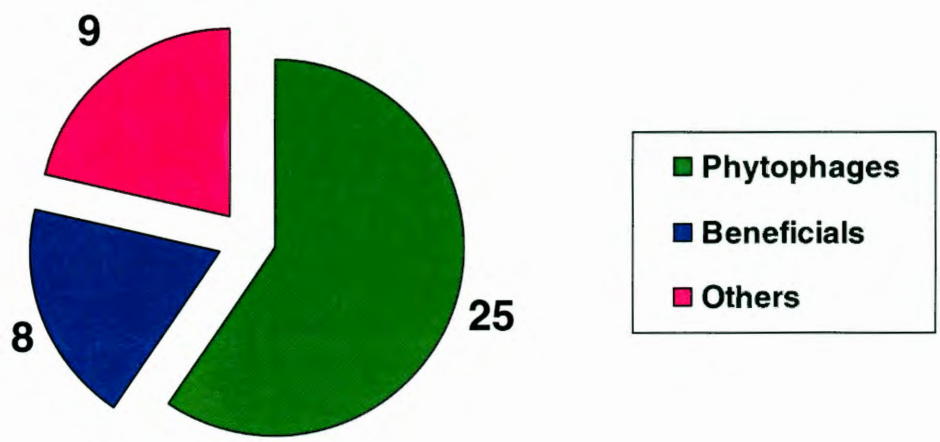


**Figure 1: Basic trophic structure of insects associated with kenaf at the Bloemfontein site (2000-2002). Numbers at the slices depict the species diversity.**

**Table 6: Phytophagous insects recorded on kenaf at the Bloemfontein site (2000-2002).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| Bruchidae sp. | Seed beetles | chewing | seeds |
| Chrysomelidae (3 spp.) * | Leaf beetles | chewing | foliage |
| *Micolarinus angustulus* (Curculionidae) | Weevils | chewing | foliage |
| *Lycus* sp. (Lycidae) | Net-winged beetles | chewing | flowers, foliage |
| *Mylabris* sp. (Meloidae) | CMR beetles | chewing | flowers |
| *Astylus atromaculatus* (Melyridae) | Spotted maize beetles | chewing | flowers, pollen |
| Nitidulidae sp. | Sap beetles | chewing | flowers |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Lygaeidae (2 spp.) | Seed bugs | sucking | seed capsules |
| Miridae (2 spp.) | Leaf bugs | sucking | growth tips |
| Pyrrhocoridae sp. | Red bugs | sucking | flower buds |
| Pentatomidae (2 spp.) | Stink bugs | sucking | seed capsules |
| Aphididae sp. | Aphids | sucking | foliage |
| Cercopidae sp. | Spittle bugs | sucking | foliage |
| Cicadellidae (3 spp.) | Leaf hoppers | sucking | new growth |
| Arctiidae sp. | Tiger moths | chewing larvae | foliage |
| Acrididae sp. | Grasshoppers | chewing | foliage |
| Phlaeothripidae sp. | Thrips | rasping | flowers |

* The diversity of Chrysomelidae is discussed in Chapter 4.

**Table 7: Phytophagous insects recorded on kenaf at the Addo site (2001-2002).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| Chrysomelidae (2 spp.)* | Leaf beetles | chewing | foliage |
| Ceutorrhynchinae sp. (Curculionidae) | Weevils | chewing | foliage |
| Elateridae sp. | Click beetles | chewing | foliage, flowers |
| *Astylus atromaculatus* (Melyridae) | Spotted maize beetles | chewing | flowers, pollen |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Miridae sp. | Leaf bugs | sucking | growth tips |
| Lygaeidae sp. | Seed bugs | sucking | seed capsules |
| Pyrrhocoridae (2 spp.) | Red bugs | sucking | flower buds |
| *Dysdercus* sp. (Pyrrhocoridae) | Cotton stainers | sucking | flower buds |
| Aphididae sp. | Aphids | sucking | foliage |
| Cercopidae sp. | Spittle bugs | sucking | foliage |
| Cicadellidae sp. | Leaf hoppers | sucking | new growth |

* The diversity of Chrysomelidae is discussed in Chapter 4.

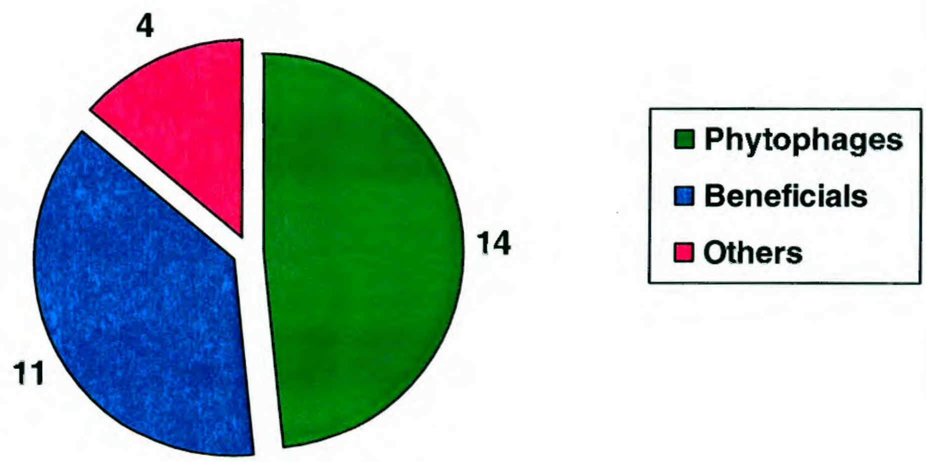


**Figure 2: Basic trophic structure of insects associated with kenaf at the Addo site (2001-2002). Numbers at the slices depict the species diversity.**

**Table 8: Phytophagous insects recorded on kenaf at the Rustenburg site (2001-2002).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| Bostrychidae sp. | Branch & twig borers | chewing | stems |
| Chrysomelidae sp.* | Leaf beetles | chewing | foliage |
| *Micolarinus angustulus* (Curculionidae) | Weevils | chewing | foliage |
| *Astylus atromaculatus* (Melyridae) | Spotted maize beetles | chewing | flowers, pollen |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Lygaeidae (2 spp.) | Seed bugs | sucking | seed capsules |
| *Dysdercus* sp. (Pyrrhocoridae) | Cotton stainers | sucking | flower buds |
| Aphididae sp. | Aphids | sucking | foliage |
| Cicadellidae (3 spp.) | Leaf hoppers | sucking | new growth |
| Phlaeothripidae sp. | Thrips | rasping | flowers |

* The diversity of Chrysomelidae is discussed in Chapter 4.

**Table 9: Phytophagous insects recorded at the Makhathini site (2001-2002).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| Bruchidae sp. | Seed beetles | chewing | seeds |
| Chrysomelidae sp.* | Leaf beetles | chewing | foliage |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Lygaeidae sp. | Seed bugs | sucking | seed capsules |
| *Dysdercus* sp. (Pyrrhocoridae) | Cotton stainers | sucking | flower buds |
| Pyrrhocoridae sp. | Red bugs | sucking | flower buds |
| Aphididae sp. | Aphids | sucking | foliage |
| Cicadellidae sp. | Leaf hoppers | sucking | new growth |
| *Maconellicoccus hirsutus* Green (Pseudococcidae) | Mealy bugs | sucking | new growth |
| Termitidae sp. | Termites | chewing | stems |

*The diversity of Chrysomelidae is discussed in Chapter 4.

**Table 10: Phytophagous insects recorded on kenaf at the Nelspruit site (2004).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| Chrysomelidae (2 spp.)* | Leaf beetles | chewing | foliage |
| *Lycus* sp. (Lycidae) | Net-winged beetles | chewing | flowers, foliage |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Miridae ( 2 spp.) | Leaf bugs | sucking | growth tips |
| Pyrrhocoridae sp. | Red bugs | sucking | flower buds |
| Aphididae sp. | Aphids | sucking | foliage |
| Cercopidae sp. | Spittle bugs | sucking | foliage |
| Cicadellidae sp. | Leaf hoppers | sucking | new growth |
| Cixiidae | Frog hoppers | sucking | foliage |

* The diversity of Chrysomelidae is discussed in Chapter 4.

**Table 11: Phytophagous insects recorded on kenaf at the Winterton trial sites (2003-2004).**

| Family & Species | Common name | Feeding action | Plant locus |
|---|---|---|---|
| *Astylus atromaculatus* (Melyridae) | Spotted maize beetle | chewing | flowers, pollen |
| Chrysomelidae (5 spp.)* | Leaf beetles | chewing | foliage |
| *Lagria* sp. (Tenebrionidae) | Long-jointed bark beetles | chewing | foliage |
| Curculionidae (3 spp.) | Weevils | chewing | foliage |
| Nitidulidae sp. | Sap beetles | chewing | flowers |
| Aphididae sp. | Aphids | sucking | foliage |
| Cicadellidae (2 spp.) | Leaf hoppers | sucking | foliage |
| Cercopidae sp. | Spittle bugs | sucking | foliage |
| Cixiidae sp. | Frog hoppers | sucking | foliage |
| Miridae (4 spp.) | Leaf bugs | sucking | growth tips |
| Pyrrhocoridae sp. | Red bugs | sucking | flower buds |
| Lygaeidae sp. | Seed bugs | sucking | seed capsules |
| Pentatomidae sp. | Stink bugs | sucking | seed capsules |
| Coreidae sp. | Twig wilter bugs | sucking | foliage |
| Acrididae sp. | Grasshoppers | chewing | foliage |

* The diversity of Chrysomelidae is discussed in Chapter 4.

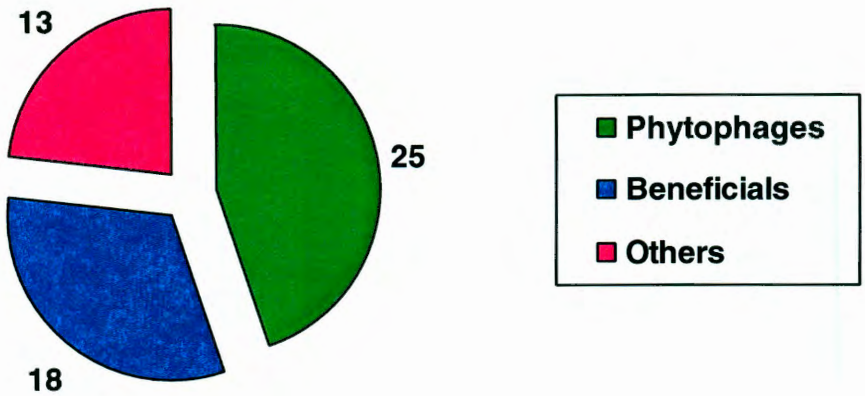


**Figure 3: Basic trophic structure of insects associated with kenaf at the Winterton site (2004). Numbers at the slices depict the species diversity.**

## 3.4 CONCLUSION

World-wide a large diversity of phytophagous insects are known from kenaf, many of which have taken on pest proportions in terms of economic thresholds and have a negative impact on the kenaf fibre industry as a whole. In South Africa, where kenaf commercialization is still in the development and establishment phase, it has been possible to identify and list the most probable insect species that utilize kenaf as food source and ultimately, also as probable reproductive host. From these, problem species with pest potential have already been identified, as have other phytophagous species that cause feeding damage. Whether their interaction with kenaf will be detrimental to the production of the crop in the country in the long-term still needs to be determined.

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## Appendix A

Diversity of insect families sampled on kenaf at all the locations, *i.e.* Bloemfontein (Free State), Addo (Eastern Cape), Rustenburg (North West), Makhathini (KwaZulu-Natal), Nelspruit (Mpumalanga), and Winterton (KwaZulu-Natal), in South Africa (2001-2004).

| Family | Common name | Localities in South Africa |
|---|---|---|
| **Coleoptera** | | |
| Anthicidae | Ant-like flower beetle | Winterton |
| Bostrichidae | Branch and twig borers | Rustenburg |
| Bruchidae | Seed beetles | Bloemfontein, Makhathini |
| Chrysomelidae | Leaf beetles | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| Coccinellidae | Ladybird beetles | Addo, Bloemfontein, Makahthini, Nelspruit, Rustenburg, Winterton |
| Cryptophagidae | Mould beetles | Winterton |
| Curculionidae | Weevils | Addo, Bloemfontein, Rustenburg, Winterton |
| Elateridae | Click beetles | Addo |
| Lycidae | Net-winged beetles | Bloemfontein |
| Meloidae | CMR beetles | Bloemfontein |
| Melyridae | Spotted maize beetle | Addo, Bloemfontein, Rustenburg, Winterton |
| Nitidulidae | Sap beetles | Bloemfontein, Winterton |
| Phalacridae | Shining flower beetles | Winterton |
| Staphylinidae | Rove beetles | Winterton |
| Tenebrionidae(Lagriinae) | Long-jointed bark beetles | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| **Homoptera** | | |
| Aphididae | Aphids | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| Cicadellidae | Leaf hoppers | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| Cercopidae | Spittle bugs | Addo, Bloemfontein, Winterton |
| Cixiidae | Frog hoppers | Winterton |
| Pseudococcidae | Mealy bugs | Makhathini |
| **Hemiptera** | | |
| Coreidae | Twig wilter bugs | Winterton |
| Lygaeidae | Seed bugs | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| Miridae | Leaf bugs | Winterton, Bloemfontein, Addo |
| Pentatomidae | Stink bugs | Winterton, Bloemfontein |
| Pyrrhocoridae | Red bugs | Addo, Bloemfontein, Makhathini, Rustenburg, Winterton |
| **Orthoptera** | | |
| Acrididae | Grasshoppers | Bloemfontein, Winterton |
| **Lepidoptera** | | |
| Arctiidae | Tiger moths | Bloemfontein |
| **Thysanoptera** | | |
| Phlaeothripidae | Thrips | Bloemfontein, Rustenburg |
| **Isoptera** | | |
| Termitidae | Termites | Makhathini |
| **Neuroptera** | | |
| Chrysopidae | Antlions | Addo, Bloemfontein, Nelspruit, Winterton |
| **Dermaptera** | | |
| Forficulidae | Earwigs | Addo, Bloemfontein, Winterton |
| **Hymenoptera** | | |
| Apidae | Honeybees | Addo, Bloemfontein, Nelspruit, Winterton |
| Braconidae | Braconids | Addo, Winterton |

| | | |
|---|---|---|
| Chalcidoidea | Chalcidoid parasitoids | Bloemfontein, Nelspruit, Winterton |
| Formicidae | Ants | Addo, Bloemfontein, Nelspruit, Winterton |
| Halictidae | Halictid bees | Bloemfontein |
| Ichneumonidae | Ichneumons | Winterton |
| Pompilidae | Spider wasps | Bloemfontein, Winterton |
| Vespidae | Paper wasps | Bloemfontein |
| **Diptera** | | |
| Asilidae | Robber flies | Nelspruit |
| Chironomidae | Midges | Bloemfontein, Winterton |
| Chloropidae | Grass flies | Bloemfontein, Winterton |
| Diopsidae | Stalk-eyed flies | Winterton |
| Drosophilidae | Vinegar flies | Nelspruit, Winterton |
| Muscidae | House flies | Addo, Bloemfontein, Nelspruit, Winterton |
| Mycetophilidae | Fungus gnats | Winterton |
| Phoridae | Humpbacked flies | Winterton |
| Psychodidae | Moth flies | Winterton |
| Sciaridae | Dark-winged fungus gnats | Nelspruit, Winterton |
| Sphaeroceridae | Small dung flies | Nelspruit, Winterton |
| Tephritidae | Fruit flies | Bloemfontein, Winterton |
| Tipulidae | Crane flies | Bloemfontein |

# CHAPTER 4

## DIVERSITY AND SEASONALITY OF CHRYSOMELIDAE ON KENAF

# DIVERSITY AND SEASONALITY OF CHRYSOMELIDAE ON KENAF

## 4.1 INTRODUCTION

The family Chrysomelidae (Coleoptera) represents a wide variety of beetles, with all members of this family following a phytophagous life-style. Adult leaf beetles feed principally on flowers and foliage. The larvae are also phytophagous, some feeding freely on foliage, whereas others are leaf miners, feed on roots and even bore in stems. Many members of this family are serious pests of cultivated plants (Borror *et al.*, 1992). During this study Chrysomelidae were collected from all the trial sites where kenaf was planted for evaluation purposes. One flea beetle species, *Podagrica testacea* (Chapuis) (Alticinae), was observed as most damaging to the plant. The physical damage they caused was by chewing holes in the leaves, resulting in a characteristic 'shot-hole' appearance.

Although kenaf was planted at different locations all over the country, it was noted that there would always be at least one or two species of Chrysomelidae utilizing the plants. This could be expected, since Chrysomelidae are one of the foremost plant-feeding insect groups (see Chapter 1). Being such a diverse family is indicative of different plant utilizing mechanisms. This ability to utilize a host plant in many different ways, and at different growth stages, results in an even more deleterious situation for the plant. In cases where the host plant provides a niche for both the adult and larvae of the beetle, double the impact of damage is instigated, which could cause immense damage indices in the long run. This situation is found in many leaf beetles, with a case in point being where both the adults and larvae of the Cabbage stem flea beetle, *Psylliodes chrysocephala* (L.), feed on the same host and are a serious pest of most Brassica seed crops (Winfield, 1992). The adults chew holes in the leaves and the larvae usually mine in the lower petioles, moving from ageing to healthy tissue. They will even move to the stem and destroy the growth tip if larval numbers are high (Williams & Carden, 1961).

## 4.2 MATERIAL AND METHODS

Initially the objective was to carry out a survey to determine the overall diversity of arthropods occurring on kenaf plants in South Africa. It soon became clear that a flea beetle, *P. testacea*, was the most abundant phytophagous species encountered at all the trial sites. As a result the focus shifted to investigating the effect that this particular species would have on the successful establishment of kenaf as a commercially produced crop. Literature records show that members of the family Chrysomelidae are pest organisms on a wide variety of cultivated crops all over the world. The fact that a wide array of chrysomelid species occur on kenaf is noteworthy. Particularly so since these beetles have a well-documented history of polyphagous trophic capabilities and, stemming from this, a strong potential to reach pest status.

Throughout the survey it was clear that Chrysomelidae were the most abundant phytophagous insect group, with the greatest species diversity. A reference collection was therefore prepared from the sampled material, and submitted to the Biosystematics Division, Plant Protection Research Institute, Agricultural Research Council, in Pretoria for identification.

Within sites, identical sampling protocols were implemented, whilst sorting and identification methodologies were similar between sites (see Chapter 3).

### 4.2.1 Study sites

For study purposes 10 kenaf cultivars (see Chapter 3, p. 47) were planted at four different trial sites during the 2001-2002 season and at two localities during the 2003-2004 season (Figure 1). The aim was to determine the optimal agronomic requisites for producing kenaf in South Africa, as well as for accumulating important data concerning potential insect and pathogen pests.

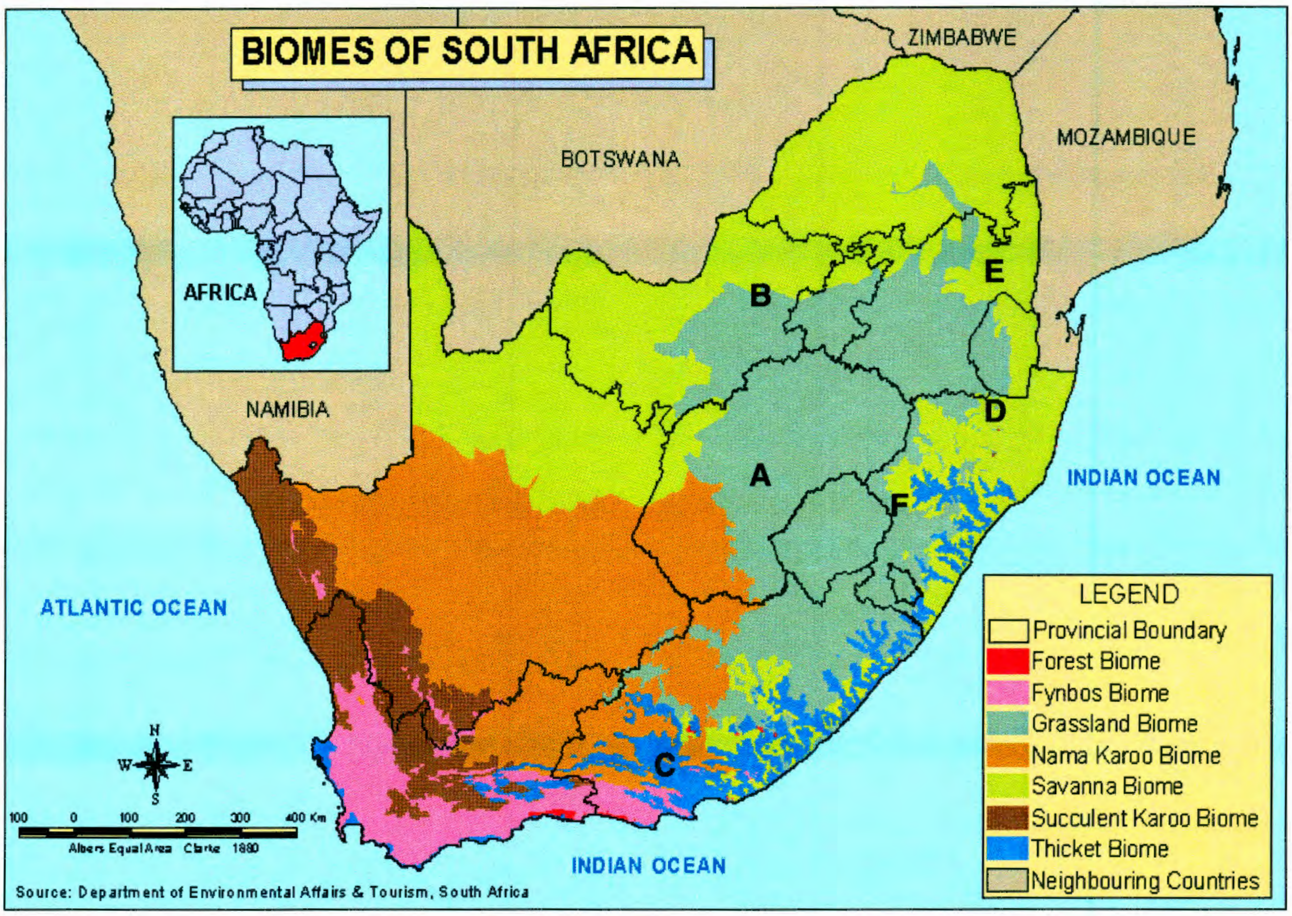


**Figure 1: Map depicting the different localities where kenaf trials were planted in South Africa (2000 – 2004). (A – Bloemfontein, B – Rustenburg, C – Addo, D – Makahthini, E – Nelspruit, F – Winterton).** Map courtesy of the Department of Environmental Affairs and Tourism, 1999. Retrieved from URL: http://www.ngo.grida.no/soesa/nsoer/general/about.htm

#### 4.2.1.1 Bloemfontein

Bloemfontein (SE 2926Aa) in the Free State Province is situated in central South Africa. The average rainfall for this region is 559 mm a year, and the average temperatures vary between 10 and 30°C, with 39°C being the highest temperature recorded (Anonymous, 2004). At the Bloemfontein site the ten kenaf cultivars were planted for evaluation. The trial setup constituted a small plot (< I ha) and did not simulate a commercial planting. The plot was partially surrounded by dense stands of maize and partially flanked by natural veld and fallow land (Figure 2). Blanket arthropod monitoring was done to determine the diversity of insects occurring on the kenaf plants at this site.

**Figure 2: Kenaf trial cultivation at Bloemfontein, Free State Province, South Africa.**

#### 4.2.1.2 Rustenburg

Rustenburg (SE 2527Ca) is situated in the north eastern part of the North West Province. It receives an average rainfall of 539 mm per year and the average maximum and minimum temperatures vary between 32 - 42°C and 18 - 23°C, respectively (Anonymous, 2004). The ten kenaf cultivars were also planted at this site for evaluation (Figure 3). Here the plots were surrounded by cotton, other fibre crops and pine windbreaks. These plots closely simulated a commercial cultivation and the cultivars were planted in a randomized block design. Besides quantitatively assessing *P. testacea* occurring on the kenaf plants, the individual plants damaged by the flea beetles in both the irrigated and dryland conditions of the October planting, were also scouted and damage indices determined.

**Figure 3: Kenaf trial cultivation at Rustenburg, North West Province, South Africa.**

#### 4.2.1.3 Addo

Addo (SE 3325Da) is situated in the southern part of the Eastern Cape Province, approximately 30 km from the coast. The average rainfall for this province is 624 mm per year and the average temperatures vary between 14 and 22°C, with a high of 41°C recorded (Anonymous, 2004). The ten cultivars were also planted in a randomized block designed plot, surrounded by cane windbreaks (Figure 4). Limited information was obtained at this site in that only the first (October) planting was scouted. Due to circumstances an overall, visual, foliage damage index assessment was used to evaluate the other two plantings and to compare these to damage sustained in the October planting.

**Figure 4: Kenaf trial cultivation at Addo, Eastern Cape Province, South Africa.**

#### 4.2.1.4 Makhathini

Makhathini (SE 2732Ac) is situated in the north eastern part of the KwaZulu-Natal Province. The average annual rainfall for this region is 1009 mm, with temperatures ranging between 11 and 35 °C (Anonymous, 2004). All ten the cultivars were planted and the trials simulated commercial plantings (Figure 5). The plots were interspersed with cotton stands and fallow land. Only target species (*i.e.* Alticinae) scouting was done at Makhathini.

**Figure 5: Kenaf trial cultivation (arrow) at Makhathini, KwaZulu-Natal Province, South Africa.**

#### 4.2.1.5 Nelspruit

Nelspruit (SE 2530Bd) is situated in the Mpumalanga Province. The average rainfall for this region is 767 mm and the average temperature ranging between 13 and 27°C, with an average maximum of 40°C (Anonymous, 2004). The trial planting was done on the grounds of the Lowveld Agricultural College. The kenaf planting was surrounded by plantings of cotton, sugarcane, rose geranium and lemon grass (Figure 6).

**Figure 6: Kenaf trial cultivation at Nelspruit, Mpumalanga Province, South Africa.**

#### 4.2.1.6 Winterton

During the 2003-2004 season, a few farmers in the vicinity of Winterton (SE 2829Dc) in the KwaZulu-Natal Province, planted commercial stands of kenaf for the first time, under both dryland and irrigated cultivation conditions. Trial sites were planted directly next to the commercial plantings at two localities. Chrysomelidae were sampled at a trial site at each of the localities (Figures 7 & 8). Hand sampling of certain Chrysomelidae species was also conducted at the commercial sites when the opportunity arose.

**Figure 7: Kenaf trial cultivation on Strawberry Creek farm in the Winterton district, KwaZulu-Natal, South Africa.**

**Figure 8: Kenaf trial cultivation on Mopona farm in the Winterton district, KwaZulu-Natal, South Africa.**

Different agronomic practices were implemented at the two localities. These were:

i) Irrigation with no-till

This practice was conducted at a trial site on the farm Strawberry Creek (SE 2829Da), situated north west of Winterton on the banks of the Tugela River. Planting took place in early November 2003 under maize no-till conditions and consisted of six rows in a nine meter plot in a randomized block design, with only nine cultivars (the Whitten cultivar was omitted because of weak germination characteristics). Spacing included 25 cm between rows, 10 cm between plants in the row, and 0.5 m between plots. According to Camp (1997), this site is situated within the Dry Tall Grassveld Bioresource Group (BRG), as classified in his report on the Bioresource Groups of KwaZulu-Natal. A bioresource group is defined as an ecological unit, based primarily on the climate, vegetation and soil of an area. The average mean annual rainfall for this BRG is 666 to 745 mm and the mean annual temperature is 17.3°C. Shallow duplex soils are common for this group, and therefore have a particularly low resistance to grazing pressure. Generally the veld based on these soils is in a poor condition and erosion is a common occurrence.

ii) Dryland with till

The dryland trial site was situated on the farm Mopona (SE 2929Ba), south of Winterton, close to the foot of the Drakensberg. This trial site falls within the Moist Transitional Tall Grassveld BRG and is characterized by an average mean annual rainfall of between 800 mm and 1116 mm and the mean annual temperature is 16.9°C. The climate favours a wide range of agricultural crops and enterprises and the terrain, which tends to be rolling with moderate slopes, and has a high percentage of arable land (Camp, 1997). Planting at this site took place in early November 2003. Kenaf was planted in tilled fields with six rows in a nine meter plot, in a randomized block design, also with only nine cultivars (the Whitten cultivar was again omitted). Spacing included 25 cm between rows, 10 cm between plants in the row, and 0.5 m between plots.

## 4.3 RESULTS AND DISCUSSION

The overall diversity of Chrysomelidae on kenaf in South Africa was sampled over a wide array of locations in the country and recorded (Figure 1). Albeit that some species were only recorded at specific sites, this does not reflect absence, but was rather regarded as a case of collector's bias (*e.g. Lema* spp. (Criocerinae) that were sampled only at Winterton (Table 1)).

Although numerous chrysomelid species are present on kenaf (Table 1), only *P. testacea* was present in large numbers and then only at the Rustenburg, Addo, Makhathini and Winterton sites.

**Table 1: Diversity of leaf beetles (Chrysomelidae) sampled on kenaf at selected research and development sites in South Africa (2001 - 2004).**

| Locality | Subfamily | Species |
|---|---|---|
| Bloemfontein | Alticinae | *Altica* sp.1 |
| | | *Chaetocnema* sp. |
| | Galerucinae | *Monolepta capicola* Chevrolat |
| Addo | Alticinae | *Podagrica testacea* (Chapuis) |
| | | *Podagrica* cf. *weisei* Jacoby |
| | Galerucinae | *Monolepta cruciata* Guérin-Méneville |
| Rustenburg | Alticinae | *Podagrica testacea* (Chapuis) |
| | | *Podagrica* cf. *weisei* Jacoby |
| Makhathini | Alticinae | *Podagrica testacea* (Chapuis) |
| Nelspruit | Alticinae | *Nisotra usambarica* (Weise) |
| | | *Podagrica maculata* Weise |
| | Clytrinae | *Peploptera* sp. |
| Winterton | Alticinae | *Altica cuprea* Jacoby |
| | | *Altica* sp.1 |
| | | *Aphthona guavae* Bryant |
| | | *Aphthona marshalli* Jacoby |
| | | *Nisotra usambarica* (Weise) |
| | | *Podagrica testacea* (Chapuis) |
| | Clytrinae | *Melitonoma* sp. |
| | Criocerinae | *Lema bilineata* (Germar) |
| | | *Lema trilinea* White |
| | | *Lema* sp.3 |
| | | *Lema* sp.4 |
| | | *Lema* sp.5 |
| | Cryptocephalinae | *Cryptocephalus callias* Suffrian |
| | Galerucinae | *Monolepta capicola* Chevrolat |
| | | *Monolepta cruciata* Guérin-Méneville |
| | | *Monolepta* sp.n. |

### 4.3.1 Bloemfontein

At Bloemfontein arthropod sampling was conducted continuously throughout the season. The focus species of this study, *P. testacea*, was absent from this site, but other Chrysomelidae species were sampled, *i.e.* *Altica* sp.1, *Chaetocnema* sp. and *Monolepta capicola* Chevrolat.

### 4.3.2 Rustenburg

Even though scouting of *P. testacea* was conducted at four sites (Rustenburg, Addo, Makhathini and Winterton), it was at the Rustenburg site that the most intense and continuous surveys of this species took place (see Table 5, Chapter 3). The scouting intensity at the other three sites was less regular due to numerous logistical factors. At all four sites where *P. testacea* was recorded, these flea beetles attacked all the kenaf cultivars that were planted.

A wide array of planting protocols were implemented at Rustenburg, and to a certain extent at Makhathini and Addo as well, but only the irrigation and dryland cultivation plots were used to evaluate all the kenaf cultivars. It was therefore only under these parameters that *P. testacea* was monitored.

At Rustenburg both irrigated and dryland plots were planted over staggered, monthly planting dates, *i.e.* 12 October 2001, 12 November 2001 and 24 December 2001. The December planting was partially replanted on 12 February 2002, but to avoid intricacies regarding data analysis these dates are lumped as one and referred to as 'December' in figures and tables.

The plant growth at Rustenburg's irrigated plots was generally flush and overall, scouting showed a high average presence of flea beetles, across all the planting dates. However, flea beetle numbers for October are markedly lower than that of the other two months at the time of scouting (Figure 9), presumably indicating that natural eclosion of flea beetle populations only commences in October and as a result the beetles only start to establish on the young kenaf plants during this time. At the time of scouting the younger November and December plants were simply preferred as a feeding source over the tougher, mature October plants, explaining the higher average peaks for these two months (Figure 9).

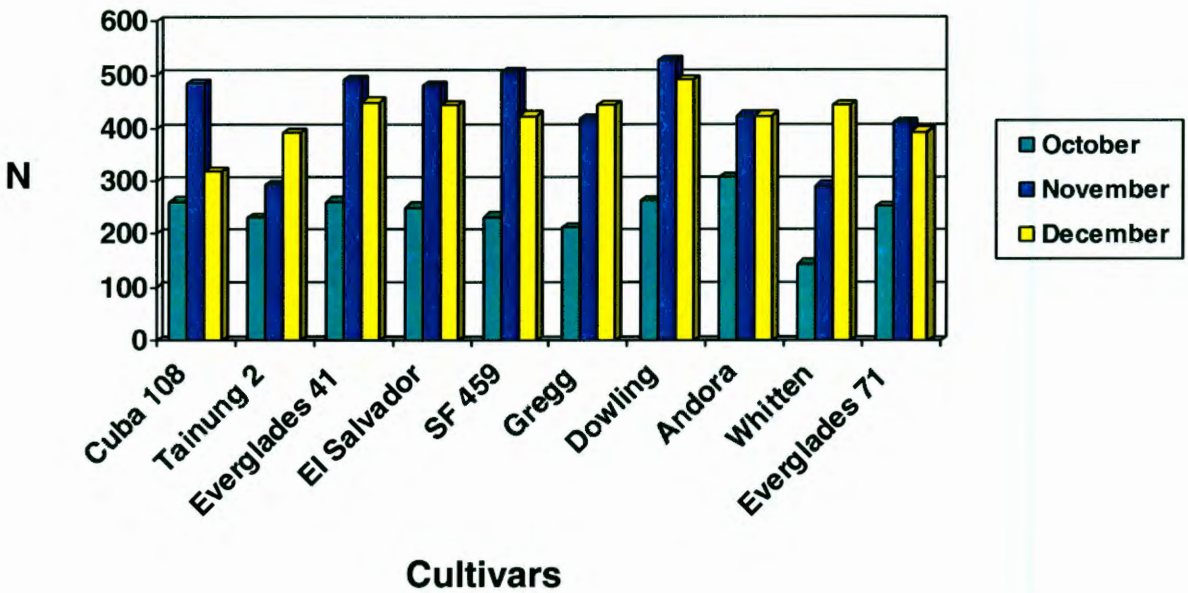


**Figure 9: Average number (N) of flea beetles on kenaf cultivars over three monthly planting dates in irrigated plots at Rustenburg. (Scouting sessions on 18 February and 4, 11, & 18 March, 2001 - 2002).**

At the Rustenburg dryland plots flea beetle numbers for the three planting dates were more or less the reverse of the irrigated plots, with the highest numbers for the October planting and numbers markedly decreasing for the November and especially December plantings (Figure 10). This phenomenon is presumably ascribed to growth stress and even mortality of the plants under the adverse natural dryland environmental conditions at the time of scouting. It is well documented in the literature that plant-feeding insects tend to aggregate on stressed plants, feeding undisturbed while exploiting the weakened metabolic defense systems of the plant (Way & Cammel, 1970). In the dryland plots the early season plants survived better, whilst the late plants were underdeveloped and severely stressed, even to the point of dying off in some cases. Eclosing flea beetles supposedly therefore preferred the 'early' plants (probably even at the expense of irrigated plants at the time), whilst scouting avoided dead plants, where there might have been aggregations of the flea beetles sheltering, but the inclusion of which would have been misleading in the datasets. Under these circumstances, where environmental conditions determined feeding preference levels, it was therefore only indirectly possible to speculate on the best cultivar. However, valuable information was gathered regarding the hardiness of the cultivar.

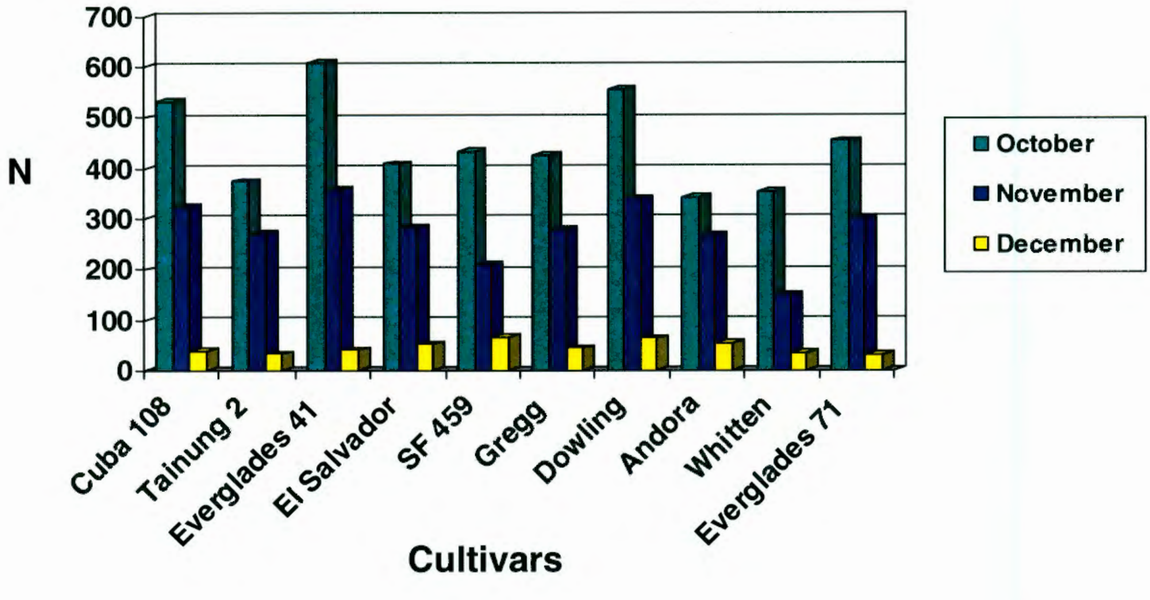


**Figure 10: Average number (N) of flea beetles on kenaf cultivars over three monthly planting dates in dryland plots at Rustenburg. (Scouting sessions on 24 January, 4 & 18 February and 4, 11 & 18 March 2001- 2002).**

An extra assessment was done by investigating the individual plants damaged by flea beetles in both the irrigated and dryland conditions on the 12 October 2001 planting. The plants were scouted on 5 November 2001, *i.e.* after three weeks of growth. Within the four planting replications, three random 0.5 m rows of each cultivar (*i.e.* 14 plants) were selected and scouted. The results (Tables 2 & 3) reflect rapid colonization and widespread plant damage by flea beetles at an early growth stage, which has important agronomic implications regarding successful kenaf cultivation in the future.

Overall it seems that, at Rustenburg, severely more plants were damaged in the dryland plots (Table 3) than in the irrigated plots (Table 2). Furthermore, cultivars that tend to be of the least damaged in the irrigated plots, for example Everglades 41 and El Salvador, are those most damaged in the dryland plots. This can perhaps be ascribed to the overall stress conditions that dryland cultivated plants experience.

**Table 2: Number of kenaf plants in 0.5m rows, damaged by flea beetles in irrigated plots, at Rustenburg (2001). [4 replication plantings on 12 October; scouting on 5 November; 3 repetitions]**

| | 1 | | | | 2 | | | | 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CUTIVAR** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **TOTAL** |
| **Cuba 108** | 6 | 5 | 6 | 10 | 6 | 8 | 9 | 11 | 6 | 6 | 8 | 5 | 86 |
| **Tainung 2** | 8 | 4 | 10 | 5 | 7 | 3 | 5 | 6 | 6 | 7 | 15 | 8 | 84 |
| **Everglades 41** | 4 | 2 | 7 | 11 | 5 | 2 | 8 | 7 | 5 | 4 | 4 | 8 | 67 |
| **El Salvador** | 6 | 1 | 9 | 8 | 2 | 1 | 2 | 8 | 4 | 2 | 5 | 11 | 59 |
| **SF459** | 2 | 1 | 3 | 5 | 5 | 2 | 9 | 9 | 7 | 3 | 5 | 6 | 57 |
| **Gregg** | 2 | 8 | 9 | 6 | 5 | 8 | 8 | 8 | 4 | 4 | 9 | 10 | 81 |
| **Dowling** | 5 | 3 | 11 | 7 | 5 | 1 | 10 | 11 | 7 | 7 | 6 | 9 | 82 |
| **Endora** | 12 | 3 | 8 | 8 | 10 | 3 | 13 | 29 | 10 | 5 | 6 | 7 | 114 |
| **Whitten** | 6 | 6 | 2 | 4 | 3 | 5 | 5 | 12 | 1 | 3 | 6 | 3 | 56 |
| **Everglades 71** | 8 | 4 | 7 | 10 | 4 | 4 | 8 | 7 | 4 | 2 | 6 | 11 | 75 |

**Table 3: Number of kenaf plants in 0.5m rows, damaged by flea beetles in dryland plots, at Rustenburg (2001). [4 replication plantings on 12 October; scouting on 5 November; 3 repetitions]**

| | 1 | | | | 2 | | | | 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CULTIVAR** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | **TOTAL** |
| **Cuba 108** | 8 | 3 | 8 | 6 | 8 | 10 | 6 | 5 | 6 | 6 | 7 | 10 | 83 |
| **Tainung 2** | 9 | 6 | 5 | 7 | 6 | 10 | 5 | 9 | 9 | 12 | 4 | 3 | 85 |
| **Everglades 41** | 13 | 11 | 6 | 10 | 13 | 11 | 6 | 8 | 9 | 8 | 6 | 7 | 108 |
| **El Salvador** | 28 | 8 | 10 | 10 | 11 | 12 | 7 | 8 | 9 | 13 | 11 | 9 | 136 |
| **SF459** | 11 | 6 | 1 | 4 | 9 | 6 | 5 | 3 | 12 | 11 | 6 | 6 | 80 |
| **Gregg** | 11 | 8 | 7 | 6 | 10 | 11 | 4 | 9 | 10 | 6 | 7 | 4 | 93 |
| **Dowling** | 12 | 11 | 8 | 8 | 10 | 11 | 8 | 8 | 8 | 13 | 7 | 8 | 112 |
| **Endora** | 9 | 11 | 3 | 6 | 13 | 8 | 6 | 7 | 7 | 7 | 5 | 5 | 87 |
| **Whitten** | 4 | 15 | 4 | 8 | 6 | 11 | 4 | 7 | 5 | 7 | 9 | 7 | 87 |
| **Everglades 71** | 9 | 12 | 9 | 7 | 8 | 11 | 9 | 7 | 9 | 9 | 8 | 6 | 104 |

### 4.3.3 Addo

At the Addo site three plantings were done on 10 - 11 October, 5 - 6 November and 6 - 7 December 2001 for both irrigated and dryland cultivations. At this site a single scouting session was possible on the October irrigated planting (Table 5, Chapter 3). Results indicated flea beetles present in large numbers on all kenaf cultivars (Figure 11). The October irrigated planting was selected for this scouting session because of the high level of damage on the plants (Table 4). Because of the limited data accumulated at this site, no specific interpretations are attempted. Although it could seem that the first planting had the most damage overall, this may be due to the fact that it was the first planting and flea beetle populations had already settled. More time had passed, allowing new generations of beetles to emerge and utilize the crop. Damage levels were not absent from the other two plantings, but far lower than those in the first planting (see Table 4). The fact that this assessment methodology can contribute to establishing threshold damage levels on kenaf foliage is important. It can be used by farmers to determine when management practices are necessary, as has been demonstrated for Elm leaf beetles, *Xanthogaleruca luteola* (Müller)(Lawson & Dahlsten, 2003), as well as for Crucifer flea beetles, *Phyllotreta cruciferae* (Goeze), on Canola (Knodel & Olson, 2002).

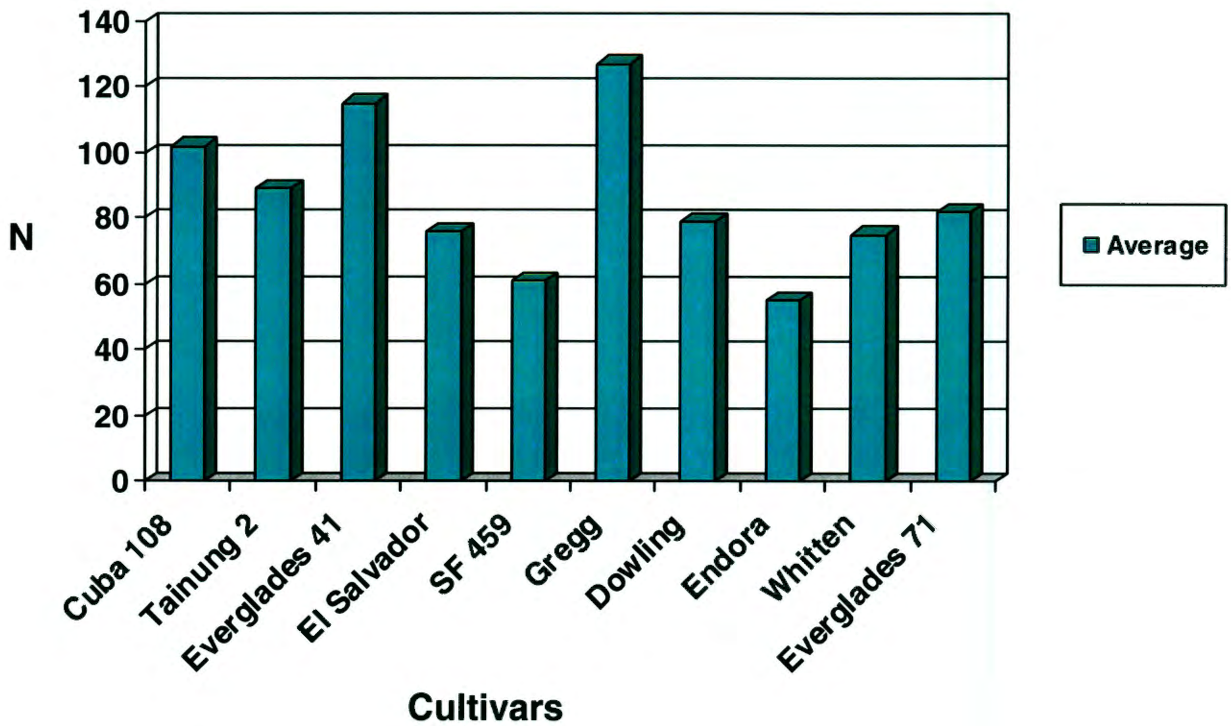


**Figure 11: Average number (N) of flea beetles on kenaf cultivars for the October planting in irrigated plots at Addo. (Scouting session on 25 February 2002)**

Snails (*Helix* sp.), which rasp the outer stem tissue of kenaf plants, thereby weakening the plant and causing large-scale plant lodging, was also recorded at Addo (Figure 12). At the time of scouting at this site, the occurrence of plant lodging due to snails was wide-spread, which could have implications should commercial development of kenaf be envisaged in this area.

**Table 4: Flea beetle damage on leaves of kenaf plants in the irrigated plots over three plantings at Addo (2002). [Leaf surface damage index: 1 = 0 - 10%, 2 = 11- 20%, 3 = 21- 30%, 4 = 31 - 40%, 5 = 41 - 50%, 6 = 51 - 60%]**

| CULTIVAR | PLANTING 1 | PLANTING 2 | PLANTING 3 |
|---|---|---|---|
| Cuba 108 | 5 | 3 | 2 |
| Tainung 2 | 6 | 4 | 3 |
| Everglades 41 | 5 | 3 | 2 |
| El Salvador | 5 | 3 | 1 |
| SF 459 | 6 | 3 | 1 |
| Gregg | 6 | 3 | 1 |
| Dowling | 5 | 3 | 1 |
| Endora | 5 | 3 | 2 |
| Whitten | 6 | 3 | 1 |
| Everglades 71 | 5 | 3 | 3 |

**Figure 12: Snails (*Helix* sp.) sampled at the kenaf trial cultivation at Addo, Eastern Cape Province.**

### 4.3.4 Makhathini

At the Makhathini site two plantings were done on 22 November and 19 - 21 December 2001, for both irrigated and dryland cultivations. At this site only a single scouting session was possible in both the irrigated and dryland plots (Table 5, Chapter 3). At the time of scouting the Makhathini plants were already full-grown and even though it was relatively late in the season, flea beetles were recorded in high numbers on all the kenaf cultivars under both types of cultivation (Figures 13 & 14). At the irrigated plots flea beetles numbers were consistently higher on all the cultivars of the earlier November planting (Figure 13). However, the irrigation setup was malfunctioning, influencing accurate data interpretation at this cultivation. The dryland plots showed possible seasonal shifts in cultivar preference, with higher numbers of beetles on cultivars Cuba 108, Tainung 2, Everglades 41, El Salvador and Gregg in the later December planting, as opposed to higher numbers of beetles on cultivars SF 459, Dowling, Endora, Whitten and Everglades 71 in the earlier November planting (Figure 14). Of all the cultivars, Tainung 2 showed the lowest flea beetle numbers under both conditions.

### 4.3.5 Nelspruit

*Podagrica testacea* was not present at the Nelspruit site. About 1 km from the kenaf planting a weed (*Hibiscus trionum*), also known as Terblansbossie, Bladder hibiscus or Bladder weed (Bromilow, 1996), was found growing next to the road. *Podagrica maculata* Weise was collected from these plants. Why *P. maculata* had not dispersed to the *Hibiscus cannabinus* plants at the trial site is open to speculation. It could be an indication of strict monophagous feeding specificity by *Podagrica* species on specific kenaf hosts. It could, however, also be due to the presence of certain aromatic plants, *i.e.* Rose geranium (*Pelargonium* sp.) and Lemongrass (*Cymbopogan* sp.), which were growing in the close vicinity of the trial site and could have influenced the presence of certain beetle species. According to Simon *et al.* (1984) geranium and lemongrass repel insects because of their citronella content. Whichever the case, this scenario is worthy of further investigation with regard to flea beetle management on cultivated kenaf.

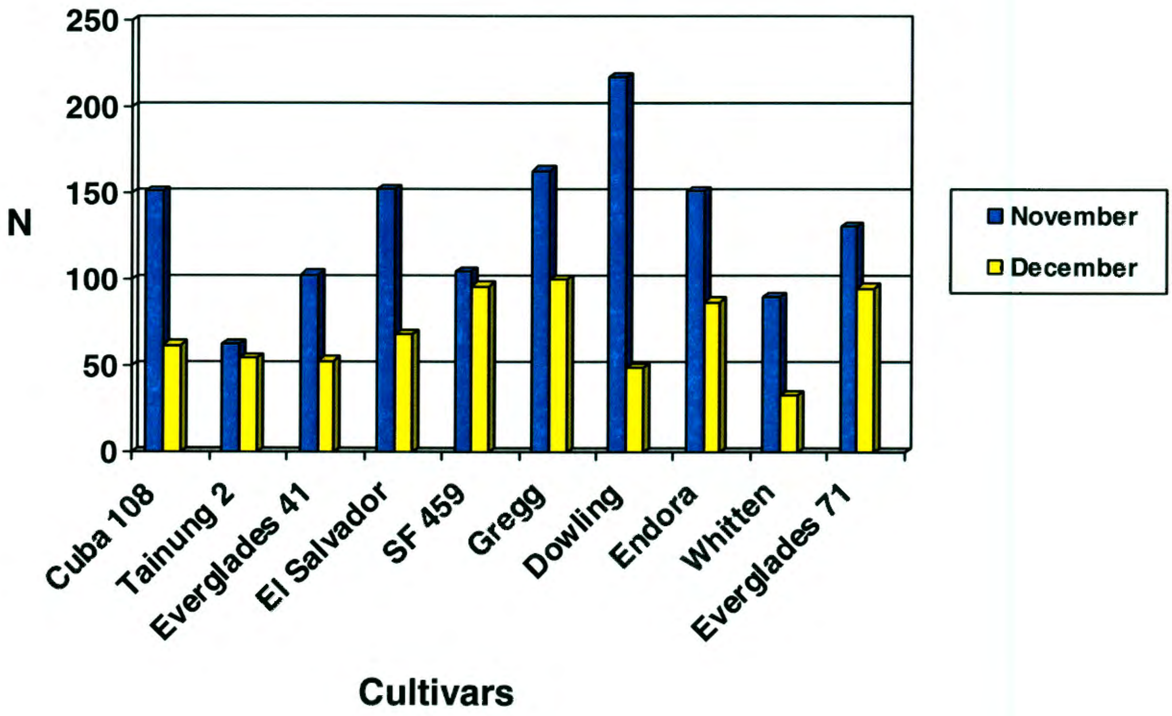


**Figure 13: Total number (N) of flea beetles on kenaf cutivars over two planting dates in the irrigated plots at Makhathini. (Scouting session on 7 March 2002)**

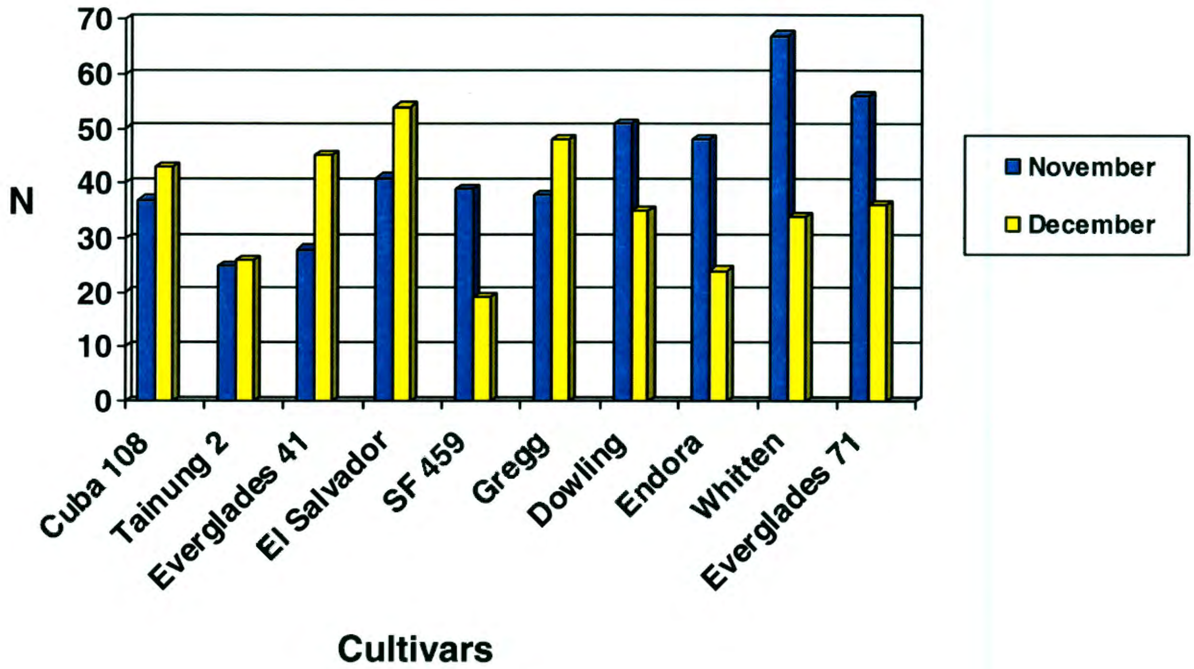


**Figure 14: Total number (N) of flea beetles on kenaf cutivars over two planting dates in the dryland plots at Makhathini. (Scouting session on 7 March 2002).**

#### 4.3.6 Winterton

*Podagrica testacea* was present at both trial sites causing high damage indices. Another Chrysomelidae species was noted at the irrigated site, namely *Monolepta cruciata* Guérin-Méneville (Galerucinae) (Table 1). This species was abundant at the irrigated site, albeit not in densities equal to that of *P. testacea.* It was noticeably scarce to absent from the dryland site.

In some instances, due to logistical constraints and time, hand collecting was also done. A number of species in low numbers were sampled and of these some are known crop pests, *e.g.* the three-lined potato beetle, *Lema trilinea*

White (Criocerinae), which feeds on potato and related plants (Borror *et al.*, 1992) (Table 1).

At the Winterton trial sites there was a difference in the number of *P. testacea* sampled from the two sites (Figure 15). On the dryland cultivation, the numbers were higher than at the irrigated plot. This can be explained in a number of ways. Firstly, due to plant stress experienced by the plants as a result of water deficiency under dryland conditions, the plants were more accessible to the beetles (see Rustenburg scenario in this chapter). Secondly, it could also be ascribed to the specific microclimate created within the plot, especially in terms of the high humidity and high temperature regimes, rendering the conditions, relative to the immediate surroundings, optimal in terms of survival. Thirdly, sampling was done very late in the season which could imply population build-ups. In this regard the low population numbers of the irrigated plot are still questionable, especially if compared to the Makhathini sites, where large numbers of flea beetles were sampled in both cultivations late in the season. Finally, cultivation practices could also have played a role. The tilling at the dryland site most probably renders it easier for pupating leaf beetle larvae to settle in the soil, whilst eclosing adults would also break out of the soil more readily.

Overall *P. testacea* chews the leaves of kenaf plants, resulting in a characteristic 'shot-hole' appearance (Figure 16). The preferred feeding site on plants is the growth tips, where the new growth of the plant contains less fibre and is more nutrient rich. This feeding strategy ties in strongly with the Plant Vigor Hypothesis (Price, 1997), which describes intra-species variation in plant quality for herbivores. Amongst others, this hypothesis is based on *Chrysomela confluens* (Chrysomelinae) on narrowleaf cottonwood (Kearley & Whitham, 1989).

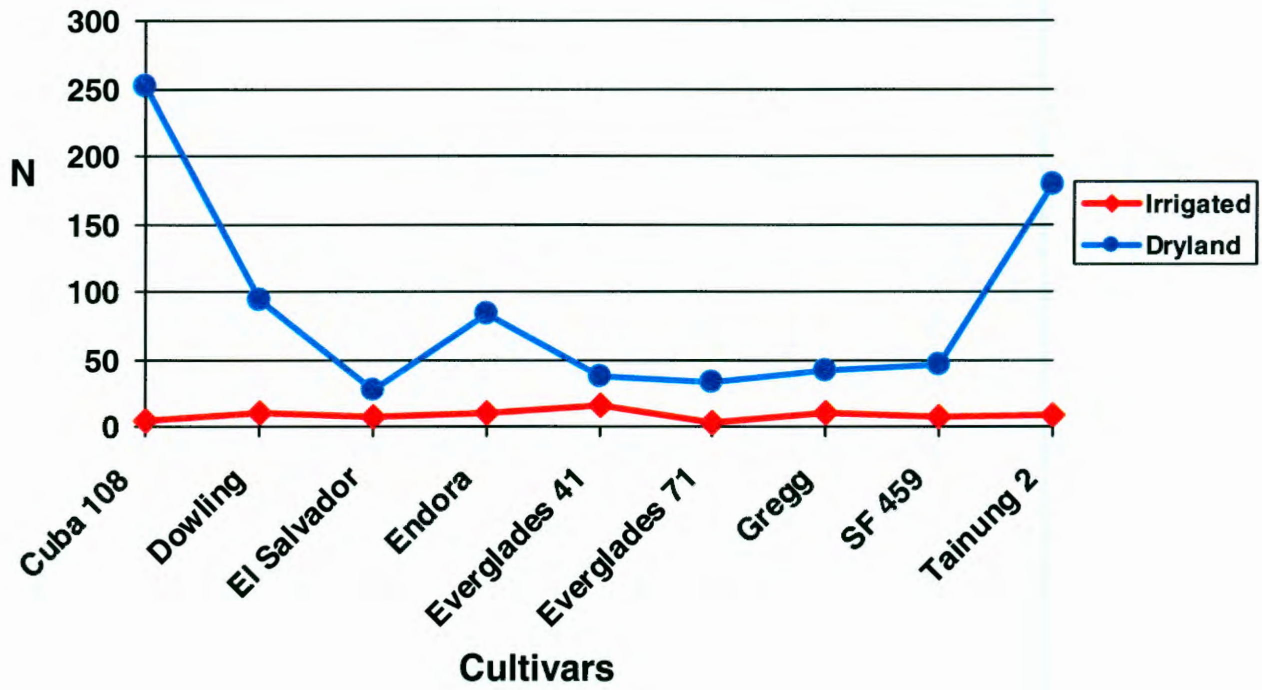


**Figure 15: Number (N) of *Podagrica testacea* flea beetles sampled from different kenaf cultivars at the dryland and irrigated trial sites at Winterton (2004).**

At high population densities, older leaves are also utilized as the plant matures and, in the case of severe densities, leaves can be sceletonized and the total foliage canopy of the plant severely damaged (Figure 17). Questions could be asked in terms of the relevance of leaf damage in relation to kenaf fibre quality and yield, which is in turn associated with the main stem. In this regard, consideration should be given to the fact that leaf damage to a plant affects photosynthesis, thereby disturbing the overall phenology and resulting in sub-optimal growth. This in turn results in stunted plants with reduced stem girths. Flea beetle damage to kenaf therefore affects the fibre yield indirectly. The feeding scars also create entry points for pathogens which, could secondarily, cause further damage to the plant.

**Figure 16: 'Shot-hole' appearance on kenaf foliage, resulting from the feeding damage by *Podagrica testacea* flea beetles.**

## 4.4 CONCLUDING REMARKS

Through monitoring *P. testacea* at the different kenaf sites, different activity and host association patterns emerged. This could possibly relate to the occurrence of different biotypes of this species at the different sites. A biotype is here defined as "a designation below the species level, for organisms that are distinguished from other members of the same species by morphological, ecological (*e.g.* temperature or humidity requirements) or physiological characteristics (parasite susceptibility or host preference)" (Norris *et al.*, 2003).

With regard to future kenaf establishment in South Africa, and taking into consideration the significance that *P. testacea* obviously has in this regard, it would be imperative to follow up this issue in future studies.

**Figure 17: Foliage canopy of kenaf plants severely damaged by *Podagrica testacea* flea beetle feeding (see inside circle).**

*Podagrica testacea* beetles seem to prefer kenaf as their host plant. The question is whether the commercial development of this crop would be able to accommodate the damage caused by these beetles. Whether simply compensating for losses, or introducing alternative methods, to manage this insect - plant interaction in an economically acceptable and sustainable manner for the farmer.

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# CHAPTER 5

## SCREENING OF *BEAUVERIA BASSIANA* AS BIOPESTICIDE ON *PODAGRICA TESTACEA* (CHAPUIS) FLEA BEETLES ON KENAF.

# SCREENING OF *BEAUVERIA BASSIANA* AS BIOPESTICIDE AGAINST *PODAGRICA TESTACEA* (CHAPUIS) FLEA BEETLES ON KENAF

## 5.1 INTRODUCTION

Interactions between insects and their natural enemies are essential ecological processes that contribute to the regulation of insect populations. In situations where this interaction is disrupted, potential pest populations may develop unconstrained and excessive population growth, which constitutes a pest outbreak, may occur. Pest outbreaks can occur when alien insects are introduced into new geographic areas, or when detrimental insects became dissociated from their natural enemies, due to a habitat modification that differentially favors the pest, *e.g.* habitat simplification with a monoculture (Dent, 2000). The latter scenario would more or less be the case with newly introduced plantings of kenaf in an area. The use of natural enemies in pest management is mainly concerned with redressing the imbalance that has occurred through this dissociation, whether by reintroducing natural enemies into the system or by trying to recreate conditions where an association can occur (Dent, 2000).

Through the developmental phases of commercializing kenaf in South Africa, the flea beetle *Podagrica testacea* (Chapuis), appeared to be the biggest threat to kenaf cultivation. Damage caused by this flea beetle occurs when it feeds directly on the foliage of the plant.

Due to the detrimental effect of chemical control on the environment, evaluating a biopesticide on these beetles was thus deemed beneficial. Biopesticides are pest management tools that are based on beneficial microorganisms (bacteria, viruses, fungi and protozoa). Benefits of biopesticides include the effective control of insects, plant diseases and weeds, as well as human and environmental safety. Other benefits include the provision of alternatives to conventional pesticides and increasing public awareness of environmental and food safety concerns. Thus far biopesticides have been used in areas where pesticide resistance, niche markets and environmental concerns limit the use of chemical pesticide products (Anonymous, 2005). Characteristics of conventional pesticides include: good storage capabilities, a relatively wide spectrum of activity, fast speed of kill, relatively short persistence (necessitating frequent applications) and the potential for environmental harm and toxicological concerns. In contrast, biological control agents tend to have: relatively poor storage capabilities, high specificity, slow speed of kill and potentially long persistence through secondary cycling and hence lower frequency of application (Anonymous, 2002b).

Entomopathogenic fungi constitute a unique group of insect pathogens. The most widely used group in the biological control of insect pests are the Deuteromycetes, of which *Beauveria bassiana* (Balsamo) Vuillemin and *Metharizium anisopliae* are the most prominent members. *Beauveria bassiana* has been tested both in the laboratory and in the field against numerous pests in various cropping systems, *e.g.* European corn borer, Russian wheat aphid, Coffee berry borer, Sugarcane stalk borer, Whiteflies, as well as for effects on non-target organisms (Ahmed, 2002; Ivie *et al*., 2002). According to Fargues *et al.* (1994) and Furlong & Groden (2001), *B. bassiana* is effective against Colorado potato beetle, *Leptinotarsa decemlineata* larvae, whilst Kuepper (2003) reports on its effective control capabilities against the adult stage as well. Furthermore, once *B. bassiana* has been applied, it can continue to propagate and provide a significant level of Colorado potato beetle control throughout the remainder of the season.

*Beauveria bassiana* (Hyphomycetes), a naturally occurring fungal pathogen has been widely studied as a potential biological control agent (Furlong & Groden, 2001). Infection occurs when the insect comes into contact with the fungus, usually the spore form (conidia). The spore adheres to the insect's cuticle, germinates, and a tubule penetrates the cuticle of the insect. Once it has gained access to the haemocoel of the insect it begins to multiply, basically consuming the interior of the insect (Anonymous, 2003).

## 5.2 MATERIAL AND METHODS

Experiments were conducted at the Department of Zoology & Entomology, University of the Free State. Flea beetles used in this experiment were sampled on 13 February and 27 March 2004 on the kenaf planting at Winterton (KwaZulu-Natal). Insects were collected directly from the plants with an aspirator, mostly from the underside of the leaves. They were transferred to a resealable, circular plastic container, covered with netting material to allow adequate aeration, but preventing the insects from escaping. Kenaf leaves were placed in the container with the beetles and sprayed with water. The beetles were kept in a cool chamber at ±5 °C.

About 24 hours before the actual experiment would commence, the beetles were placed in containers, at room temperature, to acclimatise. They were then treated with a *B. bassiana* formulation.

### 5.2.1 The biopesticide

Two formulations of the biopesticide were used, the one a registered product and the other a product that was still in a developmental phase. Both the formulations were in the form of a wettable powder, contact insecticide, made up into an aqueous suspension with distilled water.

Formulation 1

The product was obtained from Dr. Mike Morris, Plant Health Products (PHP), Nottingham Road, South Africa. It is a wettable powder, contact insecticide. First of all, one gram of wettable powder was thoroughly mixed with distilled water and four drops of Tween 80 in a small container. The Tween 80 mixture enhanced the contact and water binding capabilities of the suspension. The mixture was shaken until the suspension was homogenous. It was then transferred to a one liter plastic container and filled to 1l in volume with distilled water. Before use this container was shaken vigorously. The mixed formulation was kept in the refrigerator.

Formulation 2

*Bb*Plus™ is a wettable powder, contact insecticide for the biological control of aphids and red spider mite in gardens, tunnels, glass houses and intensive production units under nets. The active ingredient is a minimum of $2 \times 10^{10}$ spores/gram of *B. bassiana.* The product was obtained from Biological Control Products SA (Pty) Ltd, Pinetown, South Africa.

For this formulation 0.25 g of wettable powder was diluted in 500 ml of distilled water, and two drops of Tween 80 was added to the mixture. Again, the mixture was vigorously shaken before use and stored in the refrigerator until required.

### 5.2.2 Experimental setup

Indoor conditions

A humidifier was continuously run in the experimental room to maintain humidity levels between 70-80%. A photoperiod of 12 :12 (L : D) was maintained on a constant basis. The temperature in the room varied from 18 - 27 °C throughout the trials. Four actual trials (A-D) took place, and three types of experimental setups were used (Table 1), of which one type was repeated.

The setups were as follows:

1) Caged plants.

In this experiment three one month old kenaf plants, ± 40 cm in height, were planted in a plastic container and covered with sleeve netting. Circular cardboard was cut and placed around the stem of the plant, at the top of the container, to keep the plant in position. The net was then opened at the top and 10 flea beetles released on to the plant inside the netting.

2) Plastic containers with kenaf leaves.

This experiment consisted of a simple, resealable, circular plastic container, of which the centre of the lid was removed, and covered with netting material to allow aeration. The container was lined with tissue paper which was kept moist. Kenaf leaves were placed on the tissue paper. Subsequent to this, 10 flea beetles were released in each of the containers.

3) Plastic containers without leaves.

This setup was basically the same as for 2) above, except that no leaves were placed in the container. The main reason for this being that fresh leaves were often not available. However, it also exposed the fact that the beetles tended to hide underneath the leaves during administration of the biopesticide. Five flea beetles were used in the containers.

**Table 1: Experimental setup used during the four trials.**

| Trials | Experimental setup | Number (N) of beetles/container | Formulation |
|---|---|---|---|
| **A** | 1 | 10 | 1 |
| **B** | 2 | 10 | 1 |
| **C** | 3 | 5 | 1 |
| **D** | 3 | 5 | 2 |

Trial A

Experimental setup 1 was used. Plants with beetles (N=10) were placed in the experimental room to acclimatise for two days. The biopesticide was then administered using a hand-held sprayer (350 ml), to which the biopesticide formulation was transferred. Through an opening in the sleeve that covered the plant, about 30 ml of formulation was evenly sprayed onto the plant and the beetles. Special care was taken to ensure that the plant and the beetles were thoroughly wetted.

Trial B

Experimental setup 2 was used. Three plastic containers were lined with tissue paper that was regularly sprayed with water, to maintain a high moisture level. A few kenaf leaves were placed on the tissue paper. Ten flea beetles were transferred into each container. The containers with the beetles were placed in the experimental room to acclimatise for two days. Formulation 1 was then administered using a hand-held sprayer (see Trial A). By lifting the container lid on the one side, and making sure no beetles escaped, about 30 ml was sprayed into the container. Care was taken to ensure that all the beetles were well wetted.

Trial C

Experimental setup 3 was used. The procedure was the same as for Trial B, but without any leaves. The containers, each with five beetles, were placed in the experimental room to acclimatise and two days later Formulation 1 was administered. In the same manner as above (trial B), beetles were thoroughly wetted.

Trial D

Experimental setup 3 and trial C were repeated, but nine plastic containers were used. Five beetles were placed in each of the containers and after acclimatisation, Formulation 2 was administered. Later, due to poor mortality results, the same biopesticide was again administered on the same beetles.

## 5.3 RESULTS AND DISCUSSION

Trial A

Four days after administration of the biopesticide, it was noted that all ten beetles were still alive on all three of the plants. However, the condition of the plants was deteriorating, with some already having lost some of their leaves. On the following day, one flea beetle was dead. It was removed and placed in a glass vial to determine if any fungal growth would develop. As there was none, it was assumed that cause of death could not be ascribed to the entomopathogen. Six days later, all the plants had withered, but no new beetle mortalities were encountered. After another two days the trial was terminated. All in all only one individual out of 30 beetles was affected, with no certainty that *B. bassiana* was the causative organism.

Trial B

Four days after biopesticide application, all the beetles were still alive and active, hiding underneath the leaves. Eight days later one individual was dead. This specimen was isolated to determine if fungal growth would develop, but the results were negative. Four days later another specimen died. After another eighteen days, the experiment was terminated. At this stage the total number of mortalities stood at 12 out of 30 specimens, but there was no distinct indication that the cause of death could be ascribed to the biopesticide. It is speculated that conditions for the development of fungal hyphae were not ideal, mortality results therefore not being indicative of anything in particular. Even if the cause of death was due to *B. bassiana* infestation, a lapse of almost a month before attaining positive results would not be acceptable in practice.

Trial C

Five days after application, no deaths had occurred in any of the containers. Thirteen days later the experiment was terminated, with a total mortality of 3 out of a possible 15 beetles. Again the dead beetles were kept in individual glass vials to see if any fungal growth would develop, but there were no positive results.

Trial D

Seven days after application all the beetles in the trial were still alive and active. Thirteen days later, nothing had changed, and only one individual had died. Subsequent to the second administration of Formulation 2, another six days passed before two more flea beetles died. Eleven days later three more beetles died. For this trial total mortalities numbered 6 out of a possible 45 beetles. The time lapse after application of the biopesticide and beetle mortality combined with no visible assurance that *B. bassiana* was the causative organism, were disappointing results.

Throughout the trials conducted, the humidity was kept at no less than 70%. This could have been inadequate, and serves as an indication that a wide array of environmental factors have to be taken into consideration to ensure the effectiveness of *B. bassiana* as an entomopathogen.

## 5.4 CONCLUDING REMARKS

The effectiveness of a biological control agent depends on two factors, *i.e.* its capacity to kill the target organism and to reproduce on the target organism, thereby compounding its killing action. In ecological terms these are its functional and numerical responses (Thomas & Waage, 1996). When applying biopesticides, Childs (2002) states that it is very important to make sure that the target species are covered by the pesticide during application, whilst multiple applications are usually required for effective results. The question is, whether this will be a scenario that can be implemented for kenaf where high plant density is the norm for optimal yield, subsequently resulting in 'impenetrable' canopies. Besides, when all the necessary factors and parameters have been taken into consideration, will such a practice be efficient and economical for farmers and for the future commercial establishment of kenaf in South Africa? It is acknowledged that biological control is an expensive management tool, but even if this factor was excluded, can it really be considered to be a constructive way to move forward. Another disadvantage with regard to this control method in the field, is that the *Beauveria* spores are rendered inactive by sunlight (Groden, 1999).

Thoroughly investigating the particular situation and interaction between *Beauveria* and the possible pest species is essential. The effectiveness of implementing fungi as biocontrol agents against pest insects depends on combining the correct fungal species and strain with the susceptible insect life stage, at the appropriate humidity, soil texture and temperature (Anonymous, 2002a). Whilst all of these conditions were perhaps not met in this biopesticide trial, it must not be disregarded that *P. testacea* could simply have been able to tolerate the specific formulations, thereby implying that applying *B. bassiana* against *P. testacea* is ineffective and is not to be recommended in any case.

Albeit that no conclusive steps have been taken in finding a control measure for the flea beetles on kenaf as yet, long term planning must include an integrated pest management (IPM) program, designed specifically for this interaction.

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# CHAPTER 6

## SCREENING OF *PODAGRICA TESTACEA* (CHAPUIS) AND *MONOLEPTA CRUCIATA* GUÉRIN-MÉNEVILLE AS POTENTIAL KENAF DISEASE VECTORS.

# SCREENING OF *PODAGRICA TESTACEA* (CHAPIUS) AND *MONOLEPTA CRUCIATA* GUÉRIN-MÉNEVILLE AS POTENTIAL KENAF DISEASE VECTORS

## 6.1 INTRODUCTION

Plant diseases caused by insect-transmitted pathogens are amongst the most serious production problems encountered by crop farmers. Effective fungicidal control of insect-borne diseases is problematic because most plant disease vectors are highly mobile insects and may colonize fields rapidly before growers become aware of their presence (Zehnder *et al.*, 1998).

Plant disease pathogens can be disseminated in various ways by a variety of vectors. Due to the high incidence of flea beetles at all the localities where kenaf was planted in South Africa, and the amount of feeding damage they cause to the foliage of these plants, it is important to also investigate the degree of 'secondary' damage they can cause, *i.e.* disease transmission. Transmission of pathogens would probably be mainly mechanical, but the feeding scars of beetles do pose another potential threat. They create entry points for non-insect transmitted pathogens, leading to further damage to the plant (Wheeler, 1976).

According to Wheeler (1976) diseases result from the interaction of a pathogen with its host, but the intensity and extent of this interaction is markedly affected by the environment. This is important when considering the introduction of new host plants to an already established environment, and anticipating the interactions when pathogens and vectors are included.

## 6.2 MATERIAL AND METHODS

During observations in the vicinity Winterton (SE2829Dc) it was noted that *Podagrica testacea* (Chapuis) (Alticinae) and *Monolepta cruciata* Guérin-Méneville (Galerucinae) were quantitatively dominant on cultivated kenaf pants. Specimens of these species were hand-picked from plants at the two locations, *i.e.* Strawberry Creek (SE 2829Da) and Mopona (SE 2929Ba). The two farms differed in the cultivation practices used, with the former under irrigation and no-till and the latter under dryland and till.

According to the Bioresource Group (BRG) index of KwaZulu-Natal (KZN) (Camp, 1997), Strawberry Creek falls within the Dry Tall Grassveld BRG and Mopona within the Moist Transitional Tall Grassveld Group. A bioresource group is an ecological unit, based primarily on the climate, vegetation and soil of a particular area.

For the purpose of the particular investigation relating to this chapter, leaf beetles were sampled from all nine kenaf cultivars at each site. This material was not sampled according to cultivars, but lumped per site. The reason for this being that the cultivars were planted so close to each other that it was virtually impossible to separate which specimens were present on which cultivar during sampling.

### 6.2.1 Sampling methodology

The first sample of beetles was collected in mid December 2003. A total of 39 specimens of *P. testacea* and 68 specimens of *M. cruciata* were collected from the irrigated site. At the dryland site 80 *P. testacea* and 11 *M. cruciata* beetles were collected. During the second sampling session late in March 2004, more than three months later, only *P. testacea* was collected, with 26 beetles taken at the irrigated site and 39 beetles taken at the dryland site. Thus the total of *P.*

*testacea* sampled over the two sessions was 65 beetles from the irrigated site and 119 beetles from the dryland site.

The beetles were hand-picked randomly from kenaf plants at the trial sites and preserved individually in glass vials to avoid fungal contamination. Initially beetles were difficult to sample individually, since they settled on the underside of the seedling's leaves. However, once the 'silhouette technique' was established, beetles were easily recognized by their silhouettes showing through the leaves when the sun shone from behind the person sampling. Beetles were killed by freezing in a -70 °C freezer at the laboratory.

Beetles specimens were plated in individual Petri dishes (65 mm in diameter) on corn meal agar (CMA; Difco®), which had been supplemented with 0.3 ml. $l^{-1}$ Novostrep® streptomycin sulphate (with active ingredient concentration at 0.333 g. $ml^{-1}$). They were incubated at 25°C, in a light-dark cycle, each of 12 hours. When fungal colonies had reached approximately 50 mm in diameter they were identified by means of light microscopy by Michael Tesfaendrias (Department of Plant Sciences, UFS).

## 6.3 RESULTS AND DISCUSSION

Twelve different fungal species were isolated from the incubated beetle specimens (see Table 1). The highest percentages belonging to the pathogens that commonly cause pre- and postharvest diseases, *i.e. Alternaria* spp., *Fusarium* spp. and *Penicillium* spp.

In Table 1 the fungal diversity isolated from both *P. testacea* and *M. cruciata* is listed. The number of *M. cruciata* beetles sampled from the dryland site was very low, and the results do therefore not represent a good test sample. However, compared to fungi sampled from the remaining groups of beetles (see Table 1), the highest percentages of fungal incidence still belonged to the genera *Alternaria*, *Fusarium* and *Penicillium*. Overall it would seem that the fungi isolated aren't location or beetle specific.

**Table 1: Fungal diversity (expressed as %) isolated from the flea beetles *Podagrica testacea* (Chapuis) and *Monolepta cruciata* Guérin-Méneville selected at two sites in the Winterton vicinity (KwaZulu-Natal) (2003-2004).**

| | ***Podagrica testacea*** | | ***Monolepta cruciata*** | |
|---|---|---|---|---|
| **Fungal disease** | **Irrigated (N=65)** | **Dryland (N=119)** | **Irrigated (N=68)** | **Dryland (N=11)** |
| *Alternaria* spp. | 32 | 30 | 29 | 46 |
| *Aspergillus* spp. | 2 | 7 | 0 | 9 |
| *Botrytis cinerea* | 2 | 7 | 1 | 0 |
| *Chaetomium* spp. | 5 | 0 | 4 | 0 |
| *Cladosporium* spp. | 12 | 4 | 1 | 0 |
| *Curvularia* spp. | 2 | 3 | 4 | 0 |
| *Epicoccum* spp. | 0 | 3 | 1 | 9 |
| *Fusarium* spp. | 23 | 13 | 15 | 9 |
| *Penicillium* spp. | 15 | 13 | 21 | 27 |
| *Phoma* spp. | 2 | 6 | 4 | 0 |
| *Drechslera* sp. | 0 | 0 | 1 | 0 |
| *Rhizopus* spp. | 0 | 3 | 0 | 0 |
| Yeast-like growth | 0 | 7 | 0 | 0 |
| Clean insects | 6 | 6 | 16 | 0 |

Table 2 shows that, the total number of *P. testacea* collected during mid-December (A) and late March (B) differ for the irrigated and dryland trial sites. Even so, it is still the same three fungal species that tend to be present in highest numbers. For the total number of *P. testacea* represented at the two sites, the different sampling date's totals were lumped to avoid further intricacies. The values represent flea beetle numbers.

**Table 2: Fungal incidence isolated from *P. testacea* beetles, sampled over two sampling dates (A= mid-December 2003; B= late March 2004), for both irrigated and dryland trial sites in the Winterton vicinity (KwaZulu-Natal).**

| | Irrigated (65) | | | Dryland (119) | | |
|---|---|---|---|---|---|---|
| **Fungi** | **A** | **B** | **Total** | **A** | **B** | **Total** |
| *Alternaria* spp. | 8 | 13 | **21** | 19 | 17 | **36** |
| *Aspergillus* spp. | 1 | 0 | **1** | 8 | 0 | **8** |
| *Botrytis cinerea* | 1 | 0 | **1** | 0 | 8 | **8** |
| *Chaetomium* spp. | 3 | 0 | **3** | 0 | 0 | **0** |
| *Cladosporium* spp. | 3 | 5 | **8** | 1 | 4 | **5** |
| *Curvularia* spp. | 0 | 1 | **1** | 1 | 2 | **3** |
| *Epicoccum* spp. | 0 | 0 | **0** | 3 | 0 | **3** |
| *Fusarium* spp. | 8 | 7 | **15** | 13 | 3 | **16** |
| *Penicillium* spp. | 10 | 0 | **10** | 14 | 1 | **15** |
| *Phoma* spp. | 1 | 0 | **1** | 6 | 1 | **7** |
| *Rhizopus* spp. | 0 | 0 | **0** | 0 | 3 | **3** |
| Yeast-like growth | 0 | 0 | **0** | 8 | 0 | **8** |
| Clean insects | 4 | 0 | **4** | 7 | 0 | **7** |
| **Total** | **39** | **26** | **65** | **80** | **39** | **119** |

Figures 1 and 2 show the peaks for the most abundant fungal groups overall, namely *Alternaria*, *Fusarium* and *Penicillium*, isolated from the *P. testacea* flea beetles collected in mid-December (A) and late March (B) at the irrigated and dryland trial sites. Despite disparity in collection intensity between the two sampling sessions, these results are indicative of the degree of dominance shown by these fungi.

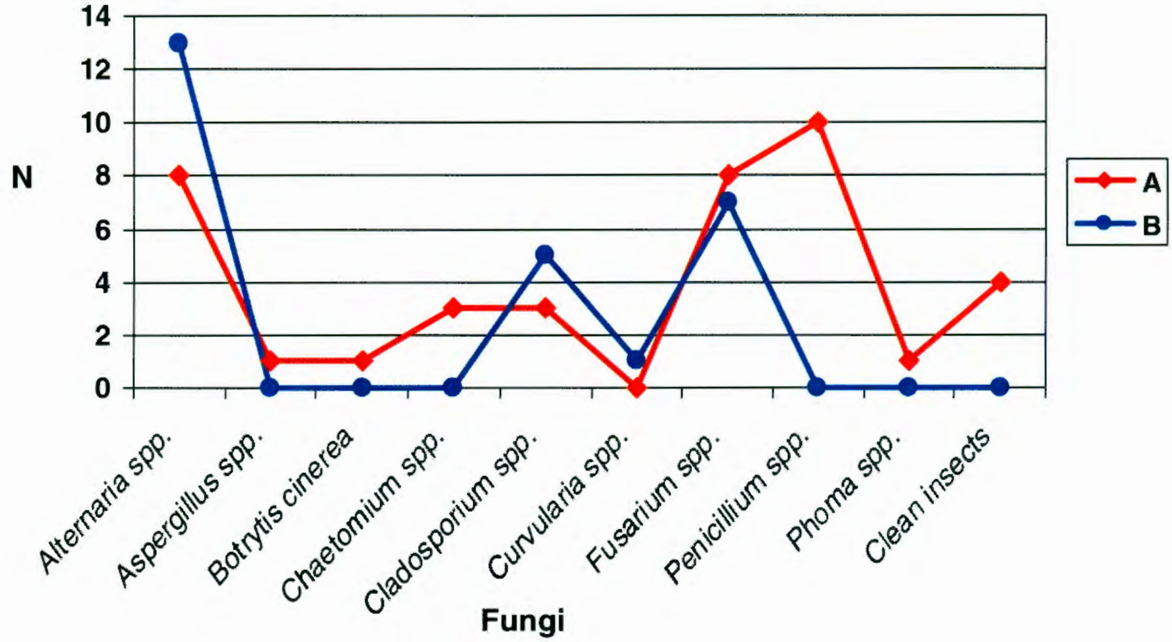


**Figure 1: The fungal incidence isolated from *P. testacea* flea beetles collected during two separate sessions [A= mid-December 2003 (N=39); B= late March 2004 (N=26)] on the irrigated trial site near Winterton (KwaZulu-Natal).**

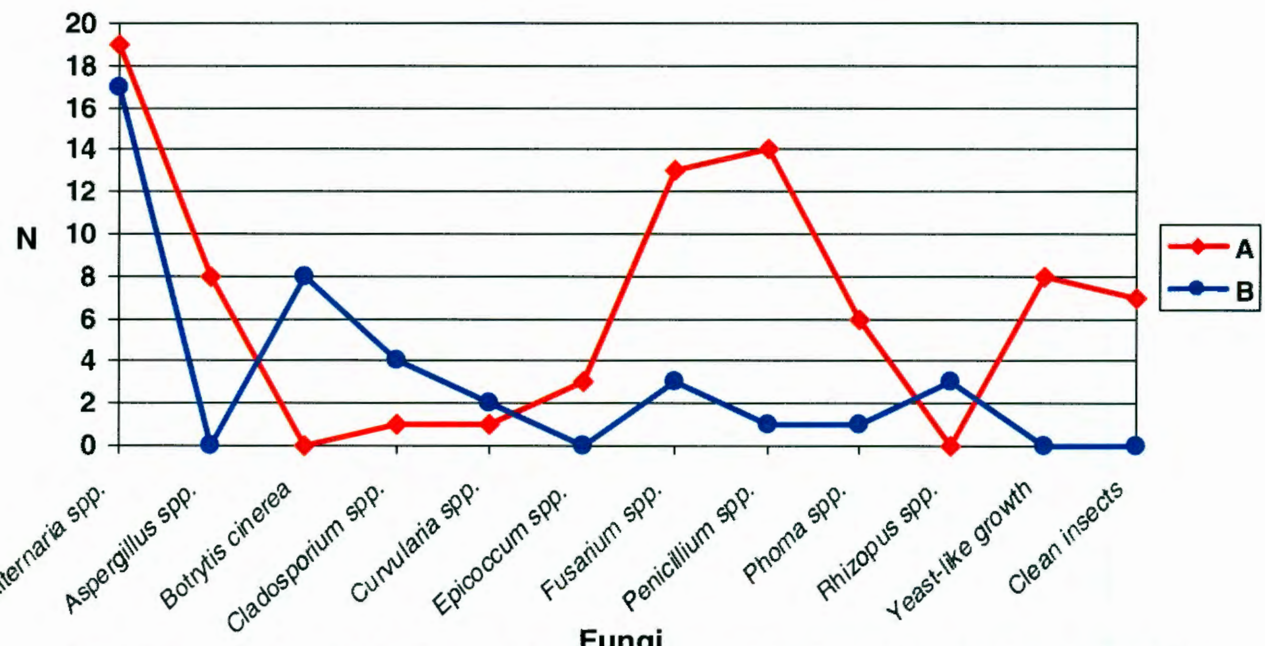


**Figure 2: The fungal incidence isolated from *P. testacea* flea beetles collected during two separate sessions [A= mid-December 2003 (N=80); B= late March 2004(N=39)] at the dryland trail site near Winterton (KwaZulu-Natal).**

Various species of *Alternaria* cause decay on fresh fruit and vegetables, either before or after harvest. Symptoms appear as brown or black, flat or sunken spots with definite margins, or large, diffuse, decayed areas that are either shallow or penetrate deeply into the flesh of the fruit or vegetable (Agrios, 1997). *Alternaria* thrives well at a wide range of temperatures, even in the refrigerator, albeit at a slower rate (Agrios, 1997). *Alternaria* has also been noted to specifically cause damping-off disease in kenaf (Dempsey, 1975).

*Alternaria* was isolated in high percentages from beetles collected on plants in a commercial kenaf stand near Mtubathuba (KwaZulu-Natal) (SE 2732Ac) during April 2003 (Swart, personal communication*). Of all the fungi isolated from specimens collected at both the irrigated and dryland kenaf trials near Winterton, irrespective of where they were collected, *Alternaria* spp. were most abundant. As *Alternaria* is known to affect the leaves of a plant, it can be expected that photosynthesis will also be indirectly affected. If infection by this disease is severe in a kenaf plantation, it could ultimately have an impact on the yield of the crop. A focused, long-term study will prove whether this holds true for this specific tri-partite interaction between kenaf, *Alternaria* and *P. testacea*.

The destruction of young seedlings by soil organisms, such as *Fusarium*, is referred to as damping-off. There are two types of damping-off. Firstly, pre-emergence damping-off causes rot of the sprouting seed before it breaks through the soil and is recognized by the bare spaces, in what should have been uniform rows, in a field. Secondly, post-emergence damping-off causes rotting or wilting of seedlings soon after they emerge from the soil (Horst, 1979). According to Dempsey (1975) *Fusarium* spp. attack both young kenaf seedlings and older kenaf plants, causing black or brown stem lesions near the ground surface that result in the lodging and death of plants.

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*Fusarium* also causes post-harvest pink or yellow moulds on vegetables and ornamentals and especially on root crops, tubers, and bulbs (Agrios, 1997). It is also associated with stem, root and boll rot in young cotton seedlings (Hillocks, 1992). *Fusarium* wilt of cotton occurs when the pathogen penetrates through the roots and spreads upwards in the vascular tissue, thus depriving the plant of water. *Fusarium oxysporum f.sp. vasinfectum* causes wilting and necrosis of kenaf, and is also known to attack cotton. It favours hot, dry conditions, followed by rain (Tesfaendrias, 2002). This is important and implies that this particular disease is wide-spread. Since kenaf and cotton belong to the same plant family, the potential of these two crops becoming infected by the same pathogens can be expected. This should be borne in mind for possible future mixed cropping associations utilising these two fibre plant species.

Although not present in high percentages, *Fusarium* was also isolated from beetles collected on a kenaf commercial stand near Mtubatuba (KwaZulu-Natal) during April 2003 (Swart, personal communication*). Dempsey (1975) also states that *Fusarium* could decimate a crop and should therefore be considered a serious disease. With the abundance and diversity of Chrysomelidae present within a planting, the dissemination potential of pathogens is definitely important to consider when attempting successful cultivation of kenaf.

Various species of *Penicillium* cause the blue and green mould rots and are usually the most destructive of all postharvest diseases. Infection mostly occurs through wounds (Agrios, 1997). According to Hillocks (1992) *Penicillium* gains entry to cotton bolls after the boll has been damaged by insects, or after the suture of the boll has ruptured. Although chrysomelids have not yet been reported vectoring *Penicillium* to kenaf, the potential exists they can transport these particular pathogens to the 'right' places for infection, thereby helping to create an opportunity for infection and development of the disease. In this regard these beetles would indirectly be responsible for having a negative impact on the crop.

Dempsey (1975) also noted that the fungus *Phoma sabdariffae* causes a leaf disease on kenaf and is reported to actually attack kenaf in several places, especially the Philippines. Some *Phoma* spp. were also isolated from *P. testacea*, thereby indicating that most diseases transmitted by these beetles have the potential to be harmful to the kenaf plant.

Another pathogen that has been noted to attack kenaf is the grey mould, *Botrytis cinerea*. Although the percentage of *B. cinerea*, isolated from the leaf beetle specimens sampled in this study was not high, this disease has been reported to be especially damaging to the plant. Infected plants display brown necrotic lesions that girdle the stem, resulting in wilting and lodging of the plants (Figure 3). Grey mould reported on kenaf stems in South Africa (Swart *et al.*, 2001), was the first record for this interaction in Africa. The pathogen attacks kenaf plants during periods of high humidity, and causes partial or total defoliation (Dempsey, 1975). Once again, *B. cinerea* was isolated from both *P. testacea* and *M. cruciata* (only on a single specimen of the latter), demonstrating that this important disease can, potentially, also be vectored by these beetles.

Overall, results from this study have revealed that *Podagrica testacea* and *Monolepta cruciata* are successful disseminators of fungal pathogens on kenaf. The mechanical transmission of these pathogens could be a chance, once off occurrence, but in reality there is a strong possibility that this insect-pathogen interaction could have some degree of impact on the fledgling kenaf industry in South Africa. It should be noted that even though the influence of a disease on a crop is not always clearly discernable, it is in actual fact very important for long-term production success of the particular crop.

According to Wheeler (1976), the growth of the host plant depends on its ability to synthesize sugars from carbon dioxide and water in the presence of light. Many pathogens kill the leaf tissue, thereby affecting photosynthesis. The fungus *Phytophthora infestans*, which causes potato blight, is but one example, which given suitable conditions, can totally destroy a crop within a few weeks. Generally it is considered that when 75 % of the foliage of a plant is destroyed, no photosynthesis is possible and the plant stops growing (Wheeler, 1976).

**Figure 3: Stem lesions caused by *Botrytis cinerea* on a kenaf stalk, during the initial stage of infection (photo on left) and later of an advanced stage of infection (photo on right). (Photo's courtesy of Prof WJ Swart, Department of Plant Sciences, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein)**

## 6.4 CONCLUDING REMARKS

Control of plant diseases refers to the prevention of a disease, or reduction in the incidence or severity of a disease, and is usually concerned with plant populations rather than individual plants in a field crop. The control of a disease can be achieved by a single procedure, but satisfactory control of most diseases requires the application of multiple control measures and usually involves an integrated program of manipulation of environmental, biological and chemical factors (Singh, 2001).

Any integrated approach to disease control requires knowledge of the cause, whilst the selection of effective control procedures requires some knowledge of the dynamics of the particular disease. Environmental factors, such as temperature, humidity and light intensity, are known to affect disease severity in a broad sense, it may range from a response in the inoculum of the pathogen to the control measures. A well conceived control program should be based on knowledge of the characteristics of the pathogen and the host, the cultural and climatic conditions under which the crop is grown, and knowledge of available disease control procedures, including cultural, genetic and chemical approaches. A critically important factor is the correct diagnosis of the disease, which is essential to the success of a disease management programme, but often not given serious consideration. Disease management in a particular field is also dependant on the insight and co-operation of neighbouring growers who should buy into the management programme, thereby ensuring that a large continuous area falls under the same protective umbrella. Working together and keeping the 'bigger picture' in mind, is not always shared by all neighbouring farmers, but if achieved, more agricultural potential is brought to such an area. This ensures the longevity of effects emanating from the adopted measures and ultimately enhances economical sustainability (Singh, 2001).

Further investigation into the relevance and impact of plant diseases, transmitted by insect vectors to kenaf, is necessary to accentuate the importance and essential value of such an information base to farmers planting a new crop.

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# CHAPTER 7

## INFLUENCE OF ARTIFICIAL DEFOLIATION ON KENAF GROWTH AND YIELD.

# INFLUENCE OF ARTIFICIAL DEFOLIATION ON KENAF GROWTH AND YIELD

## 7.1 INTRODUCTION

Everywhere in the world defoliation of kenaf plants by insect herbivores has been causing ramifications in terms of its successful cultivation (Carberry & Muchow, 1992; Carberry *et al.*, 1993; Waterhouse, 1998). South Africa, with its fledgling kenaf industry is experiencing the same problems, which necessitated investigations into the impact of insect defoliation on kenaf plants through artificial defoliation trials.

Many artificial defoliation studies indicate that there are plants which tend to compensate for damage sustained. This, however, depends on the level of damage sustained, the age at which damage occurred and which plant parts were affected. Artificial defoliation is regarded to be a simulation of insect feeding damage. The actual application of artificial defoliation is, however, to obtain information on how strong the phenotypical activity of a plant would be if its foliage were removed, and to use this information to compare damage levels to yield. There is a limited prospect that selective artificial defoliation could be used as a partial insect control mechanism. It implies removing leaves from the plant, thereby excluding the insect on the basis that their food source is no longer available.

## 7.2 MATERIAL AND METHODS

A trial planting of kenaf was established near Ficksburg (SE 2827Dd) in the Free State Province, to investigate the reaction of the crop to different defoliation levels. The main objective of this trial was to simulate hail damage, but it was decided that the same dataset could also be useful to simulate flea beetle feeding indices.

Planting took place on 4 December 2003, with a plant density of 240 000 plants/ha. Two evaluation methods were used to determine the damage influences, firstly, by removing the leaves and secondly, by cutting the stem at different stages of growth.

The two growth stages assessed were V5 (five leaves unfolded from the growth tip, three weeks after planting) (Figure 1) and V18 (18 leaves unfolded from the growth tip, seven weeks after planting) (Figure 2). Different assessments were used for each stage. Removing all the leaves of the plants (100% defoliation) was done for both growth stages.

For the second type of evaluation, a total of six assessments were done, three for each growth stage (V5 = S1, S2, S3 and V18 = S4, S8, S12). This implied cutting the stem at a certain stage of growth, thereby retaining a certain number of axils, *e.g.* S4 implies that four axils were retained. Figure 3 shows the condition of the plants prior to assessment, in this case specifically S1 in growth stage V5.

An extra stand loss (SL) assessment was also done for growth stage V5, with defoliation levels varying from 40%, to 60% and 80%.

At the end of the season all of the trial plants were evaluated for biomass, yield, yield loss, height and stem girth.

## 7.3 RESULTS AND DISCUSSION

Results obtained reflect that the kenaf plants in the trial were affected in different ways at the different stages of growth and manipulation. This complete dataset is summarized in Table 1.

**Figure 1: Complete (100%) defoliation of kenaf plants at growth stage V5 (Ficksburg, Free State Province).**

**Figure 2: Complete (100%) defoliation at growth stage V18 (Ficksburg, Free State Province).**

**Figure 3: The 'stem cut' method implemented as V5 – S1, whereby only one axil was left on the young plant (Ficksburg, Free State Province).**

When the total defoliation method was used, the average differences in biomass and yield for growth stage V5 were 3366.5 g and 13466 t/ha respectively, whilst for growth stage V18 they were 3538.8 g and 14155.2 t/ha. The control plants produced a biomass of 4406 g and a yield of 17624 t/ha respectively. The biomass figures did not differ much between V5 and V18, but both were noticeably less than that of the control. The yield loss sustained at V5 (*i.e.* 23.6%) was clearly more than at V18 (*i.e.*19.7%). Plant height varied between 2.9 m and 3.5 m for V5 and 2.8 m and 3.5 m for V18, which were surprisingly, similar to the 2.8 m – 3.5 m for the control. With regard to stem girth, V5 varied from 11 mm to 18 mm and V18 varied from 12 mm to 23 mm. Surprisingly variation in the stem girth of the control was 13 mm – 20 mm, in an overall sense, incorporating both V5 and V18.

Although total leaf loss did influence the biomass and yield of the plants, the affect on the two growth stages differed, with V18 seemingly compensating more for the damage sustained than was the case in V5. Japhet (2001) conducted a study in Nigeria between 1999 and 2000 to evaluate the effect of leaf removal on the different growth stages of kenaf. Results showed that defoliation six weeks after planting did not adversely affect kenaf, which may be due to the rapid regeneration of leaves during this particular growth stage. This would explain the rapid regeneration of the seven week old V18 plants, and in this regard, Figure 4 shows how much plants regenerated only seven days after defoliation for growth stage V5. More importantly, however, Japhet (2001) goes on to demonstrate that plant height, stem girth and stem and ribbon biomass, all of which relate directly to fibre yield, were significantly reduced when plants were defoliated at four weeks after sowing. This shows that plants damaged before 6 weeks of growth have taken place, suffer more severely and do not experience regenerative growth as successfully. If this were to be directly applied to the damage indices of flea beetle feeding on kenaf, the ramifications would be noteworthy. It is clear that kenaf seedlings younger than 6 weeks are the vulnerable growth stage of the plant, ultimately affecting yield.

Japhet (2001) also mentions that when defoliation was conducted at eight and ten weeks after sowing, the number of pods per plant, pod diameter, number of seeds per pod and seed biomass were significantly reduced. This, in turn, indicates that damage to kenaf by flea beetles at a later growth stage would affect seed production and seed augmentation. In this regard the kenaf industry would also be influenced, albeit indirectly. The importance here lies in the fact that kenaf seed has a relatively short period of germination viability, rendering the constant production of new seed for the industry imperative.

Results obtained from the second method of defoliation, whereby the stem of the plant was cut off at a particular growth stage, delivered interesting, but expected, results.

For growth stage V5, stems were cut retaining three (S3), two (S2) and one (S1) axils. This resulted in a progressive decrease in biomass and yield as less axils were retained (Table 1).

**Table 1: Biomass, yield variation and growth morphometrics of kenaf plants evaluated according to different levels of defoliation (Ficksburg, 2004).**

| Treatment * | Weight (g) | Yield (t/ha) | % Yield loss | Plant height (m) | Stem girth (mm) |
|---|---|---|---|---|---|
| **Control** | 4406.0 | 17624.0 | 0.0 | 2.8 – 3.5 | 13 – 20 |
| **V5 – 40% SL** | 4482.5 | 17930.0 | -1.7 | 2.9 – 3.6 | 19 – 24 |
| **V5 – 60% SL** | 4342.6 | 17370.4 | 1.4 | 2.7 – 3.5 | 15 – 24 |
| **V5 – 80% SL** | 3900.7 | 15602.8 | 11.5 | 2.9 – 3.8 | 18 – 33 |
| **V5 – S3** | 4621.1 | 18484.4 | -4.9 | 2.6 – 3.2 | 15 – 23 |
| **V5 – S2** | 3509.6 | 14038.4 | 20.3 | 2.7 – 3.5 | 11 – 18 |
| **V5 – S1** | 3343.4 | 13373.6 | 24.1 | 2.6 – 3.4 | 12 – 20 |
| **V5 – 100% BI** | 3366.5 | 13466.0 | 23.6 | 2.9 – 3.5 | 14 – 22 |
| **V18 – S12** | 3837.0 | 15348.0 | 12.9 | 2.4 – 3.0 | 14 – 22 |
| **V18 – S8** | 3224.0 | 12896.0 | 26.8 | 2.3 – 3.0 | 11 – 20 |
| **V18 – S4** | 1981.7 | 7926.8 | 55.0 | 2.3 – 3.0 | 7 – 17 |
| **V18 – 100% BI** | 3538.8 | 14155.2 | 19.7 | 2.8 – 3.5 | 12 - 23 |

(V5 = 5 leaves pulled away from growth tip; V18 = 18 leaves pulled away from growth tip; 40%SL = 40% stand loss; 60%SL = 60% stand loss; 80%SL = 80% stand loss; S3 = stem cut off, leaving 3 axils; S2 = stem cut off, leaving 2 axils; S1 = stem cut off, leaving one axil; 100%BI = 100% defoliation; S12 = stem cut off, leaving 12 axils; S8 = stem cut off, leaving 8 axils; S4 = stem cut off, leaving 4 axils)

**Figure 4: Re-growth of leaves on kenaf plants, seven days after total defoliation at growth stage V5 (Ficksburg, Free State Province).**

This manipulation did not reveal any significant difference in height and stem girth between the three conditions. Figure 5 shows regeneration by V5 plants, 28 days after the stems were cut under condition S1 in the foreground, and the control plants in the background. Figures for biomass and yield were higher in some cases (e.g. S3 was 4621.1 g biomass and 18484.4 t/ha yield) than with the total defoliation method. Should foliage manipulation be considered as a management tool against flea beetle attack, 'stem cutting' as opposed to 'defoliation', would therefore be a better option. However, this manipulation of the plant results in a high degree of secondary branch development (Figure 6), a phenomenon which would downgrade fibre quality and complicate harvesting practices. Both are factors which are altogether undesirable when regarding the objectives of the kenaf industry.

**Figure 5: Re-growth of leaves on kenaf plants, 28 days after the stem was cut and only one axil (S1) was retained at growth stage V5, against a background of control plants (Ficksburg, Free State Province).**

**Figure 6: Secondary branching of kenaf plants, a phenomenon that develops as a result of cutting the main stem (Ficksburg, Free State Province).**

Results obtained with 'stem cutting' for growth stage V18 (Table 1; Figure 7), also showed a progressive decrease in biomass and yield for manipulation assessments S12, S8, and S4. The highest figures were for S12 which produced a biomass of 3837g and yield of 15348 t/ha and the lowest for S4, producing 1981.7 g and 7926.8 t/ha for biomass and yield respectively. Figures obtained for S4 were the lowest for all assessments throughout the trial. This could be ascribed to the fact that the plant was set back severely when only four axils were retained at a late stage in its growth, and that the plant could simply not fully compensate for the damage sustained. However, this also indicates how plants can relatively successfully compensate for severe damage.

The stand loss (SL) assessment, conducted during growth stage V5, implemented 40%, 60% and 80% levels of defoliation. As expected, biomass and yield were affected, with both sets of figures decreasing from less defoliated (40%) to most defoliated (80%) (seeTable 1). Interestingly stem girth range was the highest (*i.e.* 18 – 33 mm) when the defoliation level of the plants was the highest and not the opposite as one would have expected.
It should be kept in mind that low plant population densities also result in stalks with higher diameter (girth). Obtaining the required stalk diameter is manipulated by the initial plant population density, *i.e.* seed quantity per ha as well as in-row spacing in the plot. The diameter also has an effect on the percentage of bast fibre, meaning that if the stem girth is higher, the bast fibre percentage decreases, thereby indirectly influencing the type of product these particular stalks would be used for.

Incidental observations during the kenaf trails at Bloemfontein, where inconclusive artificial defoliation experiments were conducted, the plants also tended to compensate for defoliation and vigorously regenerated new leaf growth, even within a week of defoliation.

## 7.4 CONCLUDING REMARKS

Further study is necessary to ascertain if artificial defoliation methods which simulate leaf beetle feeding indices can be corroborated by actual leaf beetle damage on kenaf plants, to eventually establish an economic threshold level for farmers to use. This would imply using defoliation percentages to determine at what level yield is still economically acceptable and, importantly, fibre quality has not been affected due to photosynthesis or other disturbances. Ultimately threshold levels should contribute towards developing a model, whereby the degree of defoliation will determine the timing of management actions. Further more, the eventual implementation of such an approach, regarding the most damaging insect herbivore found so far on kenaf in South Africa, leaf beetles, should provide an important management tool which is available to the farmer.

**Figure 7: Aggressive manipulation of kenaf with the 'stem cutting' method during late growth stage V18, which retains only four axils (S4) (Ficksburg, Free State Province).**

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# CHAPTER 8

## GENERAL DISCUSSION

# GENERAL DISCUSSION

Although kenaf represents a single plant species, it becomes numerically abundant when planted as a trial or commercial crop. When considering the different parts of the plant in such a setup, many resources are available for attack, *i.e.* flowers, leaves, stems, etc. Within an insect-plant interaction scenario, the other role player is the herbivorous insect. In this case the flea beetle, *Podagrica testacea* (Chapuis), which utilises its host plant differently during its adult and larval life stages. Seen as a whole, a number of different ecological interactions take place between the plant and the herbivore (Price, 1997).

Phytophagous insects have been important in agriculture since it was found that, either due to their feeding or oviposition, the plant sustained injury or damage. Although this seems as a fairly simple concept, the incorrect assumption is often made that a specific insect is only responsible for damaging the plant with which it is associated in one way. In Chrysomelidae for example, different life stages, belonging to a single species, may be temporally separated, but both are damaging to the host plant. This phenomenon seems to be underestimated and sometimes not even considered. However, it may culminate in severe damage indices to a crop and enhances, and often complicate, management strategies that have to be devised and implemented. Furthermore, certain Chrysomelidae species are also vectors of plant pathogens (see Chapters 1 & 6), thereby exerting even greater pressure where plant health is concerned.

Within the mentioned scenario there are chrysomelids which have been successfully utilised as biological control agents on alien plants. This method of control involves obtaining an insect species that actually attacks and consequently controls a specific plant species. However, if this particular plant species should be developed as a potential commercial crop, this same insect species used as biological control agent could achieve pest status.

With the chemical control era as we know it, being increasingly and seriously challenged, we are being forced to revert to alternatives that are environmentally safe, such as biopesticides and other practices. Although results obtained from the use of the entomopathogen *Beauveria bassiana* in this study (Chaper 4) were inconclusive and did not provide the positive results hoped for, it has been reported that this particular entomopathogen is effective against the larval form of a related beetle species, the Colorado potato beetle, *Leptinotarsa decemlineata* (Fargues *et al.*, 1994; Furlong & Groden, 2001), as well as its adult stage (Kuepper, 2003).

It is important to always consider of all the variable parameters influencing the seemingly simple interaction between the primary producer (the plant) and the herbivores attacking it. In this study, specific environmental conditions, as well as locality and cultivation practices, appeared to be the important role players. Also, planting kenaf in six different locations and sampling *P. testacea* from four of them has to be indicative of the adaptability of this particular species. One hundred percent of the individuals in a herbivore population and species, in each generation, must relate intimately to plants as food. Therefore the ecological requirements of plants serving as food are of paramount importance in the population biology and evolution of the particular herbivores (Price, 1997). The occurrence of *P. testacea* at varying localities in South Africa, should therefore be considered in this regard.

Thus far it is not sure what effect or reaction the feeding of *P. testacea* beetles cause in the kenaf plant, and which defence mechanisms of the plant are already in place, or beginning to evolve, due to this interaction. It is a fact proven by many interactions between plants and insects in the so-called 'arms race', that some kind of defence mechanism will eventually develop in the plant, stimulated by the sudden feeding intensity of one particular beetle species, as well as the environmental conditions leading up to this point. Should kenaf commercialization be considered by farmers in South Africa, trials at different locations during this study have shown that each alternative location provides and creates new opportunities for interaction between herbivores and the introduced plants. This kind of interaction is nothing new to us, but provides a new challenge where the kenaf - *P. testacea* interaction in South Africa is concerned. This is accentuated by the fact that each location is characterized by different climates and soils, already existing farming practices, as well as a variety of crops surrounding the new plantings. Factors to take into consideration are that existing crops at these localities provide the potential to present this newly introduced crop with an already existing 'inoculum of general herbivore species'. Existing agricultural setups already represent an oasis with wide-ranging possibilities for certain herbivores. By adding kenaf to this equation, the diversity and variety available to insects is multiplied.

Why this specific species of Chrysomelidae is the most damaging insect pest on kenaf in South Africa, is a topic for speculation. The Chrysomelidae represent a wide variety, of numerous species that are all phytophages, and may be mono-, oligo- or polyphagous. *Podagrica testacea* probably utilized plants from the same family (*e.g.* wild kenaf or commercialized cotton) before kenaf was introduced, and with kenaf suddenly available in monoculture, the migration was simple and to be expected. In attempting to explain this interaction, plant apparency (*sensu* Feeney, 1975, 1976; Rhoades & Cates, 1976), based on plant abundancy at the trial sites, comes to mind. The Plant Apparency Hypothesis deals mainly with the large differences in investment of chemical defence in different plant parts of different plant species. Specifics of chemical defence in kenaf are not known, but the apparency of this plant species intensified when this crop was planted in pure stands, thereby making the plants "bound to be found" by a plant-feeding insect species, does seem to fit this hypothesis in a certain way.

Another hypothesis that could explain this phytophage - plant interaction is the Plant Vigor Hypothesis (*sensu* Price, 1991), which relates to 'within-plant variation in quality' for herbivores. Young vigorous plants are more susceptible to attack by herbivores than mature plants. In kenaf, flea beetle populations were very high even at the end of the growing season, but this could simply mean that the beetles kept on utilizing the most vigorous, highly nutritious, less fibrous plant parts throughout the growing season.

At the Winterton trials sites, a zero tillage practice was used at the irrigated trial site. However, the effect of this on beetle populations could not really be determined, since it would have to be more thoroughly investigated over more seasons. According to Dosdall *et al.* (1999) minimum or zero tillage systems have recently been adopted by many canola producers in western Canada, because they offer considerable potential for maintaining or improving soil productivity, particularly in regions where moisture is limiting. The benefits of reduced tillage include less soil erosion, improved moisture conservation, increased soil organic matter, a decrease in human labour requirements and improved crop yields. Reduced tillage is generally associated with the accumulation of more organic crop residues on the soil surface, the opposite to what occurs with conventional tillage. Unfortunately these residues may harbour or protect the over-wintering stages of certain pest species, such as flea beetles. Increased over-wintering survival as well as a closer proximity to the newly seeded crop could cause an increase in pest populations and greater economic damage the following season. In spite of this, Dosdall *et al.* (1999) found that plants grown in a zero-till regime showed less damage by pest species than plants grown under conventional tillage. Dosdall *et al.* (1999) also speculates that the physical properties of a microhabitat can influence the ability of insect herbivores to utilize food resources. Since conventional and zero tillage systems differ significantly in physical properties such as soil temperature, moisture level, and organic matter content, these factors have to contribute towards pest performance. In zero tillage systems, the accumulation of organic residues from the previous season cause temperature reduction at or near the soil surface early in the growing season, the time of year when adult flea beetles eclose, seek out and attack host plants. Zero-till systems are also characterised by less evaporation and higher soil moisture levels than those occurring in conventional systems. *Podagrica testacea* seems to prefer warm, dry conditions and these are more characteristic of conventional tillage systems than zero-till systems. Monoculture practices promote habitat simplicity, and this can lead to population increases or even outbreaks of some insect species. The presence of bare soil should signal colonizing insects, such as flea beetles, that favourable conditions exist for feeding and reproduction. Further, in this study stubble and debris from the previous cropping season could have served as a barrier to host plant location by flea beetles. From an agricultural point of view, structural heterogeneity may then have importance for limiting the impact of such pests. This could be something that needs to be investigated in the future, to ascertain whether alternative management tactics are an option.

Another important observation was the fact that at Nelspruit (Mpumalanga) the main problem species, *P. testacea,* was absent at kenaf trial plots. However, about 1 km from the trial planting of kenaf, individuals of another *Podagrica* species, namely *Podagrica maculata* Weise, were sampled from the Terblansbossie, *Hibiscus trionum*. *Podagrica maculata* was also sampled from a wild kenaf species, Wilde stokroos, *H. cannabinus* at Melmoth in KwaZulu-Natal during January 2004, thereby indicating that this species is also wide-spread. At the Nelspruit site *P. testacea* was absent, but the trial planting was surrounded by plantings of aromatic plants *i.e.* Rose geranium (*Pelargonium* sp.) and Lemongrass (*Cymbopogon* sp.). It is possible that these plants could have had an influence on insect presence or absence due to their fragrant qualities.

Future recommendations for the successful cultivation of kenaf in South Africa would be to invest in a resistant cultivar breeding program, for cultivars particularly suited to South African conditions. Accompanying this would have to be an understanding of the array of anthropocentric activities in the agroenvironment and their influence on the status of pests, crop cultivar and density, and environmental variables, and to what extent all of these would contribute to the justification and scope of a pest management program.

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