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SPECIES COMPOSITION AND LARVAL INSTAR POPULATION STRUCTURE OF SCARABAEIDS IN FORESTRY IN THE NATAL MIDLANDS

by

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ABSTRACT

White grub is the common name of most scarabaeid larvae and some are considered as grubs of economic importance to agricultural crops. Expansion of forestry into previous croplands has resulted in some pests of previous agricultural crops becoming important in forestry. Field trials planted over three seasons, determined the mortality factors influencing the establishment of commercial eucalypt and black wattle plantations in the Natal Midlands. White grubs had the highest pest status. Characteristic raster pattern was used to identify larvae as a particular morphospecies with the aid of the dissecting microscope. Head capsule width pattern was used to determine the larval instars responsible for the damage. High incidences of seedling damage was recorded from December to April. Several morphospecies were found damaging seedlings simultaneously. Morphospecies 1, 2, 3, 4, 5 and 6 were responsible for the damage but morphospecies 1, 2, 4 and 5 were the most predominant. First, second and third instar larvae were found damaging seedlings and they sometimes occurred simultaneously. Second and third instar larvae were the predominant larval instars.

Keywords: White grubs, morphospecies composition, larval instars, forestry, Natal Midlands.

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INTRODUCTION

Govender (1995) showed that during the years (1990 to 1993) the area planted to exotic forestry trees species increased by 0.45% per annum in South Africa. The total area under plantations increased by 11 676 hectares (ha) from the 1990 / 91 season (1 295 531 ha) to the 1992 / 93 season (1 307 207 ha) (Department of Water Affairs and Forestry, 1992, 1993, 1994).

Within a range of about 367 ha to 449 ha trees (average of 398 ha) were annually damaged by white grubs and cutworms in the Natal Midlands. This estimate excludes damage by white grubs to established saplings (where the saplings were not killed by white grub feeding but had reduced growth because of a reduced root mass), the re-establishment of pine plantations and the conversion of pine to other plantations species (Govender, 1995).

In *Acacia* and *Eucalyptus* plantations, most of the mortality that caused the failure of *Acacia mearnsii* and *Eucalyptus grandis* to establish in the Natal Midlands was associated with white grubs. Other members of the pest complex include termites, cutworms, tipulid larvae, wireworms, millipedes and nematodes. Where damage was observed, white grubs had a higher pest status than cutworms (Govender, 1995).

In this study predominant morphospecies of white grubs associated with some of the failure of *Acacia mearnsii* and *Eucalyptus grandis* to establish in plantations in the Natal Midlands were determined as morphospecies 1-6.

Little is known about Scarabaeidae in South African forestry and information on similar pests (e.g. wireworms, cutworms and millipedes) attacking agricultural crops is also limited (Govender, 1995). Studies of white grubs, their identification and description are important to help in understanding the important pest species in forestry. It is important to know which of the larval instars are responsible for the damage of the trees. It is also necessary to know when high incidence of damage occurs, as this information can assist in the integrated management of pests.

The aims of the study were to determine the morphospecies composition of the larvae, their distribution pattern across trials, the population structure of larval instars and the incidence of damage by white grubs in forestry.

1. LITERATURE REVIEW

1.1. Background

The family Scarabaeidae (Order: Coleoptera) has many sub-families, viz., Scarabaeinae, Cetoniinae, Dynastinae, Rutelinae and Melolonthinae (Scholtz and Holm, 1985). The adults are commonly known as fruit and flower chafers, rhinoceros and leaf-chafer beetles. Important pest species belong to the sub-families Dynastinae, Rutelinae, and Melolonthinae. The larvae are known as white grubs (Ritcher, 1966; Veeresh, 1977).

Various authors define white grubs differently. Peterson (1951) refers to white grubs as the common name of all scarabaeid larvae. Blatchley (1910) refers to white grubs as those subterranean larvae that damage roots and Ritcher (1966) considers white grubs as those grubs of economic importance to agricultural crops. Many white grub species are recorded as serious pests of lawns and the roots of crops (Hayes, 1929; Ritcher, 1966; Scholtz and Holm, 1985). Adults feed on the above ground parts of the plants. When grubs hatch from the eggs, they first feed on organic matter in the soil and then attack the fine roots of seedlings and plants (Speers and Schmiegi, 1961, Govender, 1995).

1.2. Biology of the pest

White grubs are C-shaped larvae, have six well-developed legs, a dark head and are whitish in colour with a blue tinge where the gut shows through the body wall. The end of the abdomen is dark and distended. Size varies from 3-36 mm long, according to age and species of larvae (Govender, 1995).

Several species can simultaneously damage trees. Some species have a one year life cycle and other species have a two year life cycle, e.g. *Hypopholis sommeri* has a two year life cycle (Prins, 1965). Ritcher (1958) noted that white grubs have three larval instars, as do all scarabaeids. *Heteronychus licas* larvae, for example, undergo three larval instars where the second and third instars feed on roots and tillers of sugarcane (Taylor, 1965). During each larval stage the flexible thoracic and abdominal segment increase in size, but the head capsule increases only when moulting occurs. The head width varies little between individuals of the same larval instars, but varies considerably between species and instars (Jarvis, 1927).

1.3. Reported examples of white grubs attacking some agricultural crops in South Africa.

1.3.1. Sugarcane

Several species of white grubs damage sugarcane in southern Africa. Species include *Heteronychus licas*, *Heteronychus tristis*, *Temnorrhynchus clypteatus*, *Hypopholis sommeri* and *Schizonycha affinis*. Although *Heteronychus licas* is not a serious pest in South Africa, it sometimes attacks sugarcane in the Eastern Transvaal (Carnegie, 1974). It was recorded causing damage to sugarcane for the first time in Nigeria (Taylor, 1965). Scholtz and Holm (1985) also reported *Heteronychus licas* to feed on sugarcane.

1.3.2. Pineapples

Asthenopholis subfasciata, *Trochalus politus*, *Macrophylla ciliata*, *Congela valida* and *Adoretus ictericus* larvae were reported as pests in South Africa because of their damage to the root systems of the pineapple plants (Smith *et al.*, 1995). *Heteronychus arator* was reported to also feed on pineapples, besides maize and potatoes (Scholtz and Holm, 1985). Adults of *H arator* cause considerable economic damage to the root systems of pineapple plants, leading to fungal infection and lower yields (Smith *et al.*, 1995).

1.3.3. Maize

In South Africa *Heteronynchus arator*, *Adoretus cribrosus* and *Anomala ustulata* are recorded as pests of maize (Du Toit, 1996). Scholtz and Holm (1985) also reported *Heteronychus arator* to feed on maize.

1.3.4.Turfgrass

Scarabaeid larvae are also known as pests of turf grass in South Africa. Annecke and Moran (1982) reported that seven species are economically important: *Anomala vetula*, *Macrophylla maritma*, *Schizonycha infantilis*, *Schizonycha plausibilis*, *Heteronychus tristis*, *Rhyssemus promontorii* and *Bolboceras peringueyi*. In the Eastern Cape Province, *Pentodontoschema aries, Macrophylla maritima, Macrophylla pubens,* and *Aegosthetha* sp. were also recorded as pests of turfgrass, where severe damage was caused by their feeding on turf grass roots (Omer-Cooper *et al.*, 1948).

1.4. White grubs in forestry

Some pests of previous agricultural crops are now attacking forestry transplants as a result of the expansion of forestry into previous crop-lands (Govender, 1995). In South Africa, forestry competes intensively with agriculture for land and in some areas it is competing successfully with crops such as sugarcane for prime sites (Burley *et al.*, 1989). In the Natal Midlands, where wattle was grown after sugarcane or *vice versa*, the larvae of *Hypopholis sommeri* and *Schizonycha affinis* have been common pests and resulted in economic losses (Carnegie, 1974, 1988).

White grubs are found in the soil and eat the fine roots of young trees. This causes a reduction in growth, and frequently the death of newly emerged wattle seedlings and young wattle, pine and eucalypt transplants. The foliage of damaged seedlings initially appears stressed and then turns brown and dries out. In severe cases the root plug of transplants is completely devoured and the taproot is ring barked up to the ground level. Trees older than one year was affected less because the developed lateral roots are able to withstand white grub attack better. High populations of white grubs in the soil can also cause the failure of re-establishment of plantations as well as loss in growth of young trees with consequent reduction in bark and timber yield (Govender, 1995).

The beetles of *Adoretus ictericus*, *Hypopholis sommeri* and *Monochelus calaratus* have been recorded to occur in the Cape Province, and in the Natal Midlands. The adults feed on leaves of wattle trees and the larvae (white grubs) feed on the roots of various plants, often causing severe damage to young wattle trees, pastures, bowling greens and golf courses. Severe attacks have been reported in the following areas of Kwazulu Natal: Greytown, Kranskop, Seven Oaks, New Hanover, Ixopo, Richmond, Harding, Wartburg, Springgrove, Hilton, Lions River, Inhluku, Umvoti and Vryheid (Prins, 1965).

Adoretus, *Anomala*, *Hypopholis, Monochelus* and *Schizonycha* were recorded as the main genera responsible for damage to wattle transplants and other plantation trees in South Africa (Atkinson *et al*., 1991; Hepburn, 1966; Sherry, 1971).

Although the adults of some scarabaeids were identified to species level, little work has been done on the identification of their larvae in South Africa. Oberholzer (1959) studied the morphology of some South African scarabaeid larvae, for example *Oryctes boas* and *Hypopholis sommeri*. Omer-Cooper *et al.* (1948) studied four species of Coleoptera attacking turf. These included *Pentodontoschema aries* and *Macrophylla maritima*. Smith *et al.* (1995) described and identified the white grubs that attack pineapple crops in South Africa, e.g. *Adoretus ictericus* and *Asthenopholis subfasciata*. Prins (1965) studied the biology and morphology of wattle chafers, for example, *Monochelus calcaratus*, *Hypopholis sommeri* and *Adoretus ictericus*. Despite the above work though, further studies on the identification and description of scarabaeid larvae are necessary in South Africa.

1.5. Control measures

Control measures such as the use of chemicals, natural enemies and cultural methods can be used to reduce the damage to plants by white grubs.

1.5.1. Chemical control

Wattle and eucalypt seedlings can be preventatively treated for the control of white grubs by the application of gamma BHC 0,6% dust at 0,06g a.i./tree or carbosulfan 10% CRG at 1,00g a.i./tree or chlorpyrifos 10% CRG at 1,0g a.i./tree or deltamethrin 5% SC at 0,025g a.i./tree (Govender, 1995). Gamma BHC 0,6% dust applied at 0,06g a.i./tree was reported to be effective against white grubs and is persistent enough to be applied as early as October in planting season. The deltamethrin treatment was persistent enough to be applied early in the planting season. Deltamethrin applied at 0,013g a.i./tree was only effective when the incidences of white grubs were high but lacked persistence (Govender, 1995).

1.5.2. Biological control

White grubs also have natural enemies. The larvae of robber flies (Asilidae), horse flies (Tabanidae), click beetles (Elateridae), tiphiid wasps (Tiphiidae), assassin bugs (Reduviidae), the larvae and adults of ground beetles (Carabidae) and earwigs (Dermaptera) are predacious and parasitic insects which destroy white grubs in the soil (Prins, 1965). Vertebrate enemies of white grubs and adult chafers include pigs, shrews, moles, rats, toads, birds and monkeys (Prins, 1965; Veeresh, 1977). Carnegie

(1974) identified the heron, *Bubulcusibis linnaeus*, and the hadeda, *Hagedashia hagedash*, preying on white grubs.

Viruses that attack insects can also be used in the control of pests in forest ecosystems (Govender, 1995). Viruses are very specific, they can kill the pest rapidly, are easy to produce, and can be stored for years without losing effectivity (Govender, 1995). Veeresh (1977) recorded the green *Muscardine* fungus, *Metarrhizium anisopleae* as a control agent of grubs of *Holotrichia nilgiria* in India.

1.5.3. Cultural control

In Karnataka (India) the cleaning of infested fields to keep them free from plants and then heaping the plants at intervals, helped to concentrate the white grubs into limited areas under the heaps. Grubs were then killed either chemically or mechanically. The soil was also ploughed and disced to clear away weeds after harvesting the previous crop and thus prevented oviposition in the soil by adults. Trap crops may be planted and then destroyed before planting the main crop (Veeresh, 1977).

1.5.4. Mechanical control

In Bangalore (India) the collection and killing of adults of *Holotrichia serrata*, especially when the adult emergence was synchronous after the first rains appeared to be a satisfactory control measure in host plants like *Azadirachta indica*, *Swietenia mahagoni* and *Acacia arabica* (Veeresh, 1977).

2. MATERIALS AND METHODS

2.1 General

Specimens used in this study were collected in field trials conducted by Govender (1995). Three trials (Table 1) were conducted during three successive growing seasons at the Bloemendal Field Experiment Station (South African Wattle Growers Union), 14km SE of Pietermaritzburg. The first trial was conducted in January 1991 (first growing season); the second trial was conducted in January 1992 (second growing season) and the last trial was conducted in October 1992 (third growing season). The trials were planted in a summer rainfall region.

During the first year, each trial was assessed at monthly intervals after planting. The insects (especially white grubs) that were responsible for seedling mortality were collected while digging out the stressed, dead or dying trees (Govender, 1995). The insects were preserved in Peterson's KAA (paraffin-glacial acetic acid- ethanol) mixture which consists of 1 part commercial kerosene, 10 parts 95% ethyl alcohol and 2 parts acetic acid (glacial) (Peterson, 1955). Specimens were not preserved directly into 70% ethanol because they turn black and this makes it difficult to observe the raster pattern (Govender, 2000).

Table 1. Geographical features, compartments and planting date of the trials

	Trial 1	Trial 2	Trial 3
Compartments	28C	20B2	21B
Latitude	29° 32' 38" S	29° 33 '03" S	29° 33' 11" S
Longitude	30° 27' 57" E	30° 27' 15" E	30° 27' 20" E
Altitude	930 m	840 m	900 m
Mean annual rainfall	875 mm	990 mm	990 mm
Soil type	Inanda	Magwa	Inanda
Organic carbon	4.519%	4.027%	4.122%
Previous crop	Wattle	Wattle	Wattle
Planting date	14-16 Jan. 1991	13-16 Jan. 1992	19-21 Oct. 1992

2.2. Morphospecies composition

White grub species have a characteristic raster pattern on the ventral surface of the abdomen. Torre-Bueno (1950) defines the raster as the "complex of definitely arranged bare places, hairs and spines on the ventral surface of the last abdominal segment, in front of the anus". These characteristic raster patterns were used to identify morphospecies. All white grub species were identified as a particular morphospecies, using a dissecting microscope. There were six morphospecies. Preliminary studies by Govender (2000) indicated morphospecies 1 as *Hypopholis sommeri*, morphospecies 2 as *Schizonycha affinis*, morphospecies 3 as *Adoretus ictericus*, morphospecies 4 as *Schizonycha fimbriata*, morphospecies 5 as *Maladera* sp. Morphospecies 6 was undetermined.

2.3. Instar population structure

A previous study showed that the head capsule width of scarabaeid larvae was a reliable indicator of the larval instar stage (Carnegie, 1974). Therefore the head capsule width of all larvae were measured in the laboratory using a dissecting microscope fitted with an occular micrometer (Table 2). A lens with a 10x magnification was used. The widest part of the head (ocular region) was measured. The head capsule widths were converted into millimetres using convention factors in Table 2 depending on the magnification used. The frequency distributions of head capsule widths (mm) from all larvae of the same morphospecies in each trial were graphed to determine ranges of the different instars (Van Steenwyk and Rough, 1989). For *Hypopholis sommeri*, *Adoretus ictericus* and *Maladera* sp. ranges used were those determined by Oberholzer (1959), Prins (1965) and Smith *et al*., (1995). The ranges for each of the other morphospecies was determined by using the median and the bell shaped pattern of the frequency distribution of the head capsule width.

3. RESULTS AND DISCUSSION

3.1. Morphospecies composition

3.1.1. Introduction

Arrangement of the setae on the raster is a character used by entomologists to classify white grubs into different species (Omer-Cooper *et al*., 1942). The raster patterns are visible at low magnification and without dissection (Smith *et al*., 1995). Within each trial the larvae were sorted and identified as belonging to different morphospecies (Figure 1a-1f).

Annotations of morphospecies (Ritcher, 1966):

(i) Morphospecies 1- large setae with no particular rastal pattern (Figure 1(a))

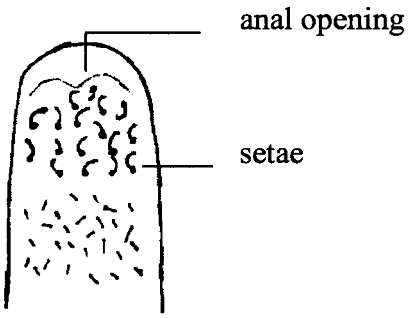
(ii) Morphospecies 2- two rows of setae, 10-16 in each row forming a V-shaped palidium (Figure 1(b))

(iii) Morphospecies 3- two rows of setae, 4-6 in each row (setae around anal opening both long and slender, but short, sharp on the dorsal surface of the anus) (Figure 1(c))

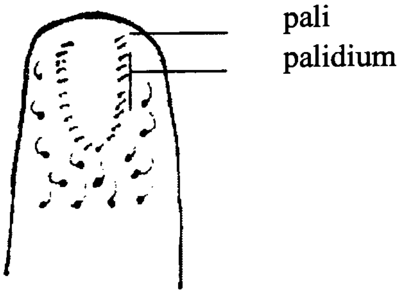
(iv) Morphospecies 4- transverse palidium of 28-30 stout pali, pali considerably longer and stouter than tegillar setae (Figure 1(d))

(vi) Morphospecies 5- palidia forming an arc with 10-12 pali and long setae around anal opening (Figure 1(e))

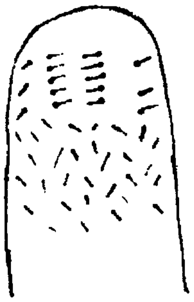
(vii) Morphospecies 6- two longitudinal palidia, each set with 10-12 pali (Figure 1(f))



1a. Morphospecies 1



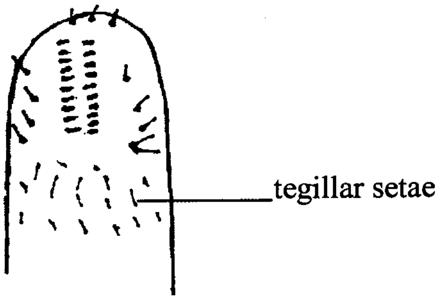
1b. Morphospecies 2



1c. Morphospecies 3

1d. Morphospecies 4

1e. Morphospecies 5



1f. Morphospecies 6

Figure 1. Illustrations of the raster patterns of the different morphospecies

3.1.2. Trial 1

The trial was planted on the 14-16th January 1991 and the first survey was conducted ten days after planting. Eighty four percent of all larvae of the different morphospecies that were collected were found in January (15%), February (28%) and March (41%), with the peak in March (Table 3). Thereafter larval numbers steadily decreased. The highest incidence of white grub damage to seedlings was in March (197) (Table 3). During the peak period (March) predominant morphospecies were morphospecies 2 (79) and morphospecies 4 (83) (Table 3, Figure 2). Throughout trial 1, the predominant morphospecies were 4, 2, and 1.

Table 2. Morphospecies larval counts and incidence of damage during monthly surveys in Trial 1 at Bloemendal (January 1991)

Month	No. of morphospecies 1 (larvae/month)		No. of morphospecies 2 (larvae/month)		No. of morphospecies 3 (larvae/month)		No. of morphospecies 4 (larvae/month)		No. of morphospecies 5 (larvae/month)		No. of morphospecies 6 (larvae/month)		Total No. of larvae/ month		Plants damaged/ month
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Jan 91	20	14	26	16	27	39	03	01	11	48	02	13	89	15	12
Feb 91	51	36	36	23	06	09	68	37	03	12	04	27	169	28	102
Mar 91	46	33	79	50	26	38	83	45	05	22	06	40	246	41	197
Apr 91	12	09	12	08	06	09	26	14	02	09	01	07	59	10	36
May 91	10	07	-	-	-	-	06	03	-	-	-	-	16	03	-
Jan 92	02	01	05	03	04	05	-	-	02	09	02	13	15	03	-
Total	141	100	158	100	69	100	186	100	23	100	15	100	594	100	347

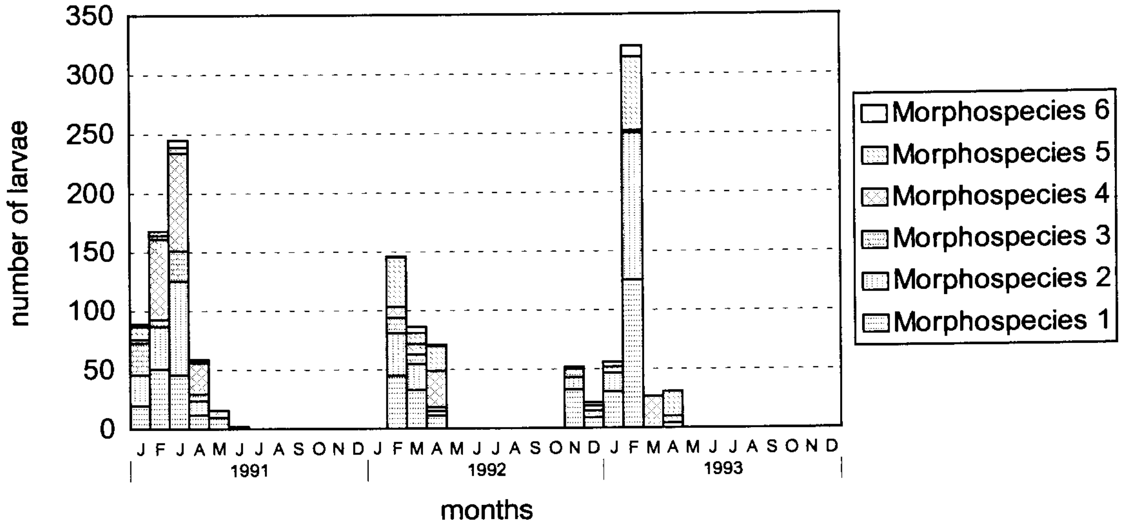


Figure 2. Morphospecies composition of all trials at Bloemendal

3.1.3. Trial 2

The trial was planted on the 13-16th January 1992. The first survey was conducted in February 1992, unlike the first trial. Eighty five percent of all larvae of the different morphospecies that were collected were found in February (41%), March (24%) and April (20%) with the peak in February (Table 4). The highest incidence of white grub damage to seedlings was in February (63) (Table 4). During the peak period (February) predominant morphospecies were morphospecies 1 (45) and morphospecies 5 (42) (Figure 2, Table 4). Throughout the whole trial, the predominant morphospecies were 1, 5, 2 and 4.

Table 3. Morphospecies larval counts and incidence of damage during monthly surveys in Trial 2 at Bloemendal (January 1992)

Month	No. of morphospecies 1 (larvae/month)		No. of morphospecies 2 (larvae/month)		No. of morphospecies 3 (larvae/month)		No. of morphospecies 4 (larvae/month)		No. of morphospecies 5 (larvae/month)		No. of morphospecies 6 (larvae/month)		Total No. of larvae/ month		Plants damaged/ month
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Feb 92	45	46	36	54	13	38	09	15	42	49	01	11	146	41	63
Mar 92	33	34	22	33	08	24	09	15	09	11	05	56	86	24	37
Apr 92	12	11	04	06	03	09	31	51	21	24	01	11	71	20	22
May 92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	01
Aug 92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jan 93	08	08	05	07	10	29	12	19	14	16	02	22	51	15	06
Total	97	100	67	100	34	100	61	100	86	100	09	100	354	100	129

3.1.4. Trial 3

The trial was planted on the 19- 21st October 1992 with the first survey conducted in November. Few white grub larvae were collected. In November and December 14% of the total larvae collected, were found. Seventy four percent of larvae of the different morphospecies were found in January (11%) and February (63%), with the peak in February. Thereafter larval numbers steadily decreased. The highest incidence of damage to seedlings was in February (114) (Table 5). During the peak period (February) predominant morphospecies were morphospecies 1 (125) and morphospecies 2 (125) (Figure 2, Table 5). Throughout the whole trial, the predominant morphospecies were 1, 2, and 5.

Table 4. Morphospecies larval counts and incidence of damage during monthly surveys in Trial 1 at Bloemendal (October 1992)

Month	No. of morphospecies 1 (larvae/month)		No. of morphospecies 2 (larvae/month)		No. of morphospecies 3 (larvae/month)		No. of morphospecies 4 (larvae/month)		No. of morphospecies 5 (larvae/month)		No. of morphospecies 6 (larvae/month)		Total No. of larvae/ month		Plants damaged/ month
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Nov 92	33	16	10	06	07	54	01	04	01	01	-	-	52	10	42
Dec 92	09	05	06	04	04	31	-	-	-	-	03	19	22	04	23
Jan 93	31	15	16	09	-	-	-	-	05	05	04	25	56	11	14
Feb 93	125	62	125	77	02	15	-	-	62	70	09	56	323	63	114
Mar 93	-	-	-	-	-	-	27	96	-	-	-	-	27	06	-
Apr 93	04	02	06	04	-	-	-	-	21	24	-	-	31	06	10
Total	202	100	163	100	13	100	28	100	89	100	16	100	511	100	203

In all three trials, larvae were present from November to June. In trial 1 the first survey was conducted during the same month as the planting date and white grub damage to the seedlings was recorded. This shows that white grub damage to the seedlings occurred soon after planting.

Morphospecies that featured predominantly were 1, 2, 4 and 5 in all trials. Morphospecies 4 had the highest number of larvae in trial 1. Morphospecies 1 was the predominant species in trials 2 and 3. Morphospecies 1 and 2 were common in all trials. Carnegie (1974, 1988) also reported *Hypopholis sommeri* (morphospecies 1) and *Schizonycha affinis* (morphospecies 2) to be pests of economic importance especially in areas where wattle was grown after sugarcane or *vice versa*. Morphospecies 4 was common in trials 1 and 2 but not trial 3 whereas morphospecies 5 was common in trials 2 and 3 but not in trial 1.

Govender (1995) reported that white grub damage to the seedlings commenced soon after planting. The incidence of damage followed a bell-shaped curve, starting soon after planting, peaking in February and tailing off sharply towards June. The peak period in trial 1 was during March and morphospecies that were predominant were morphospecies 4, 2 and 1. For trials 2 and 3, the peak was in February irrespective of their different planting dates (January and October, respectively). Predominant morphospecies during the peak period were morphospecies 1, 5, and 2 in trial 2 and morphospecies 1, 2 and 5 in trial 3. Carnegie (1974) observed a similar incidence of larval numbers of *Hypopholis sommeri* (morphospecies 1) over a period of three years in soils where wattle and sugarcane were planted.

In all trials, several morphospecies were found to be simultaneously causing damage to the seedlings in the same month. All six morphospecies were present in each of the three trials. In January, the predominant morphospecies were 1, 2 and 3 in trial 1. In February to April, predominant morphospecies were 1, 2 and 4. Other morphospecies were present but in lower numbers. Predominant morphospecies were 1, 2 and 5 in February to April in trial 2. Morphospecies 3, 4 and 6 were present but in lower numbers. In November, morphospecies 1, 2 and 3 were predominant in trial 3. Very few larvae of morphospecies 4 and 5 were collected but no larvae of morphospecies 6. In December, morphospecies 4 and 5 were absent and morphospecies 3 and 4 were also absent in January. Predominant morphospecies for both months were 1 and 2. Morphospecies 4 was absent in February whereas morphospecies 1, 2 and 5 were predominant. In March, only morphospecies 4 was present but in low numbers and in April, morphospecies 3, 4 and 6 were absent with morphospecies 5 predominant. It would appear that morphospecies varies in their predominance; both monthly and annually.

There also appears to be a relationship between the number of larvae and the number of plants attacked. Where high numbers of larvae were collected high numbers of seedlings were attacked (in February to March in trial 1 and January to February in trial 3). Govender (1995) considered white grubs to be the most important soil pest compared to other soil pests (cutworms, millipedes, nematodes, termites, tipulid larvae, wireworms and grasshoppers/ crickets) that might attack commercial forestry seedlings. Seedlings were susceptible to white grub attack for the first 3 to 4 months after planting. When the trees grow older, and develop lateral roots and withstand white grub attack better (Govender, 1995).

3.2. Instar population structure

3.2.1. Introduction

Carnegie (1974) determined the instars for *Schizonycha affinis* and *Hypopholis sommeri* although it was not stated how the instars or the instar size range were determined. Van Steenwyk and Rough (1989) used the frequency distribution of the head capsule widths of all larvae collected to determine the various instars and the results clearly indicated that there were three instars.

The range of the head capsule widths for *Adoretus ictericus* were 1.063-1.130 mm for the first instar (Prins, 1965) and an average head width of 3.200 mm for the third instar larvae (Smith *et al.*, 1995). The maximum head capsule width for the first instar larvae of *Hypopholis sommeri* was 1.440-1.700 mm (Prins, 1965) and the third instar larvae was 4.400-5.000 mm (Oberholzer, 1959). For *Maladera* sp. the head capsule width for the third instar larvae was 2.660-2.800 mm (Ritcher, 1966).

In this study the frequency distribution of the head capsule widths from all larvae of the same morphospecies in all trials were used to determine the larval instars. The results obtained did not clearly distinguish between the three different larval instars. The frequency distribution followed a bell shaped curve and this was used to estimate the ranges of the head capsule widths (Figures 3, 4, 5, 6, 8; Table 6). The determined range is wider than the ones determined by Oberholzer, 1959; Prins, 1965; Ritcher, 1966; and Smith *et al.*, 1995. Some head capsule widths were excluded from the range (Figures 7, 8) because while grouping the larvae into a particular morphospecies, we suspect a mixture of larvae from morphologically similar species. Taxonomic studies to clarify species identification are currently in progress (Govender, 2000).

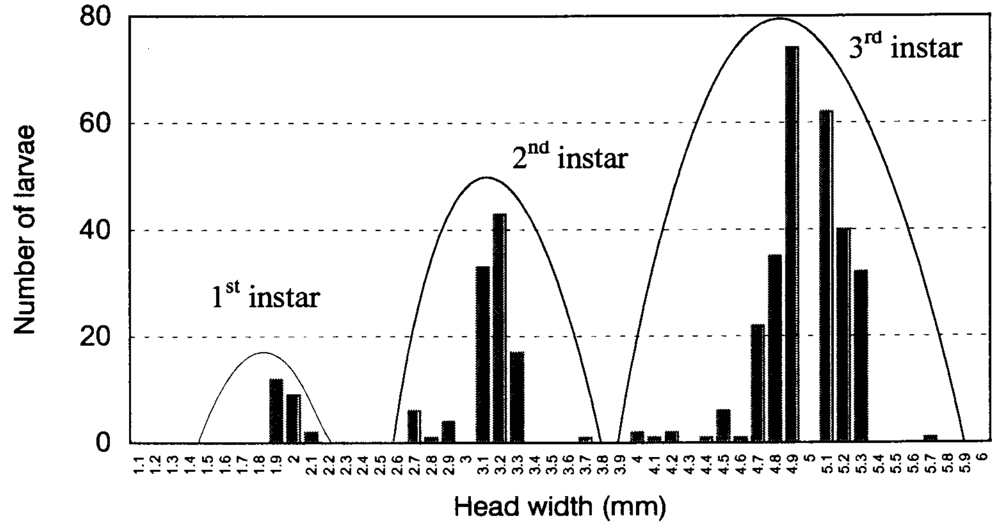


Figure 3. Head capsule width (mm) of all morphospecies 1 larvae in three trials at Bloemendal.

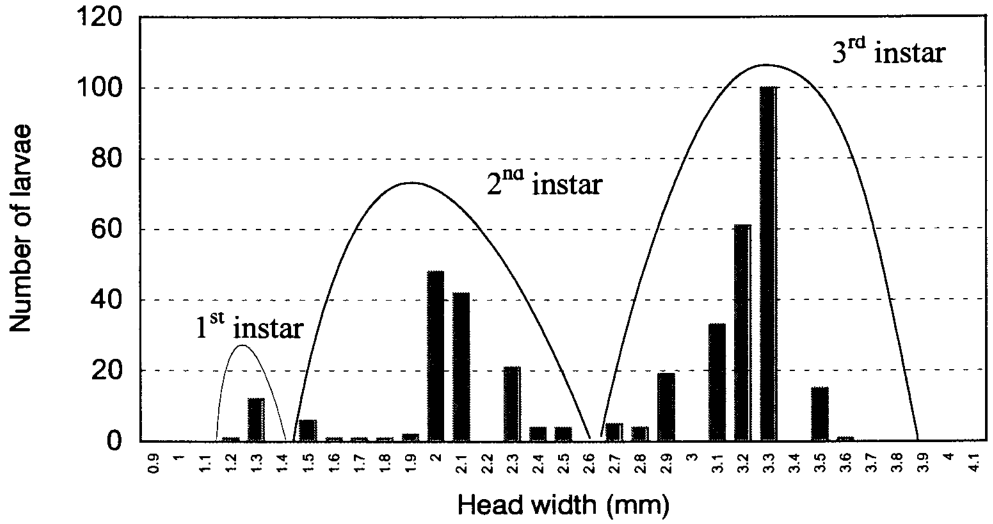


Figure 4. Head capsule width (mm) of all morphospecies 2 larvae in three trials at Bloemendal.

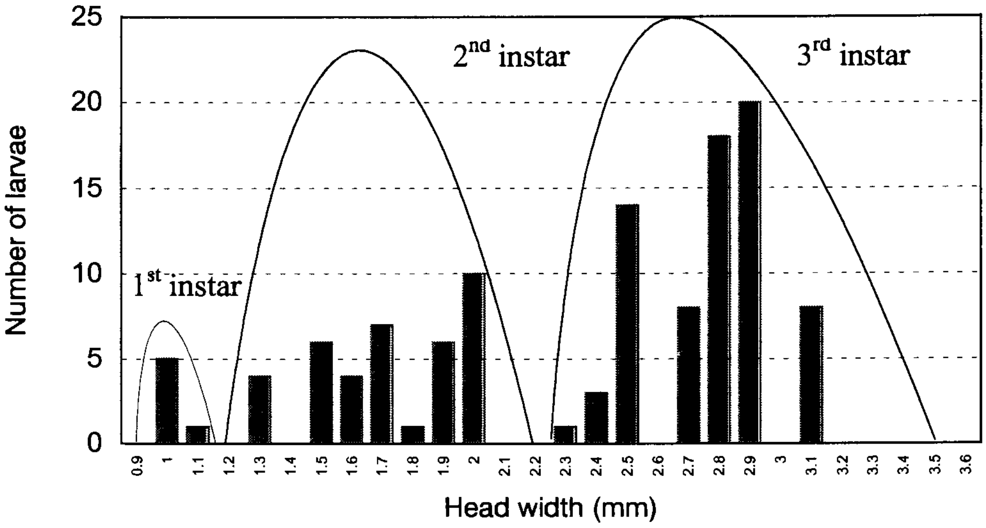


Figure 5. Head capsule width (mm) of all morphospecies 3 larvae in three trials at Bloemendal.

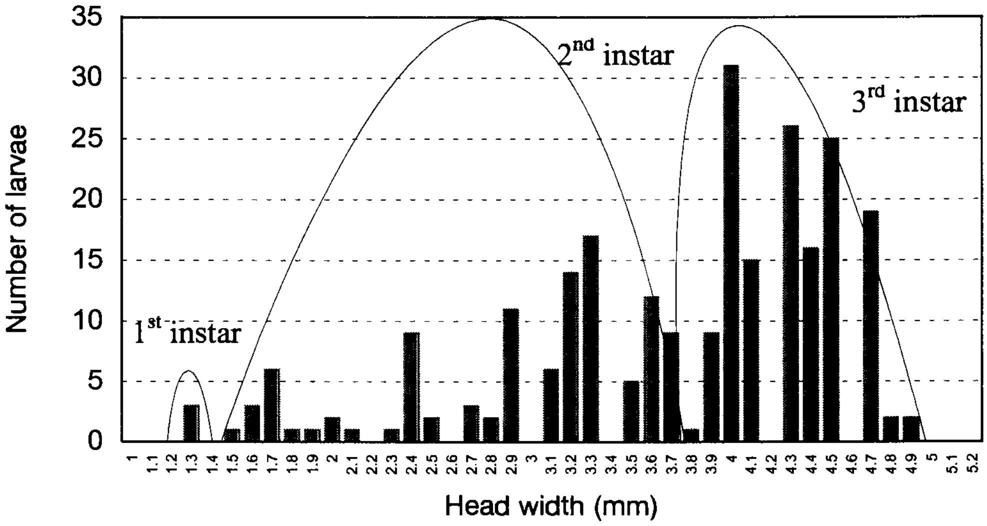


Figure 6. Head capsule width (mm) of all morphospecies 4 larvae in three trials at Bloemendal.

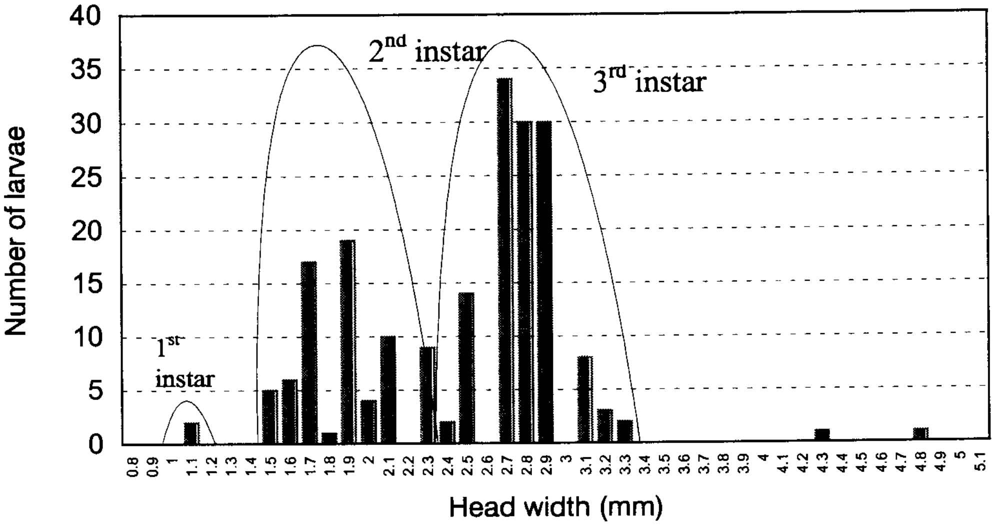


Figure 7. Head capsule width (mm) of all morphospecies 5 larvae in three trials at Bloemendal.

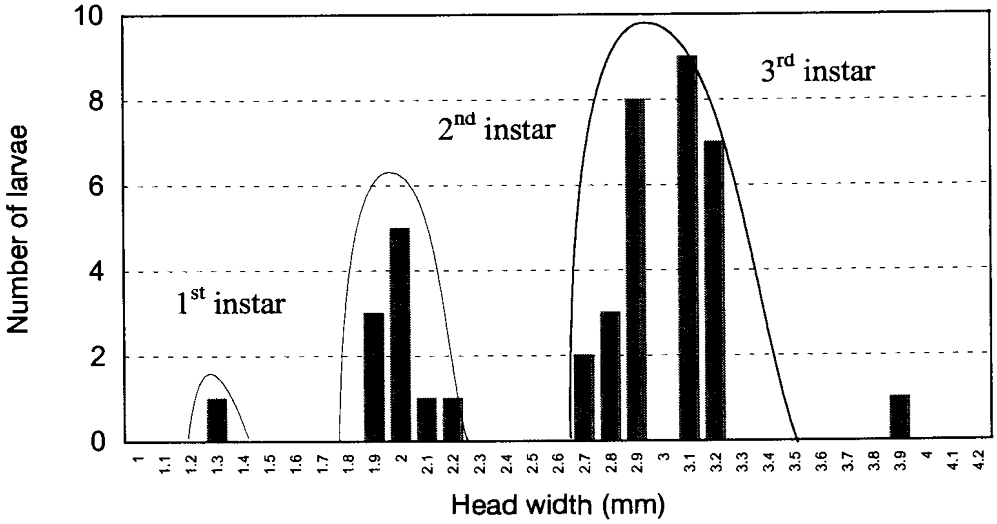


Figure 8. Head capsule width (mm) of all morphospecies 6 larvae in three trials at Bloemendal.

Table 5. Morphospecies diversity and instar head capsule width (mm) and ranges from the Bloemendal trials

Morphospecies	Number of instars	Range (mm)
Morphospecies 1	3	1.440-2.100
		2.600-3.800
		3.900-5.900
Morphospecies 2	3	1.200-1.400
		1.500-2.600
		2.700-3.900
Morphospecies 3	3	0.900-1.100
		1.200-2.200
		2.300-3.500
Morphospecies 4	3	1.200-1.400
		1.500-3.700
		3.800-4.900
Morphospecies 5	3	1.000-1.200
		1.500-2.300
		2.400-3.300
Morphospecies 6	3	1.200-1.400
		1.800-2.200
		2.700-3.500

3.2.2. Morphospecies 1

All three larval instars were present in trials 1 and 3. There were few first instar larvae and they were found from about December to February. Trial 2 had only second and third instar larvae. Second and third instar larvae were present in higher numbers than the first instar larvae in all the trials. During the peak period, second and third instar larvae were predominant with third instar larvae being the most abundant (Figure 9).

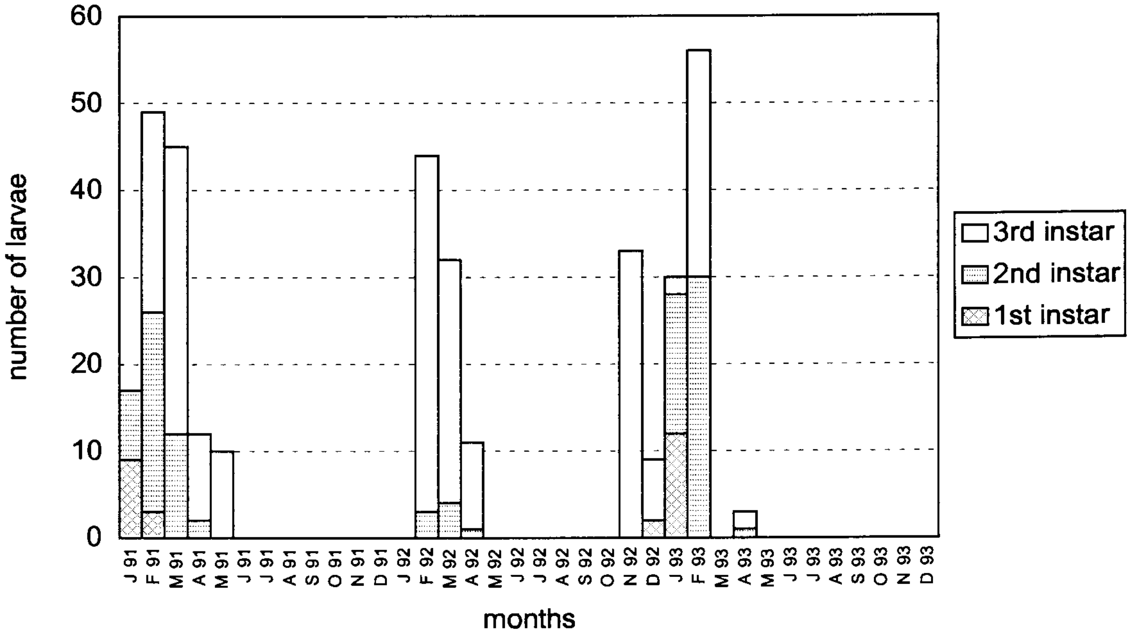


Figure 9. Instar population structure of morphospecies 1 in three field trials at Bloemendal

3.2.3. Morphospecies 2

First, second and third instar larvae were present only in trials 1 and 3. First instar larvae were present in lower numbers than the other instar larvae and were present from January to March. Throughout the study, second and third instar larvae occurred in high numbers. During the peak period, the highest number of larvae was recorded for third instar larvae followed by the second instar larvae (Figure 10).

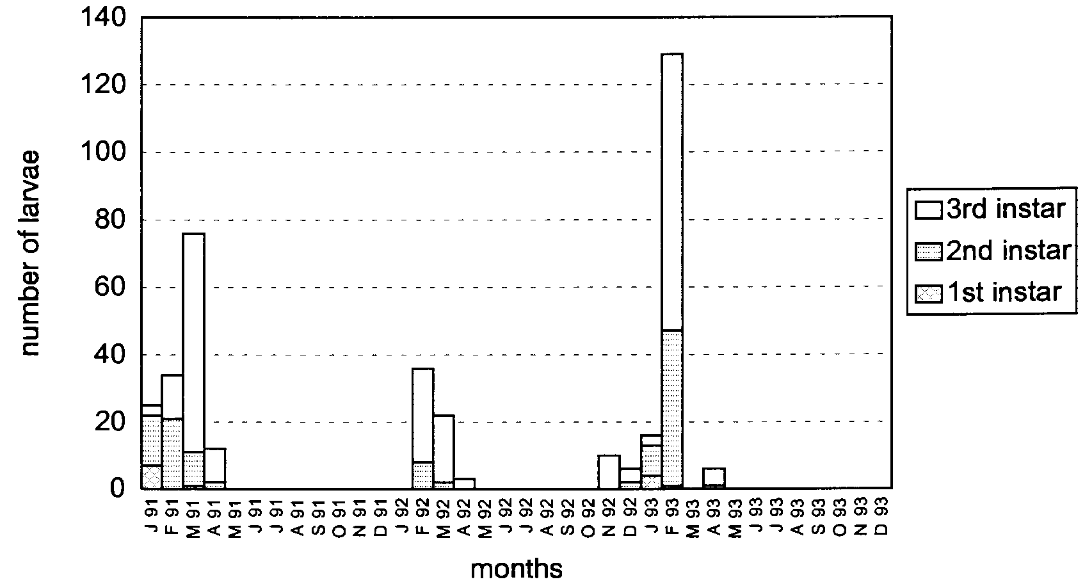


Figure 10. Instar population structure of morphospecies 2 in three field trials at Bloemendal

3.2.4. Morphospecies 3

Larvae of all 3 instars were only recorded at trial 1. First instar larvae were found in January, but second instar larvae predominated. In trials 2 and 3 only second and third instar larvae were observed. Second and third instar larvae were present in higher numbers than the first instar larvae in all trials. During the peak period, in trials 2 and 3, the third instar larvae were predominant, while in trial 1 the second instar larvae were predominant (Figure 11).

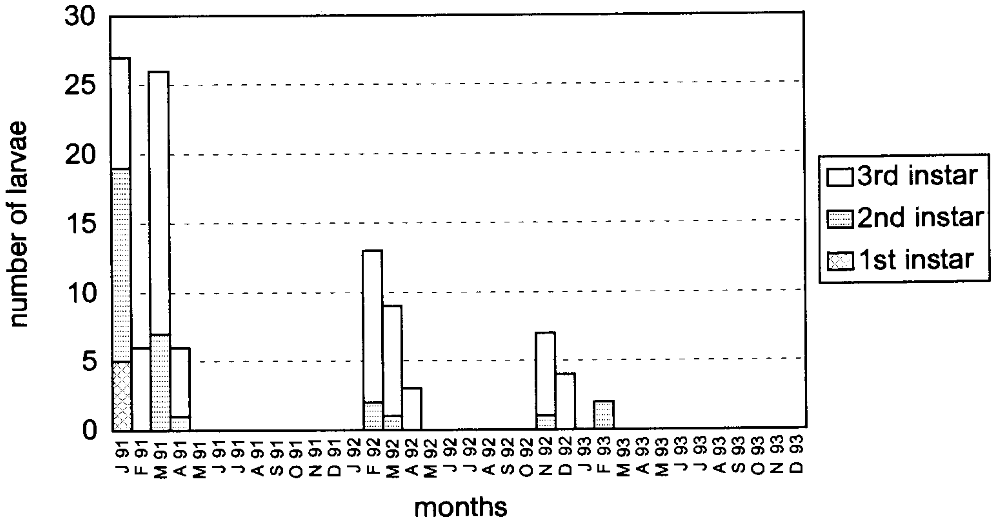


Figure 11. Instar population structure of morphospecies 3 in three field trials at Bloemendal

3.2.5. Morphospecies 4

All three larval instars were present only in trial 2. First instar larvae were found in April but in very low numbers. Second and third instar larvae were the only larval instars in trials 1 and 3. Second and third instar larvae were present in higher numbers than the first instar larvae in all trials. During the peak period, second instar larvae were predominant in trial 2 and third instar larvae in trials 1 and 3 (Figure 12).

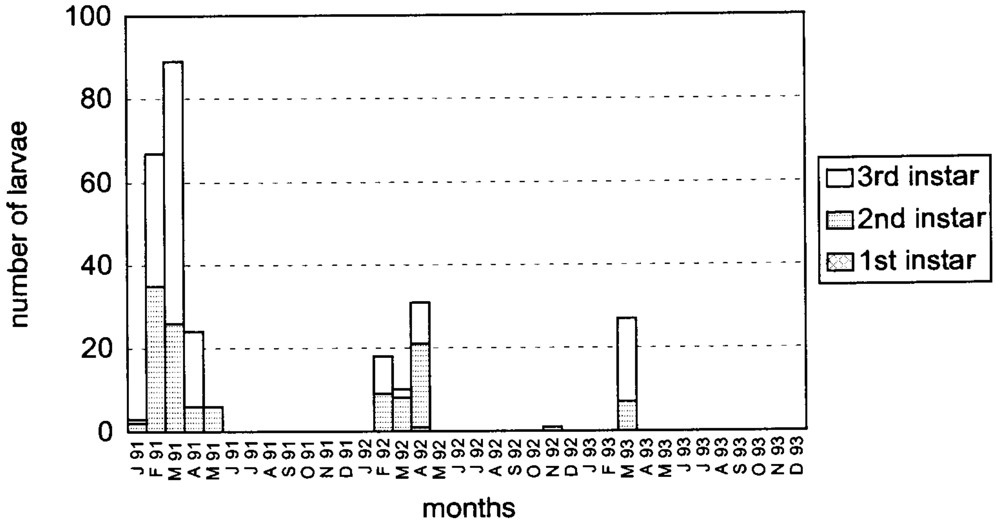


Figure 12. Instar population structure of morphospecies 4 in three field trials at Bloemendal

3.2.6. Morphospecies 5

First instar larvae were only present in trial 1 in low numbers during January. Second instar larvae were predominant during that month. Trial 2 and 3 had second and third instar larvae only. Second and third instar larvae were present in higher numbers than the first instar larvae in all trials. During the peak month, second instar larvae were predominant in trial 1 and third instar larvae in trials 2 and 3 (Figure 13).

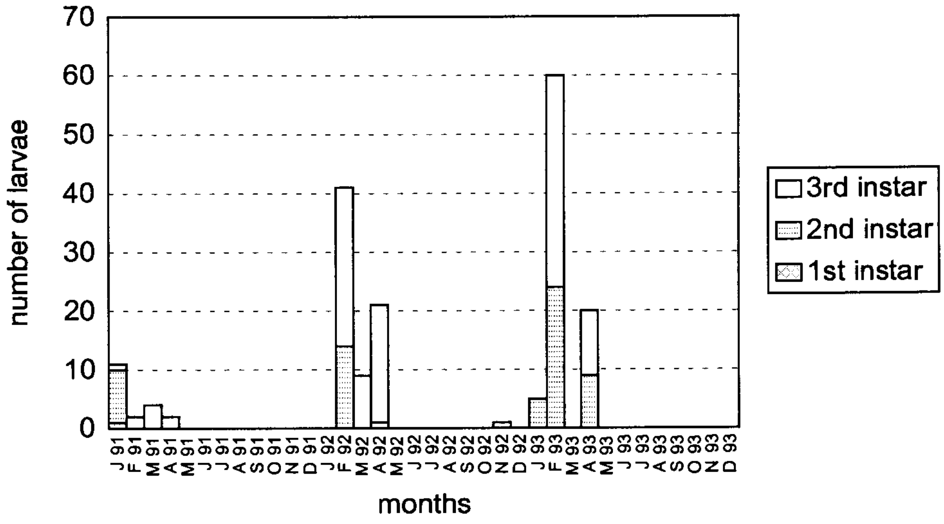


Figure 13. Instar population structure of morphospecies 5 in three field trials at Bloemendal

3.2.7. Morphospecies 6

First, second and third instar larvae were present only in trial 1. First instar larvae were, however, only found in March in low numbers. Only second and third instar larvae were found in trials 2 and 3. Second and third instar larvae were present in high numbers in all trials. During the peak period, predominant larval instars were second instar larvae in trial 2 and third instar larvae in trials 1 and 3 (Figure 14).

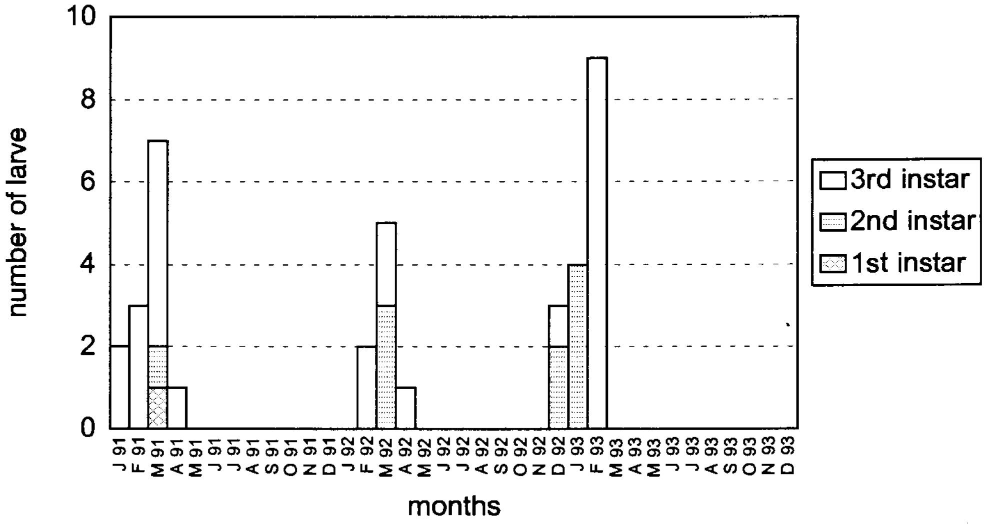


Figure 14. Instar population structure of morphospecies 6 in three field trials at Bloemendal

Except for morphospecies 4, all three larval instars of each morphospecies were collected in trial 1. Only second and third instar larvae of the majority of morphospecies were observed in trials 2 and 3. Only morphospecies 4 had all three larval instars in trial 2 and morphospecies 2 in trial 3. In situations where first instar larvae were found, they were present together with the second and third larval instars suggesting that there are overlapping generations. Sherry (1971) reported *Hypopholis sommeri* (morphospecies 1) to have a life cycle that extends over two years, hence reporting it to be the most damaging pest to wattle. Prins (1965) also reported *Hypopholis sommeri* to have 2 year life cycle.

The second and third instar larvae were the most damaging larval instars. The two larval instars were found in higher numbers than the first instar larvae in all trials.

During the peak periods and where high incidence of damage occured, third instar larvae were predominant over the second instar larvae. A high incidence of damage was recorded when the second and third instar larvae were present because of their root feeding nature, whereas first instar larvae feed on organic matter in the soil (Scholtz and Holm, 1985).

5. Conclusion

Several morphospecies of white grubs simultaneously cause damage to commercial forestry seedlings. Morphospecies differ in their predominance over a period of time (one morphospecies can be predominant in a particular month and be less predominant in another month). The most predominant morphospecies were 4, 2, 1 and 5. However, predominance varies from year to year. Second and third instar larvae are more predominant than the first instar larvae and were responsible for damaging wattle and eucalypt seedlings.

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