

BIONOMICS AND CONTROL OF
THE SUGARCANE INSECT
NUMICIA VIRIDIS MUIR
(HOMOPTERA: TROPIDUCHIDAE)

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ABSTRACT

Numicia viridis Muir (Homoptera : Tropiduchidae) is an indigenous southern African insect which was described in 1931 from specimens collected in Pondoland and Natal. In 1962 it became of economic importance when it was associated with damage caused to sugarcane in both Swaziland and South Africa. Affected cane turned yellow, its leaves dried off prematurely, and an abnormally large amount of trash was produced. Growth was retarded, and in extreme cases stem texture was affected. Since 1962 the insect's association with both sugarcane and alternate host plants has been investigated, and its economic importance assessed.

Insectary investigations included studies of life history, developmental stages and behaviour of N. viridis and of its parasites. Two Mirid egg predators (Tytthus mundulus (Breddin) and T. parviceps (Reuter)) were introduced from Mauritius, but neither became successfully established.

Field studies included general ecology, population dynamics, movement, distribution and the development of infestations. The association of N. viridis with 12 sugarcane varieties and with grass communities formed the subject of seven field experiments. All locally grown cane varieties and most grass species could serve as host plants, but differences in egg mortality rates for different host plants were noted.

Natural controlling factors were recognised, including biological agents. Of these, two useful egg parasites (Ootetrastichus ?beatus Perkins (Eulophidae) and Oligosita sp. nov. (Trichogrammatidae)) were the most important.

Attention was given also to chemical control, and it was found that of ten insecticides tested in large scale field experiments, dust and low volume formulations of endosulfan and mercaptothion gave very satisfactory control.

CHAPTER 1

INTRODUCTION

1.1 Affinities, distribution, investigatory methods

Numicia viridis Muir (Muir, 1931) belongs to the Homopteron family Tropicuchidae (Plates 1, 8 and 9). Apart from the dubas bug, Ommatissus binotatus lybicus de Berg (Ramchandra Rao, 1922; Alfieri, 1934; Dowson, 1936; Lepesme, et al., 1947; Hussain, 1962) it appears to be the only Tropicuchid to have become a pest of agricultural crops.



Plate 1 Numicia viridis Muir. Eggs in midrib; third instar nymph left; fifth instar female centre; adult females right.

This family is a subdivision of the superfamily Fulgoroidea. According to Imms (1964) and Brues, Melander and Carpenter (1954) the distinguishing characteristic of the family is the presence of a groove or fine line cutting off the posterior angle of the mesonotum.

Melichar (1915) distinguished 140 species of Tropicuchidae, mostly from the Indo-Malaysian and Neotropical regions.

The genus Numicia appears to be entirely African, (including Madagascar and Zanzibar), six species being included in the British Museum collection. A list of species, abstracted from the above collection is shown in Table 1, together with records from the following collections: National collections, Pretoria, Bulawayo, Nairobi; Transvaal and Cape Town Museums; Kawanda Research Station, Uganda; Tananarive Museum, Madagascar; Sugar Industries Research Institute, Mauritius.

N. viridis may be assumed to be indigenous to southern Africa. It is not mentioned in the Review of Applied Entomology before 1962, neither does the name appear in the list of sugarcane insects by Box (1953), nor in Wade's bibliography (1951).

It is interesting that it was not until 1962 that N. viridis was recognised as a pest of sugarcane, and then on a comparatively recently-established estate. It is an excellent example of a harmless, indigenous grass-inhabiting insect which, under conditions of agricultural enterprise, turned its attentions to an introduced plant and became of economic importance.

Since the invasion of Natal cane fields by the red locust (Nomadacris septemfasciata Serv.) in the 1930s, numicia (as it is now commonly known) has received more attention and publicity than any other local sugarcane pest, and with good reason. Damage caused by it is conspicuous (Plate 2), and a fear that over the years the problem might be progressive, prompted the investigation which is described in the following chapters.

The form of the investigation was, of necessity, mainly a practical field approach. The immediate objective was to discover how best to kill the insect, and so check the spread of any infestation. There was envisaged also a longer term project to investigate more fundamental aspects; but priority had always to be given to immediate practical measures and a minimum of attention could be devoted to the more academic aspects of the problem.

TABLE 1 Collection records of Numicia spp.

Species	Collection	Locality	Date collected
<u>N. viridis</u> Muir			
Holotype	British Museum	Pt. St. Johns, South Africa.	5-30. 4.1923
	" "	" "	16-28. 4.1924
	" "	Eshowe S.A.	6.1926
	" "	Gingindhlovu S.A.	15. 4.1926
	" "	" "	9. 4.1926
	" "	" "	26. 4.1926
	" "	" "	29. 4.1926
	" "	" "	29. 5.1926
	" "	Empangeni "	26. 4.1926
	" "	Malkerns Swaziland	7.1962
var. <u>infuscata</u> Muir			
Holotype	" "	Weenen S. Africa	4.1924
	" (Muir 1931)	" "	4.1924
	" "	" "	3.1925
<u>N. viridis</u> Muir			
	" "	" "	3. 4.1924
	" "	Pt. St. Johns, S.A.	4. 5.1923
	National, Pretoria	Umtentweni, S.A.	9-14. 3.1961
	" "	Pongola "	19.10.1966
	" "	Nelspruit "	23.11.1967
	" "	Mooi River "	28. 2.1967
<u>N. insignis</u> Dist.			
Holotype	British Museum	Durban "	1911
	" "	Myombo, E. Africa	11. 3.1914
	" "	Mt. Mlanje, Malawi	11.12.1912
	" "	" "	3.12.1912
	" "	Chagwe, Uganda	16-25. 7.1911
	" "	Pietermaritzburg South Africa	2. 5.1917
	" "	Malawi	4. 4.1913
	" "	Kampala, Uganda	4-10. 2.1919
	" "	Yingo, "	30. 4.1916
	" "	Njala, Sierra Leone	11.12. ?30

TABLE 1 (Continued)

Species	Collection	Locality	Date collected
<u>N. insignis</u> Dist.			
	British Museum	Pt. St. Johns, S.A.	11.1923
	" "	Kenya	8. ?47
	" "	Maji Moto, Zanzibar	20.8-11. 9.1924
	" "	Rabai	8.1937
	" "	"	8.1930
	Kawanda Res. Stn.	Kampala, Uganda	18. 1.1917
	" "	" "	19.11.1915
	" "	" "	4. 5.1916
	" "	" "	14. 9.1930
	" "	" "	1.12.1938
	" "	Kawanda, Uganda	23.11.1940
	" "	" "	30. 8.1945
	" "	" "	7.11.1943
	Cape Town Museum	Uganda	Unknown
	National, Pretoria	Pietermaritzburg, South Africa	2. 5.1917
	" Nairobi	Unknown	Unknown
	" Bulawayo	Katambora, Rhodesia	4.1962
	" "	Amatonga, Mocambique	3.1930
<u>N. culta</u> Melichar (= <u>albicans</u> Walk.)			
Holotype	British Museum	Gambia	Unknown
	" "	Bambi, Senegal	6. 6.1943
<u>N. taenia</u> Fabr.			
	British Museum	Njala, Sierra Leone	19.11.1930
	" "	Mando "	25. 5.1925
	" "	Tinana, "	23. 7.1924
	" "	Gold Coast	20.10.1943
	National Nairobi	Kampala, Uganda	12.1920
<u>N. dorsalis</u> Jac.			
	British Museum	Madagascar	16-17. 9.1958
	(Muir, 1931)	Njala, Sierra Leone	17. 9.1927
	Tananarive Museum	Madagascar	Unknown
<u>N. nitida</u> Muir			
Holotype	British Museum	Yingo, Uganda	26. 3.1916

TABLE 1. (Continued)

5.

Species	Collection	Locality	Date collected
<u>N. nitida</u> Muir	(Muir, 1931)	Kampala, Uganda	16. 7.1926
<u>N. canopus</u>	Transvaal Museum	Kruger Nat. Park, South Africa.	1952
<u>N. aethiopica</u>	Cape Town Museum	South West Africa	10.195?
<u>Numicia</u> (spec. indet.)	National, Bulawayo	Nuanetsi, Rhodesia	Nil
	" "	Marromen, Mocambique	21. 5.1969
	National, Pretoria	Kaapmuiden South Africa	9. 5.1968
	" "	Schoemans Kloof S.A.	7. 5.1968
	" "	St. Lucia "	21. 1.1968
	" "	Kruger Nat. Park "	20. 5.1969
	" "	Pt. St. Johns "	19. 3.1969
	" "	Pt. Edward "	22. 3.1969
	S.I.R.I. Mauritius	Madagascar (on sugarcane)	10.1954



Plate 2.

Sugarcane leaves, showing progressive symptoms resulting from numicia feeding.

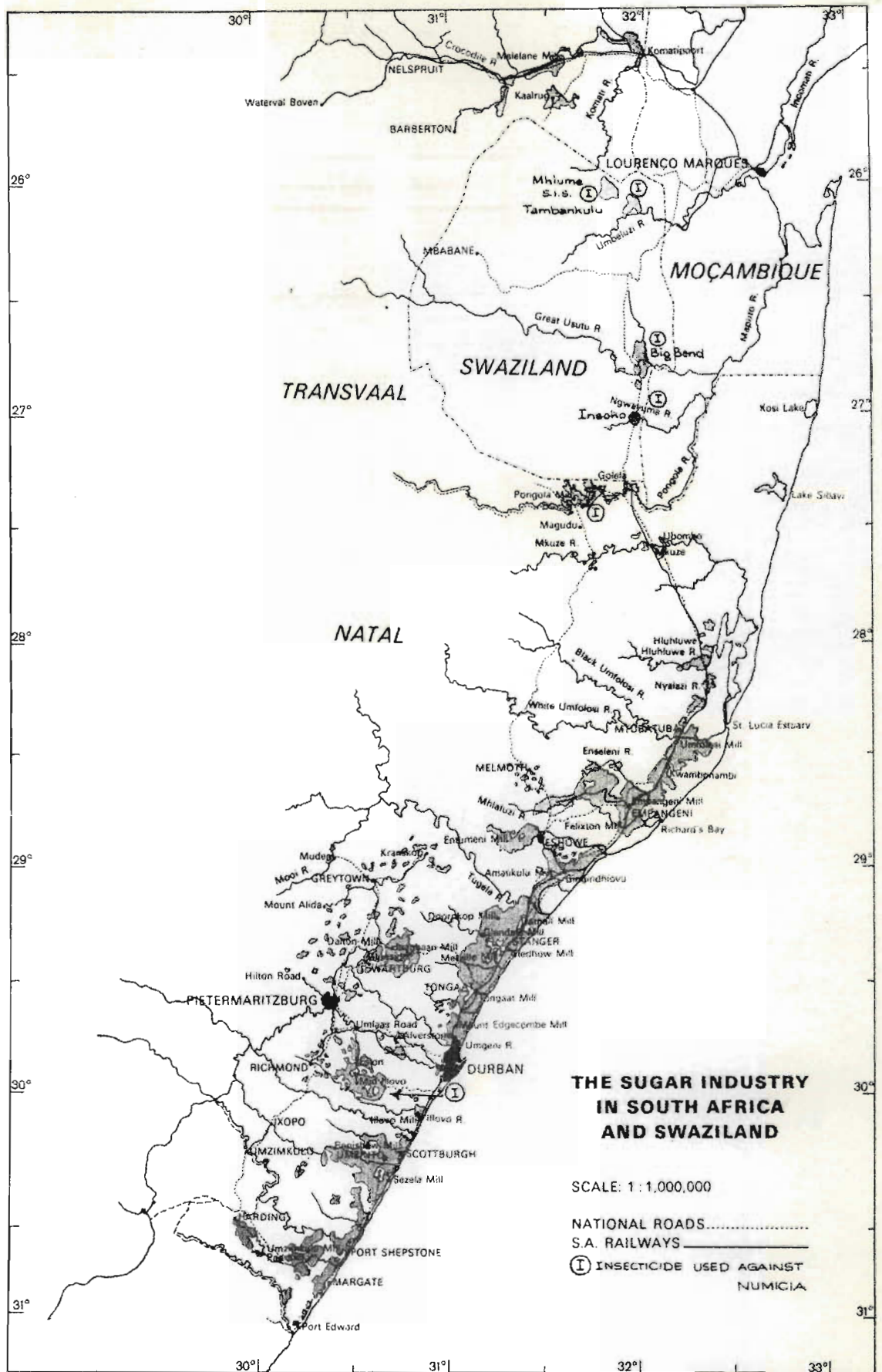


Fig. 1

Sugarcane areas of S. Africa and Swaziland.

Most areas in which numicia occurred in large numbers were 300 km or more from the Mount Edgecombe Experiment Station. From 1964 until 1968, the years during which some of the heaviest infestations occurred, these areas were visited regularly at approximately monthly intervals; and in 1966 a period of three months was spent on a Swaziland sugar estate (Carnegie, 1967a). It was during these periods that most field observations were made and field experiments initiated, checked and supervised; and it was from these areas that numicia material was returned to Mount Edgecombe for further study. Other field work was done nearer home, on the Natal coast, but in these areas large infestations were rarely available.

In 1967 a good insectary was built at Mount Edgecombe, where more detailed investigations were made. The account given in the following chapters covers the period from shortly before the writer's appointment in 1964 until 1970, when the problem was no longer considered to be important and the project was shelved.

1.2 History

Originally an indigenous harmless insect, it was many years after its scientific description that numicia first attracted the attention of agriculturists, who were to associate its presence with poor cane growth.

It was first described (Muir, 1931) from three males and eight females collected in Pondoland and Natal. They were collected at Port St. Johns by R.E. Turner in 1923, and by H.P. Thomasset at Weenen in 1924. Host plants are not mentioned, but sugarcane was not grown in those areas, and it is likely that they were taken on grasses.

No further mention of the species was made until it became associated with damage to sugarcane (Dick, 1963). It was first recognised as a pest of sugarcane in 1962 as a result of damage to the variety NCo 310 at Tambankulu Estate in northern Swaziland (Fig. 1).

This four year old estate was a model of its kind, being situated in good soil and enjoying a scientifically-designed and efficiently-operated system of overhead irrigation, channelled in ample supply from the Komati river. Generous fertilizer application resulted in exceptionally good cane growth.

Towards the end of 1961, rather more than four years after cane was first planted in the area, it was noticed that in some fields the crop was beginning to suffer from a malady, the cause of which was not immediately apparent. A number of factors were investigated, including soil and fertilizer, trace elements, water supply and drainage, and the possible occurrence of diseases. By July the following year, when cane over a considerable part of the 400-hectare plantation had become affected, insects were present in such large numbers that their connection with the malady became apparent.

Specimens were collected and submitted to the South African Division of Entomology, who had them identified by Dr. H. Synave, an authority in Brussels as Numicia viridis Muir.

How long numicia had been present in cane fields is impossible to say. Possibly the occasional yellowing of cane had sometimes been due not only to a trace element deficiency, or natural ageing, but also to the undetected presence of numicia. Possibly it had moved from indigenous grasses on to cane, and been present in low numbers for many years. Had it been present in anything but low numbers it is unlikely that it would have remained undetected, for the Experiment Station at Mount Edgecombe had been in existence since 1926, and officers from it (including, since 1940, an entomologist) had made regular visits to the various sugarcane-growing areas. These visits included field experimentation and other insect problems, and routine disease inspections.

Until comparatively recently sugarcane was not grown in the areas now regarded as most susceptible to numicia damage; and since 1962 when numicia assumed pest status, the only coastal area to be badly affected was Illovo, and that outbreak was short-lived. It is possible then that numicia existed at a low population level in the cane belt, and remained undetected for many years before 1962, and that it was not until an artificial environment, in the form of irrigated cane was created, that populations increased to a level where damage was caused.

Following the episode at Tambankulu estates in 1962, numicia was collected in small numbers throughout the cane belt, and at Pongola and Illovo it occurred in sufficiently large numbers to warrant insecticidal treatment. At Illovo in March, 1964 rather more than 40 hectares were treated with insecticide, and certain heavily-infested fields were burned and harvested prematurely.

Approached by the Pongola Mill Group Board, the S. African Sugar Association agreed to participate in a campaign which was regarded as a large scale experiment in insecticide use against numicia (5.2). At the same time the Department of Lands undertook to finance the treatment of State-owned grasslands surrounding cane fields of the Pongola Settlement. Thus encouraged, the Pongola growers, almost unanimously, decided on an insecticide campaign in which the whole area would be treated as a single unit. By mid-March 1964 the first aerial application of insecticide dust to the entire Pongola sugar growing area was completed. The 7000 hectare area included roadsides, grazing land, "dongas" and other non-cane-producing sites within farm boundaries. In addition, 2000 hectares of grassland outside farm boundaries were similarly treated by the Department of Lands.

During these operations considerable knowledge was gained concerning the merits of various insecticides and formulations, and it was found necessary in some instances to treat twice with insecticide (see Chapter 5).

By 1964 numicia was widespread on Swaziland sugar estates, some of which started regular population assessments to enable them to anticipate any serious outbreak.

Towards the end of 1963, numbers on several Swaziland estates became very high, and the cane suffered visibly. At Tambankulu 132 hectares were treated. At another badly affected estate no insecticidal action was taken, and the infestation disappeared.

In late March and early April 1964 at Pongola a further 3600 hectares of sugarcane and 82 hectares of grassland were treated.

By this time considerable knowledge of the insect and of its susceptibility to insecticide had been gained. The fear of financial ruination had dwindled, and the ability to counter any sudden emergency was appreciated. Attention was then directed to more fundamental aspects of the problem, and the S. African Sugar Association Experiment Station decided to appoint a second entomologist, whose immediate priority commitment would be to investigate, on an agronomic basis, the numicia problem.

Since 1964 numicia numbers in the Natal cane belt have remained relatively low. Small outbreaks occurred at Umzinto in 1965 and at Paddock in 1966, but no insecticidal treatment was necessary. At Pongola, populations were occasionally high, but no further large scale insecticide campaign was conducted. On certain Swaziland estates numbers continued to be periodically high, but insecticide was used only occasionally.

With the intensification of sugar production in the eastern Transvaal, numicia made its appearance, reaching high numbers in the Komatipoort area in April 1969, and in the Kaalrug area in February 1971. However, no insecticidal measures were taken, and subsequent populations have remained low.

At the time of writing the numicia situation is "quiet".

1.3 The problem

A considerable number of insect species attack sugarcane in South Africa, but fortunately relatively few of them assume the status of a serious pest. It has been said that, when compared with other sugarcane-producing countries, we are fortunate in this respect. This is true, especially when we compare our situation with that of certain more tropical countries, and it is probably due partly to our relatively cold winter. A policy of restricted insecticide use may also have helped to prevent the assumption of pest status by normally harmless insects, and strict quarantine regulations must have restricted the introduction of exotic species.

It is interesting that the usual types of crop spoilers, i.e. leaf eaters, sap suckers, borers, soil insects and secondary insects are all found in our cane fields, but most of them maintain a low population level. Included among these are some species which are actually regarded as serious pests in other countries, for example the borer Eldana saccharina Walk. and the scale insect Aulacaspis madiunensis (Zehnt.).

Our sugarcane pests include both indigenous and introduced insect species, although at present our most serious ones are all indigenous (Carnegie, 1971a).

It was the odd appearance of certain Swaziland cane fields which first drew attention to the numicia problem. The growing cane took on a yellow colouration which was too marked and widespread to be dismissed simply as "winter yellows" (which is a mild leaf yellowing which may accompany the onset of winter). Closer inspection showed that trash was unusually heavy, and that the stem texture of badly damaged plants was also affected. A number of specialists in various disciplines were consulted, before a pathologist among them noticed the presence of small light green insects, which immediately became suspect.

The onset of symptoms has been observed in the insectary (Table 2). During life history studies (Chapter 2) when daily observations of the type 3 cultures were made, notes were made regarding the state of leaves on which numicia were feeding, attention being given to the onset and progress of symptoms. In the cultures included in Table 2 only leaves on which numicia fed became affected, the other leaves on the same plant continuing to grow vigorously. Indeed, when a leaf became too dry to support numicia within the cage it was replaced with a fresh leaf from the same plant. In considering a particular affected leaf, the other leaves on the plant could be used as a standard of comparison. It was found that rate of production of leaf symptoms was not influenced by actual numbers of numicia feeding on it, nor by the stage of development of the insect. The presence of a few nymphs might produce symptoms within a matter of days (culture No. 5), while in an adjacent culture a colony of both nymphs and adults might take a matter of months to produce any discolouration (culture No. 2). There was great variation, with an average period of 42 days. Once symptoms were visible, the subsequent deterioration of the leaf was usually rapid.

The leaf is the first tissue to be visibly affected. Distal to the feeding insect it takes on a yellow discolouration, which gradually spreads towards the leaf tip. Initially only the lamina on the side of the midrib which supports the feeding insect may be affected; but eventually a general yellowing of the leaf occurs, and spreads down towards the leaf base. Following the yellowing, the leaf takes on a parchment-like texture, dry but not brittle at first, but eventually becoming dry and producing premature trash (Plate 2). Less frequently and at a more advanced stage, the quality of the stalk is affected, becoming flaccid and pliable and losing its usual brittle quality. This results in a general drooping of the entire plant, so that in a badly affected field plants appear yellow and wilting and are over-endowed with trash, which appears heavier in some varieties than in others.

TABLE 2. Onset of leaf symptoms in insectary cultures

13.

Culture No.	Numicia Nos		Date feeding started	Date symptoms noticed	No. of days after culture started	Notes made
	Nymphs	Adults				
1		2	17.4			
	2		30.5	21.6	65	7.7 leaf dry
1a		1	8.7	(nil at 4.8)		
2		2	17.4			
	1	2	27.5	27.5	40	3.6 intensifying
	7	2	n/r			16.6 leaf dry on one side
	9	1	"			19.6 leaf dry
2a	5	1	19.6			
	12	0	n/r	17.8	59	21.9 yellow with dry streak
3	1		5.6	24.7	49	28.7 drying leaf replaced
3a	1		10.8	9.9	30	
4		2	22.4	25.5	33	27.5 symptoms severe
5	1		31.3			12.6 leaf dry
	3		6.5			
	6		4.6			24.7 leaf entirely yellow
	7		13.6			28.7 leaf drying
	8		16.6	20.7	111	28.8 leaf dry
5a	3		29.7	3.8	5	
5b	2	1	29.8	21.9	23	
6		2	22.4			
	2	2	1.6			
	5	2	4.6			20.7 leaf partly yellow and dry
	7		n/r	17.6	56	23.7 leaf dry
7		2	22.4	27.5	35	27.5 symptoms just discernibl
						5.6 intensifying
						4.7 almost dry
						17.7 leaf dry
8		2	6.5			
	12	2	7.6			
	13	1	13.6			21.6 intensifying
	9	6	19.6	20.6	45	25.6 leaf dry

TABLE 2 (Continued)

Culture No.	Numicia Nos		Date feeding started	Date symptoms noticed	No. of days after culture started	Notes made
	Nymphs	Adults				
8a	13		25.6			
	14		7.7	29.7	34	12.8 intensifying
9		2	22.4			28.6 intensifying
		1	21.5	24.6	63	7.7 leaf dry
9a		2	25.8	21.9	27	
14		7	12.6			26.7 intensifying
	2		21.7	23.7	41	28.8 leaf dry

n/r = no record

Average 44,7 days

Once an infestation is brought under control, recovery of the plant is surprisingly rapid. Stems regain their turgidity, and new leaves are produced, with no side-branching. However, an unusually heavy mass of trash remains; for individual leaves, once they become affected, do not recover.

For any agricultural crop, losses resulting from attack by insect or other pest species are notoriously difficult to assess (Chiarappa, 1967). From severe numicia infestations a loss must occur, but it has not been accurately assessed even from insecticide trials which were planned largely to this end (5.3.1). From estate records a possible loss of 1,05 tons per hectare-month has been calculated (Appendix XIIa). Also, on one occasion a heavy infestation in one field necessitated the postponment of its harvesting for four months, at which time close approximation to the originally expected yield was achieved, which could perhaps be assessed as a loss of four months growth (3.8.1).

It is to the small grower that a loss from numicia attack is important for, should it occur shortly before harvest, he might not be in a position to postpone harvest until the crop had recovered, and be forced to suffer from loss of both weight and sucrose content (the two

factors which decide rate of payment).

An investigation of the basic causes of the yellowing and subsequent symptoms was beyond the limits of this project, and they were never fully ascertained; but they appeared to be caused by a toxin which was injected by the feeding insect. The fact that recovery of affected cane occurred, and that affected stalks, when planted, produced normal cane, suggested that no virus was involved. However, the fact that a definite leaf discolouration occurred, suggested that symptoms were caused by something more than a mere tapping of the sap stream.

Until intensive insectary studies were started, it was thought that numicia produced no honeydew; for even the heaviest field infestations were never accompanied by the sticky mess and subsequent sooty mould (Capnodium sp.) which accompanied infestations of aphids (Melanaphis sacchari Zehnt., Rhopalosiphum maidis (Fitch)) and the Delphacid Perkinsiella saccharicida Kirk. in the same areas. Neither were numicia colonies ever attended by ants. However, in the insectary it soon became apparent that a sticky excretion was produced in droplets by the feeding insect (Plates 1 and 8), and discharged in sufficient quantities to foul the perspex sides of culture cages. Fungus mould did eventually form on the excretion, but far less readily and extensively than it did in neighbouring cultures of P. saccharicida. Numicia honeydew is bitter to taste, although a test done on an aqueous suspension showed sugar to be present, and in insectary cultures hymenopterous egg parasites fed on it.

All varieties of locally grown cane were affected (3.10) but some varieties suffered less visibly than others, and it is not possible to state a threshold of tolerance in terms of actual numbers on the plant. It became customary to assess populations by sampling for numbers per ten square metres (3.2.2). It was found that well grown cane, particularly of certain varieties, could withstand populations of 500 or more per ten square metres for a matter of several weeks without visible deterioration.

In advising growers and extension officers, it was recommended that where less than 100 numicia per 10 square metres were recorded, the sampling should be repeated at monthly intervals. When numbers recorded ranged from 100 to 500, intensification of sampling was recommended. Figures from 500 to 1000 justified even more frequent sampling, with consideration being given to early harvesting or treatment with insecticide. Where 1000 or more numicia were recorded, it was recommended that the Experiment Station be consulted, so that each case could be assessed separately, with full consideration being given to stage of life cycle, time of year, crop age and any other prevailing circumstances which might influence the efficiency of insecticidal action. It was found that careful timing was essential for successful insecticidal control, the eggs being protected by leaf tissue, and therefore unaffected by non-persistent chemicals.

Both large and small numicia populations were recorded in cane of all ages, but there was a tendency for cane of seven months and more to be more heavily infested (3.7.1.6).

Numicia occurs throughout the cane-growing areas of South Africa and Swaziland, and in recent years has been recorded in Mocambique as well, although not in epidemic proportions. However, during visits to cane-growing areas of Rhodesia, Malawi, Kenya, Tanzania and Uganda no signs of the insect nor symptoms of its damage were noted; neither has it been recorded from Zambia. Figure 1 shows a map of the cane-growing areas of S. Africa and Swaziland. Numicia can be found in all these areas. In areas marked I on the map, populations have at some time between 1964 and the time of writing been sufficiently high to warrant treatment with insecticide. Generally speaking, it has been restricted as a pest to the northern, inland irrigated areas i.e. Pongola, Swaziland and the eastern Transvaal. These areas are of comparatively recent development, and they all enjoy a relatively mild dry winter, during which time

The cultivation in these areas of irrigated sugarcane has provided an artificial environment of perpetually lush vegetation. When the planted crop is harvested (after approximately 16 months) the cane sticks are removed, and the subterranean parts allowed to regenerate (or "ratoon") to produce up to five or six or even more successive crops. Harvesting is always staggered, the cutting season lasting from about April until December, and there is therefore never a time when all fields are barren. This enables numicia to survive the dry winter in very much greater numbers than it would do if it had to depend for survival on the restricted environment provided by river banks and other small areas of green winter grasses.

1.3.1 Annual survey

During the years 1964 to 1968, when numicia was troublesome and was considered to be a potential threat to the industry, an annual numicia survey was conducted (Dick, 1967). Swaziland, where most interested estates kept a routine check anyway, was not included in these surveys. Otherwise, with the assistance of company agronomists and the plant inspection service of the Experiment Station, a survey of the entire S. African cane belt was made, the objectives being to note any tendency to build up to threatening numbers in any area, and to detect any association between numicia numbers and locality, cane age, cultural practices etc.

In each selected site five square metres were sampled (in the manner described in 3.2.2/c, except that non-adhesive plastic sheets were used). Numicia counts, together with records of locality, irrigation, variety, crop and cane age were made.

There were enormous discrepancies between the large numbers found in the northern areas and those found further south, (where counts exceeding 50 individuals per 10 square metres were rare). Therefore, for the purposes of the annual survey, it was decided to use, as a standard for comparison, the percentage of positive sites, in preference to the

actual numbers of individuals; (Tables 3 and 4).

TABLE 3 Numicia populations from annual surveys of all areas.

Year	Over 5 per m ²		Up to 5 per m ²		None found	
	Sites	%	Sites	%	Sites	%
1964	86	11,0	425	54,1	274	34,9
1965	36	5,5	294	45,0	324	49,5
1966	28	5,4	266	51,6	222	43,0
1967	14	2,7	278	53,9	224	43,4
1968	14	2,4	341	57,5	238	40,1

TABLE 4 Numicia incidence by regions (% sites in which numicia occurred)

Region	1964	1965	1966	1967	1968
Eastern Transvaal	-	-	8	80	66
Pongola	.97	100	97	90	69
Zululand	70	46	37	49	59
North Coast Natal	66	65	74	69	80
Midlands	3	4	38	46	28
South Coast	65	71	64	40	50

It can be seen that throughout the period 1964-1968 numicia was common to all areas, but that during the latter years numbers tended to fall - especially at Pongola. The most recently developed area was the eastern Transvaal, which was not included in the survey before 1966, because it was only after that that commercial cane production began. (These surveys receive further mention in 3.3 and 3.10.5).

1.3.2 A comparison with West Indian cane fly, Saccharosydne saccharivora

As a problem of sugarcane, numicia is, in many ways, reminiscent of the West Indian cane fly, Saccharosydne saccharivora (Westw.) (Delphacidae). Throughout this investigation striking similarities and differences between the bionomics of these two Fulgoroids were encountered, and it is considered timely therefore briefly to mention cane fly.

It exists in cane in egg nymph and adult stages (Guagliumi, 1962; Metcalfe, 1971), and damage is done by nymphs and adults which tap the sap stream, and may cause losses estimated at 11 metric tons cane per hectare. Eggs are laid in leaf midribs, and in general appearance all stages bear a certain resemblance to numicia. Type of damage caused is rather different and the insect becomes conspicuous not through leaf discolouration, but as a result of the large quantity of honeydew produced, and the subsequent sooty mould which grows upon it. It is indigenous to, and restricted to the Central American and Caribbean areas, occurring on several wild grasses, and has been known as a sporadic pest of cane for approximately 250 years. In recent years, with more intensive cane production its importance has increased, especially in Jamaica, where it is their most important pest. Relatively large numbers are found in plant cane, in which outbreaks start, parent stock migrating there from other older cane or from grasses. One of its egg parasites, Tetrastichus sp., closely resembles an egg parasite of numicia, Ootetrastichus ?beatus Perkins, and an unsuccessful attempt was made to introduce into Jamaica the Mirid egg predator Tytthus mundulus (Bredd.), which was tried in S. Africa against numicia (4.4). Cane fly has, under epidemic conditions, a synchrony of generations (unusual in a tropical insect), but its causes are apparently different from those causing a similar synchrony in numicia generations (3.5; 3.7.1.8). Despite the presence of natural enemies, insecticidal control of cane fly has been necessary. Over the last two centuries cane fly numbers have waxed and waned, independent of any applied control measures, but the

problem remains. Numicia has been studied for less than a decade, and the present quiet situation does not justify an attitude of complacency.

CHAPTER 2

LIFE HISTORY STUDIES

2.1 Introduction

In order to plan and develop control policy it was important initially to investigate essential points of life history under field conditions, and to learn how the different stages of numicia tied in with the life of the cane crop.

A knowledge of the broader aspects of the life cycle, i.e. duration of egg, nymph and adult stages under field conditions, was obtained from the regular observations and sampling conducted in Swaziland and Natal between 1964 and 1970. These are discussed in Chapter 3. Early field studies were followed, some years later, by more detailed insectary investigations.

Under insectary conditions, early attempts to rear numicia for life cycle and general biological studies failed. It was found that eggs laid in the insectary by adults introduced from the field failed to hatch, although subsequent examination of them revealed no apparent deterioration (Anon., 1964). A further complicating factor was competition from aphids (Melanaphis sacchari), ants (Pheidole megacephala F.) and mites (Oligonychus grypus (Baker and Pritchard)).

Harris (1970), using one large cell (2m x 2m x 4m tall) of a large botanical glasshouse at Mount Edgecombe, was able to rear numicia to a second generation. The west-facing glasshouse cell was large enough to permit 8 stools of cane to be grown from setts under circumstances approaching field conditions. On to these were introduced field-collected numicia nymphs and adults, which developed and reproduced. His most striking finding was that numicia hatching from eggs introduced from the field did not survive. He concluded that in order to survive, the hatching nymph had to feed immediately on living material, within a few

millimetres of the eggs from which it hatched. Even when newly collected egg-containing leaves were placed into leaf axils on growing plants, none of the 2000-odd nymphs survived. Approximately 6000 nymphs, newly hatched from cane leaves, and collected in the glass tubes of parasite emergence boxes died, even though placed on growing cane. A further 3000-odd nymphs, similarly collected, died after being placed on leaves of Kikuyu grass (Pennisetum clandestinum) a known alternate host. Even when the exit from emergence boxes led directly on to growing leaves of cane and Kikuyu grass, the emerging nymphs (over 2000) all died.

Subsequent studies of development and life cycle (discussed below) were conducted in a new insectary, which was originally designed largely to suit the rearing of potential biological control agents (Plate 3; Fig 2). Within this building were used three different types of cage as described below:

2.2 Type 1

This was a gauzed cell, approximately 2m x 2m x 3m tall, within one room of the insectary, and was similar to that used by Harris (1970). One side of the insectary was lined with 4 such cells, which were fitted with intervening removable gauze partitions. Each cell had a door opening into the main room (Plate 4; Fig. 2).

2.3 Type 2

This consisted of a vertical transparent plastic cylinder approximately 50 cm tall and 20 cm in diameter, closed above by an organdie panel. In the cage sides there were one or two organdie covered windows to allow air circulation, and a small door through which insects could be inserted. The cylinder was placed over a young potted cane plant and rested on a base of sheet plastic in which there was a hole through which the plant grew (Plate 5).

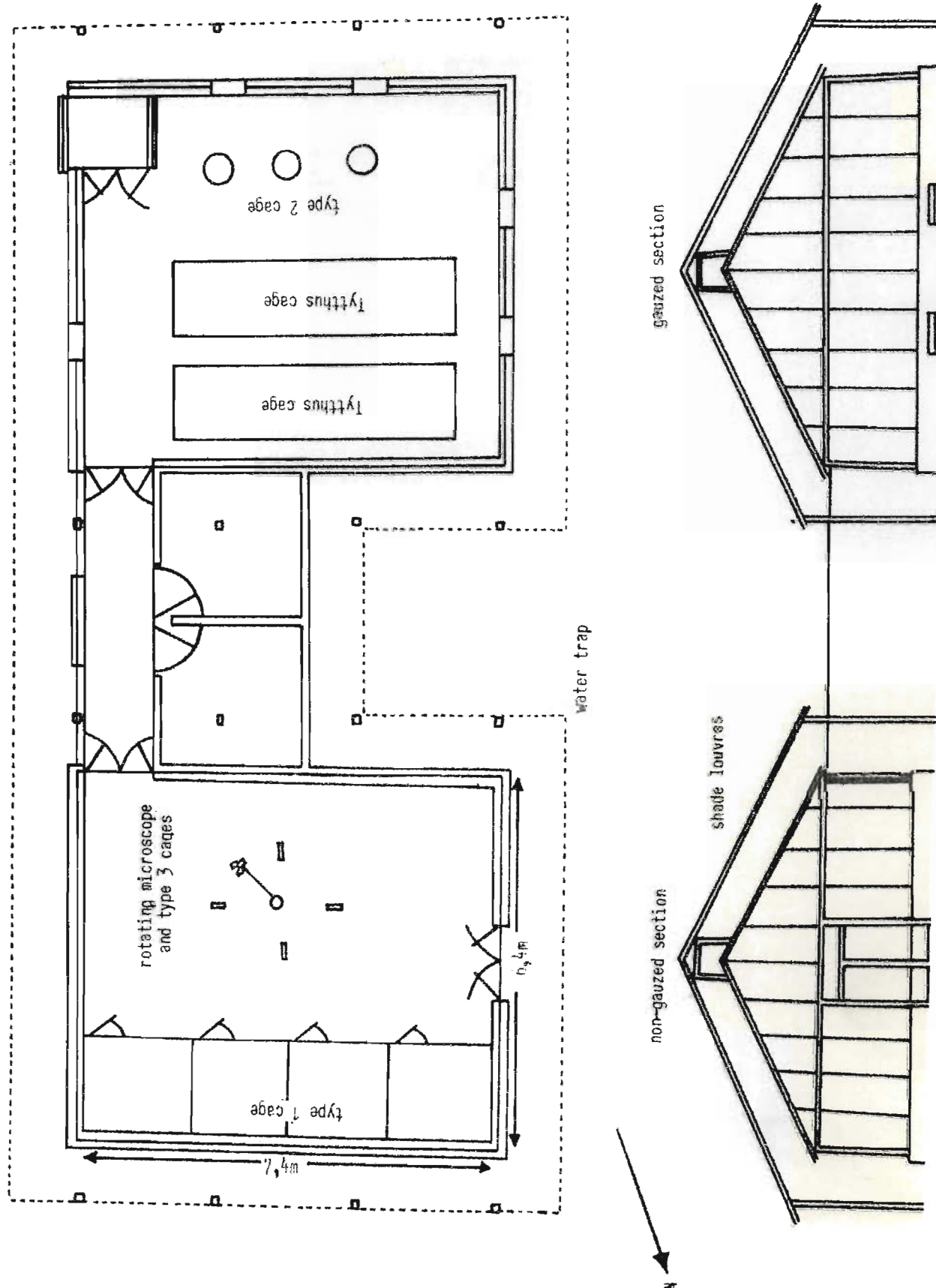


Fig. 2

Plan of the insectary at Mount Edgecombe.



Plate 3 – Insectary at Mt. Edgecombe



Plate 4 – Type 1 cage

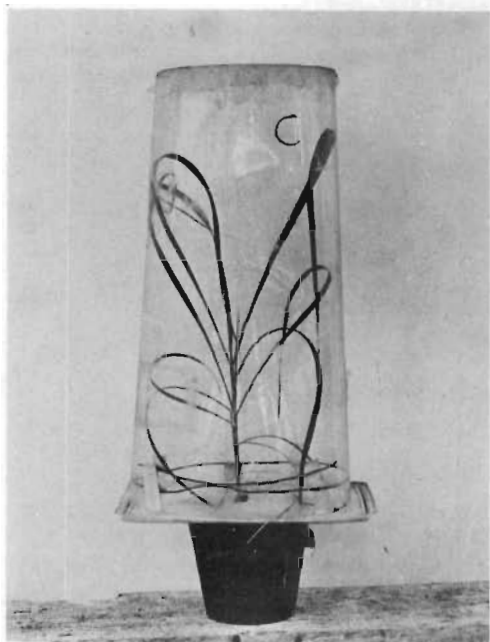


Plate 5 – Type 2 cage

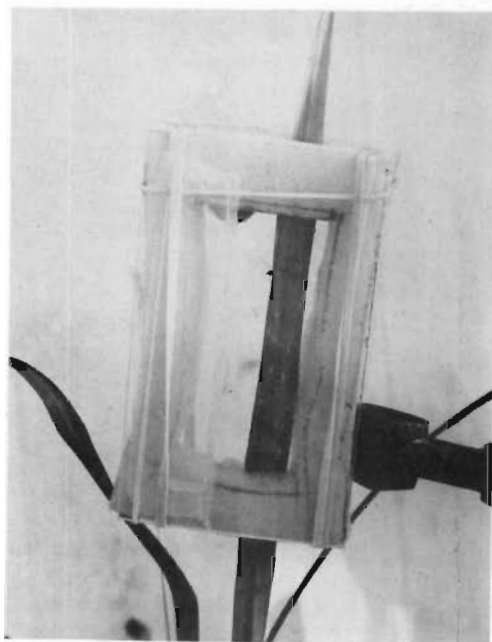


Plate 6 – Type 3 cage

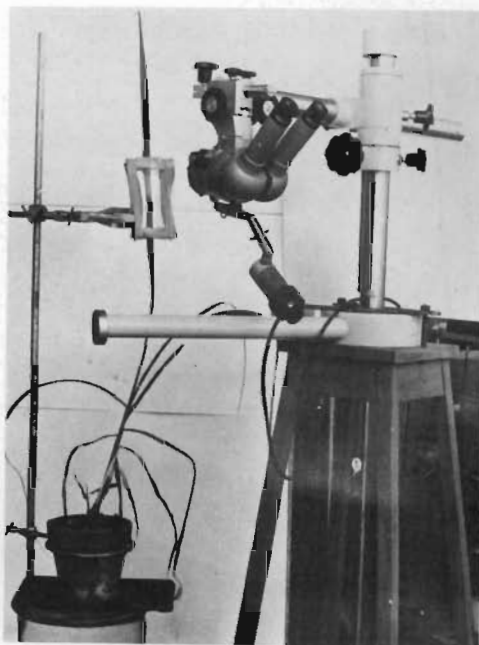


Plate 7 – Type 3 cage with microscope

2.4 Type 3

This was a modification of the cages used in Jamaica for studying cane fly (Saccharosydne saccharivora (Westw.)), (Metcalf, 1969). It was made by enclosing a growing leaf between 2 pieces of 1,5 mm gauge perspex 12,5 cm x 7,5 cm. These were kept distant from the leaf surface by two frames of 1 cm gauge plastic foam placed on each leaf surface between it and the perspex (Plate 6). This was held together by two rubber bands. In one piece of perspex a round hole was cut in such a position that the leaf surface was not obscured. This was bunged with a perforated cork, and served as a passage for inserting insects. In the other piece an organdie covered window was cut, again in such a position as to leave the leaf surface visible.

Type 3 cages were used in two positions. In one case they were used on plants (variety NCo 376) growing in one of the type 1 insectary cells, and were strung from the cell roof or side. They could be used with the leaf passing through them upwards or downwards, and their position was adjusted periodically so as not to distort the growing leaf. These were used for general observation, moulting and hatching records, effect on cane, movement etc.

For more detailed observations, four such cages were positioned in the main insectary in such a way that they could be served by a rotating binocular microscope (Plate 7). Each cage enclosed part of a leaf from a potted cane plant. Retort stands and burette clamps held the cages in position, and the clamp height could be adjusted as the plant grew. The cage could be viewed through the microscope from one side only, but, if insects were present on both leaf surfaces there was sufficient flexibility in the leaf to permit the cage to be rotated. As a result of insect feeding, leaves sometimes deteriorated and the perspex became obscured by honeydew. It was then a fairly simple exercise to replace the leaf or to clean the perspex without causing

great disturbance. In this position type 3 cages permitted detailed observations to be made and, with an eyepiece micrometer, actual body measurements could be made. With a x 10 eyepiece and a x 1 objective, 50 divisions equalled 5 mm (measured through the perspex). With this combination it was possible to make measurements to 0,05 mm. (For occasional more accurate measurements a stronger objective was used).

The microscope light included a heat filter and a heat disperser.

2.5 Developmental stages; study methods

Type 3 cages (Plates 6 and 7) were used for insectary studies of development from eggs to adult, and for behaviour of nymphs and adults. Twelve of these were placed on growing cane leaves in one of the large type 1 insectary cells. Into each cage were placed adult insects, collected either from the field or from type 2 cages in the adjacent room of the insectary. The type 3 cages were inspected at least once every day, and more frequently whenever possible, notes being made particularly at approximately 8 a.m., 12 noon and 4.30 p.m. Using diagrams of the sort illustrated in Fig. 3, records were kept of the following: position of all stages on the leaf; eclosion; ecdysis; copulation; oviposition; death; symptoms developing on the leaf.

Four other type 3 cages were positioned for microscopical examination and measurement of dimensions, (as described in 2.4). Records were kept for these as for the others; but, in addition, daily readings were made of total body length, width, and length of caudal filaments of the occupants, from newly hatched nymph to adult.

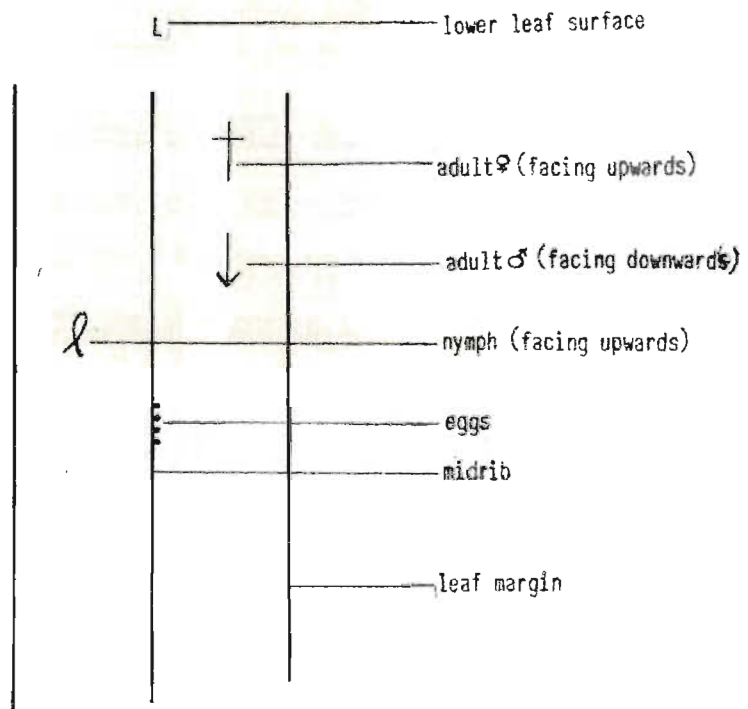


Fig. 3 Diagrammatic record of numicia positions on cane leaves in insectary cultures.

Into these four cages were placed newly hatched nymphs from other insectary cultures. These nymphs were of known age (usually less than 24 hours), and were transferred from one culture to the next by one of three methods:-

(a) One section of a 5 mm diameter pharmaceutical gelatin capsule was pierced with pointed forceps and placed over a recently hatched nymph

on a leaf. It was then moved very gently against the nymph so as to disturb it sufficiently to interrupt its feeding without damaging its mouth parts. A further slight movement caused it to move slightly and either jump into the capsule or climb up its side. The capsule was then transferred to the new cage and placed with its open end against the cane leaf. After a period, which varied from a few minutes to hours, the nymph would move on to the leaf and begin feeding.

(b) A fine-squirrel hair brush was moistened and its hairs flattened and splayed. It was then used to disturb the chosen nymph gently, and when it had moved, to secure it between the brush hairs, to which it would usually adhere sufficiently well to permit its transportation to the new culture, where it would be gently brushed off against the leaf. Access to the original culture was made between one of the plastic foam frames and the perspex, where there could be inserted a short, open-ended glass tube through which the brush could pass.

(c) A leaf with hatching eggs was placed next to one on which nymphs were to be established and on to which the hatching nymphs moved. Some nymphs were established by this method, but it was the least successful of the three, for reasons mentioned in 2.1.

Measurements of the nymphs' waxy caudal filaments were included because they gave an indication of the age, in that instar, of the nymph under observation. Secretion of these filaments began shortly after eclosion, and again after each moult until the adult stage was reached.

The number of cultures which could be served by the rotating microscope was limited to three fixed ones and one portable one which could be moved in and out of position at each reading. It was necessary therefore for each culture to contain several nymphs (between two in cage 10, and six in cage 12). In some cases these were actual siblings, and in others they were of such similar ages and dimensions, that identity

could become confusing. At each reading the position of each nymph on the leaf was noted diagrammatically and by description; but between readings some nymphal movement frequently occurred, either as a response to changing light intensity, outside disturbance (especially in the case of the one movable culture), or disturbance caused by other insects or mites. First instar nymphs of the aphid Melanaphis sacchari and crawlers of the mealybug Saccharicoccus sacchari and mites were all common competitors which managed to gain access to type 3 cages. The additional information provided by filament length was of great assistance in tracing back the development stages of each individual insect once the adult stage had been reached.

2.6 The egg

Eggs are inserted into the tissue of the leaf midrib of sugarcane (Plates 1, 9, 10).

The newly-laid egg is translucent and off-white in colour with a pearly appearance. It is ampullaceous in shape (Fig. 4). Measurement of 133 eggs from 15 batches showed an average length of 0,745 mm (max. 0,833; min. 0,667 mm), and an average width of 0,458 mm (max. 0,533; min. 0,367 mm). A slight concavity may be present on a portion of the longer sides. At the anterior end there is a conspicuous operculum, which protrudes from the plant tissue into which the egg is inserted, and which serves a protective function (4.3.1.2; 4.4.4.5).

As the egg matures it becomes more spherical, and yellowish-green in colour. A few days before hatching there appear towards the operculum end two dark spots, which are the eyes of the developing nymph.

In the insectary considerable differences in incubation periods were noted, even between eggs of the same batch, with an average of 30,53 days (97 hatchings). The shortest incubation period was 21 days, and the longest 129 days, with one unconfirmed record of 146 days.

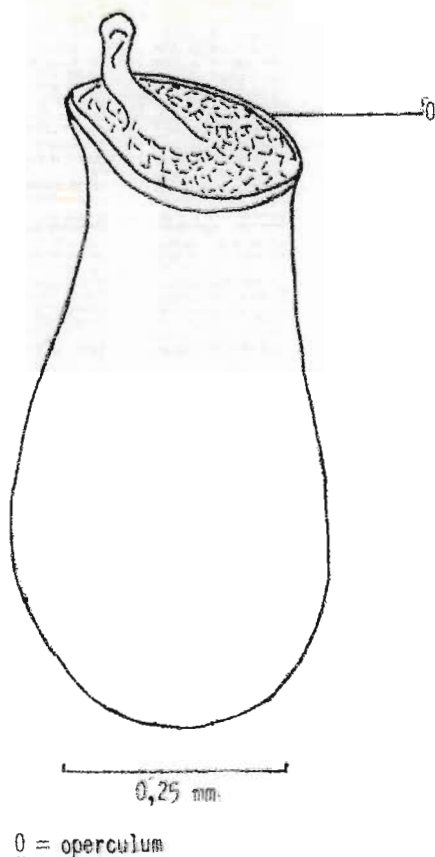


Fig. 4

Numicia egg

Within the same egg batch incubation periods of 55 days and 129 days were recorded (Appendix I). Similar long incubation periods may have given rise to the early impression that field-laid eggs did not hatch in the insectary. Such differences in incubation time were shown by eggs in adjacent cages and even in the same cages, where environmental conditions such as temperature and humidity were very similar.

Insectary records showed that most eggs hatched in the forenoon (Appendix II).

The presence of eggs causes a local discolouration of surrounding plant tissue, attributed to the presence of a secondary bacterial infection.

In cane leaves this discolouration is not apparent immediately after oviposition; but after a few days a pinkish darkening of the midrib may be seen on the upper leaf surface opposite the egg batch. This becomes progressively darker until after about four weeks a dark red or black stage is reached, and serves as an indication of the presence of eggs and of their age.

Field-collected eggs, when examined in the laboratory for investigatory or routine purposes, were divided into several categories depending on their condition (3.10.2; 4.3.1.3). One category included those unhatched eggs which had failed to survive through causes (not specifically determined) other than predation or parasitism e.g. desiccation or fungus attack. Of 15 611 eggs examined from cane, 9,4% were so classified (50 samples). Of 15 766 eggs examined from grass leaves, 16,0% were so classified (45 samples; all Ubombo Ranches, 1965).

2.7 The first instar nymph

Hatching is effected via the operculum. The "cap" of the operculum is pushed partly or entirely off by the head of the nymph forcing its way through the aperture, which is considerably narrower than the nymph (0,15 mm; mean of 21). In order to do so it wriggles in a vermiform manner. The legs are not used, but there is much body movement, with the nymph sometimes projecting out vertically from the leaf. The process may take 10 to 15 minutes to complete and the body movements resemble those performed during ecdysis (2.13).

Immediately after hatching the nymph is white in colour, with compressed abdomen, and almost transparent (Fig 5; Plate 8). It is 1,20 mm long and 0,49 mm wide (mean of 21 individuals), and the abdomen is relatively short. Normally it will begin feeding almost immediately, within 1 or 2 cm of its egg, but if it hatches into bright light or on to a dry leaf surface, it will move away in search of shade and a suitable food supply.

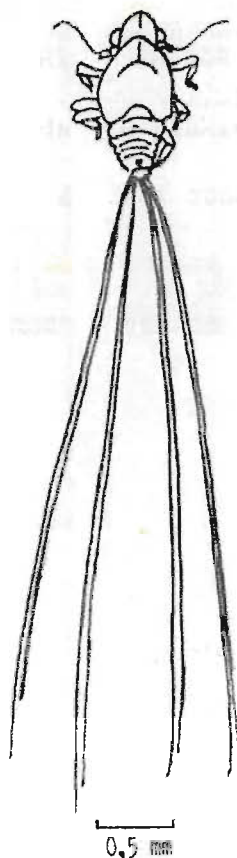


Fig. 5

First instar numicia nymph.

Within an hour of hatching, the growth of caudal waxy filaments begins, even when the nymph has not yet fed. Provided it has settled in a suitable place the nymph may remain stationary for days on end. In insectary cultures, disturbing factors causing it to move included strong light, drying of the leaf, and disturbance from other insects - including its own siblings.

As it feeds it loses its white transparent appearance, and becomes light green in colour, usually within 72 hours. The abdomen expands relatively faster than the thorax and, towards the end of the instar it has a distended appearance, i.e. as it fills it becomes less compressed.

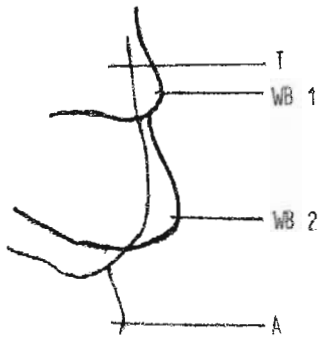


Plate 8 Numicia viridis Muir showing var. infuscata left centre. Two newly-hatched nymphs on left of midrib, and the Mirid egg predator Tytthus parviceps (Reuter) on right of midrib, with third instar numicia nymph lower right.

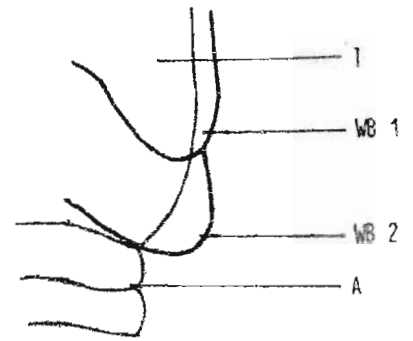
In the first instar nymph a slight lateral extension of thoracic tergites is apparent, and in later instars these become more conspicuous as wing buds (Fig 6). These extensions vary slightly with individuals, and appear exaggerated where the abdomen is small, but measurements of many individuals provided insufficient evidence for the establishment of any constant dimorphism (Appendix III).

The waxy terminal filaments are produced from four glands in the last abdominal segment (Fig. 8b). In the first instar nymph only one or two strands could be detected arising from each point, but with successive instars these increased in number. Rate of growth of caudal filaments was steady (Fig. 7), and on a first instar nymph they may reach a length of 9.0 mm. At ecdysis filaments are cast with the exuviae, and the growth of further filaments by the next instar nymph begins.

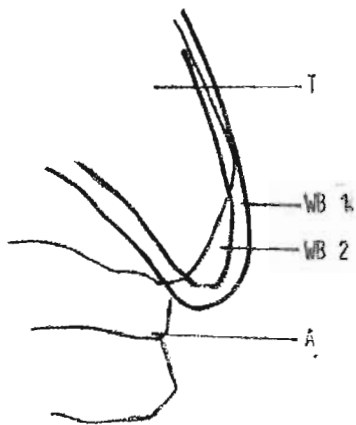
Instar 2



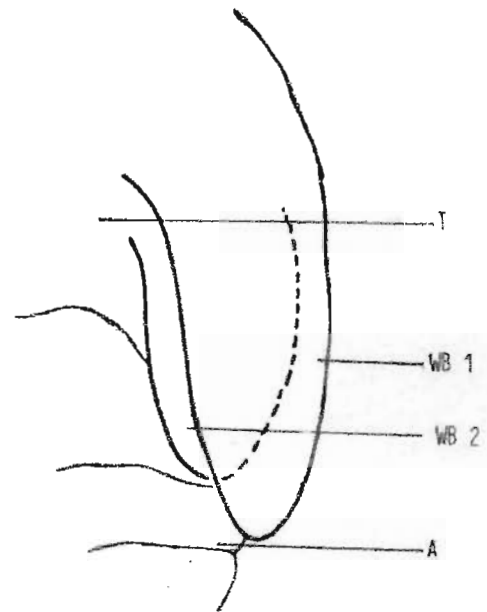
Instar 3



Instar 4



Instar 5



T = thorax
 WB 1 = bud of fore wing
 WB 2 = bud of hind wing
 A = abdomen

Fig. 6

Development of wing buds

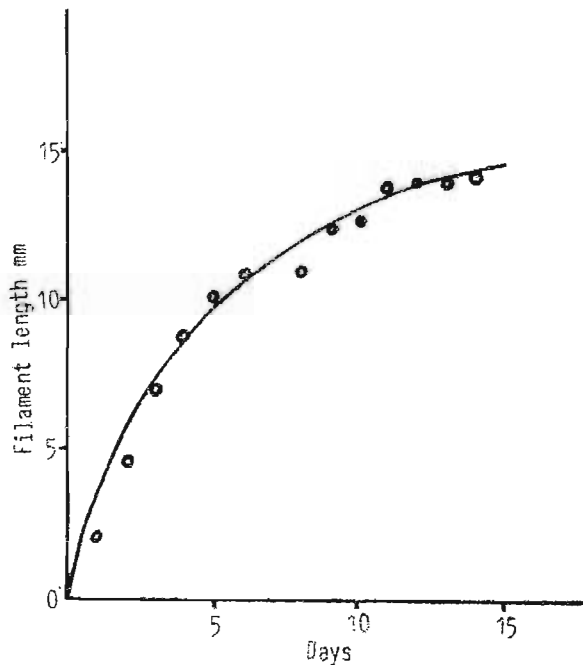


Fig. 7 Growth rate of caudal filaments of 5th instar numicia female.

The first instar nymph behaves very similarly to those of later instars, but is more strongly averse to bright light. It was found that when nymphs hatched from eggs placed in parasite emergence boxes, they moved readily into glass tubes which were facing a window, rather than remain in the darkened box. However, if they were illuminated by a microscope light shining on a leaf, they soon became agitated and moved away to the darkened side of the leaf. Even when nymphs were separated from the heat-filtered light source by glass or perspex they reacted equally quickly, and the reaction appeared to be to light rather than to heat generated by it. They reacted similarly to direct sunlight, which may partly explain why relatively large numbers are found on lower leaf surfaces (2.23).

In the insectary the first instar forms of 14 individuals studied lasted from 12 to 24 days (average of 15,9 days), and reached lengths of from 0,95 mm to 1,90 mm; and widths of from 0,50 mm to 0,60 mm. Maximum recorded filament length was 9,00 mm with an average maximum length of 8,75 mm (16 specimens).

2.8 The second instar nymph

The newly moulted nymph settles and begins feeding usually within a few millimetres of its cast exuviae. In appearance and behaviour it is little different from the first instar form (Fig. 5; Plate 8). During this instar individuals varied in length from 1,30 mm to 2,30 mm, and in width from 0,50 mm to 0,85 mm; and the completion of this instar took from 11 to 23 days (average of 15,3 days). Maximum recorded filament length was 12,00 mm, with a mean maximum of 9,50 mm (16 specimens). Up to four filaments per sheath were recorded.

2.9 The third instar nymph

During this instar (Plates 1 & 8), individuals measured varied in length from 1,95 mm to 3,20 mm, and in width from 0,60 mm to 1,10 mm. The instar took from 10 to 21 days to complete (average of 14,5 days). Maximum recorded filament length was 11,50 mm, with a mean maximum of 10,33 mm (16 specimens). Up to 5 filaments per sheath were recorded.

2.10 The fourth instar nymph

During the fourth instar, individuals measured varied in length from 2,30 to 4,20 mm, and in width from 0,80 to 1,80 mm. Completion of the instar took from 12 to 24 days (average of 15,3 days), and maximum recorded filament length was 13,00 mm, with a mean maximum of 10,85 mm (16 specimens). Up to 10 filaments per sheath were recorded.

It is during this instar that the larger size of females becomes apparent (Fig. 9), and wing buds become conspicuous.

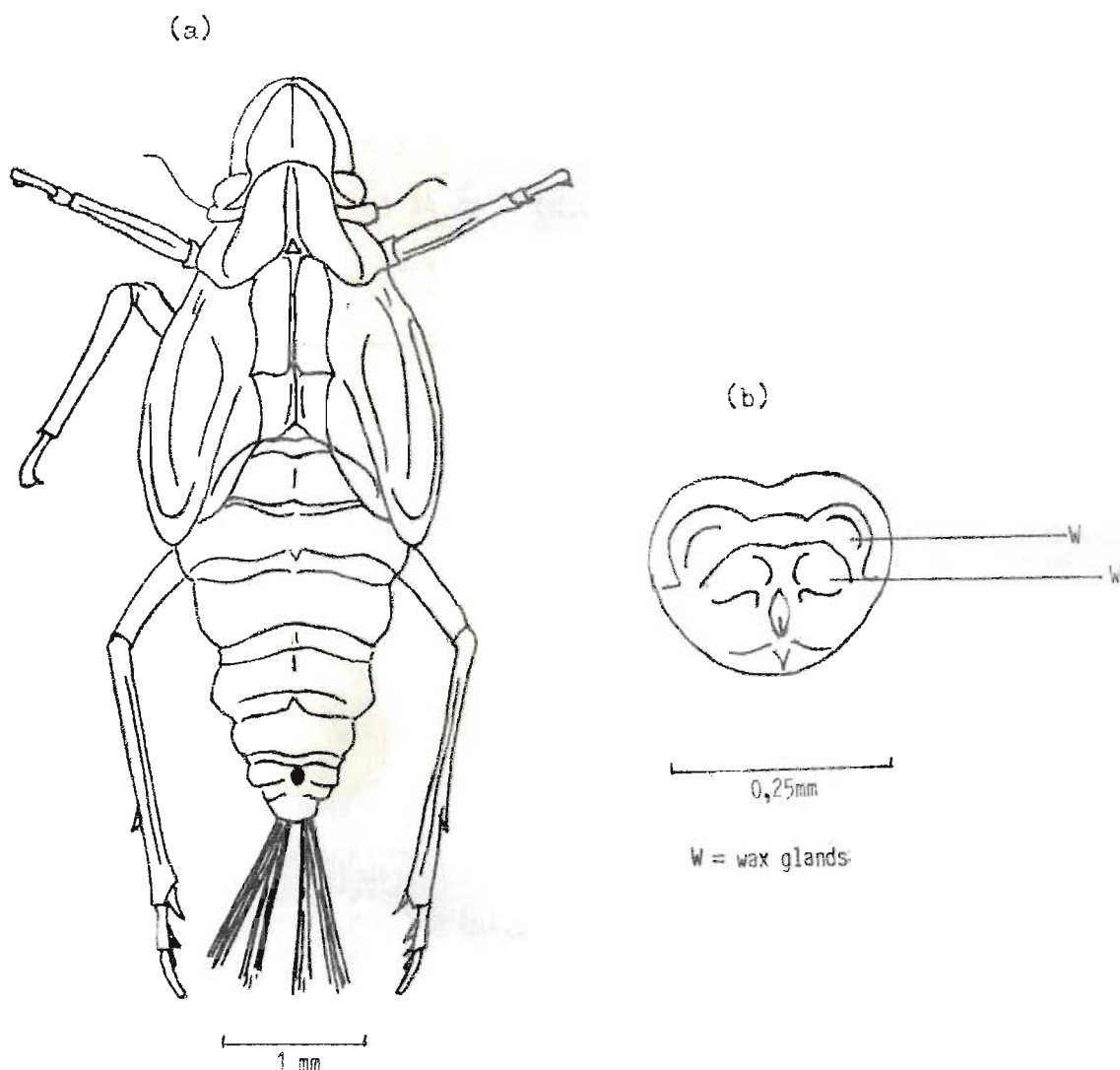


Fig. 8 (a) Fifth instar numicia nymph

(b) Last abdominal segment showing origins of waxy filaments.

2.11 The fifth (final) instar nymph (Fig. 8a; Plate 1)

During this instar there is a marked difference in corresponding dimensions of males and females, the female being larger (Fig. 10).

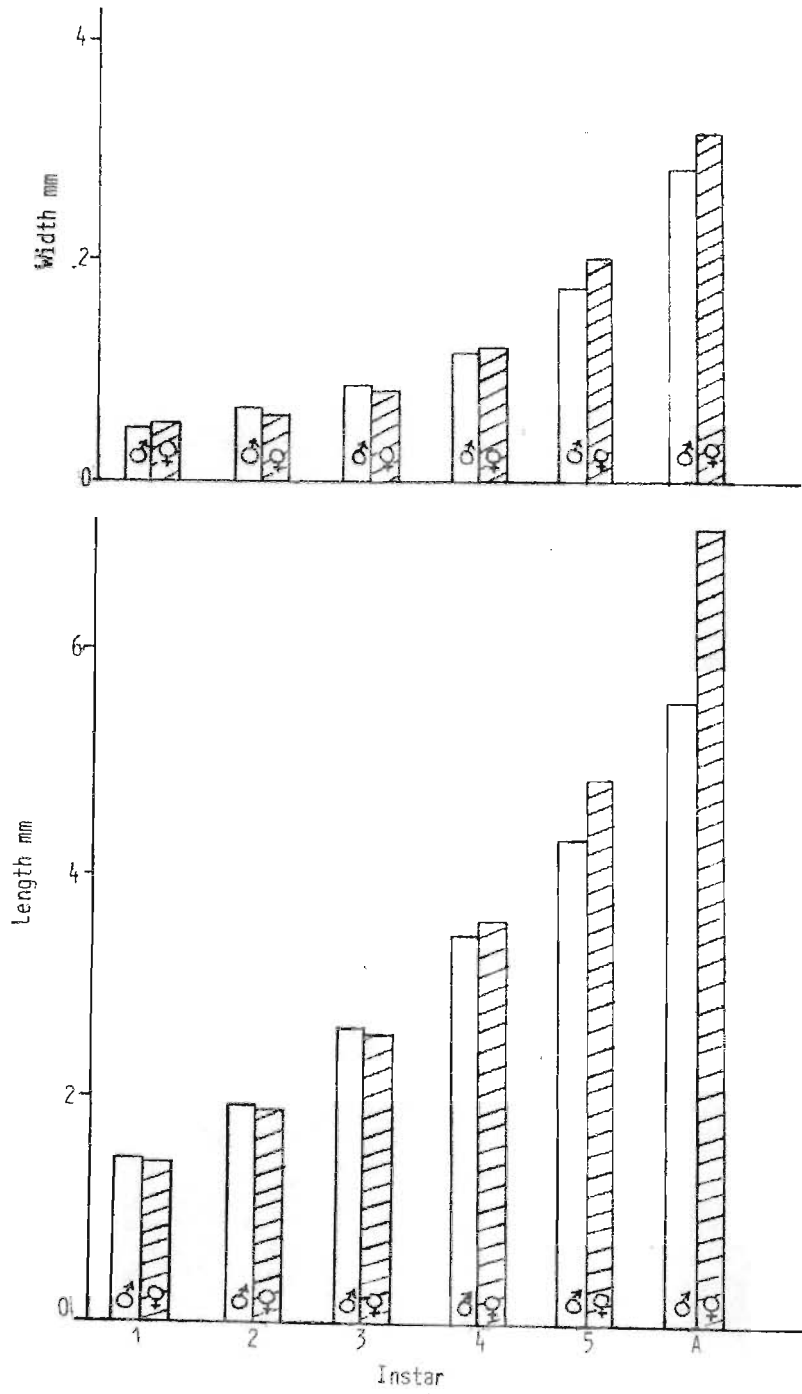
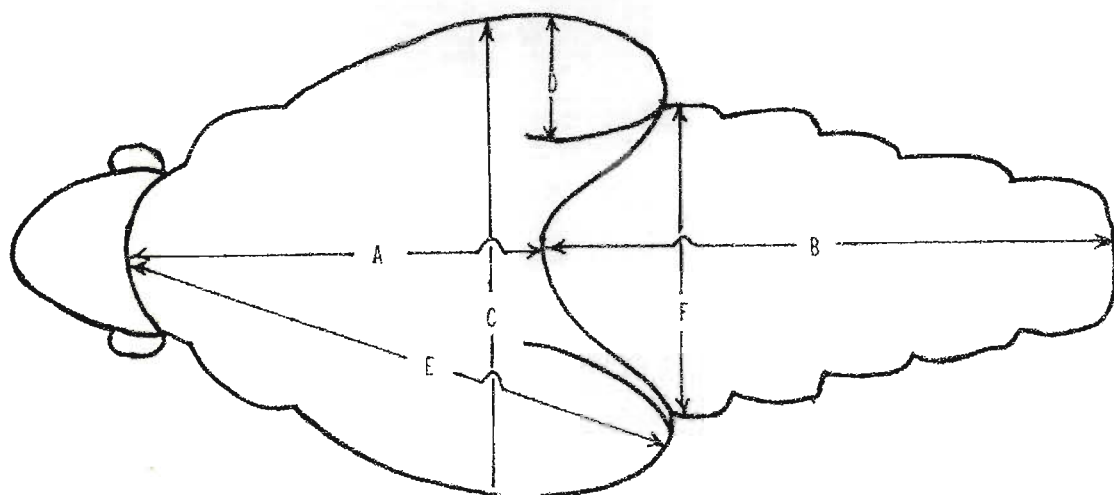


Fig. 9 Body length and width of different instars (excluding caudal filaments).

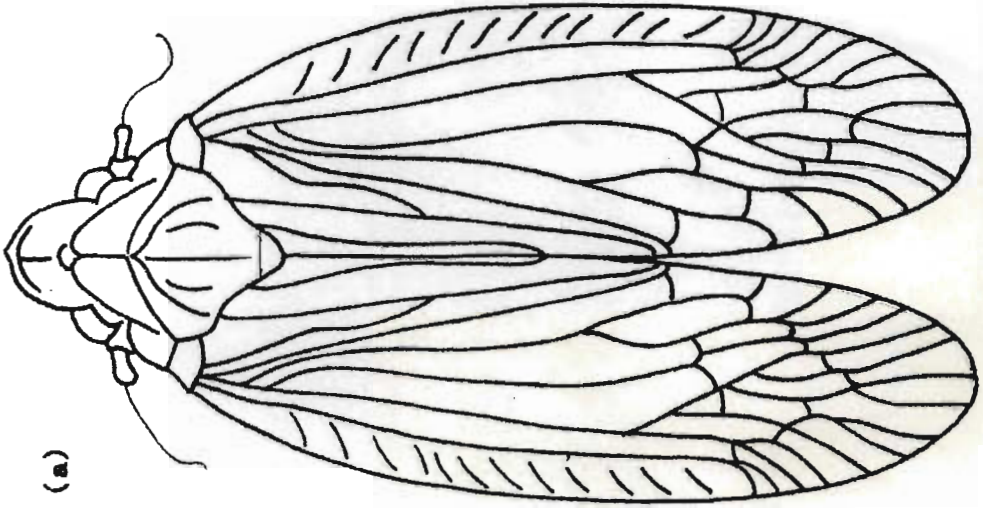


Measurement	Female mm	Male mm
A	1,6	1,4
B	2,8	2,5
C	2,1	1,8
D	0,4	0,3
E	2,5	2,1
F	1,5	1,3

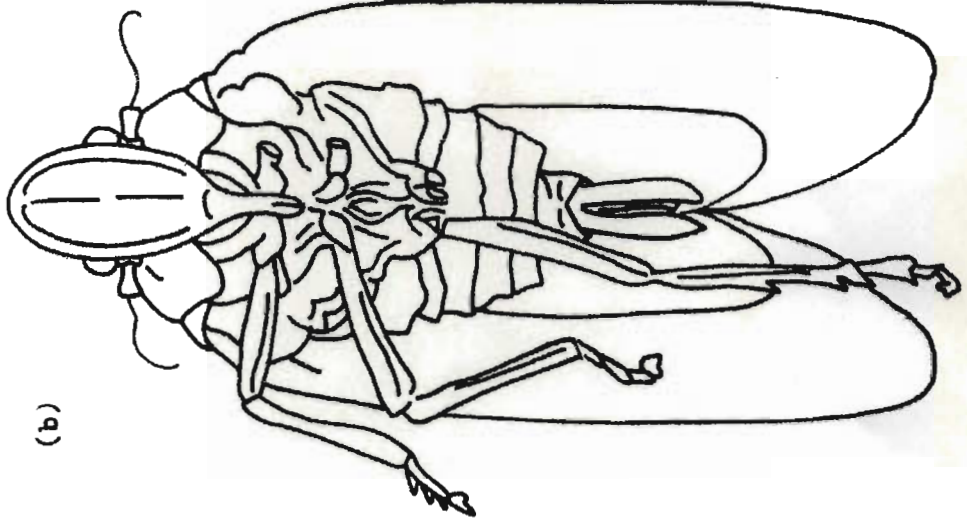
Fig. 10. Comparative dimensions of 5th instar male and female numicia.

Wing buds are conspicuously enlarged (Fig. 6). Males of this instar measured from 3,60 mm to 4,95 mm long, and from 1,20 mm to 2,10 mm wide, and the instar lasted from 12 to 21 days, (average of 16,5 days). Females measured from 3,90 mm to 5,65 mm long, and from 1,50 mm to 2,35 mm wide, and the instar lasted for 15 to 20 days (average of 15,9 days). Maximum filament length recorded was 15,00 mm, and there were up to 10 strands per sheath.

Before ecdysis to the adult stage (Fig. 11), nymphs of this instar become particularly distended, with the abdomen stretched to such an extent that the intersegmental indentations almost disappear.



(a)



(b)

2.12 Nymphal development and behaviour; general discussion

Before discussing transformation to the adult stage, various points which apply to the nymphal stage as a whole, may be mentioned.

In 1966, during a 3-month period spent on a Swaziland sugar estate (Carnegie, 1967a) attempts were made to observe nymphs in the field, and to make notes on their behaviour, but little was achieved. It was obvious that they favoured the lower leaf surfaces, which made observation difficult and inconvenient with light conditions unsatisfactory; and (not unexpectedly) it soon became apparent that once they had hatched, they did very little but feed. If they were suddenly disturbed, they hopped from the leaf, often falling to the ground, from which they made their way, by hopping, back on to the cane.

Subsequently at Mount Edgecombe, in 1969, a type 1 culture was established in the insectary, and daily observations were made of individual nymphs and adults on certain tagged leaves. Once again the most striking thing was the general lack of activity; but it was noted that the lower leaf surface was preferred, especially by the nymphs, and that they tended to face upwards.

In January 1970, type 2 cages were established, and further observations made; but these drew attention to the fact that a more restricted sphere of activity was desirable for acquiring any quantitative information, and in April 1970, type 3 cages were established on growing cane. The following notes are based on observations made on numicia in 12 type 3 cages which were placed on growing cane in a type 1 cage, and reared from egg to adult; and on four type 3 cages on growing potted plants in the open insectary (2.4). In the course of these observations certain nymphs died or disappeared, and one was in its third instar when measurements started. These incomplete records are not included in Fig. 12.

Fig. 12 Growth curves for four male and ten female numicia reared in the insectary.

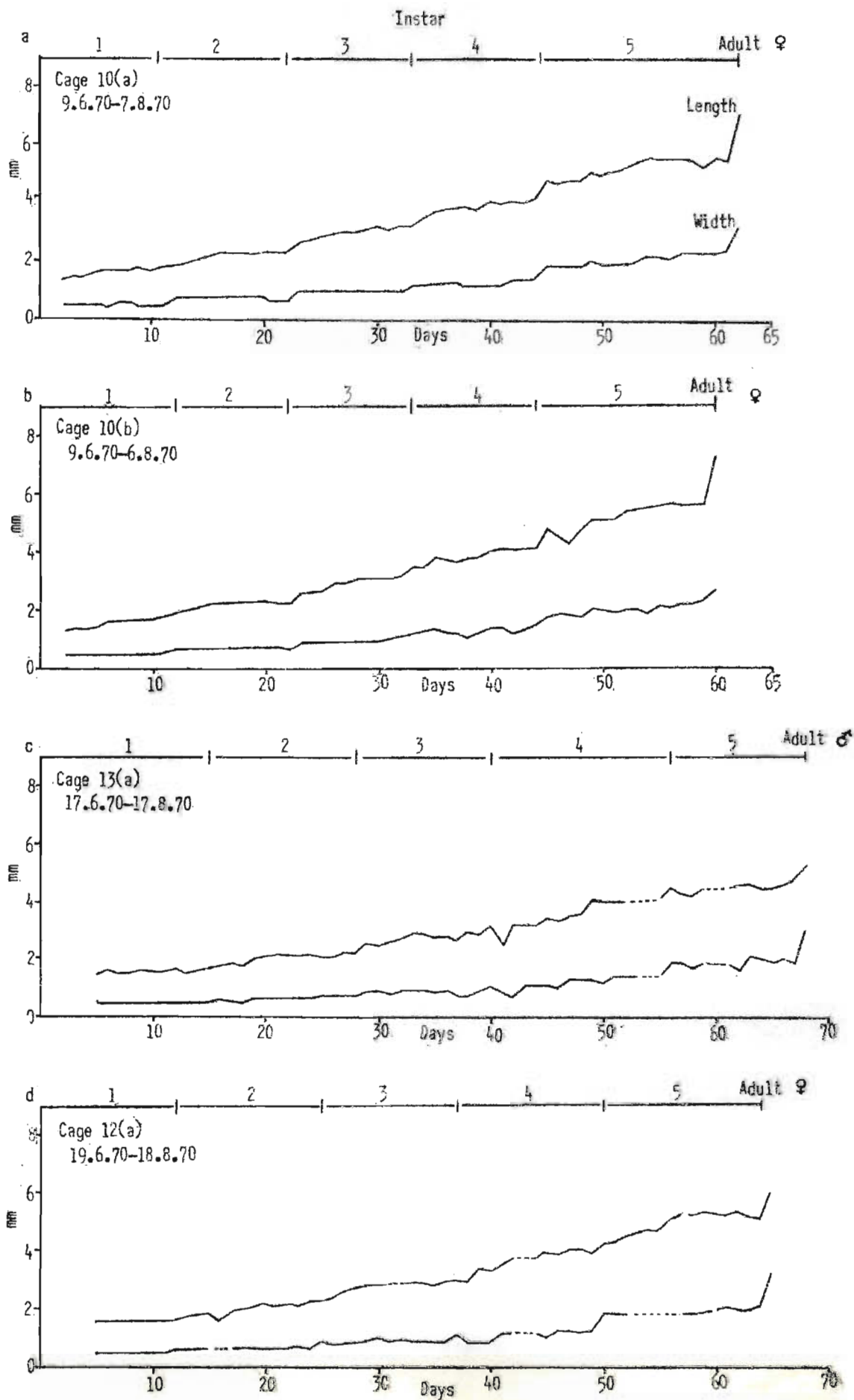


Fig. 12 (Continued)

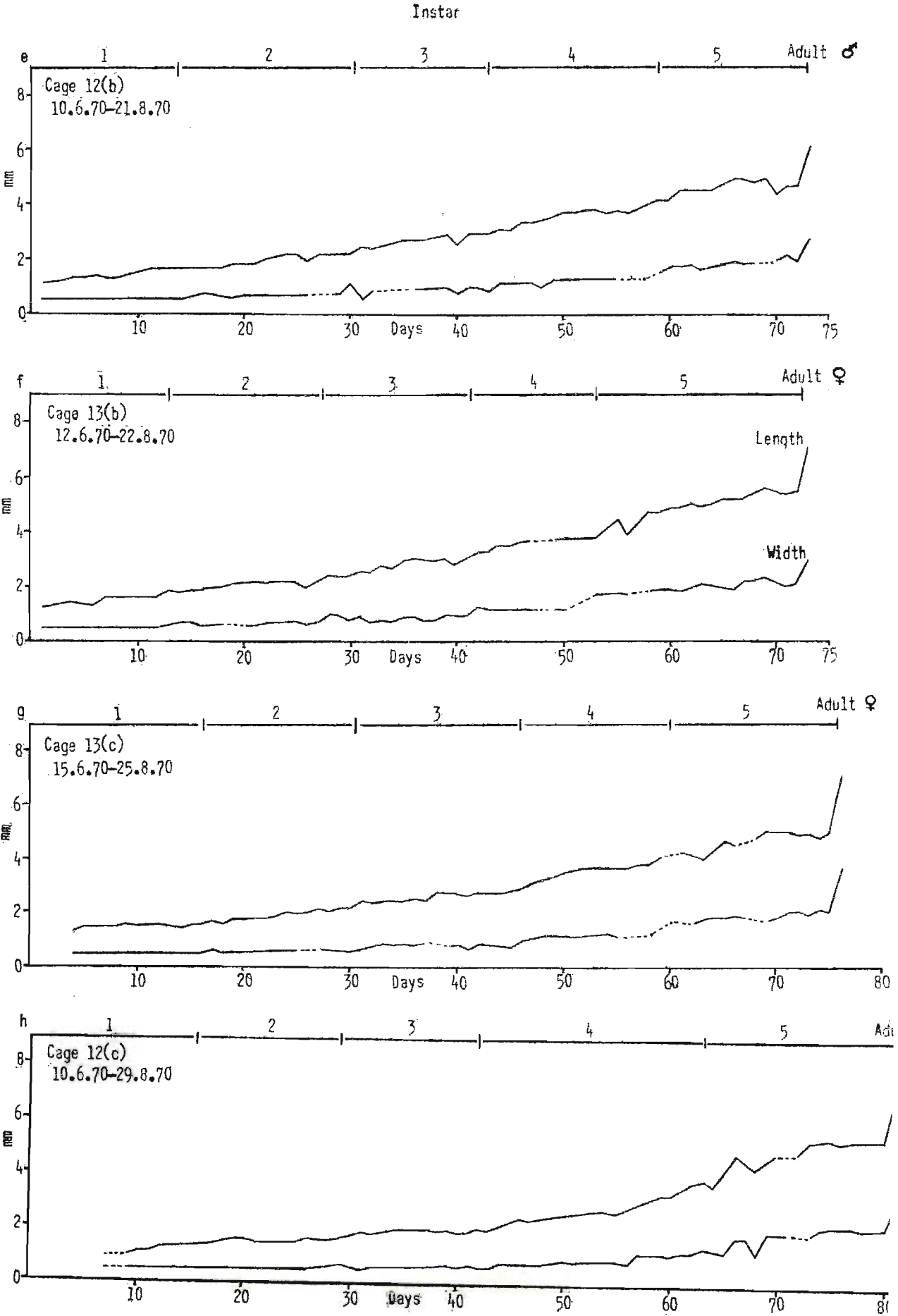


Fig. 12 (Continued)

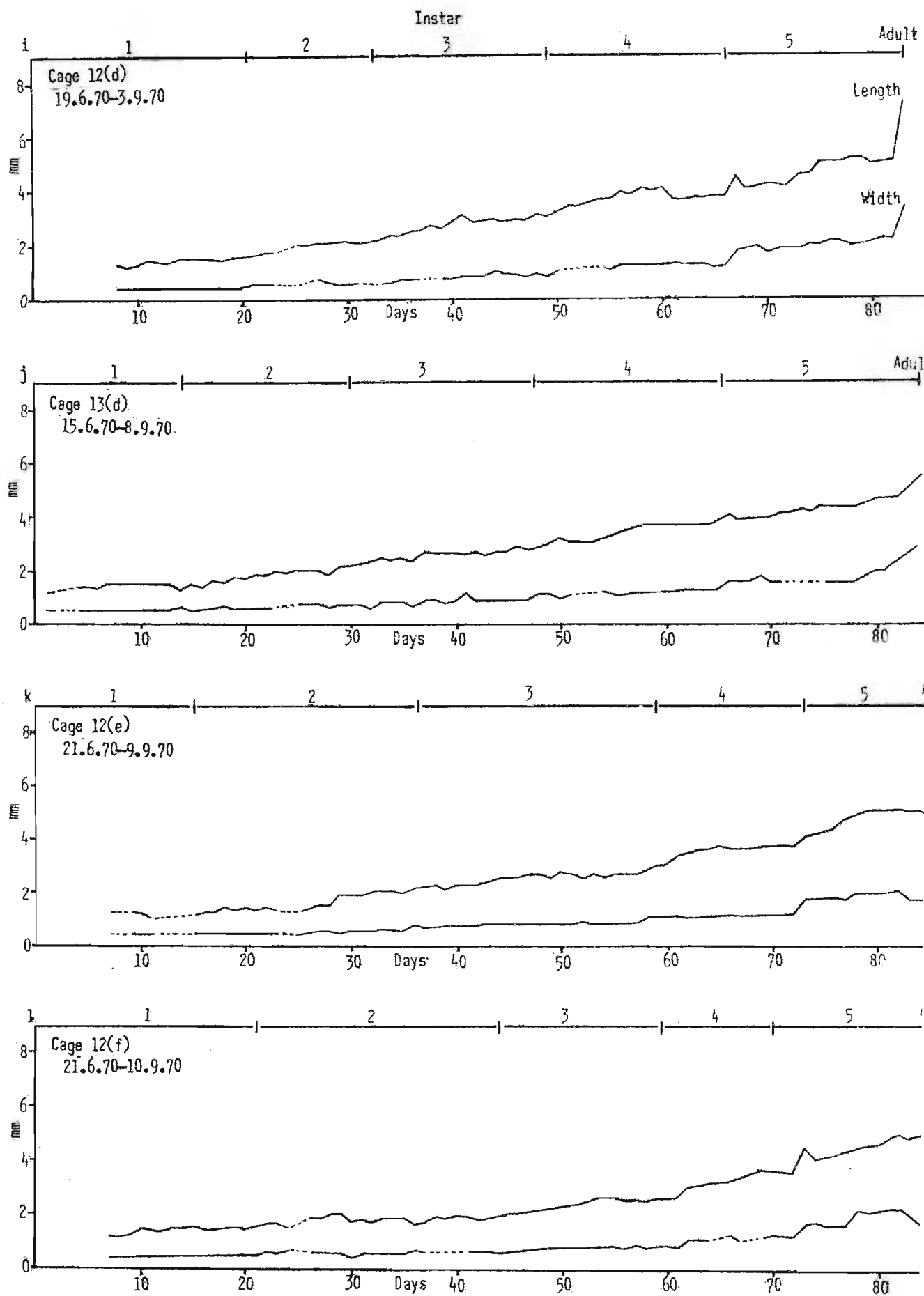
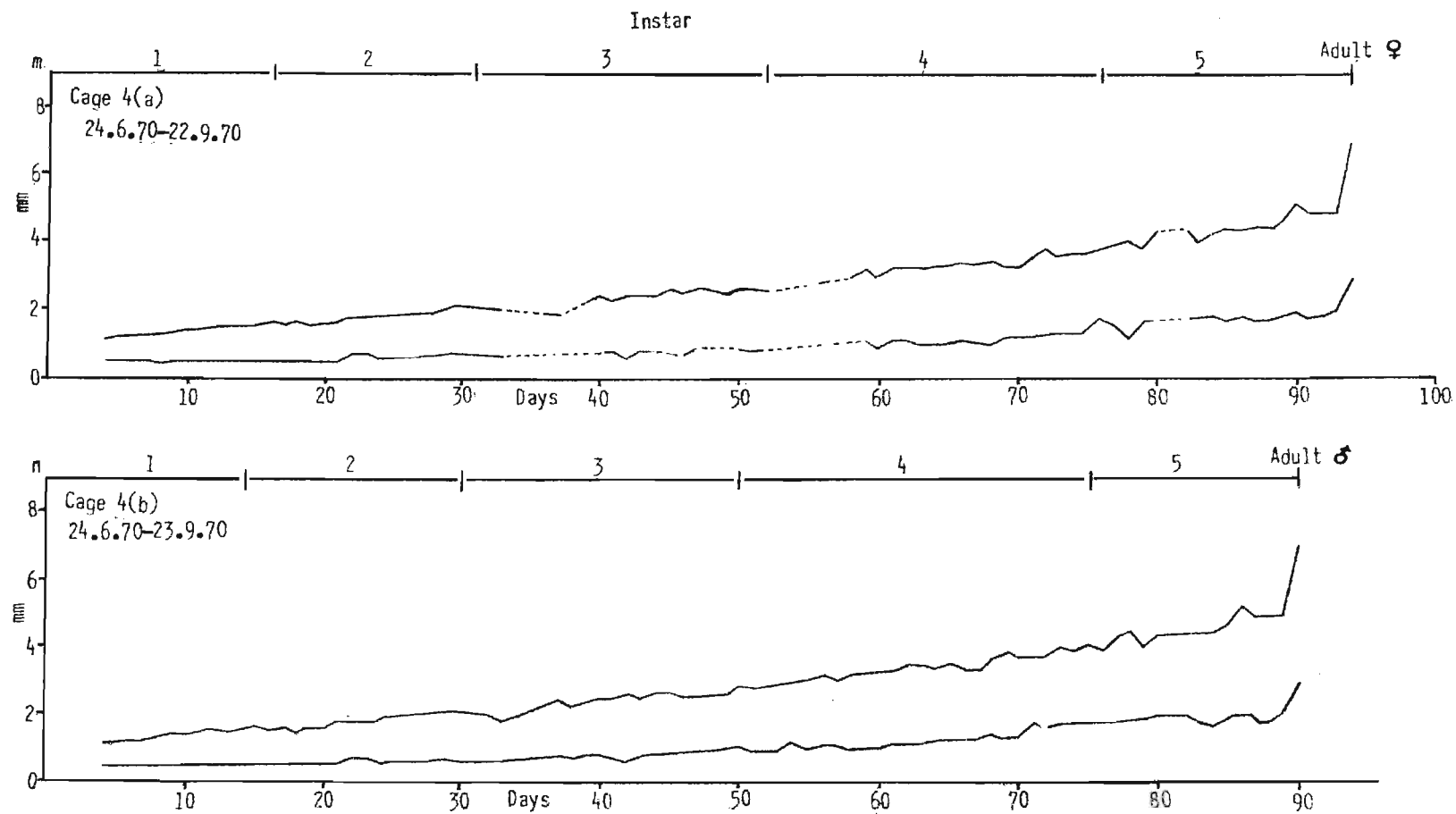


Fig. 12 (Continued)



Little difficulty was experienced in establishing cultures. Harris (1970) found that any disturbance between hatching and feeding resulted in death (2.1) and on several occasions in the course of this study, the findings were repeated. However, this was not always so, and cultures were frequently started with newly-hatched nymphs. In some cases these moved on to the green culture leaf after hatching from an egg in a length of dried leaf placed next to it. Some survived even after remaining still and unfed for 24 hours.

In making microscopical measurements certain minor difficulties were encountered. Measurement of length presented few problems, for nymphs usually perched vertically on the leaf surface (2.23), and slight lateral rotation was of no importance. Width measurement was not always simple nor sometimes possible for, where the leaf was curved, the nymph would sometimes rest with one side directed partly towards the microscope. Accurate measurement of caudal filaments was sometimes difficult, for they became compressed against the cage sides, or when nymphs occasionally faced downwards, their filaments tended to curve over the dorsum. Also, where honeydew or webs of mites were present, the filaments occasionally became entangled and broke off. Occasional movement of nymphs on to the sides of cages, or away from the microscope light (a necessity on dull days) sometimes presented a problem. No distortion from refractive aberration caused by the perspex, or by the artificial light could be established. The perspex surfaces of the cages occasionally became obscured by the excretions projected upon them, but cleaning them with a pair of forceps and moist cotton wool was a simple process.

It was occasionally necessary to change the leaf in the cultures. Natural ageing of the leaf, or the feeding of numicia on it sometimes rendered it unsuitable for supporting cultures, as did the various competitors mentioned earlier (2.1) although these could sometimes

be cleaned off. If necessary a new leaf was threaded through the cage with as little disturbance to its occupants as possible. In three of the four cages in which measurements were made the condition of the potted plants remained much the same, there being a gradual deterioration mainly as a result of the numicia feeding on them. Cage No. 4 suffered more heavily, the plant requiring replacement on three occasions, and there occurred infestations of both mites and aphids. These adversities are reflected in the particularly erratic growth curves of its occupants, and by the relatively long periods required to complete their development (Fig. 12 m and n).

The cultures were so arranged that they did not receive long periods of direct sunlight, for this tended to disturb the occupants, nymphs especially, and cause them to seek the more shady regions of the cages.

Five nymphal instars were confirmed, an impression which had already been gained by measurement of the hind tibiae on numerous cast exuviae collected in the field, and of hind tibiae measured on living nymphs (Appendix IV).

With the exception of wing bud development, no conspicuous features characterised the different instars. Growth was fairly steady with no sudden large increase in size following each moult. Also there was an overlapping in size between individuals of different instars (Table 5). In the first instar nymph a slight lateral extension of the thoracic tergites was apparent, and these became more conspicuous as wing buds in subsequent instars, particularly in the fourth and fifth instars, when they projected over the anterior abdominal segments (Fig. 6).

In the first instar nymph a relative disproportion between thoracic and abdominal dimensions, which is repeated to some extent after each moult, gave the impression initially that a sexual **dimorphism** might begin with the first stage nymph.

TABLE 5. Length and width of nympha and adults, and maximum length of caudal filaments.

Instar	Measure- ments	Mean body length in mm			Mean body width in mm			Filament length mm	
		Max.	Min.	Mean	Max.	Min.	Mean	Absolute max.	Mean Max.
1 M*	56	1,7	1,1	1,47	0,6	0,4	0,50	9,00	8,75
1 F*	104	1,7	0,9	1,47	0,6	0,4	0,50		
2 M	59	2,2	1,3	1,95	0,8	0,6	0,64	12,00	9,50
2 F	141	2,3	1,3	1,86	0,7	0,5	0,62		
3 M	52	2,9	2,2	2,63	1,1	0,6	0,86	11,50	10,33
3 F	141	3,2	1,9	2,58	1,1	0,6	0,85		
4 M	59	4,2	2,9	3,48	1,4	0,9	1,18	13,00	10,83
4 F	135	4,2	2,3	3,53	1,4	0,8	1,18		
5 M	60	4,9	3,6	4,30	2,1	1,2	1,66	15,00	13,30
5 F	146	5,7	3,9	4,90	2,4	1,5	1,97		
Adult M (living, including wings)	27	5,9	4,5	5,45	3,1	2,0	2,69		
" F (" " ")	18	7,2	6,0	6,91	3,5	2,7	3,14		
Adult M (in alcohol excluding wings)	50	4,9	3,5	4,33	1,8	1,3	1,52		
" F (" " " ")	50	5,7	4,7	5,09	2,1	1,6	1,87		

*M = male

*F = female

The impression was that in some individuals the thorax was particularly broad. To investigate this more fully additional measurements were made of nymphs, and the ratio of thoracic length to width were calculated (Appendix III). There was insufficient evidence for establishing any constant dimorphism, and any difference in appearance was assumed to be due to the relatively small, unfilled abdomen which resulted from interruption of feeding, or which was present before feeding had started. Sexual dimorphism, which results in a larger adult female, became apparent in the fifth, and to some extent the fourth instar only (Fig. 9; 2.10).

Daily measurements of length and width of 14 numicia (4 males, 10 females) are illustrated in Fig. 12 a - n. In each case, nymphal length is the distance from the foremost part of the head to the posterior end of the last abdominal segment; width is the widest part of the thorax. (With adults, length is the distance from the foremost part of the head to the farthest margin of the wings which, in repose, are held parallel with the body axis. Adult width is the widest part between anterior wing margins, when in repose). Measurements were made almost always from the dorsal aspect; but very occasionally, when the insects were resting on the perspex cage sides, the ventral aspect was measured. With very few exceptions, measurements were made by the writer, and at approximately the same time of day, so that time intervals remained constant.

For the 14 numicia of which daily measurements were made, the length of the period from egg to adult increased between the 8th June, when measurements were started, and the 23rd September, when the last adult emerged. During this period no marked change in environmental conditions within the insectary occurred, and the slower rate of development was thought to have been due to a progressive deterioration in nutritional value of the leaves. No chemical analysis of leaves was made, because destructive sampling was not possible, but the plants used were grown from setts in small pots, and there was some visible deterioration

presumably from restricted soil nutriment and restricted root development. The feeding of the numicia themselves caused additional deterioration and, especially towards the end of the period, there was some feeding by other insects and mites as well.

Under field conditions there are two generations in summer and one in winter, and it has been assumed that this is a direct reflection of seasonal temperature (3.5).

Over the period in question, in the insectary, there was actually a gradual increase in mean temperatures, which might have been expected to accelerate development rate. In Fig. 13 date of adult emergence is shown against period of nymphal development, which varied from 60 to 91 days. Mean daily temperatures for the emergence period are included; and in Fig. 13b temperatures for the entire period of development are shown. During this period a thermohydrograph, which was placed in the insectary, broke down, and the temperatures plotted were recorded at a meteorological station situated about 50 metres away. This section of the insectary was not air-conditioned, and, although extreme and day to day variation would have been less than outside, a gradual increase in insectary temperatures over this period was apparent. It has been shown that fecundity of numicia increases with leaf nitrogen level (Harris, 1968; 2.20), and it is reasonable to suppose that growth rate might be reduced by a deficiency of nitrogen.

The plotted measurements of Fig. 12 indicate a fairly steady growth rate. At ecdysis there was usually a small but noticeable change in dimensions, often including a period of contraction, which sometimes occurred also during the period between moults. This was probably a direct result of suspension of feeding, when through inter-segmental muscular contraction the abdomen would shrink. It was noted that contraction occurred immediately after excretion, which is well illustrated in Fig. 12 1, where excretion occurred during measurements on the 71st day, and the nymph decreased in length by 0.40 mm, an unusually large amount.

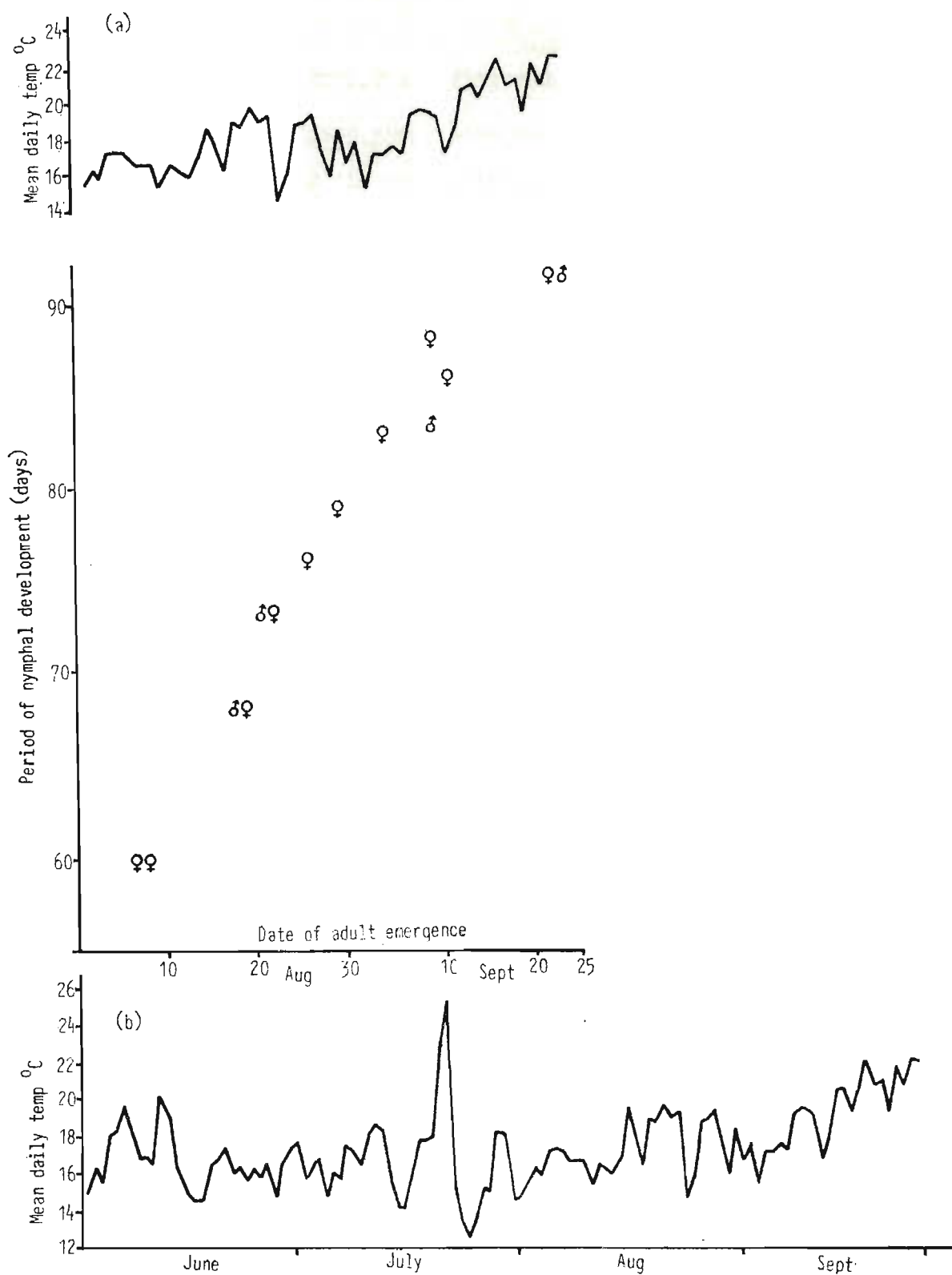


Fig. 13 (a) Emergence date and duration of nymphal development for four male and ten female numicia, with corresponding mean daily temperatures.

(b) Mean daily temperatures for the entire developmental period.

An undisturbed nymph normally fed constantly, except for a period immediately preceding and following ecdysis. Excretion occurred periodically, and was preceded by a vertical flicking of the abdomen, which increased in intensity for a few seconds until a small droplet of a clear fluid was projected a distance of up to 10 cm from the body. In the insectary this excrement accumulated as clear transparent droplets on the perspex sides of the cages where, after a few days it became congealed and opaque.

Caudal waxy filaments were present in all nymphal instars, and their function appeared to be entirely protective. Although surprisingly pliant, they were easily broken if seized, or if pressed by the insect against a resistant obstacle. When a nymph was approached by another insect, the abdomen was moved from side to side until the intruder was located, when the filaments were held between the nymph and the intruder and a flicking motion performed. If an intruder approached from the front, the caudal filaments were extended anteriorly over the head in a fan like formation and held there until the intruder was diverted. Should the intruder stand firm, the nymph would eventually move away, usually a very short distance, and then continue feeding. It was noted (Harris, 1970) that when first instar nymphs fell to the ground they usually failed to regain the plant and died. In a type 1 culture it was noted that when third to fifth instar nymphs were disturbed and fell to the ground, they began almost immediately to crawl and hop towards stems or trailing leaves, up which they climbed. During field sampling similar observations were often made.

A detailed description of ecdysis to the adult stage is given in the next section (2.13), and it was noted that nymphal ecdysis followed the same pattern. Before moulting the nymph appeared distended and a periodic pulsating of the body occurred. There occurred no clearly visible split in the integument, but the nymph moved slowly anteriorly

out of the old exuviae in a vermiform manner, the legs not being used, and the nymph at times standing out almost at right angles from the leaf surface. It finally came to rest just anterior to the exuviae which remained attached to the leaf by its closed terminal end and splayed filaments. In the insectary ecdysis was occasionally preceded by a short period of some activity, when the nymph might move on to the cage walls and stop feeding for one or two days; but that was unusual. In most cases ecdysis occurred on the leaf, an obligatory process, which interrupted feeding for little more than 40 minutes. It always occurred with the head facing upwards.

It has already been mentioned that close observation of nymphs of all stages, both in the field and in the insectary was not an immediately rewarding exercise. They did very little but feed. However, it is interesting to venture speculative comparison between conditions in sugarcane and in natural grass communities. Sugarcane must present a far more open, three-dimensional environment than most grass communities would. Under natural conditions the hatching nymph would normally find an abundant food supply within a short distance of the egg, and once this had been found it would have little cause to move farther. The general inability of nymphs to survive unless food were found almost immediately has been mentioned (2.1). In a cane field this must have an important bearing on survival of first instar nymphs, for it has been found that eggs will hatch even after the leaf containing them has been dry for weeks (4.3.1.4), and when this happens on a growing cane plant there is unlikely to be any green leaf near the older, drier leaf. Furthermore, once a cane field begins to suffer under an infestation of numicia, there is, as a direct result of the infestation, an unusually large amount of trash, i.e. permanently dry leaves. In both media, where hatching occurs in a normal green leaf, the nymph simply moves a few millimetres from its egg and feeds; and, if nothing happens to prevent it from doing so, it

simply continues to feed, moult and mature.

In a grass community the sort of sudden disturbance which makes nymphs hop from the leaf, would result in the nymphs landing on more grass rather than on bare ground as so often happens in cane.

In sugarcane neither adults nor nymphs were ever seen feeding on stems, but in grasses (eg. Pennisetum clandestinum) feeding was noted on the stem at leaf bases.

2.13 Metamorphosis from nymph to adult

Notes were made over a period of two hours, during the final 30 minutes of which (under insectary conditions) a fifth instar nymph moulted to produce an adult female.

At 08:17 it was noted that one of the nymphs which were being measured daily had taken on a turgid appearance and had apparently stopped feeding. A slow steady pulsating of the body occurred, and lasted about half a minute. After a similar period of immobility it occurred again. When it again stopped the front legs were moved slightly, and this was followed by further pulsating.

At 08:22 the nymph suddenly moved about 2 cm across the leaf surface, possibly as a result of the microscope light which was shining on it.

At 08:27 there was further pulsating, and the four sets of waxy filaments had become widely splayed.

Between 08:27 and 10:30 this periodic pulsating continued, with occasional quivering of the legs.

At 10:12 the nymph had moved backwards approximately 1 cm down the leaf, where it continued to face upwards.

At 10:30 the body length was measured, and was found to be 0.33 mm shorter than it had been 2½ hours earlier. There then occurred a series of body contortions, particularly at the posterior end, and the waxy filaments became further splayed, with the outer two sets

actually pointing anteriorly.

At 10:33 the integument, without visibly splitting, began to come away at the posterior end (in much the same way as a glove is drawn directly off the end of a finger), becoming pointed and pinched in appearance, with the two outer sets of filaments becoming positioned anterior to the inner sets. There was visible through the integument considerable movement of body fluid, and there occurred a pulsating movement of the head.

By 10:35 the nymphal integument was beginning to stand out from the body, and appeared white between body segments. The body had become concave dorsally, and indentations between segments were less conspicuous.

At 10:37 there was a great deal of contortion with the head thrust forward. The wings then became free, and in their crumpled state were held out at right angles from the body. This was followed by a wriggling movement forwards, with the old integument being left behind. At this stage the legs were not being used, and the body was at an angle of about 25° from the leaf, and attached to it only at the posterior tip. (A very similar position was noted during hatching, and during nymphal moults).

At 10:39 movement of the front legs was noted, but they were still held above the leaf surface.

The insect then remained completely still for 4 minutes, after which the first and second pairs of legs were placed splayed on the leaf, with the posterior pair still in the air, and the posterior tip of the body was still held by the almost cast exuviae.

At 10:45 further jerky contortions released the posterior tip. After release from the exuviae, the forewings became convex dorsally, and began to expand. Rate of expansion was measured (Fig. 14), and was more rapid than that of hindwings, which could be seen beneath them.

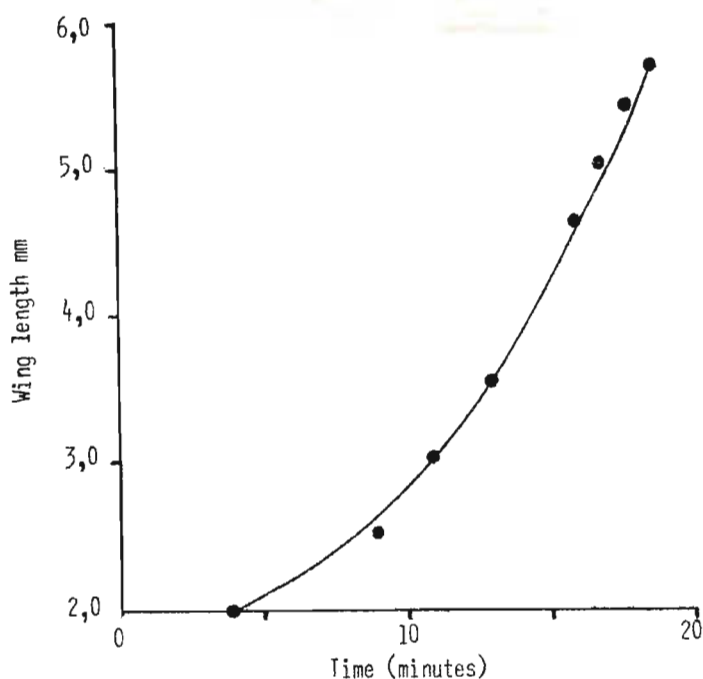


Fig. 14 Rate of expansion of forewings of newly emerged adult numicia.

At 10:49 after a period of complete immobility the insect suddenly moved about 5 mm, completely clear of the exuviae, with one hind leg resting above the leaf surface.

At this stage the adult insect was only marginally paler than the nymph, but the terminal segments had an empty appearance.

At 11:00 wings were fully expanded and all six legs were on the leaf surface. For about one minute the insect made a side-to-side swaying movement without lifting legs from the leaf surface.

At 11:03 the hind wings could be seen still expanding below the forewings, and by 11:05 they were fully expanded; after which there was no further visible change. The insect remained in the same position for at least 48 hours.

In the insectary, ecdysis of both nymphs and adults occurred at all times of the day, but more commonly in the forenoon (Appendix V).

Seasonal patterns of metamorphosis to the adult stage are discussed in Chapter 3.

2.14 The adult (Fig. 11)

There is a difference in size between male and female, the female being larger (Plate 9; Fig. 9; Table 5). In Table 5 measurements of living specimens include wings, which partly obscured the body. Measurements of specimens preserved in alcohol do not include wings.

The variant N. viridis var. infuscata was occasionally encountered (Plate 8). The impression was gained that infuscata was more common on the Natal south coast (Illovo and Paddock areas) than in the north (Swaziland, E. Transvaal and Pongola); but it was encountered in all areas. Of the many specimens of infuscata examined in the field and in the insectary, all but three were males. The three females were among insectary reared specimens. This variant has been collected from both sugarcane and grasses and was reared in the insectary together with normal siblings from the same egg batch. In January 1970 an insectary culture developed from one normal adult female, one normal male, and one male of infuscata, all taken from a type 1 culture in which the cane had been irreparably damaged by numicia feeding upon it. Of the 32 adults reared from them, five were infuscata.

The markings of infuscata may be very sharply defined and dark brown to black, or may be faint, and noticeable only on close examination. No differentiation in nymphs has been seen.

2.15 Original description

The original description of Numicia viridis is quoted below. The paper (Muir, 1931) included no figures.

"Numicia viridis, sp.n.

"Male - length 3.5 mm; tegmen 4mm.

"Except in the length of the vertex, this species is typical of the genus and cannot be placed elsewhere. In the shortness of the vertex it appears to agree with Haliartus, but that genus is described as having the medio-frontal carina 'stark wulstig', whereas this species has the fine carina of the genus.

"Vertex short, the width at base nearly double the length in the middle, the middle of the base being nearly in line with the anterior margin of the eyes; lateral carinae fairly elevated towards the base; in outline gradually narrowing from base to the rounded apex, which is slightly narrower than base (1 to 1.3).

"Light green, which becomes light stramineous in some dead specimens. In one specimen there is a faint infuscation in the first and second M apical cells.

"Female - Length 4.8 mm; tegmen 6 mm.

"Except in size, the female is similar to the male.

"Hab. Natal, Weenen (H.P. Thomasset, iii, iv, 1924); Pondoland, Port St. John (R.E. Turner, iv., v. 1923), including type. Three males and eight females.

"Var. infuscata, nov.

"There are four male specimens from Weenen (H.P. Thomasset, iv. 1924, including type, and iii. 1925), which have the same markings as N. insignis on the tegmina, but fainter, the specimen caught in March 1925 being faintest. As the structure of the male genitalia is similar, I consider that they are the same species. The specimens without markings are described as typical, as both sexes are represented".

2.16 Sex ratios

From numerous observations and counts, made both in the insectary and in the field, it was found that the two sexes occurred in

approximately equal numbers, but with some predominance of males (N.S.) (3.7.8.1/d. Appendix VI). In support of this conclusion, four sets of counts, in particular, may be mentioned.

- a. During 1965 and 1966, in the course of studying the progress of an untreated outbreak (Carnegie, 1966 ; 3.8), on twelve occasions all numicia collected from sampling a cane field in six places were counted and sexed. Results showed a total of 194 females and 191 males (1 male : 1,02 female).
- b. On the 12th October 1965, three stools of cane (5-month-old NCo 376) were fumigated in the field under a plastic cover, and all numicia collected counted and sexed (3.8). Of the 2 429 insects collected, 301 were nymphs, 925 females and 1 203 males (1 female : 1,30 males).
- c. In October and November 1968, while studying repopulation of a ratooning field counts were made of numicia males and females (Carnegie, 1969; 3.7.8). Throughout the period of sampling both sexes were common, and a total of 703 females and 803 males were collected (1 female : 1,42 males; see Table 29).
- d. During insectary rearing experiments in 1970, of the 64 adults, the sexes of which were recorded, 30 were females and 34 males (1 female : 1,13 males).

2.17 Copulation

The presence in field populations of approximately equal numbers of males and females, and the fact that copulating pairs were not uncommon, suggested that parthenogenesis did not occur.

In the insectary, four females were isolated in type 3 cultures. One of these had been reared (together with another female) from eggs, and the other three had been removed from their parent culture and isolated immediately they became adults. All but one female oviposited but none of the eggs developed (Table 6). When the eggs were dissected out of the midrib they were found to have remained cylindrical in form i.e. like a newly-laid egg (2.6). After it had died, one of the females was

dissected and was found to contain 96 eggs, which were fully developed and ready for expulsion.

During periods of high field populations, such as those of 1965 and 1966, copulation was frequently noted, and pairs in copulo were sometimes precipitated during shake-sampling (3.2.2/c). It was noted at all times of day, and no preference for any set of conditions was apparent. Copulation was not frequently seen in insectary cultures, and no records for duration were made. It was noted in only one of the more closely-observed type 3 cultures, where a coupled pair were seen at 16:28, and they remained in that state until observation ceased at 17:15. At 07:30 the following day they were no longer in copulo. The fact that copulating pairs were not frequently noted in the insectary suggested that they do not remain coupled for long periods.

During copulation the sexes face in opposite directions, with the female partly covering the male.

2.18 Pre-oviposition period

Oviposition records made during insectary rearing experiments are summarised in Table 6. They concern four main groups of females: a) virgins isolated since emergence, b) those reared with, and accessible to males in the same culture from which records were made, c) those reared with males in another culture and subsequently isolated in the culture studied, d) field-collected individuals. The exact emergence dates of groups c and d were unknown, so all periods recorded were under-estimates. On some occasions, mainly with groups c and d, batches only were recorded, and the exact numbers of eggs laid were therefore unknown.

The shortest pre-oviposition period recorded was 11 days, when ten eggs were laid four days after copulation. The longest period recorded was 24 days.

Insufficient records preclude firm reliability being attached to a pre-oviposition period of 17,5 days. However, dissections of field-

collected material showed that recently emerged females may contain no mature eggs (3.7.8), and a period of at least one week could be expected to elapse before eggs mature sufficiently for oviposition to occur.

2.19 Oviposition

Both in the field and in the insectary oviposition was noted at all times of day, and there was no evidence to suggest that any particular time was preferred.

The positioning of the eggs is determined by the shape of available plant tissue. In sugarcane, almost without exception, eggs were inserted in the midribs of leaves on the lower surface. Very rare exceptions were noted where eggs were inserted into abnormal folds in the leaf surface, and on one occasion in an insectary culture five eggs were scattered over the leaf lamina.

Younger leaves were preferred, although in cane aged about five months or more the topmost leaves were avoided, probably because of the bright conditions higher up the plant. Bull shoots, which are young shoots growing out from the bases of older cane stools, were much favoured, and whenever eggs were generally difficult to find they would be most likely to occur in the leaves of such shoots.

In sugarcane the actual part of the midrib chosen depended on its diameter. On very young leaves of germinating or ratooning cane or of bull shoots, egg batches were found almost throughout the length of the leaf. However, on normal green leaves of a plant of three months or more the area around the distal four-fifths mark was preferred (Table 30).

No case was even noted of oviposition in any other part of cane plants, not even in the stem of the inflorescence.

In grasses eggs were found mostly in inflorescence culms and in leaf midribs, where these were sufficiently robust. (A list of grass hosts is given in Table 31). In the grasses Panicum maximum and

Rhynchelytrum repens eggs were frequently found in the culms, inserted in a slightly spiral pattern for a length sometimes of several centimetres. The actual position of the egg in the culm was exactly the same as in the midrib, i.e. fully inserted in the plant tissue with only the operculum visible (Fig. 15a).

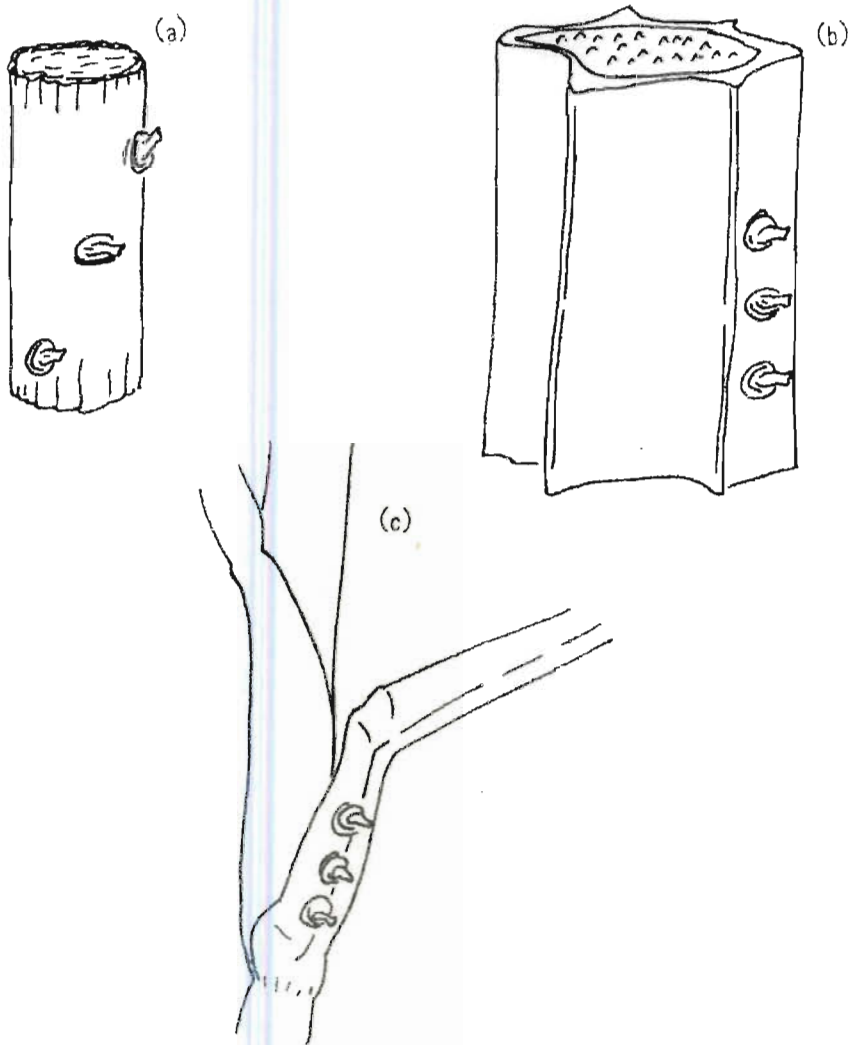


Fig. 15

Positions of numicia eggs in (a) grass stem (b) stem of Cyperus sexangularis (c) leaf sheath of Pennisetum clandestinum.

In stout leaves, such as those of P. maximum, Sorghum verticilliflorum or Cymbopogon validus, numerous eggs were found in midribs, their position being determined, as in cane by midrib diameter. In other grasses, such as Pennisetum clandestinum eggs were confined to the very base of the midrib, or the V-shaped contour of the leaf sheath (Fig. 15c).

Eggs were recorded from only one sedge, Cyperus sexangularis, in which they were very common, and were always inserted immediately adjacent to one of the six vertical ridges of the stem (Fig. 15b).

In midribs eggs are inserted in tissue of the lower leaf surface. They are positioned at right angles to the vascular bundles of the midrib, with the long axis of the egg parallel with or at an acute angle to the leaf lamina (Plates 9 and 10).

When ovipositing in leaves, the female positions herself on the lower surface at right angles to the midrib with her abdomen extending across it, the eggs being inserted in either side of the midrib. The abdomen is curved vertically bringing the ovipositor beneath the hind coxae, and a hole is made in the plant tissue with the second and third valvulae (Fig. 16). An egg then passes between the valvulae into the prepared hole, the operculum (and very occasionally a small portion of the rest of the egg) protruding. A small quantity of a powdery substance is produced also at oviposition, but is insufficient to serve any important protective function. The female then moves laterally up or down the leaf and the process is repeated. Oviposition is a slow operation, an observed female in the field taking 25 minutes to deposit two eggs.

Spacing is usually very even, and there is considerable variation in numbers per batch. An examination of 4 130 eggs from 112 cane leaves, showed numbers per batch to vary from two to 134, and that within a batch there was an average of 2.06 per 1 mm of midrib. When considering numicia eggs, "batch" is an arbitrary unit, for eggs

are continuously maturing and females oviposit repeatedly. Bayer (1965) recorded a maximum of 50 per batch. If disturbed during oviposition the female will not necessarily continue where she was interrupted.

Eggs may be inserted opposite one another along the midrib. This frequently happens when populations are very high, and it usually results in many eggs becoming compressed and failing to develop.

2.20 Fecundity

There are two lateral ovaries, each comprising eight ovarioles. Dissections and observations indicated that, following a short post-emergence period during which mature eggs could not be distinguished, there was continuous egg production throughout adult life. The abdomens of newly emerged females contained much fatty material but no distinguishable eggs, and the abdomens of old field-collected females, shortly before death, were almost devoid of body material. In the insectary old females sometimes appeared to become "egg bound" despite the presence of suitable oviposition media, 131 mature eggs being counted on one occasion. Insectary records of oviposition are summarised in Table 6.

The maximum recorded number of expelled eggs was 109, but the female concerned still contained 131 mature eggs when she died, and had been ovipositing up to 32 days after emergence. Harris (unpublished) counted 162 eggs for an insectary-reared female; and for 205 females he recorded an average per female of 28,2 eggs (Harris, 1968). In the course of dissecting 703 field-collected females a maximum of 49 eggs per female was recorded, with an average of 19,5 eggs (Carnegie, 1969; 3.7.8.1/e). Bayer (1965) states that feral *numicia* females seldom contained more than 40 mature eggs, but that in virgin or laboratory-reared females, eggs accumulate in the calyces of the lateral oviducts and that they may contain 80 or more eggs. There is therefore considerable variation in numbers of eggs laid, and in numbers present in females at any one time.

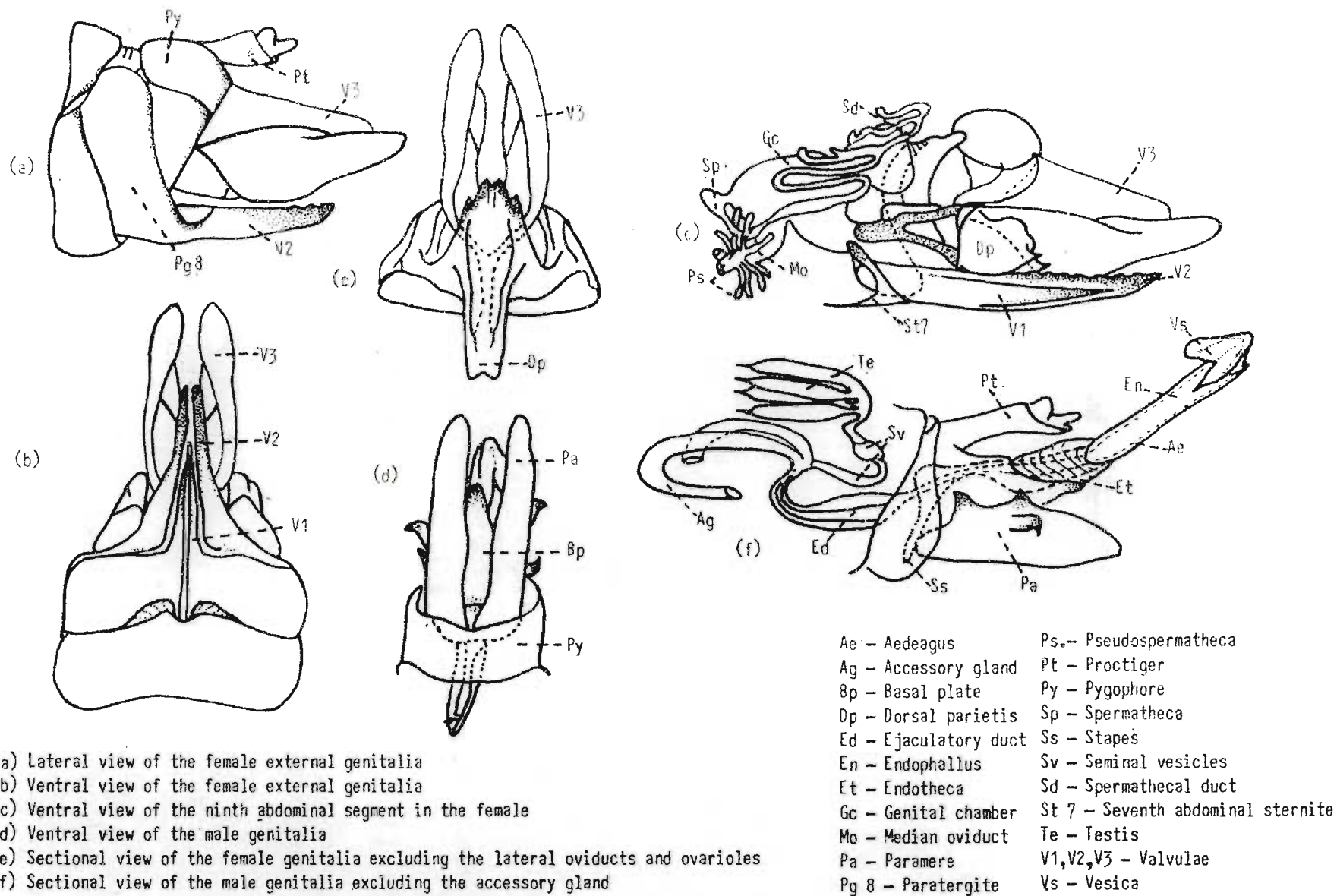


Fig. 16 Reproductive system of numicia (after Bayer, 1965).

TABLE 6 Summary of oviposition records from insectary cultures 66.

Oviposition Records															
History of female	Source	Emerged in Culture Date	Inserted in Culture Date	Numbers of eggs after how many days										Eggs (total)	Remarks
				Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days		
Isolated virgin females	Culture	7.8.70		17	22	43	30	n/r	36						Eggs never developed
	"	18.8		4	19										"
	"	23.8		0											"
	"	27.8		19	13										dead F. contained 96 eggs
Reared with males in this culture	"	18.8		10	11	4	12	5	13	21	17	13	22	53	nymphs recorded
	"	7.8		22	14	16	21	6	23	11	28	54	32	109	" " dead F. contained 131 eggs
	"	12.8		n/r	14	6	23	5(h)	27						nymphs not recorded
	"	12.8		13	24	54	28								"
	"	18.8		16	23	n/r	26								"

TABLE 6 (Continued)

History of female	Source	Emerged in Culture Date	Inserted in Culture Date	Numbers of eggs after how many days								Eggs (total)	Remarks	
				Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days			
Reared with males in another culture	Culture		17.4	6	12+								nymphs recorded	
	"		22.4	n/r	25+	n/r	27+						"	"
	"		11.5	n/r	19+								"	"
	"		22.4	n/r	38+								"	"
	"		22.4	3	76+								Nymphs not recorded; dead F* contained 24 eggs	
From field	South Coast		6.5	38	3+	n/r	7+	n/r	15+	n/r	19+	n/r	79+	Nymphs recorded
			6.5	n/r	5+								"	"

F* = female

n/r = egg numbers not recorded

(h) = holes made but eggs not inserted.

A number of amino acids are usually required for oogenesis, and in some insects there is also a relationship between the haemolymph protein and the hormonal control of ovarian development. Therefore, besides supplying materials needed for yolk synthesis, nutrition also exerts a fundamental effect on the control mechanism (Beament et al., 1966). Metcalfe (1965, 1970) found that fecundity of cane fly (S. saccharivora) was raised by an increase in the nitrogen status of sugarcane leaves.

An experiment to investigate any relationship between nitrogen status and fecundity of numicia was conducted in the insectary at Mount Edgecombe, and has been summarised by Harris (1968).

Sprouting single bud setts of variety NCo 310 were selected for equal size and development and planted, nine to a tray in each of 16 polythene trays. Five kilograms of air dried "Clansthal" sand were placed in each tray, which measured 32,5 cm long, 21,5 cm wide and 6,5 cm deep.

At planting, equal quantities of a potassium hydrogen phosphate solution were added to each tray, the amount being equivalent to 224 kg K and 179 kg P per hectare. Four levels of nitrogen were established in each of four replicates, the lowest of which was the control, to which no nitrogen was added. The other three levels received added nitrogen in the form of an ammonium sulphate solution, low, medium and high level treatments being the equivalent of 84 kg, 168 kg and 336 kg N per hectare.

Soil was maintained at approximately 50% water holding capacity. Sixty-six days after planting, third-leaf samples from one replicate were taken for total nitrogen analyses by the Kjeldahl method (Table 7).

(In the course of the experiment two cages were urgently and unexpectedly required to house a consignment of imported Mirid egg

predators (4.4.1). This necessitated discarding one low and one medium treatment from a single replicate).

TABLE 7. Third-leaf nitrogen analyses of all plants in 1 replicate from fecundity experiment.

Nitrogen level	Dry wt. of sample gms	% nitrogen	mg nitrogen
Control	1,22	1,07	13,1
Low (84 kg)	2,19	0,99	21,7
Medium (168 kg)	3,51	1,07	37,6
High (336 kg)	4,22	1,43	60,3

The experimental design was a randomised block with four replications of four treatments each (Fig. 17).

Sixty-one days after planting there were marked growth differences. Fifty 16-day-old nymphs were then caged on the plants in each tray. The cages measured 76 cm x 36 cm x 26 cm and were covered with fine nylon mesh. The nymphs were taken from an insectary-reared population. One, which died, was replaced by another from the same population. Eighty-one days after hatching no nymphs could be found, and a 100% adult population was assumed. During the experiment two escaped males were noted outside the cages, but it was unknown from which cage they came.

One hundred and fifteen days after cageing the nymphs the experiment was terminated to prevent the following generation from maturing and ovipositing. Adults were removed, counted and sexed (Table 8). For those females which were in a fit state for dissection, numbers of eggs per ovary were determined, and it was noted that all females examined were capable of further oviposition (Table 9).

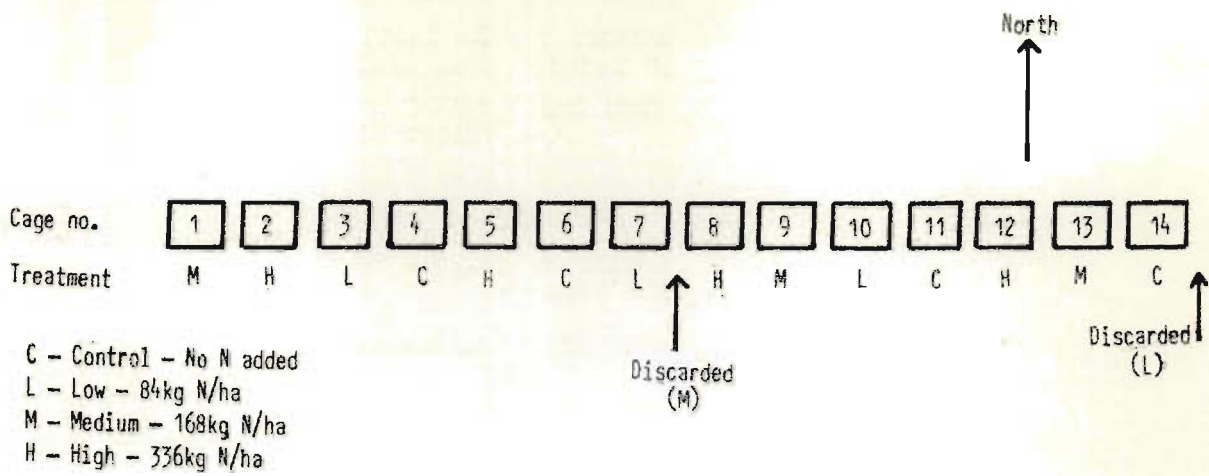


Fig. 17 Nitrogen level and numicia fecundity: experiment plan

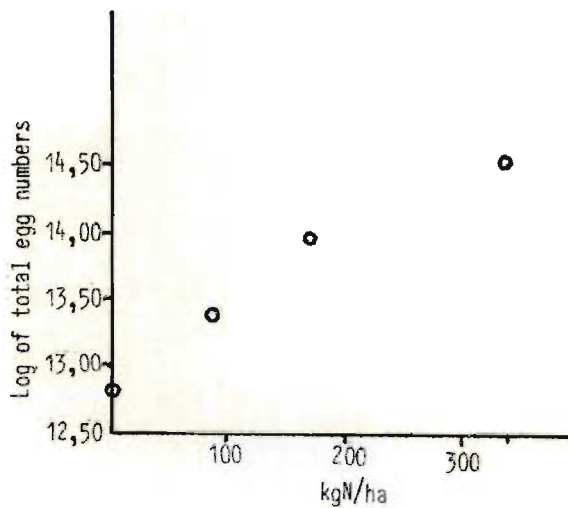


Fig. 18 Relationship between nitrogen level and numbers of eggs laid.

TABLE 8. Total male and female numicia recovered from nitrogen level experiment and weight of air-dried plant material.

Treatment and Cage No.	Recovered dead during exp.		Recovered living after exp.		Total		Weight dry plant matter gms
	M*	F*	M	F	M	F	
Control 4	3	0	13	7	16	7	33,5
" 6	4	2	15	10	19	12	37,0
" 11	7	3	14	22	21	25	38,0
" 14	2	0	10	10	12	10	47,0
Low N 3	1	1	17	19	18	20	47,5
" 7	6	0	8	16	14	16	48,0
" 10	2	8	9	5	11	13	51,0
Medium N 1	2	4	15	18	17	22	69,5
" 9	1	3	18	21	19	24	54,5
" 13	4	2	17	22	21	24	66,5
High N 2	2	8	7	14	9	22	89,0
" 5	3	5	12	20	15	25	77,5
" 8	6	12	8	9	14	21	83,5
" 12	4	8	8	13	12	21	81,5

M* = male F* = female

The plant material was then air-dried and weighed and a count made of all eggs laid (Tables 8 and 9).

Statistical analysis of the results showed that as the nitrogen level was increased there was a significant increase in the numbers of eggs laid ($P < 0,01$; Table 9).

Figure 18, where the log of total egg numbers is plotted against nitrogen rate shows a linear increase in egg numbers with nitrogen level.

In Table 8 are shown the numbers of adult insects recovered. In no instance were all 50 insects recovered from any one cage. Lowest numbers of females were recovered from control and low rate treatments, with the exception of control cage 11, whence all but four insects were recovered.

TABLE 9. (a) Numbers of eggs laid in each cage and (b) egg numbers found from dissection.

		(a)		(b)		
Treatment and Cage No.		Nos eggs laid	Total	Nos of females	Total eggs exposed	Average no. eggs/female
Control	4	1 952				
"	6	1 046				
"	11	1 364				
"	14	1 331	5 693	49	1 316	27
Low N	3	2 780				
"	7	2 502				
"	10	2 655	7 937	40	1 327	33
Medium N	1	3 123				
"	9	3 900				
"	13	3 698	10 721	61	1 900	31
High N	2	3 969				
"	5	5 939				
"	8	3 865				
"	12	3 456	17 229	55	1 226	22

	Mean log. count	detransformed egg counts
Control	3,187	1 660
Low N	3,333	2 323
Medium N	3,470	3 184
High N	3,622	4 519

Approx. S.E. of treatment mean = 0,081 C.V. = 5,2%

It is unlikely that individuals could have escaped unnoticed, and this is not considered to be the cause of relatively low numbers from some cages.

Dead insects were recovered with an adhesive-tipped rod inserted through a small temporary opening in the side of the cage; but not all were recovered, as was evident from the number of chitinous parts found among the soil and plant material when the experiment was dismantled. These decomposed specimens could not be sexed nor could their numbers be accurately assessed.

Plate 11 and Table 8 show that higher nitrogen applications resulted in more vigorous growth of the sugarcane.

From Table 7 it can be seen that by the sixty-sixth day after planting, differences in the percent nitrogen of the third leaf were detectable.

The fact that sugarcane in the inland irrigated areas of the cane belt is kept at a particularly high nutritive level may have contributed to the causes of heavy numicia outbreaks in them.

2.21 Adult behaviour

Some aspects of adult behaviour e.g. oviposition have already been mentioned in this chapter. Other points e.g. movement are discussed under general field ecology (3.6; 3.7). Further points, which were noted during insectary studies, are discussed below.

In 1967 during early rearing experiments, a large cage which could contain eight cane stools was used (2.1). On several occasions, and especially during hot weather, it was noted that adults tended to congregate around the roof of this cage, and the numbers of numicia involved seemed to vary with time of day.

These tendencies were further investigated in 1970 using a colony of numicia adults and nymphs which had developed in a type 1 insectary cage (2.2). It was noted that a varying number of both nymph and adults moved each day to and from the roof area of the cage. From the 27th January until the 14th March daily counts were made of numicia numbers on the roof and on a specified area of the uppermost cage sides. On most occasions this was done morning, noon and evening, and at the same time notes were made regarding type of day (sunny, cloudy) and the insectary temperature was recorded (Table 10).

After mid-February numbers fell suddenly, and a comparison of numbers was made only for the period 28 January to 13 February (Appendix VII).

To investigate any differences between numbers present on sunny or cloudy occasions records were compared for the period 2 February to 12 February (p.m. only), because they included neither very high nor very low figures. No relationship was apparent.

There was also no direct relationship between numbers present and temperature (p.m. only).

Numbers of numicia adults in the roof area were significantly higher in the mornings and late afternoons than at mid-day ($P < 0.001$). The reason for this is not clear, but the midday heat at that time of year may have reduced their activity.

TABLE 10

Numicia numbers on cage roof areas 27.1.70 - 14.3.70

74.

Date	Numicia numbers												Remarks
	a.m.				noon				p.m.				
	ny	ad	tot	°C	ny	ad	tot	°C	ny	ad	tot	°C	
17.1	-	-	-	-	-	-	-	-	21	81	102	-	hot, sunny
28.1	-	-	-	-	35	22	57	-	17	41	58	-	mild, overcast
29.1	42	44	86	-	32	39	71	32	31	43	74	35	cool overcast - hot sunny
30.1	11	70	81	28	14	25	39	32	15	79	91	34	hot, sunny
31.1	18	39	57	33	-	-	-	-	10	52	62	31	hot, cloudy
1.2	-	-	-	-	-	-	-	-	7	23	30	22	cool, drizzle
2.2	-	-	-	-	0	11	11	33	13	12	25	25	overcast, drizzle
3.2	13	15	28	19	-	-	-	-	6	21	27	28	cool, overcast
4.2	11	27	38	30	-	-	-	-	9	31	40	31	hot, sunny
5.2	7	16	23	32	-	-	-	-	14	10	24	34	hot, sunny
6.2	13	17	30	28	11	10	21	33	6	28	34	31	hot, cloudy
7.2	11	18	29	32	-	-	-	-	-	-	-	-	hot, sunny
8.2	14	17	31	33	-	-	-	-	12	21	33	30	warm, cloudy
9.2	15	15	30	33	-	-	-	-	19	17	36	35	hot, sunny
10.2	14	21	35	26	21	15	36	32	16	17	33	34	drizzle-hot, cloudy

TABLE 10 (Continued).

Date	Numicia numbers												Remarks
	a.m.				noon				p.m.				
	ny	ad	tot	°C	ny	ad	tot	°C	ny	ad	tot	°C	
11.2	15	11	26	21	17	9	26	31	12	6	18	34	cloudy - hot, sunny
12.2	14	11	25	32	11	7	18	32	8	5	13	31	hot, sunny-cloudy
13.2	10	8	18	25	7	5	12	32	9	9	18	34	hot, sunny
16.2	1	6	7	25	3	3	6	29	2	6	8	26	cool, sunny - drizzle
17.2	-	-	-	-	-	-	-	-	3	3	6	32	hot, sunny
18.2	1	5	6	31	2	1	3	31	1	2	3	33	hot, sunny
19.2	-	-	-	-	-	-	-	-	2	2	4	32	hot, sunny
20.2	-	-	-	-	0	2	2	34	0	0	0	34	hot, sunny
23.2	0	0	0	35	-	-	-	-	-	-	-	-	hot, sunny
24.2	0	0	0	36	-	-	-	-	-	-	-	-	hot, sunny
25.2	0	0	0	32	-	-	-	-	-	-	-	-	hot, cloudy
26.2	0	2	2	38	-	-	-	-	-	-	-	-	hot, sunny
27.2 - 13.3	0	0	0	24 - 34	-	-	-	-	-	-	-	-	various
Means 28.1 - 16.2)	13.9	22.3	36.3		15.1	14.6	29.7		12.1	24.8	36.9		

That such a movement was not necessarily a behavioural feature of all adults and nymphs was apparent from records kept of certain specified individuals on marked leaves in a type 1 cage. Between 4 November 1969 and 6 January 1970 diagrams were made daily to record the positions of adults, and later nymphs on a chosen leaf, and it was found that in most cases they moved only a matter of a few centimetres if at all between observations.

2.22 Longevity

Life span was estimated by two methods.

a. Insectary records

From records of incubation periods, instar duration and adult longevity a mean life span of 149 days (under insectary conditions) was calculated (Tables 11, 12 and 13).

This period was made up as follows:

incubation period	30,5 days
1st instar	15,9 "
2nd instar	15,3 "
3rd instar	14,5 "
4th instar	15,3 "
5th instar	16,1 "
Adult	41,8 "
<hr/>	
Total	149,4 days

Variations in egg incubation period and in nymphal instar duration have already been mentioned. It was found that under insectary conditions longevity of adults also varied considerably, even when there was no obvious cause of death. The records in Table 13 mostly concern individuals for which an emergence date was never recorded (age recorded as 2⁴ +, etc) and their ages are therefore underestimated. Ages of adults which died apparently from natural causes varied from 22 to more than 55 days and a maximum age of at least 97 days was recorded.

TABLE 11. *Numicia* incubation periods from insectary records.

Culture	Date laid	Date hatched	Days	No. of eggs	Culture	Date laid	Date hatched	Days	No. of eggs	
Type 1	29.6	10.8	42	5	Box 4	17.5	14.6	28	2	
"	29.6	11.8	43	3	"	"	16.6	30	4	
Box 8	7.5	7.6	31	12	Box 11	9.5	8.6	30	1	
Box 6	11.5	1.6	21	3	"	"	9.6	31	2	
"	11.5	3.6	23	2	"	"	10.6	32	1	
"	"	4.6	24	1	"	"	11.6	33	2	
"	"	9.6	29	2	"	"	11.6	33	3	
Box 7	30.5	1.7	32	1	"	"	14.6	36	3	
Box 5	5.2	31.3	54	1	"	"	17.6	39	3	
"	"	1.4	55	2	"	"	18.6	40	2	
"	"	14.4	68	1	"	"	20.6	42	2	
"	"	6.5	90	4	"	"	22.6	44	2	
"	"	25.5	109	1	"	"	23.6	45	1	
"	"	28.5	112	1	"	"	24.6	46	1	
"	"	30.5	114	1	"	"	30.6	52	1	
"	"	1.6	116	1	"	21.5	7.8	78	1	
"	"	13.6	128	1	"	"	21.8	92	1	
"	"	15.6	130	1	"	"	26.8	97	1	
"	"	2.7	147	1	"	"	30.8	101	1	
Box 2	27.4	27.5	30	1	"	"	31.8	102	2	
"	"	1.6	35	1	Box 9	29.8	2.10	34	3	
"	"	5.6	39	1	Total				2949	96
"	"	6.6	40	1	Average number of days				30,72	
"	"	8.6	42	1						
"	"	10.6	44	1						
"	"	13.6	47	1						
"	"	14.6	48	1						
"	"	24.6	58	2						
"	"	1.7	65	2						
"	"	4.7	68	1						

TABLE 12 Instar duration in days of the 1⁴ insectary-reared numicia which were measured daily.

Culture	Date emerged	Instar					Total days	
		1	2	3	4	5		
M A L E S	13a	17.8	15	13	12	16	12	68
	12b	21.8	14	16	13	15	15	73
	13d	8.9	14	16	17	18	18	83
	4b	23.9	24	18	14	14	21	91
Total		67	63	56	63	66		315
Average no. days		16,75	15,75	14,00	15,75	16,50		
F E M A L E S	10a	7.8	12	11	10	12	15	60
	10b	7.8	12	11	10	12	15	60
	12a	18.8	15	13	12	13	15	68
	13b	22.8	13	15	14	11	20	73
	13c	25.8	16	15	15	14	16	76
	12c	29.8	15	14	12	22	16	79
	12d	3.9	21	12	16	17	17	83
	12e	9.9	15	22	21	15	15	88
	12f	10.9	21	23	16	11	15	86
	4a	22.9	16	15	21	24	15	91
Total		156	151	147	151	159		764
Average no. days		15,60	15,10	14,70	15,10	15,90		
Grand total		223	214	203	214	225		
Average no. days		15,93	15,29	14,50	15,29	16,07		

TABLE 13 Longevity of adult numicia (from insectary records)

Culture	Sex	Date emerged (or)	Date inserted	Date died	No. of days	Probable cause of death
1	M*		17.4	11.5	24 +	natural
	F*		"	27.4	10 +	"
	F		28.4	19.5	21 +	"
1	M	19.6		3.8	45	"
2	M		17.4	19.6	63 +	" (starvation?)
	F		"	23.7	97 +	"
3	M	19.4		16.5	27	"
	F	22.4		14.5	22	"
4	M		22.4	6.6	45 +	"
	F		"	27.4	5 +	"
	F		"	13.6	52 +	"
6	M		"	17.6	56 +	"
	F		"	14.7	83 +	appeared "egg-bound" by 75 mature eggs
6	M	29.7			55 +	still alive 22.9
7	M		22.4	24.5	32 +	natural
	F		"	8.7	77 +	"
7	F	18.8		8.10	51	appeared "egg-bound" by 96 mature eggs
8	M		6.5	8.6	33 +	natural
	F		"	23.6	48 +	"
9	M		22.4	20.5	28 +	"
	F		"	13.7	82 +	24 mature eggs inside
10	M	6.8		21.9	46	natural (leaf very dry)
	F	7.8		22.9	46	131 mature eggs inside

TABLE 13 (Continued).

Culture	Sex	Date emerged	(or) inserted	Date died	No. of days	Probable cause of death
11	M*		6.5	29.5	23 +	became trapped?
	F*		"	3.8	89 +	natural
M* = male F* = female				Mean 41,8 ⁽¹⁾		
				Mean 46,4 ⁽²⁾		

Mean male span = 39,6 days (from all records)

" female " = 52,6 " " " "

(1) based only on full record
from emergence to death

(2) based on all records (with
range 5 - 97 days).

b. Field records

Estimates were made from the graphed figures obtained during field sampling over a six-year period (see Fig. 23). Assuming the time interval between peak numbers of either nymphs or adults to represent the life span of a generation for that time of year, these periods were extracted from Fig. 23, and are shown in Table 14. The period varied from 80 days in summer to 168 days in winter, with an average span of 120,8 days. This period is rather less than that calculated for the insectary, and may be due to the generally better condition of field-grown sugarcane.

Similarly, assuming the interval between a peak in adult numbers and the subsequent trough to represent adult life span, figures were estimated for adult longevity, and are shown in Table 14. The period varied from 28 days in summer to 118 days in winter, with an average

TABLE 14. Numicia longevity as measured from field population graph 1964 - 1970

Total life span (adult peak to peak)				Adult stage (adult peak to trough)			
Period		Days		Period		Days	
14 May	- 22 Oct	161		14 May	- 20 Aug	98	
23 Oct	- 4 Feb	105		22 Oct	- 15 Dec	54	
5 Feb	- 30 May	115		6 Feb	- 15 Mar	37	
31 May	- 28 Oct	151		10 May	- 26 Aug	108	
29 Oct	- 4 Feb	99		15 Oct	- 20 Dec	66	
5 Feb	- 2 June	118		4 Feb	- 18 Mar	42	
3 June	- 28 Oct	148		6 May	- 1 Sep	118	
29 Oct	- 14 Feb	109		30 Oct	- 20 Dec	51	
15 Feb	- 6 June	112		10 Feb	- 22 Mar	40	
7 June	- 26 Oct	142		10 May	- 20 Aug	102	
27 Oct	- 4 Feb	101		30 Oct	- 14 Dec	45	
5 Feb	- 22 May	108		2 Feb	- 14 Mar	41	
23 May	- 6 Nov	168		1 May	- 20 Aug	111	
7 Nov	- 26 Jan	81		30 Oct	- 30 Dec	61	
27 Jan	- 8 May	102		1 Feb	- 1 Mar	28	
9 May	- 18 Oct	163		1 May	- 1 Aug	92	
19 Oct	- 26 Jan	100		20 Oct	- 20 Dec	61	

Means:

Means:

May - Oct 155,5 (\pm 13,5)
 Oct - Feb 99,2 (\pm 18,2)
 Feb - May 111,0 (\pm 9,0)

May - Aug 104,8 (\pm 13,2)
 Oct - Dec 56,3 (\pm 11,3)
 Feb - Mar 37,6 (\pm 9,6)

Combination of spans from adult peaks and nymph peaks, similarly extrapolated.

<u>Jan - Mar</u>	<u>Feb - May</u>	<u>Mar - Sep</u>	<u>May - Oct</u>	<u>Sep - Jan</u>	<u>Oct - Feb</u>
Days 91,2	111,0	142,2	155,5	126,0	99,2

(overall mean: 120,8 days; range: 80 - 168 days)

span of 67,9 days. This is considerably more than the 41,8 days obtained from insectary records.

Field population sampling showed that adults of each generation copulated, laid eggs and died (3.4.1), and there was no indication that an adult of one generation would survive long enough to lay eggs at the same time as its progeny.

In one field experiment there was an indication that males lived longer than females (3.7.8.1), but insectary records (Table 13) suggested otherwise. In neither case however were sufficient records available for firm conclusions to be drawn.

2.23 Distribution

In the field it was noticed that both nymphs and adults were found almost exclusively on the undersides of leaves. In the very early morning adults were occasionally noted apparently seeking warm sunshine on the upper surfaces of higher leaves, but normal feeding position was on the leaf's lower surface. Indeed, during insecticide trials it was felt that their position on the undersides of leaves protected numicia from spray formulations (5.2; 5.4).

During insectary rearing for life cycle studies it was possible to investigate further the positions adopted by the feeding insects. For convenience, it will be most suitable to consider the following observations as two separate experiments.

2.23.1 Experiment 1

During the life history studies discussed earlier in this chapter diagrams were made each day of the positions of nymphs and adults in type 3 cages (Fig. 3). Between ten and sixteen cages were in use at any one time, all but four of which were positioned so as to enclose growing cane leaves in a large gauzed insectary cell. Cages used were all identical (Plate 6) and conditions of light, temperature and humidity

were similar for all. As culture media the variety NCo 376 was used. Notes were made as to whether the leaf passed upwards or downwards through the cage. In all but one cage the plane of the leaf was vertical, the exception being a cage in which the upper leaf surface faced slightly downwards. Except for those individuals resting against the upper and lower cage ends, the insects almost always perched directly parallel with the line of the leaf i.e. a vertical plane. Cages were inspected at least once every day, and more often on occasions. It was not possible to mark individual insects, and for any conclusions to be drawn regarding preferences for various positions on the leaf it was assumed that, throughout the period, the insects were free to move anywhere within the cages, and that there were no strong external influences which could have encouraged them to assume any particular position. Notes were made regarding any tendency to congregate in the upper, central or lower part of the cage. The following records were kept:

- a. Numbers of nymphs and adults facing upwards
- b. " " " " " " downwards
- c. " " " " " perching horizontally
- d. " " " " " on upper leaf surface
- e. " " " " " on lower leaf surface

Results

These are summarised in Table 15, and given in more detail in Appendix VIII.

There was a preference shown by both nymphs and adults for the lower surface of the leaf, the difference in numbers being significant ($P < 0,001$).

Regardless of whether the leaf passed upwards or downwards through the cage, more insects were recorded facing upwards than downwards ($P < 0,001$). The proportion of nymphs facing downwards was greater (on both surfaces) where the leaf pointed downwards than where it pointed

TABLE 15 Positions of nympha on cane leaves in insectary cultures (summary).

Leaf position	Surface	Total		Facing						% on lower surface
				Upwards		Downwards		Horizontal		
		nymphs	adults	Nos	%	Nos	%	Nos	%	
pointing	upper	1216		923	75,9	212	17,4	81	6,7	
upwards	lower	3836		3050	79,5	679	17,7	107	2,8	75,9 nymphs
	upper		494	361	73,1	109	22,1	24	4,9	
	lower		785	521	66,4	222	28,3	42	5,4	61,4 adults
pointing	upper	287		194	67,6	81	28,2	12	4,2	
downwards	lower	1112		831	74,7	207	18,6	74	6,7	79,5 nymphs
	upper		10	10	100,0	0	0,0	0	0,0	
	lower		132	102	77,3	28	21,2	2	1,5	93,0 adults
* lower surface	upper	532		394	74,1	99	18,6	39	7,3	
pointing slightly	lower	1260		952	75,6	265	21,0	43	3,4	70,3 nymphs
downwards	upper		59	29	49,1	30	50,8	0	0,0	
	lower		182	125	68,7	40	22,0	17	9,3	75,5 adults

TABLE 15 (Continued).

Leaf position	Surface	Total		Facing						% on lower surface
				Upwards		Downwards		Horizontal		
		nymphs	adults	Nos	%	Nos	%	Nos	%	
* lower surface	upper	96		73	76,0	9	9,4	14	14,6	
pointing slightly lower		481		406	84,4	63	13,1	12	2,5	83,4 nymphs
upwards										
			Nil							

* based on 1 culture only

Predominance of nymphs on lower surface $P < 0,001 (\chi^2)$

" " adults " " " $P < 0,001 (")$

" " nymphs facing upwards $P < 0,001 (")$

" " adults " " " $P < 0,001 (")$

upwards; but the difference was not significant. The opposite was true of adults, and observations were too few for any conclusions to be drawn.

A tendency was noted for nymphs especially, to congregate towards the upper ends of the cages.

Of the 342 occasions when numicia were recorded as resting horizontally, 318 (93%) concerned individuals which had positioned themselves against the cage side towards one or other end of the leaf. It was assumed that the presence of the cage side was responsible for their having adopted this position.

2.23.2 Experiment 2

In February 1970 and again in September, a type 3 cage containing nymphs was placed vertically in such a way that one leaf surface was in strong daylight and the other surface shielded with cardboard so that it was in heavy shadow. Numbers of nymphs on each surface were recorded periodically. During the February observations the culture was rotated through 180° every few days, but during the other set this was done once only. Both leaf surfaces were in darkness during the night.

Results

These are shown in Table 16.

When the lower surface was illuminated the percentages of nymphs on it were lower than when it was shaded. However, even when the lower surface was illuminated nearly half the nymphs remained on it.

When the upper surface was illuminated nearly all nymphs moved to the lower surface.

When either surface received direct sunlight, there was an increase in numbers on the shaded surface.

The second set of observations showed that over a period of four days, with the lower surface illuminated, there was a movement from the lower to the upper surface resulting in approximately equal numbers

TABLE 16. Positions of numicia nymphs on vertical cane leaf illuminated from one side.

Time	Illuminated surface	Nos on lower surface	Nos on upper surface	% on lower surface	mean nos on lower surface (%)
17.2.70 12:30	Lower	38	1	97,4	
18.2 08:00	"	19	24	44,2	
16:00	"(in sun-light)	15	28	34,9	
19.2 08:00	"	13	26	33,3	
16:30	" (")	9	30	23,1	
20.2 09:00	"	17	25	40,5	
17:30	"	11	30	26,8	
21.2 10:30	"	17	27	38,6	
17:00	"	17	26	39,5	
	Culture rotated 180°				42,0
22.2 08:30	Upper	35	6	85,4	
16:30	"	36	4	90,0	
23.2 08:15	"	35	5	87,5	
16:15	" (in sun-light)	38	0	100,0	
24.2 07:00	"	32	2	94,1	
16:30	" (")	36	0	100,0	
25.2 07:00	"	32	5	86,5	
	Culture rotated 180°				91,9
25.2 16:30	Lower (in sun-light)	8	13	38,1	
26.2 08:30	"	20	17	54,1	
16:30	" (")	14	24	36,8	
27.2 09:30	"	18	18	50,0	
17:00	"	18	19	48,6	
28.2 10,00	"	19	19	50,0	
	Culture rotated 180°				46,3
28.2 17:00	Upper	29	8	78,4	
1.3 08:00	"	31	7	81,6	
16:15	"	37	2	94,9	
2.3 08:00	"	31	8	79,5	
16:00	"	31	5	86,1	
3.3 07:45	"	32	6	84,2	
16:30	"	35	2	94,6	

TABLE 16 (Continued)

	Time	Illuminated surface	Nos. on lower surface	Nos. on upper surface	% on lower surface	mean nos. on lower surface (%)
4.3	08:30	Upper	28	9	75,7	
	16:30	"	30	6	83,3	
						84,3
18.9	14:30	Upper	130	48	73,0	
	15:30	Lower	124	38	76,5	
	16:15	"	131	48	73,2	
19.9	09:00	"	119	58	67,2	
20.9	10:00	"	105	64	62,1	
21.9	11:15	"	83	81	50,6	
	15:30	"	85	88	49,1	
22.9	08:15	"	82	72	53,2	
	15:30	"	77	72	51,7	61,8

2.24 Discussion of numicia distribution on leaves

Both nymphs and adults showed a preference for the lower leaf surface. Avoidance of light by newly hatched nymphs has been mentioned (2.7), an aversion which diminished as the insect developed. However, it did not seem to be the relative darkness of the lower surface alone which rendered it more attractive, for in one culture where the lower surface was predominantly uppermost, it was still favoured. Also, by exposing the lower surface of a vertically placed leaf to bright daylight, approximately 50% of nymphs present could be induced to seek the upper shaded surface. This is a higher proportion than that found on upper surfaces under more normal insectary conditions but, since so many remained on the illuminated lower surface, it seemed that there was some other factor involved besides light. Vascular tissue is more abundant near the lower surface than the upper surface (Fig. 19), which may influence numbers,

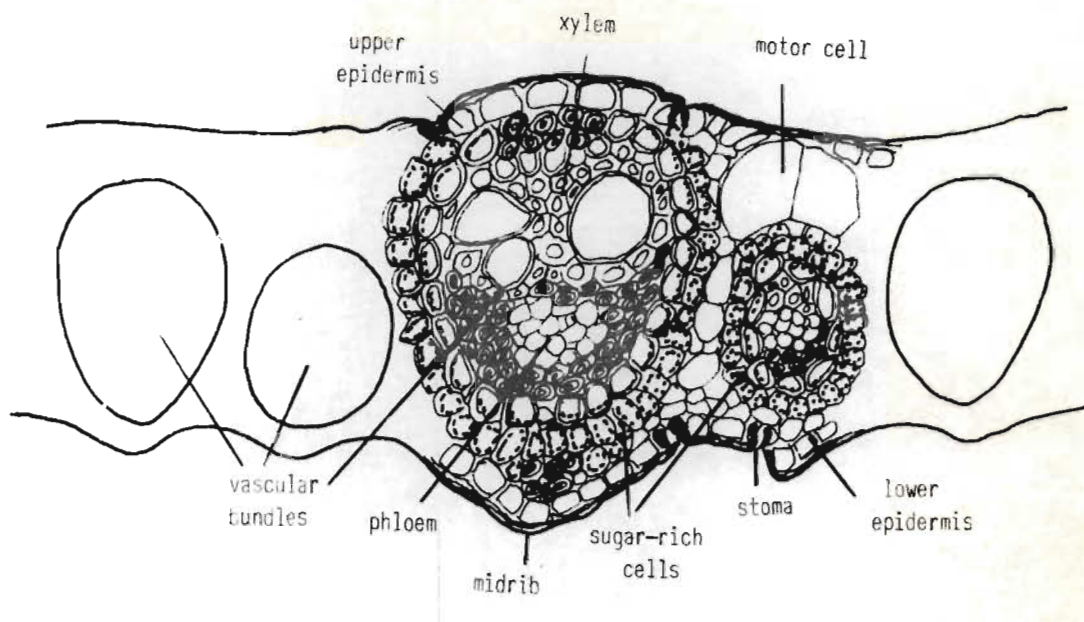


Fig. 19 Diagram of transverse section through sugarcane leaf.

The tendency for numicia to congregate towards the upper ends of cages was to be expected, since they faced predominantly upwards, and probably moved forwards as they fed.

2.25 General discussion of life histories and behaviour

Although early attempts at insectary rearing of numicia had failed, and subsequent attempts had shown that any interruption between hatching and feeding resulted in death, the insect was eventually reared quite successfully using three main types of cage. Each of these permitted the insect to develop on growing plants, and there was the minimum disturbance. The large variation in incubation period was surprising, considering that in the field there are three well synchronised generations each year. There was also considerable variation between instar duration with different

individuals, which was probably influenced by condition of host plant and by interruptions in feeding. Five clearly defined instars were recognised, with sexual dimorphism, manifested by a size difference, becoming apparent during the fourth instar. Development rate decreased as the state of host plants deteriorated.

The variant infuscata was encountered during insectary rearing and its markings were found to vary in intensity.

The two sexes were encountered in approximately equal numbers, with a slight predominance of males. Copulation was frequently observed, especially in the field, and there was no evidence of parthenogenesis. Oviposition occurred at all times of the day and the positioning of eggs was determined by the shape of the plant medium concerned. Eggs were usually inserted in leaf midribs, but in grasses the inflorescence culm was frequently used. A relationship was established between numicia fecundity and nitrogen level, numbers of eggs laid being larger where leaf nitrogen level was higher.

Numicia was not found to be an active insect and, unless disturbed, would move very little. However, significant differences in numbers on the uppermost parts of a large cage at different times were noted, and records showed some evidence of a diurnal movement. In the case of adults this movement could have been in place of a migration, but there was no evidence for this. It was found also that certain positions on cane leaves were more frequently adopted than others.

Under insectary conditions an average life span of 149 days was calculated, compared with 121 days estimated from field records.

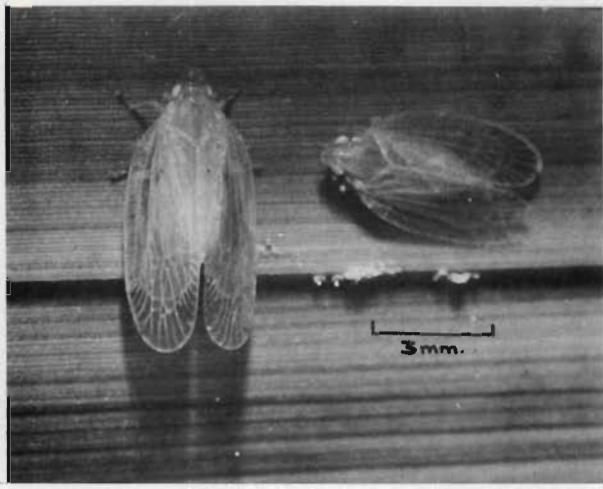


Plate 9 – Numicia female ovipositing, left; eggs in midrib and male, right.

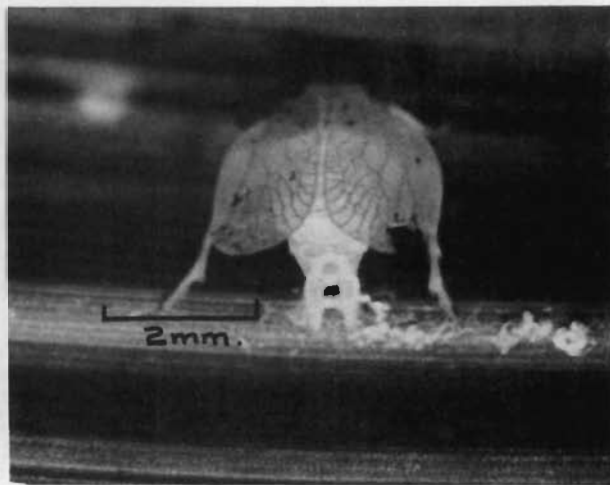


Plate 10 – Numicia female inserting egg into midrib.



Plate 11 – One replicate of numicia fecundity and N level experiment.



Plate 12 – Motorised suction sampler



Plate 13 – Counting numicia on adhesive sheet.

CHAPTER 3

FIELD ECOLOGY

3.1 Introduction

Once it had been established that numicia was feeding on and damaging sugarcane, the immediate problem was how best to stop it doing so, and there followed the insecticide trials described in Chapter 5. It was then realised that not only was some early warning system desirable, but that for proper and permanent control methods to be established, a knowledge was required of the relationship between numicia and its host plants - both indigenous and cultivated. Extensive ecological studies were started in 1964 and were based on periodic field sampling, designed to warn the estate concerned of any threatening population build up. Subsequently more intensive studies of individual fields followed, and were continued from 1964 until 1970.

3.2 Population estimates

All stages of the life cycle could be estimated, but it was found that assessments based on nymphs and adults were most satisfactory.

3.2.1 The egg

Theoretically the egg should perhaps offer the most useful assessment unit because it is static. Metcalfe (1971) found it the only useful unit for assessing populations of West Indian canefly (Saccharosydne saccharivora). It was used repeatedly with numicia especially to estimate state of egg parasitism, but was not found to give an accurate reflection of current population, probably because incubation periods even within the same batch, may vary considerably (Appendix I). Population assessment from eggs was done as follows:

In any field or part of a field to be sampled the sampler would walk along an interrow and, at a specified number of paces, would pluck the nearest lowest green leaf regardless of whether eggs were present or not. This would be repeated until 100 leaves had been so collected. Those with no eggs were then discarded and the remainder retained for further examination. (Since eggs were almost invariably laid in the distal half of the leaf (Table 30) none would be left behind in the leaf stub). Eggs were then divided into hatched and unhatched. This could be done if necessary in the field, preferably using a hand lens, for the conspicuous operculum is removed by the hatching nymph. For detailed records of parasitism and viability microscopic examination was necessary. From such a method assessments were made of all the statistics listed in the sections on varieties and parasitism (3.10.2; 4.3.1.3). (In the field an approximate assessment of parasitism could be made by examining the upper midrib opposite egg batches, where any emerging parasites would have left exit holes in the leaf tissue; parasites very rarely emerged via the lower leaf surface.)

3.2.2 Nymphs and adults

Populations were estimated by the following four methods:

a. Insecticide

An early population assessment method was to dust a given section of cane row with mercaptothion 5% dust, and make mortality counts (Dick, 1963). During the present investigation this method was used only in insecticide trials and then in modified form (5.3).

b. Motorised suction sampler

Towards the end of this investigation two different models of a "D-Vac" suction sampler were used (Dietrik, 1961). This instrument (Plate 12) consists essentially of a motorised fan which

insects are caught undamaged. These most useful and efficient samplers were used frequently to collect material for insectary experiments, and were used for field assessments mainly on the Natal south coast. However, they were used exclusively by Experiment Station personnel, and were not available for use by the various sugar estates. Almost all assessments discussed in this chapter were made by methods c or d.

c. Shake sampling

This method, which became standard on all interested estates entailed the shaking of cane foliage over adhesive plastic sheets. Ideally, metre-square black plastic sheets were used, although frequently old plastic fertilizer bags were substituted (Plate 13). These, when opened out, measure almost exactly one square metre. The plastic surface was smeared with molasses (or grease) and placed on the ground in the interrows. The sampler then embraced the adjacent cane on each side of the interrow and shook it vigorously over the plastic sheet ten times, precipitating nymphs and adults on to the sheet, where they could be counted.

Routine sampling on the Swaziland estate where most figures were obtained, was done by a team of five, who would disperse into the field to be sampled and return with their counts for two samples per man. For convenience these figures were summed, and therefore numbers per ten square metres became a standard rating.

Regular sampling by this method over a period of six years produced so regular a pattern of population, that it was considered to provide a very good reflection of numicia numbers present. However from field tests it was obvious that at least two sources of error existed, neither of which was insuperable.

Firstly, it was found that during the earlier part of cold mornings higher numbers of adults were recorded than during the hotter part of the day (Appendix IXa). Under cold conditions adults are relatively inactive and on being disturbed by the shaking foliage, fewer will fly away than would do under warmer conditions. There was far less variation in nymph numbers. During this investigation sampling in the very early morning was avoided, largely because dewy conditions made the operation difficult and unpleasant, so such an error would have been minimised. Also, separate records were always kept for nymphs and adults.

Secondly, it was possible to detect occasional discrepancies between samplers, especially when a new member joined the team. In a field test three samplers operated side by side in five different places and it was found that one in particular (a stranger to the regular team) recorded more nymphs and fewer adults than the other two did (Appendix IXb). This could have been due to misinterpretation through lack of acquaintance, although nymphs and adults are conspicuously different. Or it could possibly have resulted from less vigorous shaking of the cane, although that would not explain the relatively larger numbers of nymphs.

When numbers became very high, counting errors also must have occurred, although periodic checking of samplers showed their counts to be remarkably accurate.

It was found that after continued use the adhesive quality of the plastic sheets failed, and the molasses required replacing. This was especially noticeable during dry dusty conditions. Between sampling the sheets were folded, molasses side inwards, which served to obscure any dead insects which had not been removed, so that they would not be included in subsequent samples.

Shake sampling was possible only in cane aged about four months or more.

d. Quadrat sampling

Metre square quadrats, made from cylindrical reinforcing iron were used for sampling in grasses and in cane which was too short for shake sampling. These were simply placed over the grass or cane and the numicia nymphs and adults contained within them were counted as accurately as possible (Plates 14 and 15).

In fields which were sampled initially with quadrats and subsequently (when the cane became too tall) by shaking, there was an obvious discrepancy between the methods which is reflected in the results (Figs 29 and 30). There seemed little practical advantage in calculating an actual factor for this difference, but under comparable conditions shake sampling produced about twice as many numicia as quadrat sampling. This is understandable because firstly, by shaking cane over a metre square area a larger volume is being sampled than in short cane or grass using a quadrat; and secondly the insects, and especially young nymphs are more difficult to see and count using a quadrat than when they are trapped on an adhesive sheet. This discrepancy frequently gave the impression that in one generation adult numbers were higher than those of the nymphs from which they had developed.

3.3 Location of studies

Metcalf (1971) distinguished between endemic and epidemic cane fly populations, and the same could be done with numicia. For purposes of this investigation it was a source of regret that epidemic populations were unknown anywhere within 350 km of the Experiment Station at Mount Edgecombe. Therefore most field ecological studies were made during visits to Swaziland, or from figures collected by Swaziland estate personnel who were advised and supervised from the



Plate 14 – Quadrat sampling in a freshly burnt cane field.



Plate 15 – Quadrat sampling in Kikuyu grass (sampling site 10).

Plate 16 – Contact point between cane and green riparian grasses (sampling site 3).



Plate 17 – Contact point between cane and canal bank grasses (sampling site 5).



UBOMBO RANCHES SWAZILAND

Sampling sites ① ② etc.

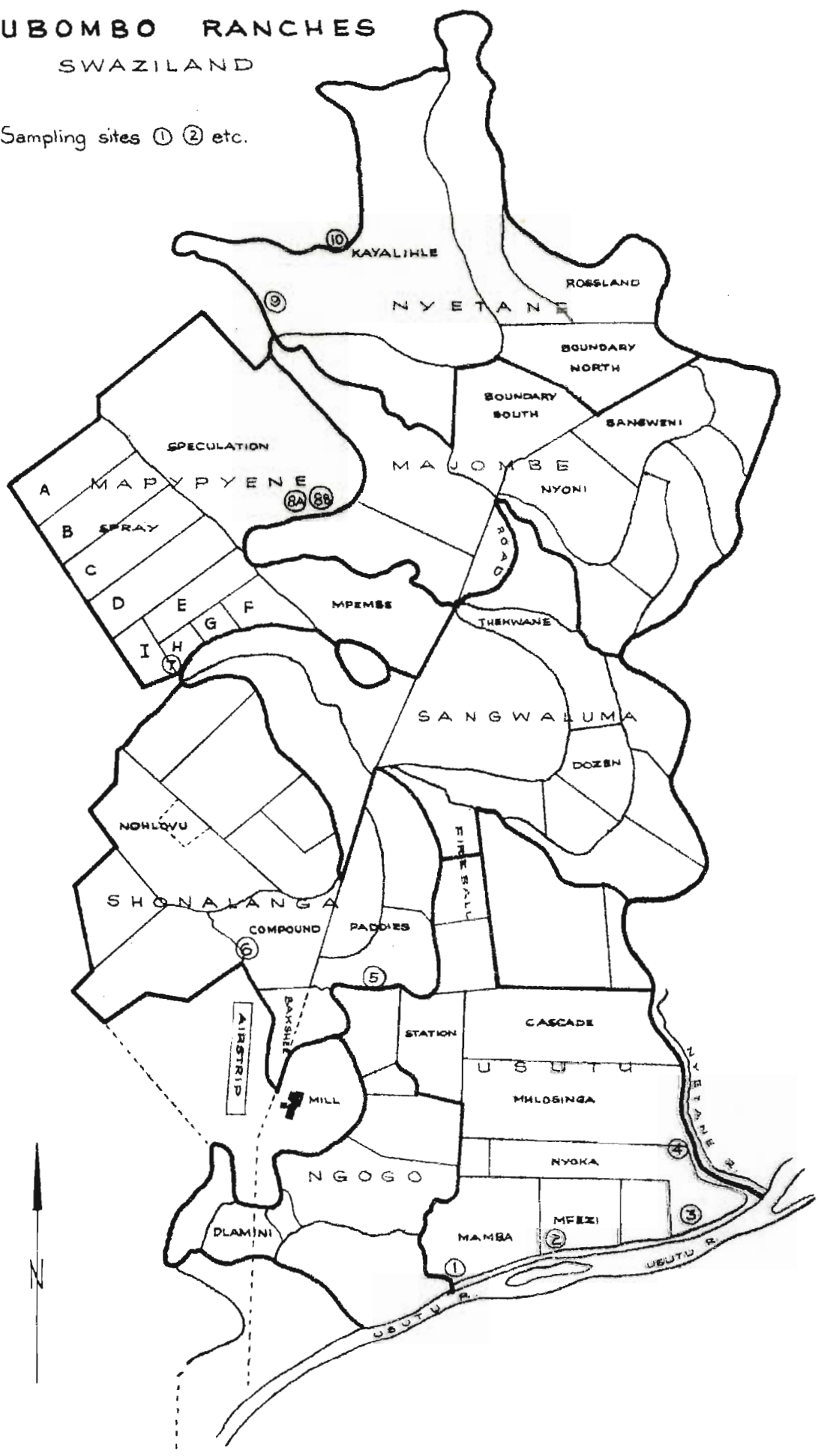


Fig. 20

Ubombo Ranches, Swaziland.

Most information was obtained at Ubombo Ranches Swaziland which, during epidemic years was visited at approximately monthly intervals. Also, during 1966 the writer was able to spend three months on the estate (Carnegie, 1967a). Between visits their agronomy staff made regular routine population counts as a precaution against population build up, and in addition did further more intensive sampling as requested by the Experiment Station, to which copies of all figures obtained and observations made were forwarded for analysis and comment. Less exhaustive field records were made available by other Swaziland estates as well.

Relatively little investigatory work was conducted at Pongola because although epidemic populations occurred, individual farms were small, and the situation was confused by sporadic insecticide use.

Populations at an endemic level were studied on the Natal south coast at Illovo and (rather more inland) at Paddock, which were visited fortnightly and monthly respectively.

Ubombo Ranches (Fig. 20) is a 4 000 hectare estate which adjoins the Usutu river from which it draws its irrigation water. No crop is grown but sugarcane, all of which is irrigated. When this investigation was started irrigation methods included both overhead and surface, but in more recent years the proportion of spray irrigated fields has been increased. Varieties grown were almost exclusively NCo 310 and NCo 376, with a planting programme in favour of NCo 376 being implemented during the investigation. Field management was of a very high order, being comparable with the best in Swaziland or South Africa. Length of crop cycle varied, with an average crop age of about 16 to 17 months.

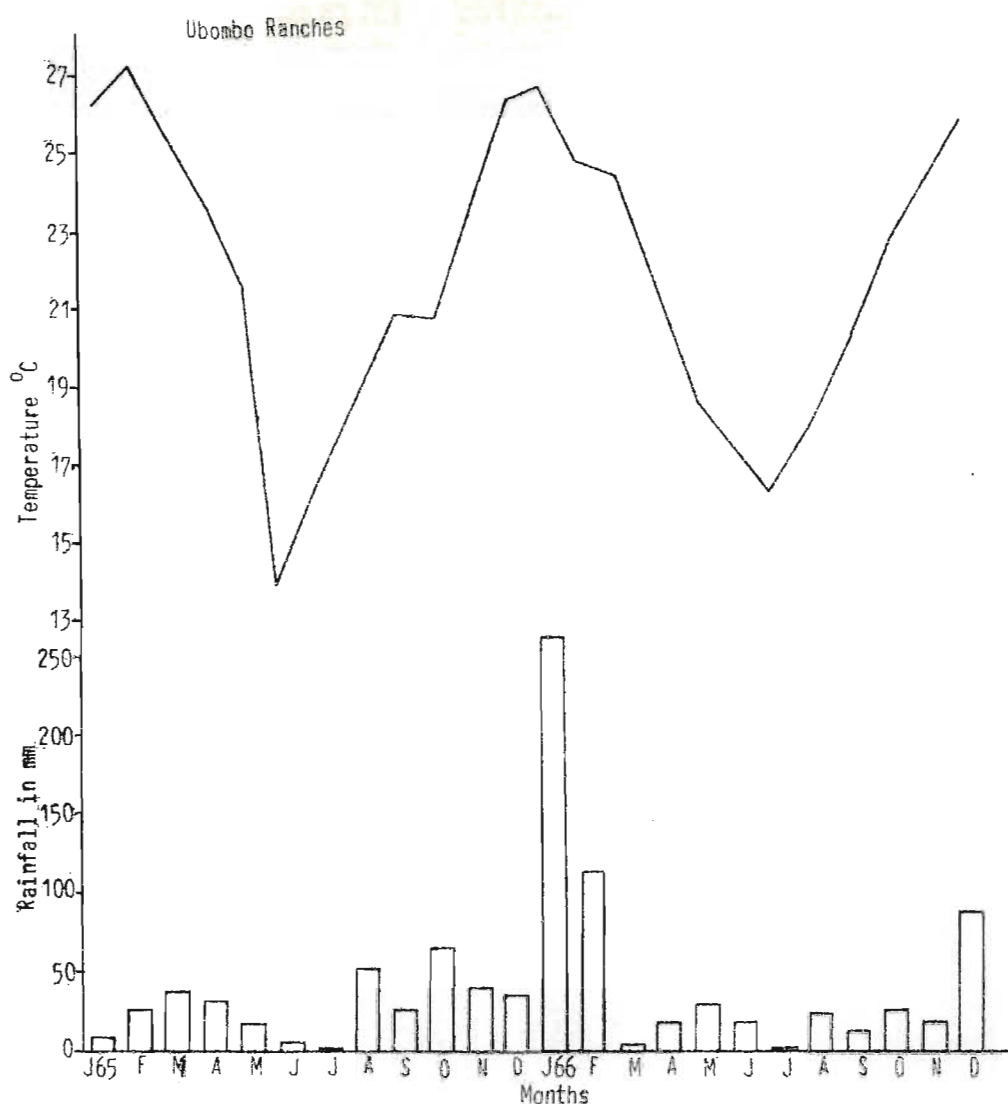


Fig. 21 Meteorological records, Big Bend, Swaziland.

Meteorological records for two epidemic years are shown in Fig. 21 (records for 1966 are the more typical). The general weather pattern is that there is a dry period from about the end of April until about October or November during which the days are warm (maxima usually above 25°C) but the nights are quite cold (minima often below 7°C). Rain falls mainly between October and April during which time very hot weather may occur (maxima often above 35°C).

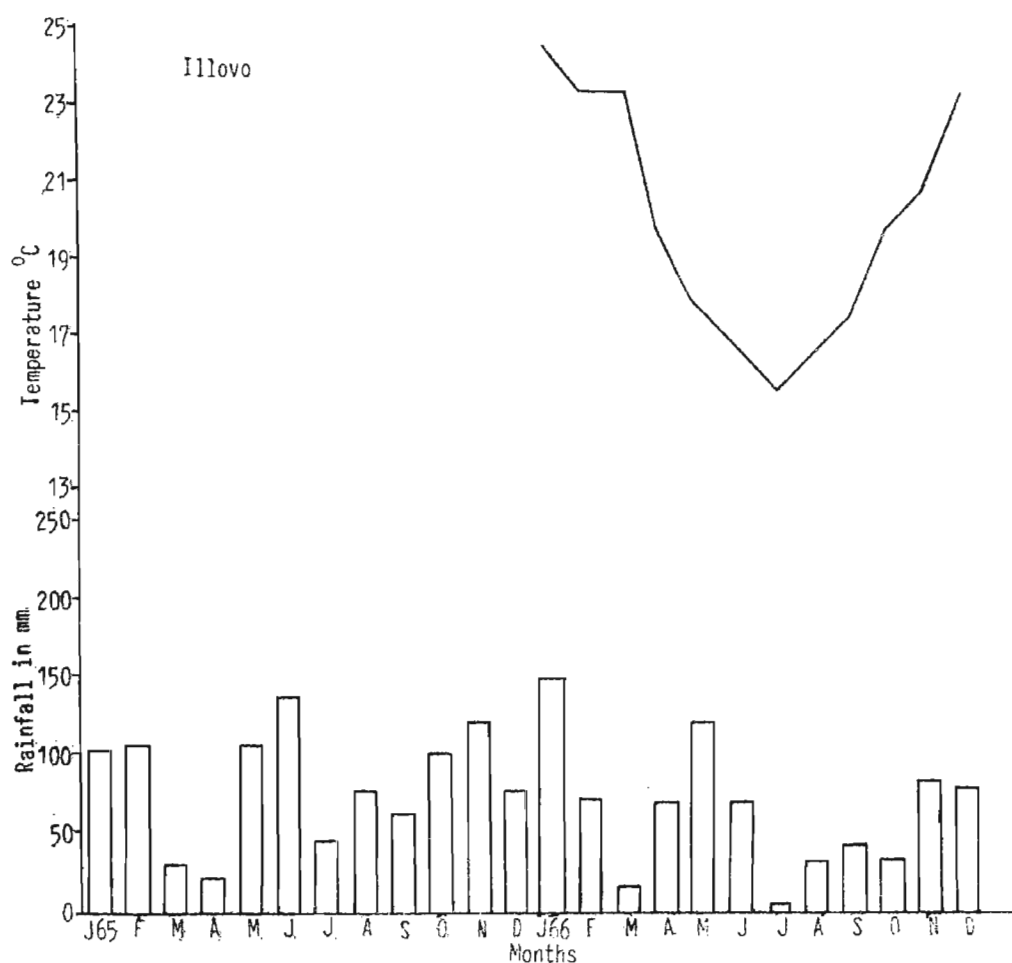


Fig. 22 Meteorological records, Illovo, Natal south coast.

Unless rains have been exceptionally heavy a routine schedule of irrigation is followed, and the state of the cane normally remains healthy throughout the year, although during the winter months growth rate is considerably reduced.

Conditions at Illovo and Paddock are rather different. Rainfall is more evenly distributed (Fig. 22) but periods of drought may occur and, with the exception of a few fields there is no routine irrigation schedule so that the crop may well undergo periods of stress. Winters are rather longer than in Swaziland and rate of cane growth slower with an average crop cycle of about 20 months.

Information of a more general nature was obtained in the course of visits made throughout the cane growing areas of South Africa and Swaziland. Also, for six years an annual numicia survey was conducted (Dick, 1967) which necessitated sampling in all areas (1.3.1).

3.4 Extensive investigations

3.4.1 Field populations at Ubombo Ranches : estate records

Following the first numicia outbreaks in 1963 and 1964 it was considered advantageous both to the estate and to the Experiment Station to keep regular records of numicia populations. These were initiated in January 1964 and continued until January 1970.

Methods

Egg sampling was done as described earlier (3.2.1), any leaves containing eggs being placed in polythene bags and refrigerated until an opportunity arose to forward them to Mount Edgecombe for detailed examination. Regular egg sampling was started in August 1964 and was continued until June 1968 when eggs became scarce.

Sampling for nymphs and adults was done exclusively by shaking the cane over adhesive sheets as described above (3.2.2/c).

The intervals between sampling were determined largely by prevailing numicia incidence. If there seemed to be no immediate danger of an outbreak sampling was done monthly, but if the position appeared dangerous fortnightly or even weekly sampling was implemented.

Sampling was always done by the same agronomy team, although within the team there were occasional personnel changes. Initially between ten and 25 fields (usually 15) were sampled on each occasion, but from August, 1967 20 fields were sampled. The same fields were not necessarily included on each occasion, it being impossible to sample by shaking until the cane was four to five months old.

Fig. 23 *Numicia* field populations, Ubombo Ranches, Swaziland
Jan 1964 - Jan 1970.

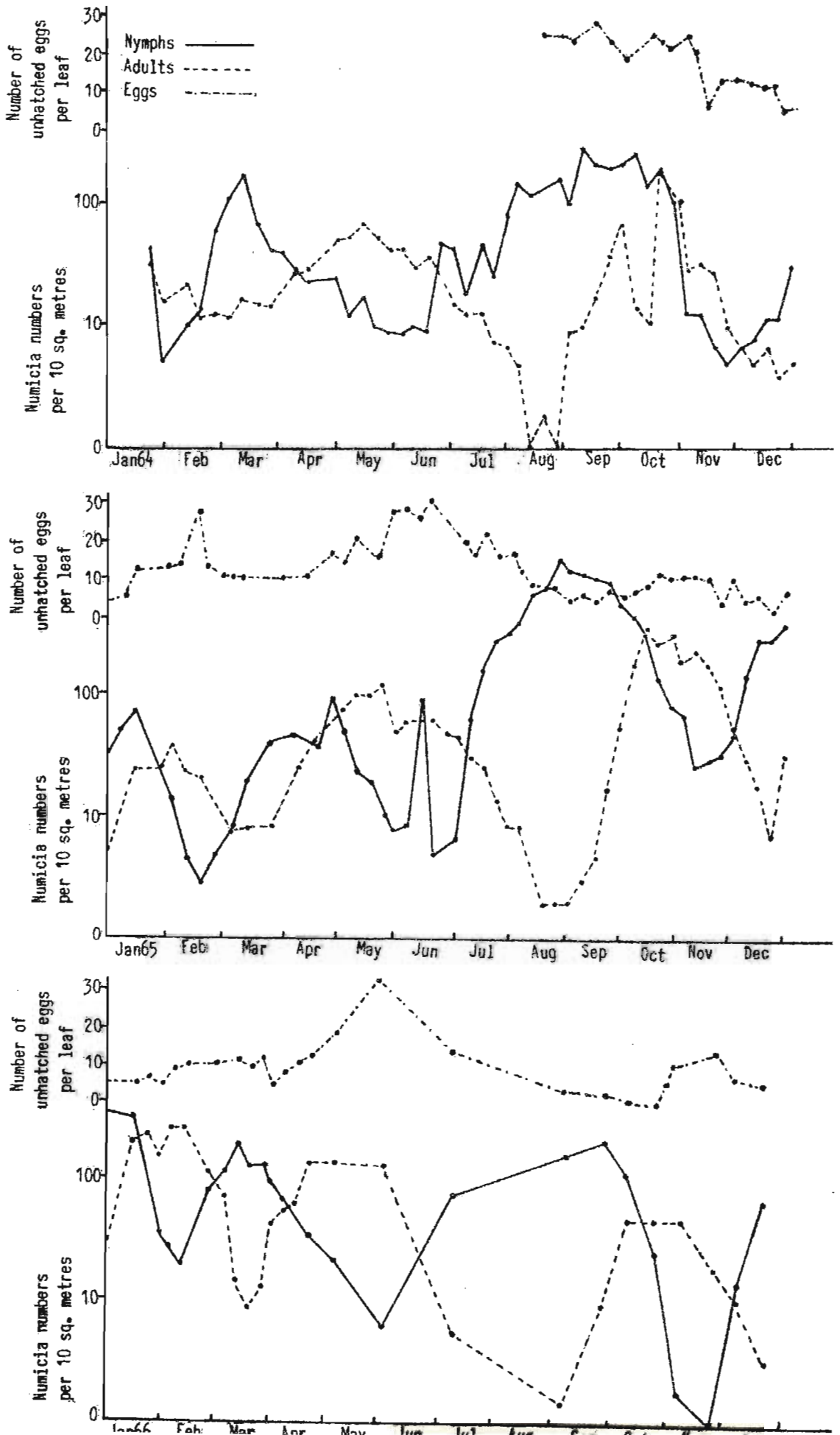
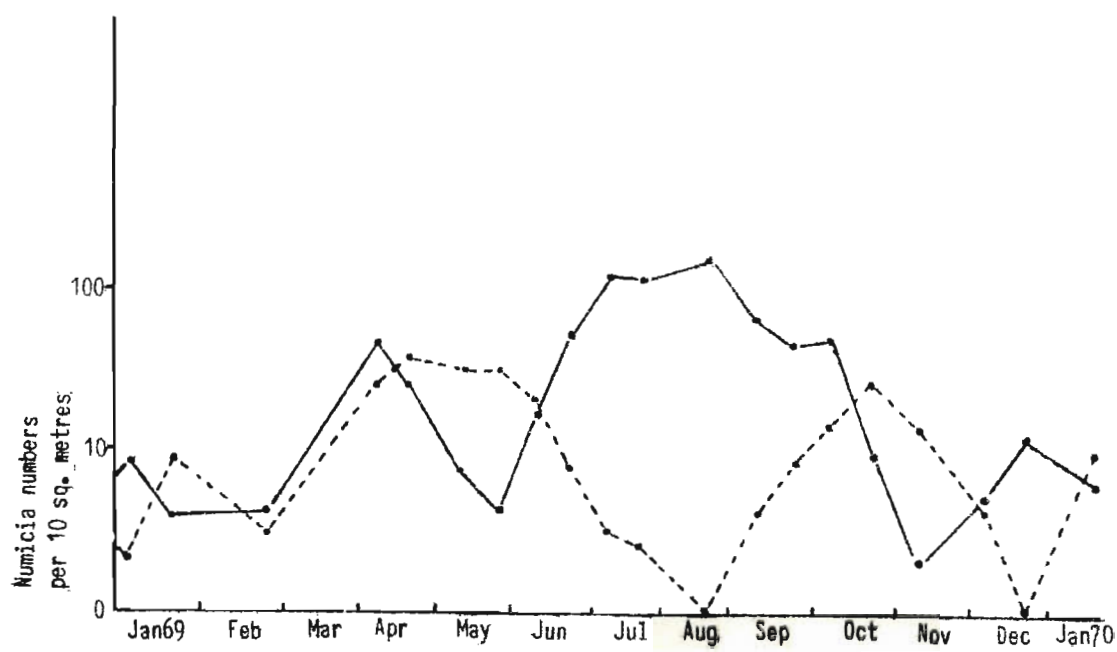
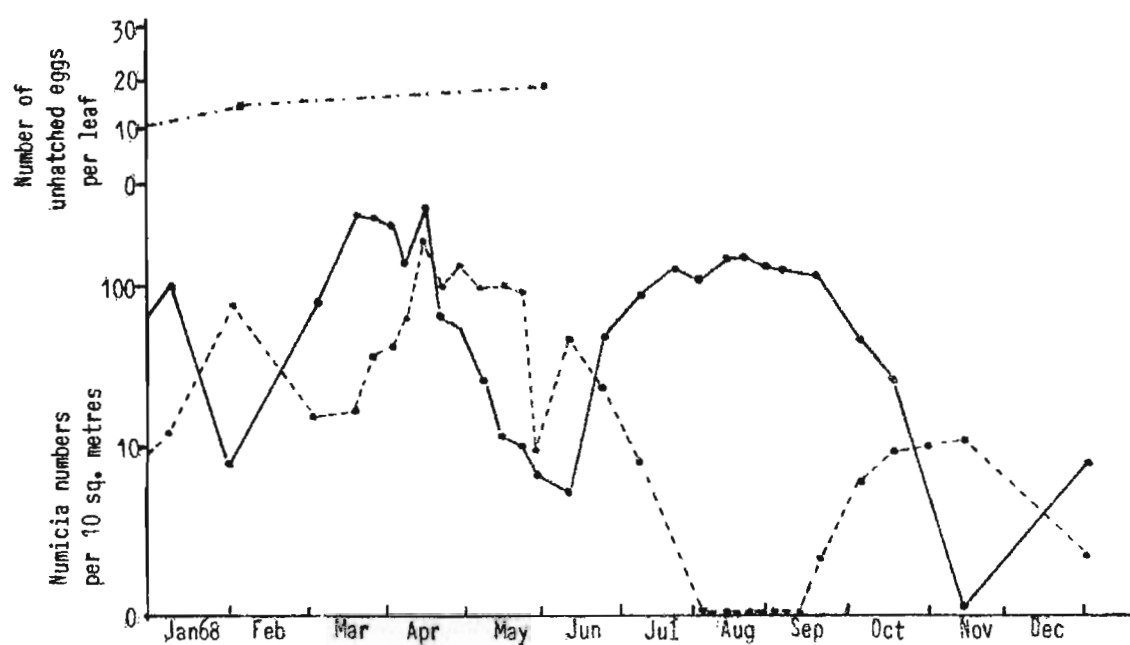
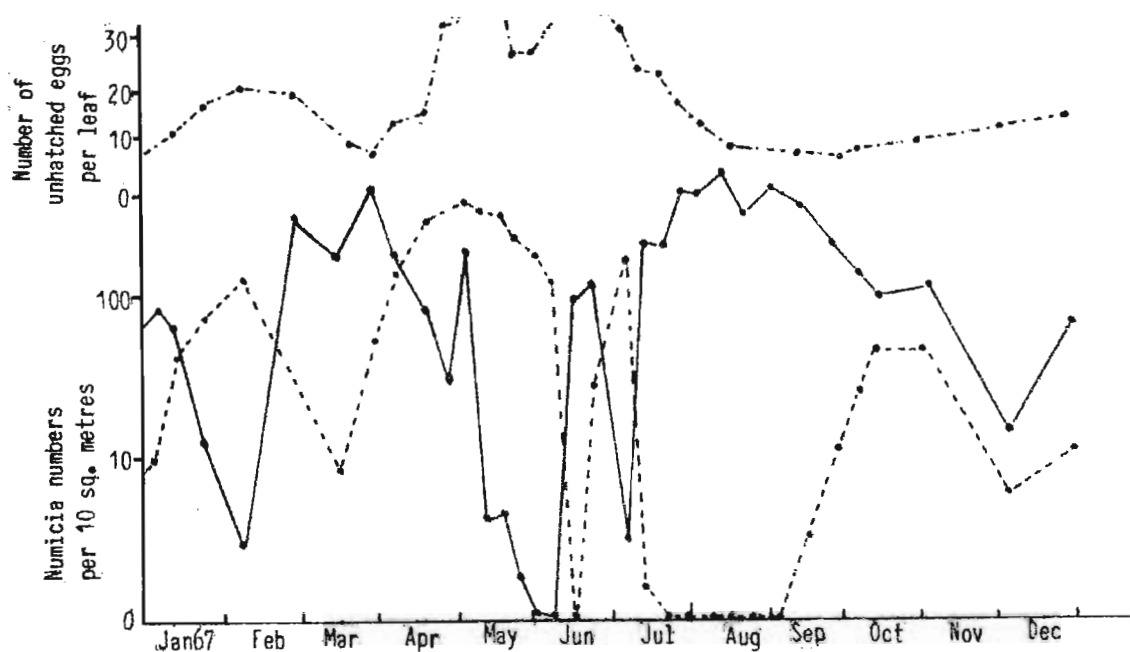


Fig. 23 (Continued)



Fields were not primarily selected because they were suspect, although any field which as a result of sampling appeared to contain alarming numbers, was included in subsequent samplings. The sampling team simply drove around the estate, sampling eligible fields in all areas on all occasions.

Results

When figures for eggs, nymphs and adults for any individual field were plotted it was found that they followed a definite pattern (Figs 27, 32, 33, 34), and that when mean figures for all fields sampled were plotted the same pattern was apparent. These results are summarised in Fig. 23.

Relative numbers of each stage (egg, nymph and adult) followed an expected pattern (Carnegie, 1966). A fall in numbers of unhatched eggs was followed by an increase in numbers of nymphs, which in turn was followed by an increase in adult numbers. There was a decrease in adult numbers following copulation, oviposition and death. Peaks in adult numbers were never higher than corresponding peaks in nymph numbers, which can be explained by natural mortality during the nymphal stages; (possibly the diurnal sampling error mentioned in Section 3.2.2/c also played a part). In some cases e.g. May 1965, peak numbers of adults and nymphs approximated more closely than might have been expected, which could have been caused by adult migration from outside; but there was no definite evidence for such a migration.

There were three generations each year with peaks in adult numbers occurring in February, May and October i.e. two generations during summer and one during winter. There was very little overlap of the various stages of the life cycle. This synchrony of generations will be discussed later (3.5).

In August of each year adult numbers reached an exceptionally low level. This can be explained by the slower developmental rate at that time of year precluding the emergence of the following generation's adults before most adults of the previous generation had died. An alternative explanation, that there was at that time a migration of adults from cane to grasses is not supported by available evidence (3.7.1). August and September are two of the driest months, when there is a minimum of green grass available.

More detailed discussion of egg analyses is provided under biological control (4.3).

3.4.2 Field populations at Big Bend Estate : estate records

Similar sampling was done on another estate situated about eight kilometres from Ubombo Ranches. Regular sampling for nymphs and adults was started in May 1968 and continued until September 1971. Sampling method was by shaking, and usually between ten and 25 fields were included on each occasion. Sampling however was less intensive, involving only one square metre per field, and was not done under supervision from the Experiment Station.

Results are shown in Fig. 24. The generation patterns are apparent, although less well defined than in Fig. 23.

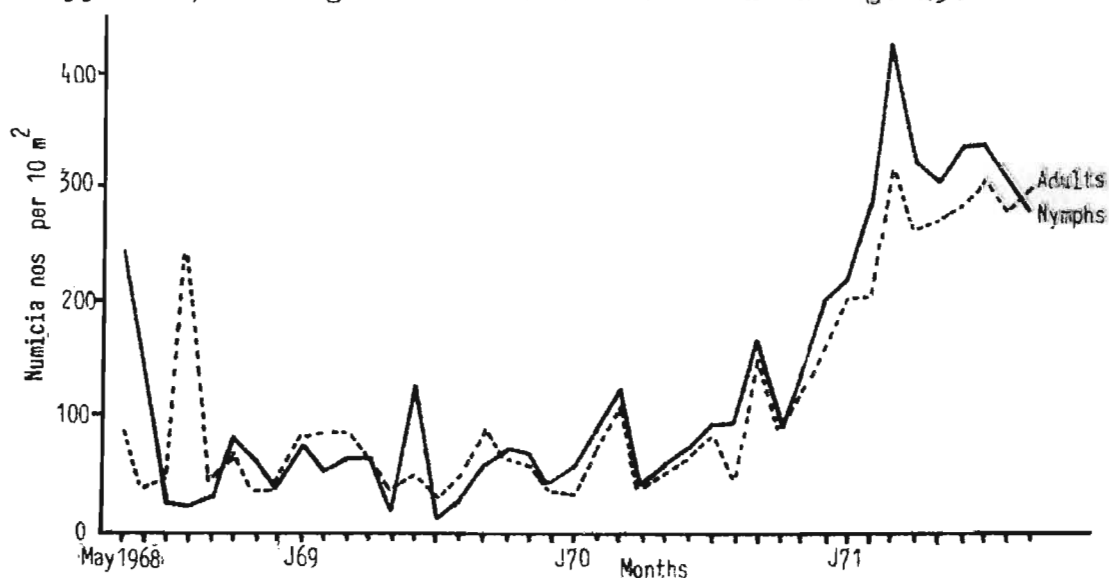


Fig. 24 Numicia field populations, Big Bend Estate, Swaziland
May 1968 - Sep. 1971.

3.4.3 Field populations on Natal south coast

From January 1967 until December 1969 visits were made at approximately fortnightly intervals to the coastal areas of Illovo Sugar Estates, where certain fields were sampled for all stages of numicia. From November 1967 until September 1969 periodic visits (approximately monthly) were made to a farm near Paddock where similar sampling was done. At both places sampling initially was done by shaking, but later a motorised suction sampler was used (3.2.2/b). (In field tests done at Ubombo Ranches it was found that suction sampling for a period of one minute was approximately equivalent to one normal sample over a square metre).

Illovo

Until July 1968 one particular field only was sampled, but from then onwards on each occasion the same five fields were sampled and an average calculated. Results for nymphs and adults are shown in Fig. 25, and egg data are discussed in 4.3.1.7/a and illustrated in Fig. 44a.

Although population level was very much lower than in Swaziland the same trends were apparent, with peaks occurring at the same times i.e. the same synchrony of generations held.

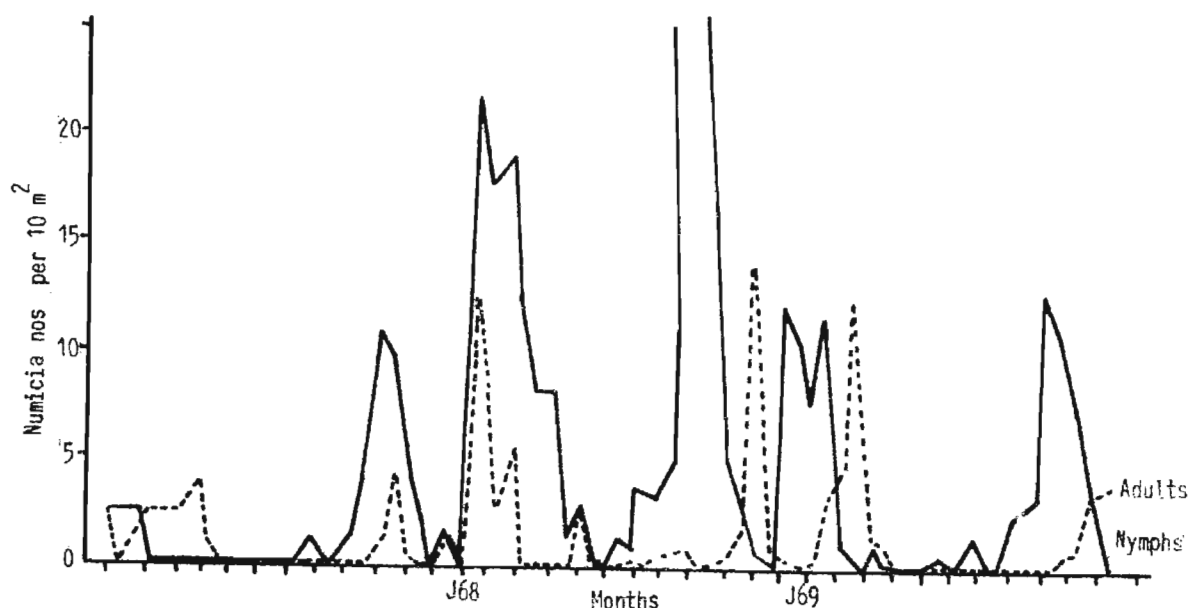


Fig. 25 Numicia field populations, Illovo Sugar Estates, Natal, 1967-1969

Paddock

Attention was drawn to one particular farm at Paddock by a plant disease inspector who noted unusually large numbers of numicia in one cane field. By Swaziland standards numbers were not alarmingly high; but it was odd that on this particular farm there should have been this resident population which was maintained throughout most of the sampling period, without epidemic levels ever being reached.

Affected fields were situated 17 km from the coast at an altitude of 280 m, and the variety was NCo 376. Conditions were not typically coastal, although they resembled Illovo conditions much more closely than they did those of Swaziland. Initially one site only was sampled, but from August 1968 two sites were included (Fig. 26).

There was great variation in population levels but a similar synchrony was discernible. Egg data are discussed in 4.3.1.7/e and summarised in Table 48.

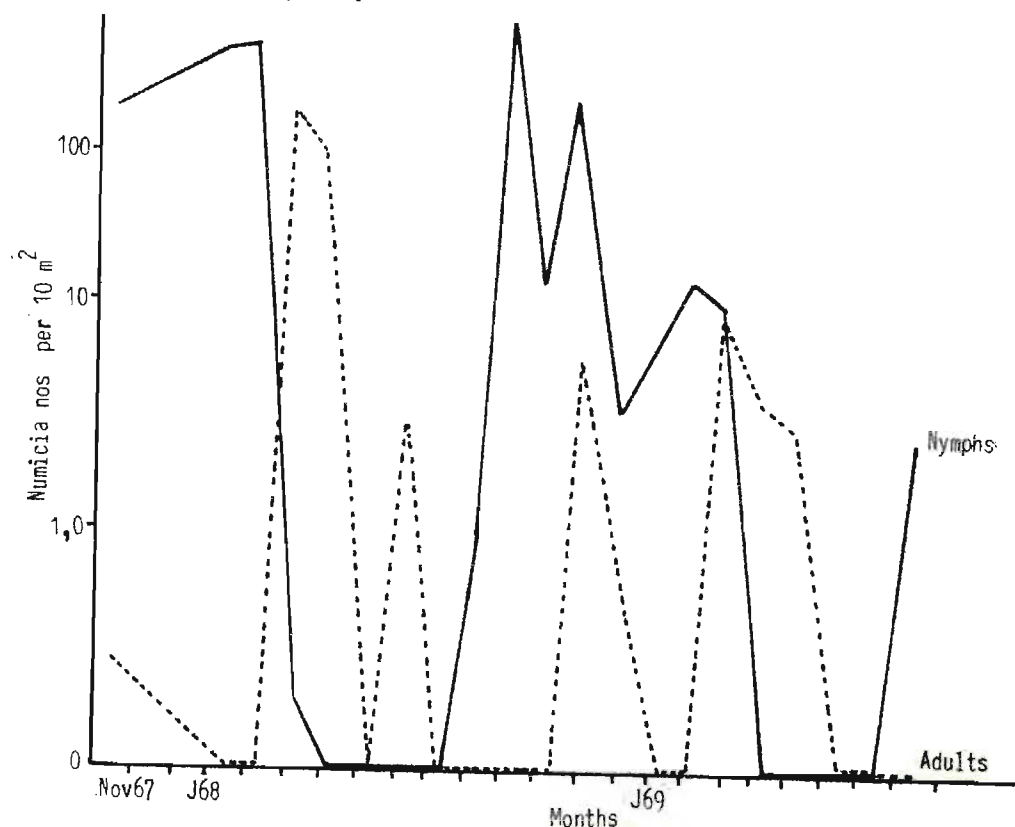


Fig. 26 Numicia populations, Penrith Plains, Paddock, Natal
Nov. 1967 - Sep. 1969

3.5 Synchrony of generations

The synchronisation of the various developmental stages which became apparent from the foregoing population counts, is an interesting phenomenon, and was of considerable importance in planning control measures.

The phenomenon occurs with many insects, especially in temperate areas, and may be caused by a number of direct or indirect factors. It may be linked with mass emergence and migration (Johnson 1969), and in armyworm (Noctuidae) studies it has been associated with wind patterns (Brown et al., 1969). Indirect dependence on climatic factors e.g. onset of seasonal rains occurs with the red locust, Nomadacris septemfasciata (Serville) (Symmons and Carnegie, 1959).

A particularly interesting and topical case occurs in Jamaica with the West Indian cane fly, Saccharosydne saccharivora, which is discussed by Metcalfe (1971) and Frank (1971) (1.3.2). With this Delphacid synchrony of generations occurs only under epidemic conditions, and has been attributed to parasitisation by the Stylopid Stenocranophilus quadratus Pierce. The female parasite liberates living triungulin larvae on to the cane leaves and these search for and penetrate new hosts, sterilising the females and probably the males also. A parasitised female which is ready to oviposit will not be affected but parasitism of an early instar nymph will produce sterilisation of the developing adult. Under epidemic conditions 100% parasitism towards the end of the time period for each cane fly generation has been observed; but under endemic conditions the state of parasitism is low. If searching success of the parasite is density dependent, then higher success rates depend upon the size of aggregations of cane fly, which in turn depend upon population size. As the cane fly nymphal population builds up so the Stylopid larvae searching for hosts have more success

Those cane fly nymphs which hatch early have a relatively better chance of surviving to reproduce. The effect is that the later-developing nymphs, when they become adults, do not reproduce and the tendency of variable development rates of the cane fly stages to produce overlapping generations is negated.

No such subtle explanation of the phenomenon in numicia populations has been forthcoming, and it is probably due simply to a slower developmental rate during the cooler months of the year - a climatic variation which might not occur under more tropical conditions.

With numicia the synchrony has been found to hold both in the hotter northern irrigated areas and on the Natal south coast. There are times when all stages i.e. eggs, nymphs and adults may be found in a field, but populations are usually predominantly of one particular stage. There are times also when one stage may be counted upon as being very scarce e.g. adults in late August and early September.

When considering causes of synchronisation in numicia populations three main probabilities arise:

a) coincidence; b) dispersal of adults; c) seasonal climate, either directly affecting the insect, its natural enemies, or the crop. There exist sufficient population records for the possibility of coincidence to be discounted.

Dispersal of adults will be discussed later (3.6; 3.7); but investigations have not suggested that there is any definite and orientated migration in any particular direction, or at any particular time, or in response to any particular stimulus, such as might result in a synchrony throughout the cane belt.

Metcalf (loc. cit.) found that in endemic cane fly populations synchrony did not occur; and states that it had not been

reported from territories other than Jamaica, although he had noted it on one farm in British Honduras. Guagliumi (1953) states that in Venezuela all stages of cane fly co-existed. With numicia, synchrony was found to occur in all places where the insect was noted regardless of population size, state of the cane, or type of host plant. This was something to be considered when contemplating the collecting of material for insectary purposes, or when planning an intensive field experiment to investigate some particular aspect of numicia biology. There were certain times when one knew that adults (for example) would not be found in any quantity from Paddock to Malelane.

In insectary rearing experiments it was found that rate of development depended on state of host plant (Fig. 13a; 2.12), and it is surprising that in the field the varying quality of host plants did not upset the synchrony.

Regarding natural enemies (Chapter 4) no Strepsipteron was ever recorded despite the numerous numicia specimens examined and dissected. Both Dryinids and Epipyropids were recorded, sometimes in considerable numbers, but it is inconceivable that they could have sterilised populations in the same way that Stylopids were found to sterilise cane fly in Jamaica. Neither is it considered possible that synchrony could have been caused by either of the two common egg parasites (4.3.1.1; 4.3.1.2).

The factor most worthy of consideration appears to be climate i.e. the direct effect of temperature on rate of development of numicia itself.

The fact that there were three developmental periods led to a prevalence of adults in (about) February, May and October. In Table 14 are recorded the number of days elapsing between peaks in adult numbers and peaks in nymphal numbers. The figures are taken

from the field records of Ubombo Ranches Swaziland, and extend from 1964 to 1970 (see 2.22 for further discussion). They show that during summer the life cycle was completed more quickly than in winter. In the course of insectary rearing experiments, discussed in Chapter 2, the synchrony broke down, which is thought to have been due to the more even temperatures maintained in insectary cultures.

3.6 Intensive investigations

3.6.1 Development of numicia populations

Throughout the inland irrigated areas it is customary to burn cane at the time of cutting to eliminate the trash. In most cases the standing cane is fired, after which it is cut, the tops are severed and the sticks stacked and removed for milling. Remaining trash is then raked into interrows and burnt, sometimes twice. By then the field consists of little more than ashes and bare ground until the ratooning crop appears and on it a new population of numicia

Regarding infestation of a field by numicia there are a number of possibilities to be considered.

a. Residual populations on cane

Such populations, surviving cutting and burning could theoretically form the nucleus of a new infestation.

If a field is cut and burnt at a time when eggs are plentiful, many may remain in leaves which are too green to burn thoroughly. Eggs in leaves which have been dry for several weeks can produce apparently healthy active nymphs which, under field conditions might be expected to move on to young ratooning cane and start feeding (4.3.1.6). An examination of ten egg-containing leaves from a typical harvested and burnt canefield at Ubombo Ranches in August 1966 showed the following: of the 214 eggs present 60 were unhatched; of these, 26 were unharmed, and 18 were parasitised.

Of 16 which had degenerated only three had been burnt, and of the 10 parasites present five were alive and active.

Whether many nymphs hatching from such eggs would survive is doubtful, for it has been found in insectary cultures that a disturbance or impediment between hatching and feeding jeopardises survival (2.1).

Nymphs and adults have been found in large numbers on green cane tops after burning and cutting, but few such nymphs could be expected to live long enough to infest new ratoons. Quadrat sampling in fields cut and burnt a few days earlier have revealed the presence on new shoots of nymphs. Plate 14 shows quadrat sampling in a recently burnt field of ratoon cane (field Kayalihle, Ubombo Ranches) in which nymphs were found very shortly after burning. They were not young enough to have hatched from eggs in incompletely burnt leaves and were too small to have migrated unaided the required 100 m from the nearest green grass. It is most unlikely that they were blown there, since conditions at the time were not windy, and it seems certain therefore that they survived the burning. They were found on what remained of the stools, whence they could move on to the young ratoons and serve as the progenitors of a future population. It is however most unlikely that large numbers survive in this manner, for in the course of extensive sampling for migrant adults on young ratooning cane, nymphs were seldom recorded (3.7.8).

In 1968 at Ubombo Ranches the carry over of numicia nymphs on trash was investigated in two ratooning fields which had supported moderate populations on the previous crop. At the time of cutting most numicia were in the nymphal stage. Using four quadrats the fields were sampled at 50 m intervals for 400 m. At each point two quadrats were placed over cane sprouting through raked trash, and two over cane without trash. Results do not warrant tabulating,

for in the 108 places sampled only two nymphs were recorded; one on cane with trash and the other on clear cane.

b. Passive transportation

All stages could be carried passively by various agents. Where seed cane with tops is transported from an infested field to a field to be planted, eggs, nymphs or even adults could be taken with it. For reasons already stated infestations starting from eggs or young nymphs are unlikely to occur and mature nymphs and adults could affect a new field only indirectly, after spending an intermediate period in an adjoining cane field or in grasses.

It has been suggested that young nymphs could be carried passively in air currents, their terminal waxy filaments having a "parachuting" effect. When it is seen how high and how far ash from a burning cane field is carried the possibility seems worth considering. During this investigation much use was made of two Johnson and Taylor suction traps, which trap small air-borne insects and automatically segregate the catch into successive samples for a predetermined time interval (Johnson, 1950; Taylor, 1951); but although many small insects were caught they never included numicia nymphs. Neither have numicia nymphs been recovered from the various adhesive traps which have been set up on occasions (3.7). Both such forms of sampling are of a very low intensity, but the fact that during routine sampling nymphs have only rarely been recovered from young plant or ratoon cane, suggests that few if any are spread in this way. The possibility of transportation of nymphs and adults in surface irrigation water deserves mention. On occasions living individuals have been recovered from irrigation furrows.

c. Adult movement

Adults flying from older to younger cane (possibly flushed by burning) or from grasses to cane, could be expected to start an

infestation. Of all possibilities considered this was undoubtedly the most important. Estate personnel occasionally reported mass orientated flights, but these were never confirmed, and on occasions it appeared that the insects seen may have been termites. No such migration was ever reported by reliable sources, and the investigation of adult movement became the subject of eight experiments which will be discussed below.

3.7 Field experiments on numicia movement and distribution

Materials and methods

Investigation of migration using adhesive traps was tried in 1964 at Pongola (Anon, 1964) where 16 traps were positioned between grass and canefields. Many insects were caught by these, but they included no numicia. In October 1966 at Ubombo Ranches five similar traps were placed along a break between the fields Compound and Bakshee, (heavily infested 10-month-old cane and young ratoon respectively). After two months only two numicia had been caught, both on the same trap, and this method therefore was not used any more extensively. It was felt that to be at all indicative very many traps would have to be used and that a considerable range in height would be necessary, making the whole operation impractical.

In the experiments described below movement was assessed by sampling populations periodically in adjacent media, using quadrats in grasses and short cane, and shaking over adhesive sheets in taller cane (3.2.2/d; 3.2.2/c). In experiments 4 and 8 a motorised suction sampler was used (3.2.2/b). Quadrat and shake sampling was done by a team of five, each of whom sampled four square metres in each position. All experiments were conducted at Ubombo Ranches, Swaziland.

3.7.1 Experiment 1

Objectives

- a. To investigate numicia movement from grasses to cane and possibly from cane to grasses. Since adult numicia can fly it was to be expected that there would be some movement of individuals from one medium to another; indeed, it had been noted that where a field was heavily infested, adults did move in what appeared to be a haphazard fashion to and fro across a cane break. But it was evidence of a mass or orientated movement that was sought. A case of what must have amounted to a minor invasion was noted in May 1966 in the field Mfezi, where young plant cane adjacent to the Usutu river became heavily infested with numicia, which could not have built up from a residual population, and must therefore have come from surrounding grasses or cane. Such a movement might have occurred in response to the grass being burnt, which might have happened by accident or as a result of land clearing operations by resident Africans who used irrigation run-off to water their vegetable gardens. Such an invasion would be expected only at those times of year when adults were plentiful, and it would not be expected in early summer from grasses which had remained dry during the winter months; for, in the absence of an overwintering dormant stage of the insect summer grass communities (as opposed to perpetually green grass communities) would require a period of summer growth before they became inhabited by large numbers of numicia. During three months spent in Swaziland many hundreds of numicia eggs in dried inflorescence stems of the previous season's grasses were examined, and no sign of an egg diapause was ever found. Eggs had either hatched, degenerated, or been parasitised earlier in the year before the grass dried out.
- b. To investigate movement from cane to cane.
- c. To study numicia survival and cane age, the impression having

been gained that for its successful survival numicia required the cover afforded by older cane.

d. To note how an infestation starts and progresses.

Procedure

Twelve sampling sites were chosen, ten of which were at points of contact between irrigated cane and perennial green grasses (Plates 15, 16, 17). These included the banks of rivers, reservoirs and canals, and small areas of greenery beside drainage channels in the middle or at the edges of cane fields. Details of each site are given in Table 17, (see also Fig. 20). The other two sites were in permanently green grass communities 800 m from the nearest cane, one being in green grass surrounding a domestic reservoir on top of a hill, and the other in green grass in a small vleis below an outlet from a large siphon on the main irrigation canal.

From August 1966 until December 1967 these sites were sampled at regular intervals (usually weekly) and numbers of nymphs and adults recorded. Notes were made also of any physical changes, such as the cane being harvested or the grass being partly burnt or disturbed during garden cultivation by local Africans. At site 1 (the only site involving newly planted cane) and at site 9 cane populations were sampled at 25 m distances into the cane to a total distance of 100 m. At site 4 cane was sampled at 5 m and at 75 m into the field. At site 8 cane was sampled across a break between two adjacent first ratoon fields, one of which was cut one week before the other.

Sampling error

A sampling error between use of quadrats and shaking in cane was mentioned in 3.2.2/d. With use of quadrats in grass another error became apparent between relative numbers of nymphs and adults recorded. Relative numbers of numicia in grass (which was sampled exclusively with quadrats) sometimes suggested that in one generation more adults were

TABLE 17. Details of sites used for sampling nympha and adult populations in sugarcane and in adjacent grass communities

Site No.	Field	Age at 12.8.66 (months)	Crop	Variety NCo	Irrig. type	Dominant grasses	Cause of green state of grass
1	Mamba 1	0	P	376	spray	<u>Panicum maximum</u>	irrigation run-off; Usutu river bank
2	Mfezi	5½	P	"	"	"	" "
3	Nyoka 3	2	3R	"	"	"	" "
4	" "	2	3R	"	"	"	" Nyetane river bank
5	Paddies south	11½	4R	310	furrow	<u>Brachiaria sp</u> <u>Cynodon dactylon</u>	" Irrigation canal bank
6	Compound	3½	4R	310	"	<u>P. maximum</u> , <u>Cyperus sexangularis</u> <u>Rhynchelytrum repens</u>	" natural small vlel

TABLE 17. (Continued)

Site No.		Age at 12.8.66 (months)	Crop	Variety NCo	Irrig. type	Dominant grasses	Cause of green state of grass
7	Spray H	7½	3R	382	spray	<u>P. maximum</u>	irrigation run-off; natural small vlei
8a	Speculation 1	0	1R	310	"	<u>Pennisetum clandestinum</u>	reservoir bank
8b	"	2	12½	1R	"	"	"
9	Kayalihle	9	12½	1R	"	furrow <u>P. maximum</u>	irrigation run-off; stream bank
10	"	10	12½	1R	"	<u>Pennisetum clandestinum</u>	reservoir bank
11	Grass community					<u>P. maximum</u> <u>C. dactylon</u>	domestic reservoir overflow
12	"					<u>P. maximum</u> <u>C. dactylon</u>	irrigation canal siphon overflow, vlei

present than the nymphs from which they had developed (Table 19). While in some instances this might have been due to adults having flown in, in many cases it was probably the result of adults being less easily missed than the early stage nymphs which were difficult to see, especially against a thick grassy background.

Results

Population curves for the different sites are shown in Fig. 27, 1-12.

3.7.1.1 Movement from grasses to cane

A conspicuous rise in adult numbers in cane accompanied by a drop in adult numbers in adjacent grass would be assumed to indicate movement from grass to cane. Likewise, high numbers of nymphs in grass, followed by very low numbers of adults could also suggest movement, if corresponding numbers of adults in cane were very much higher than previous nymph numbers.

Rises in numbers of adults in cane as compared with nymphs of the same generation were recorded at several sites (sites 2, Dec. 66; 5, Feb. and May 67; 6, Feb. 67; 7, May 67; 8A, May 67; 9, Feb. and May 67; 10, Feb. 67). It is unlikely that in all cases this was due to a sampling error since all sampling was done by shaking, and the differences in numbers were sometimes considerable. However, corresponding low adult numbers in grasses were not noted except at site 5 in February 1967, where numbers of both nymphs and adults had been low. Therefore, although it seems likely that adults did enter the sampling areas in cane on those occasions, there are no firm grounds for assuming that they came from grasses. Such a movement from grasses would be most reasonably expected in April and May when grasses became drier. However, at sites 3 and 4 in April, 1967 when grasses were cultivated out, adult numbers in cane were much as expected considering the numbers of nymphs from which they had developed.

Fig. 27 Numbers of numicia nymphs and adults in sugarcane and in adjacent grasses at ten sites (1-10), and in grasses at two sites remote from cane (11 and 12); August 1966 to December 1967.

At sites 1, 4 and 9 cane was sampled at progressive distances into the field (a, b, etc); and at site 8 two adjacent fields were sampled at either side of the break between them (8A and 8B).

S → cane sampled thereafter by shaking
Q → " " " " quadrats
(grass always sampled by quadrats)

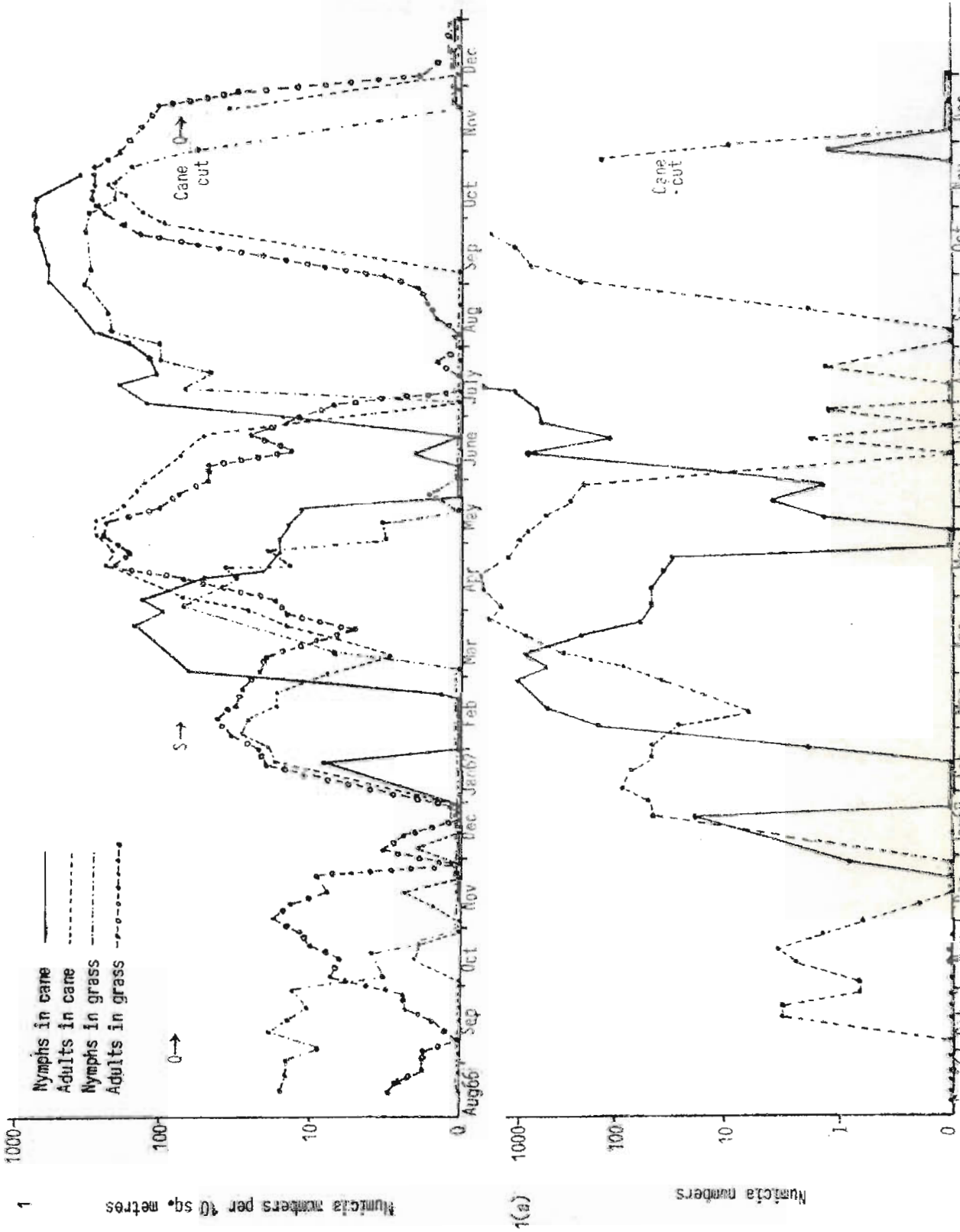


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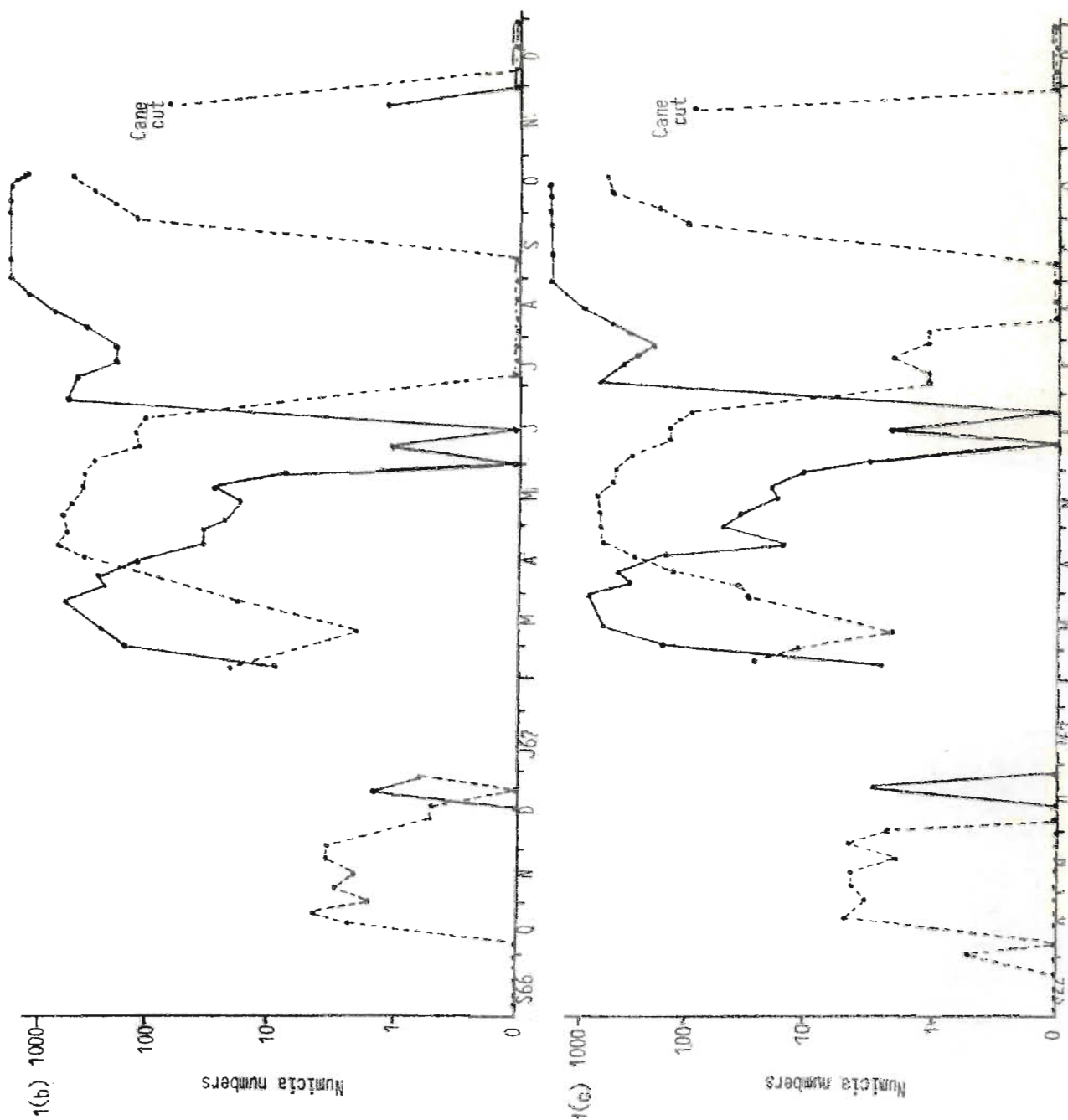
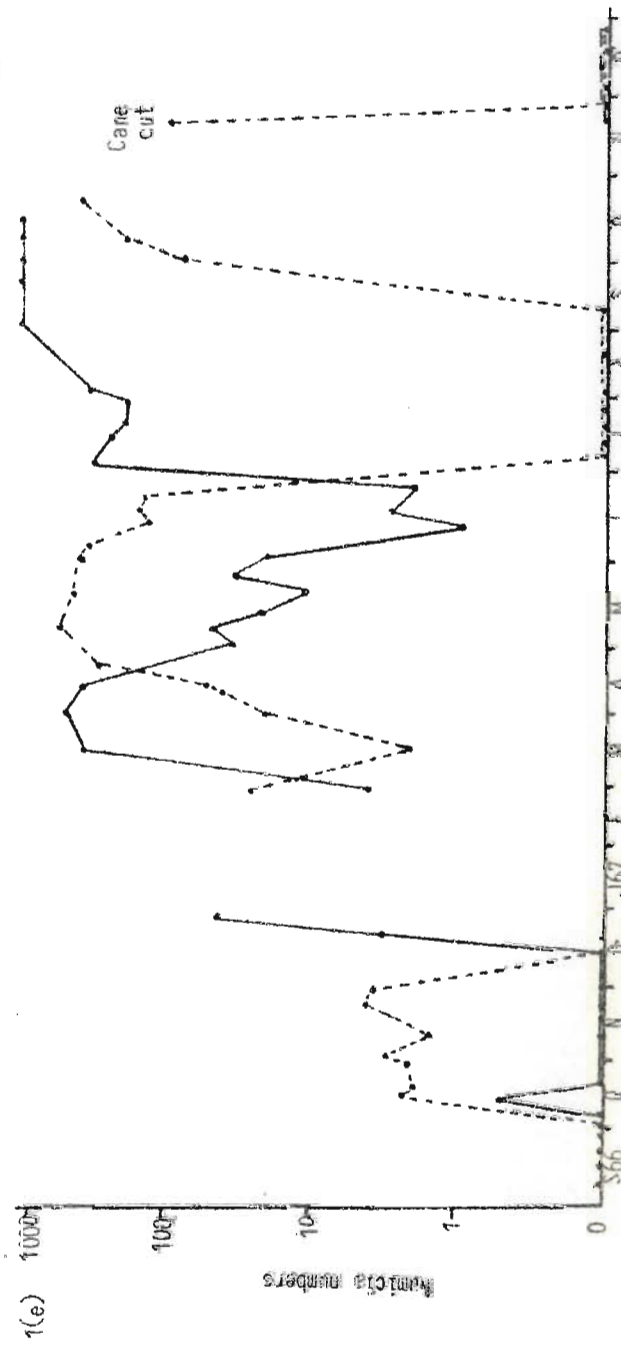
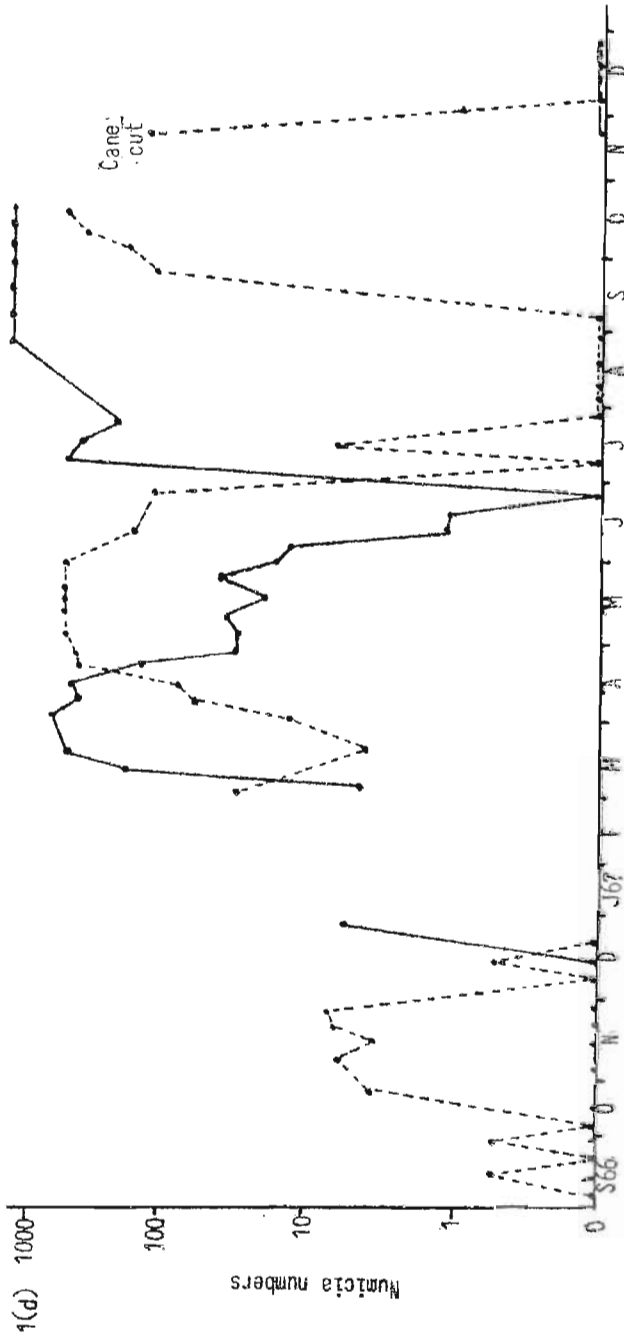


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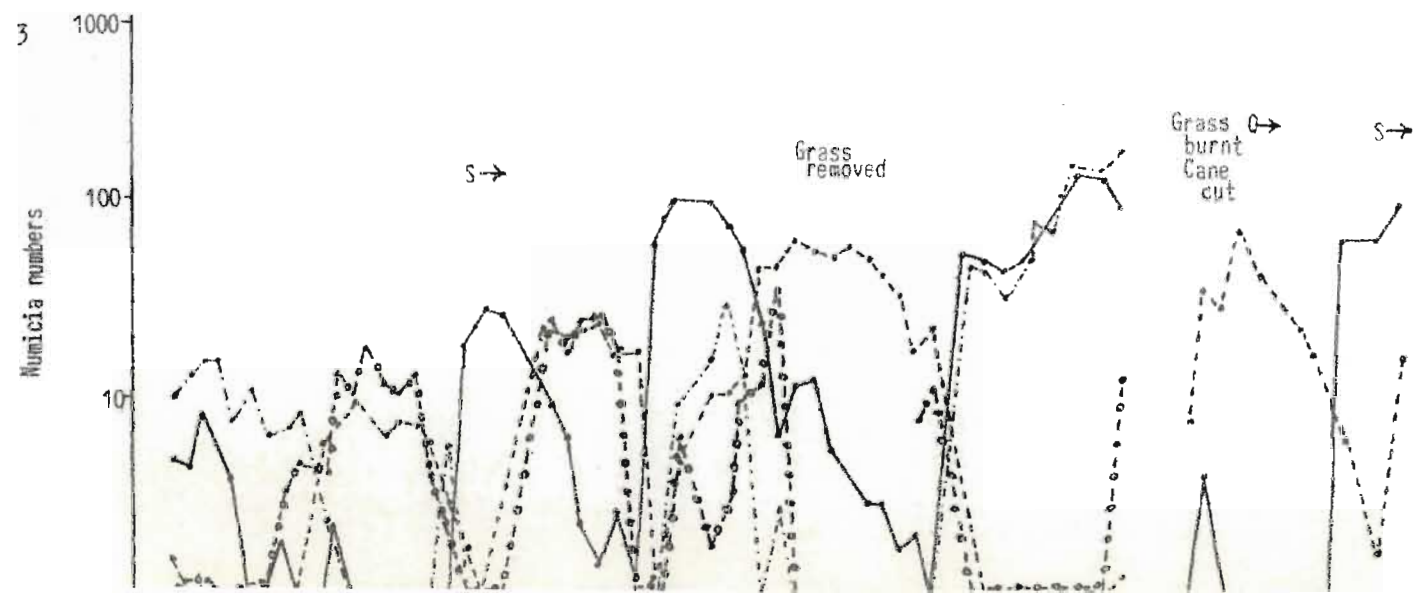
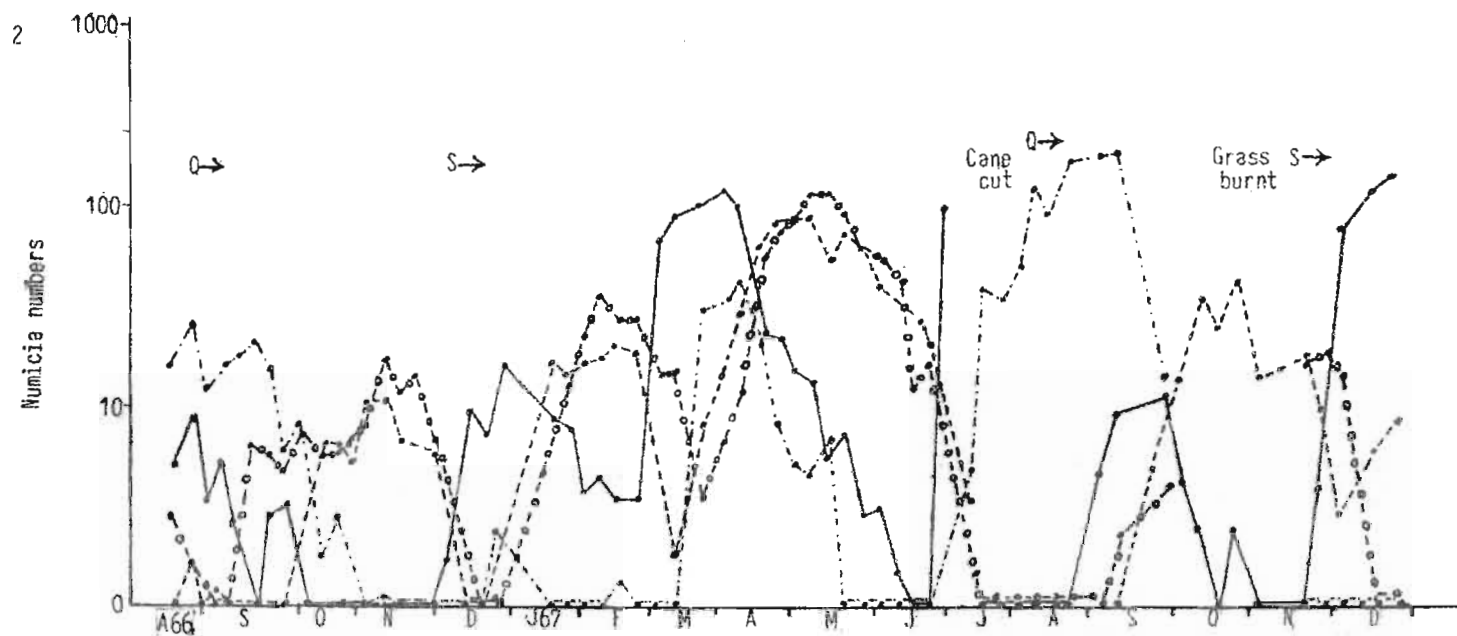


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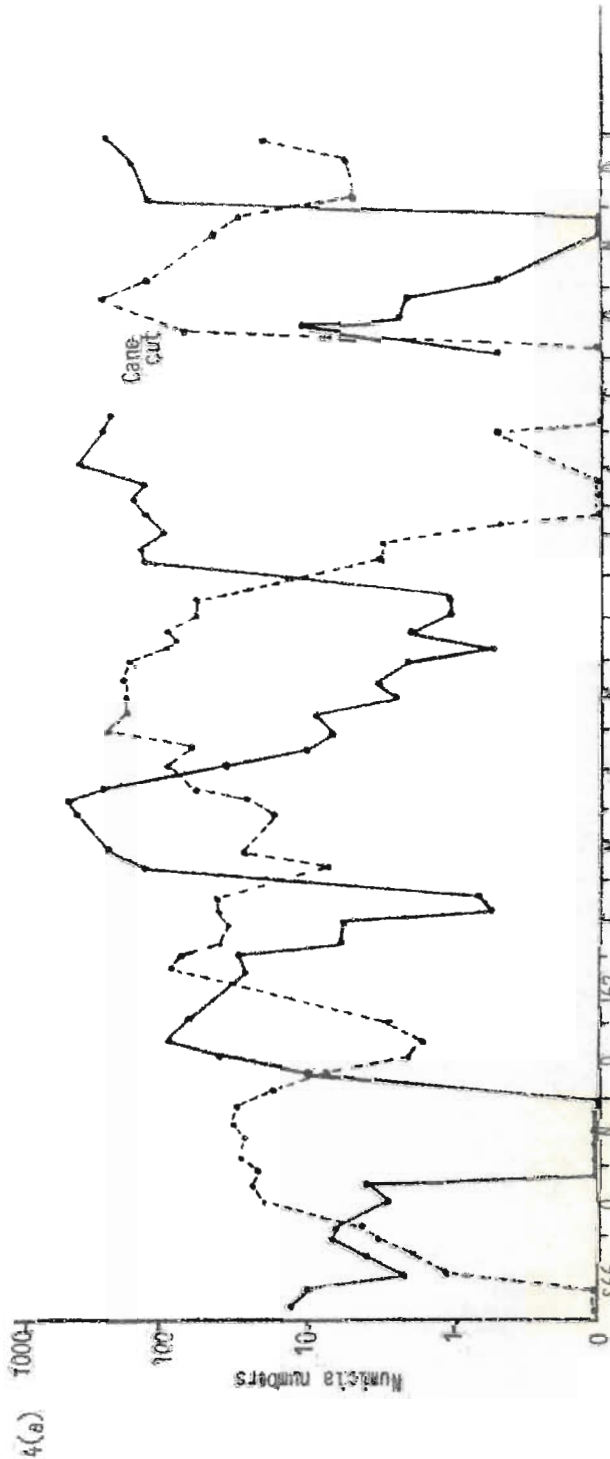
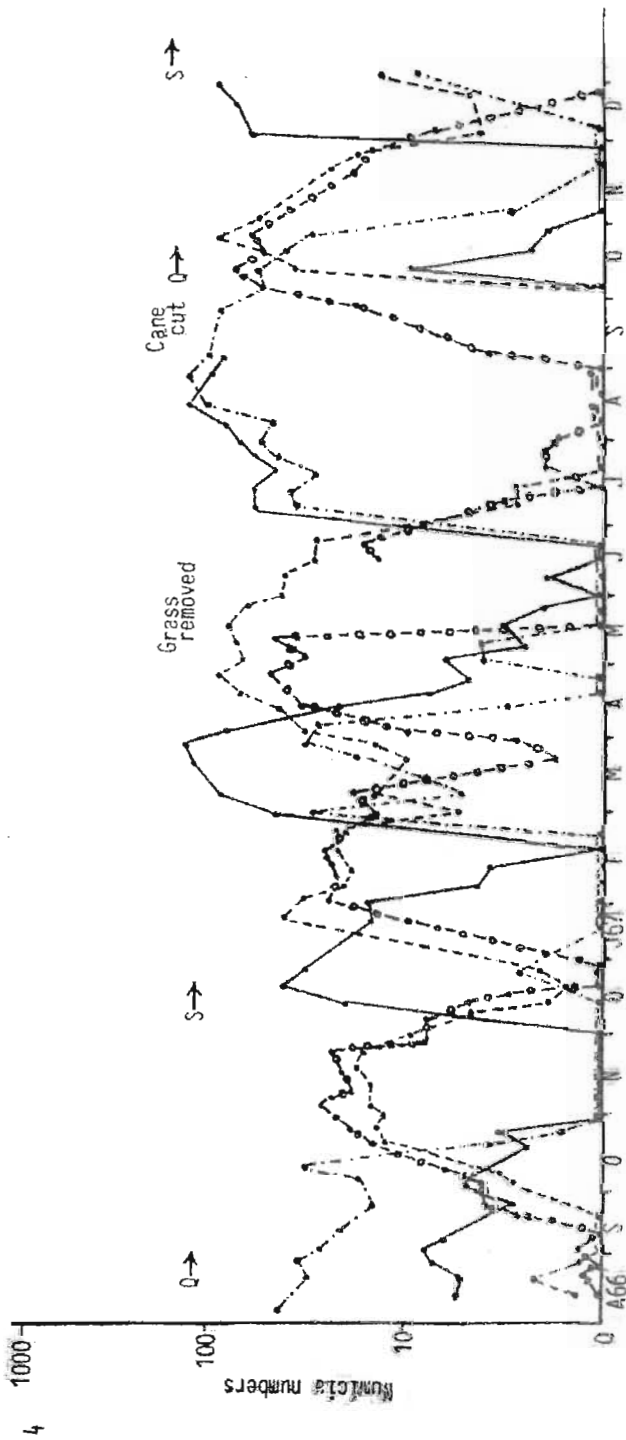


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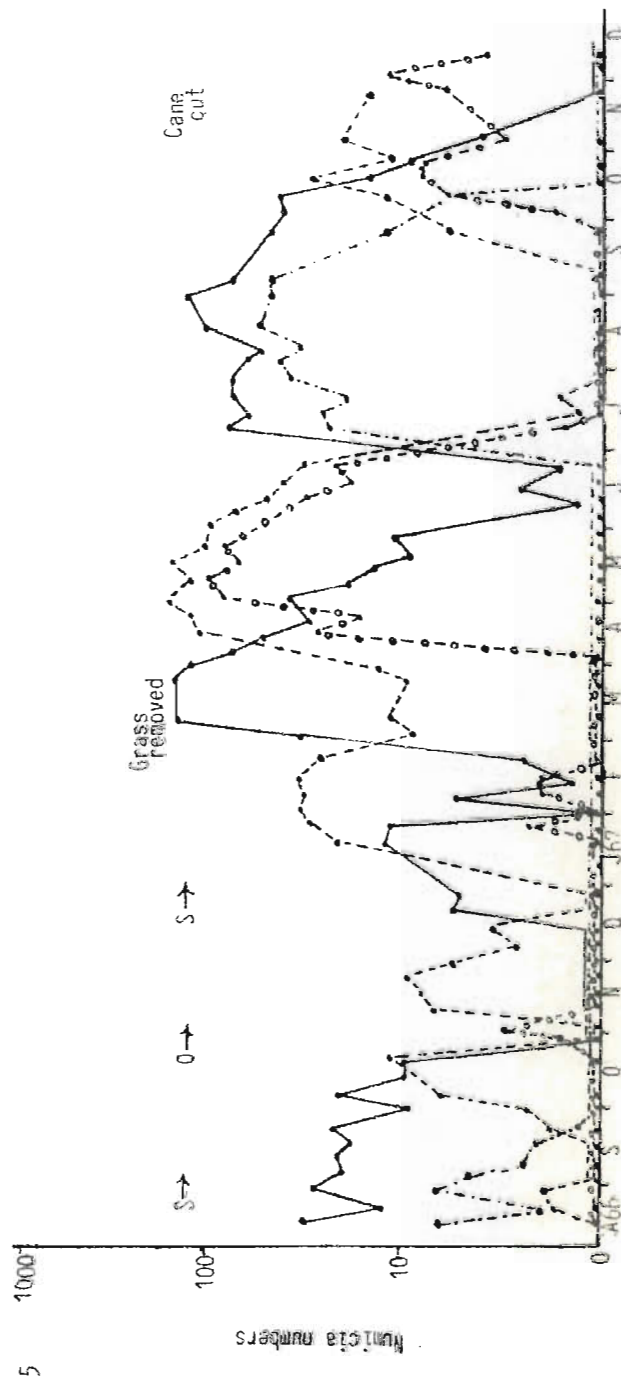
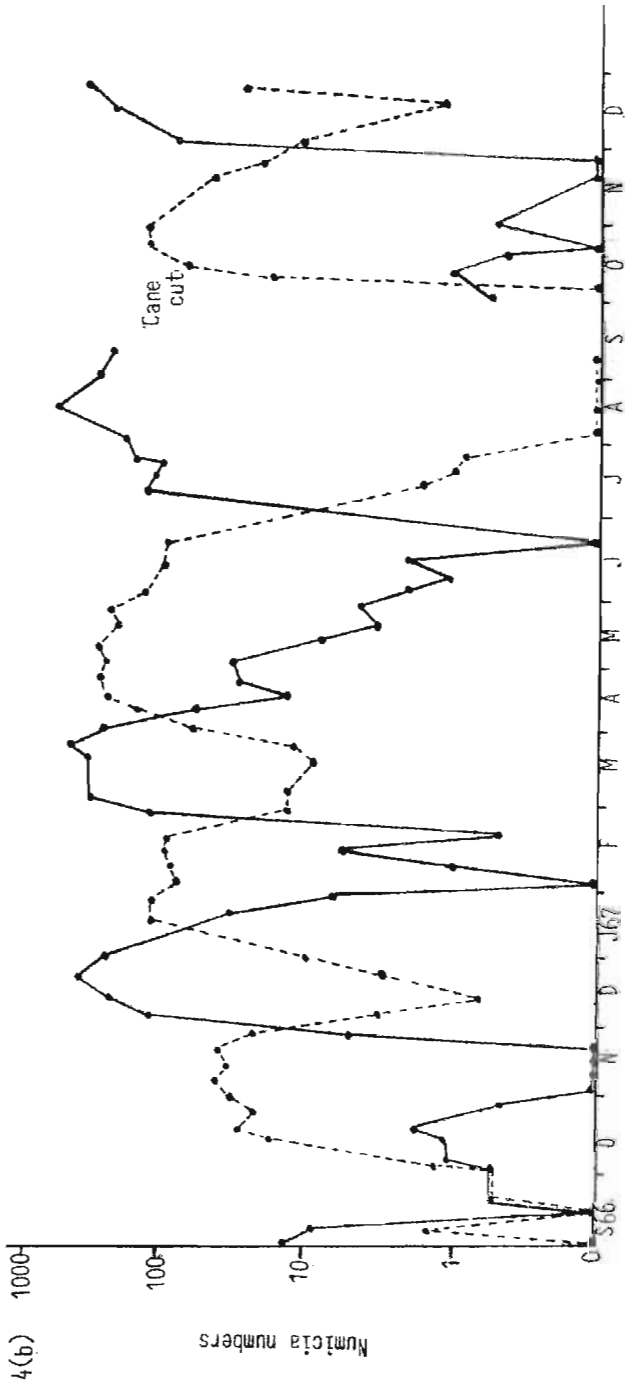


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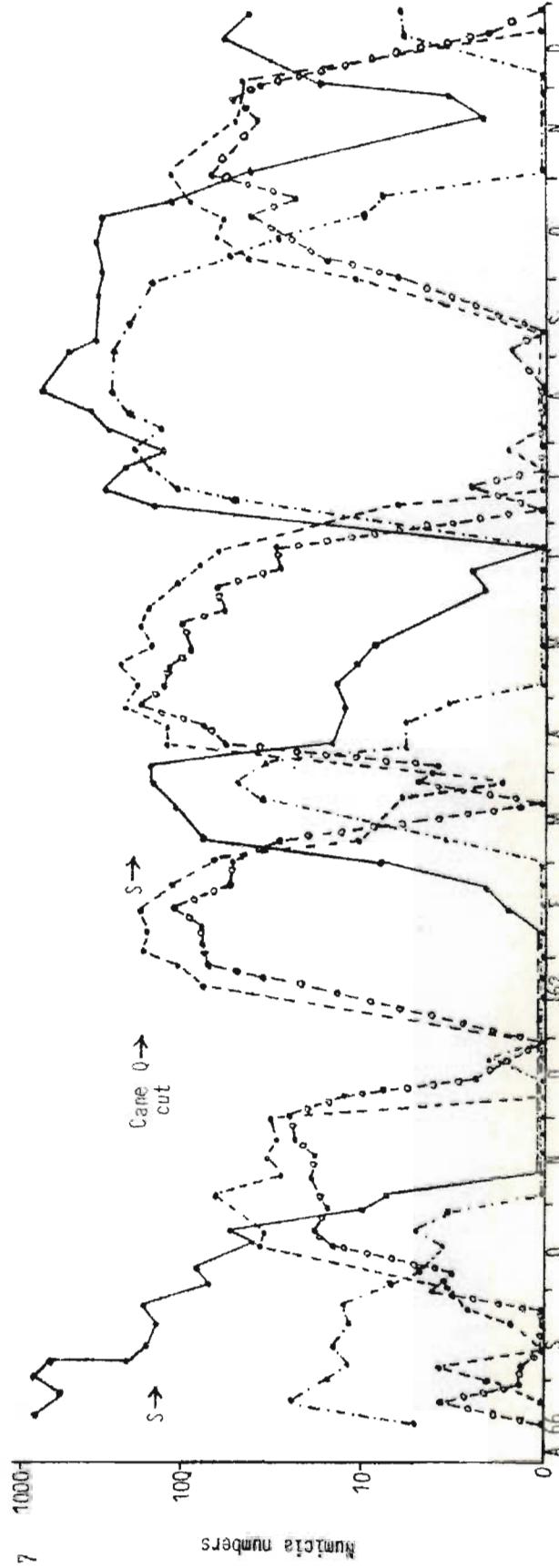
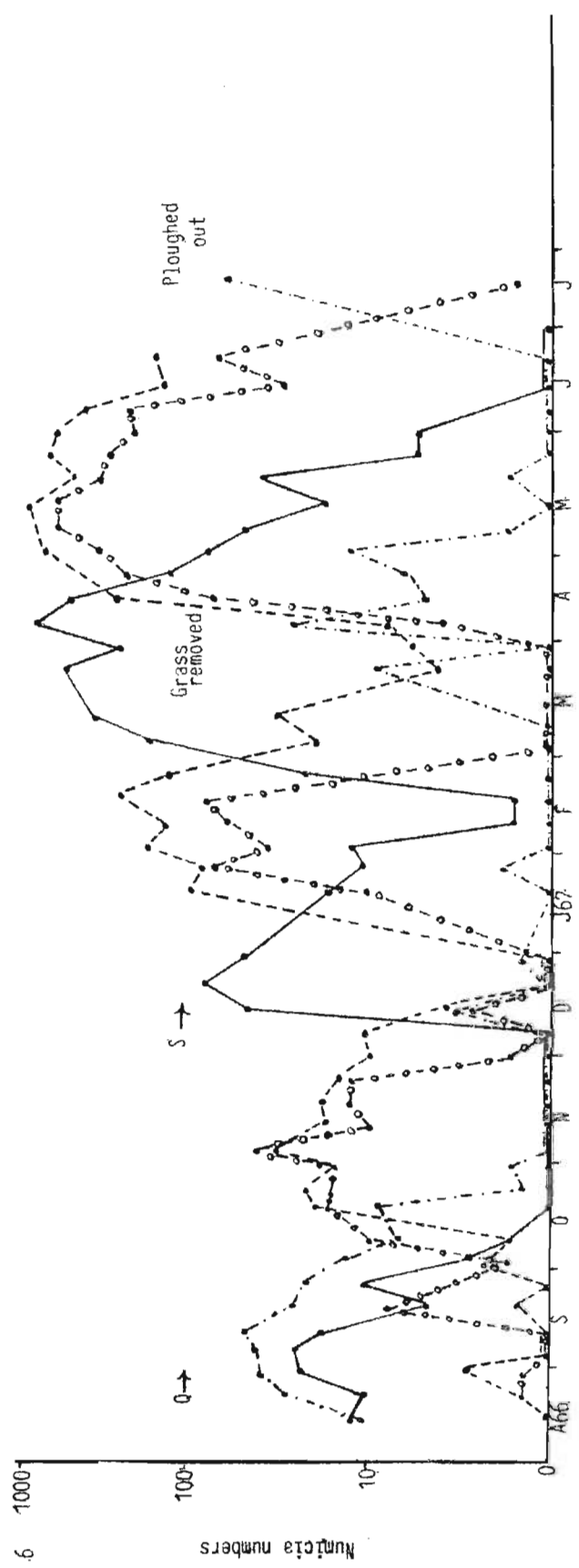


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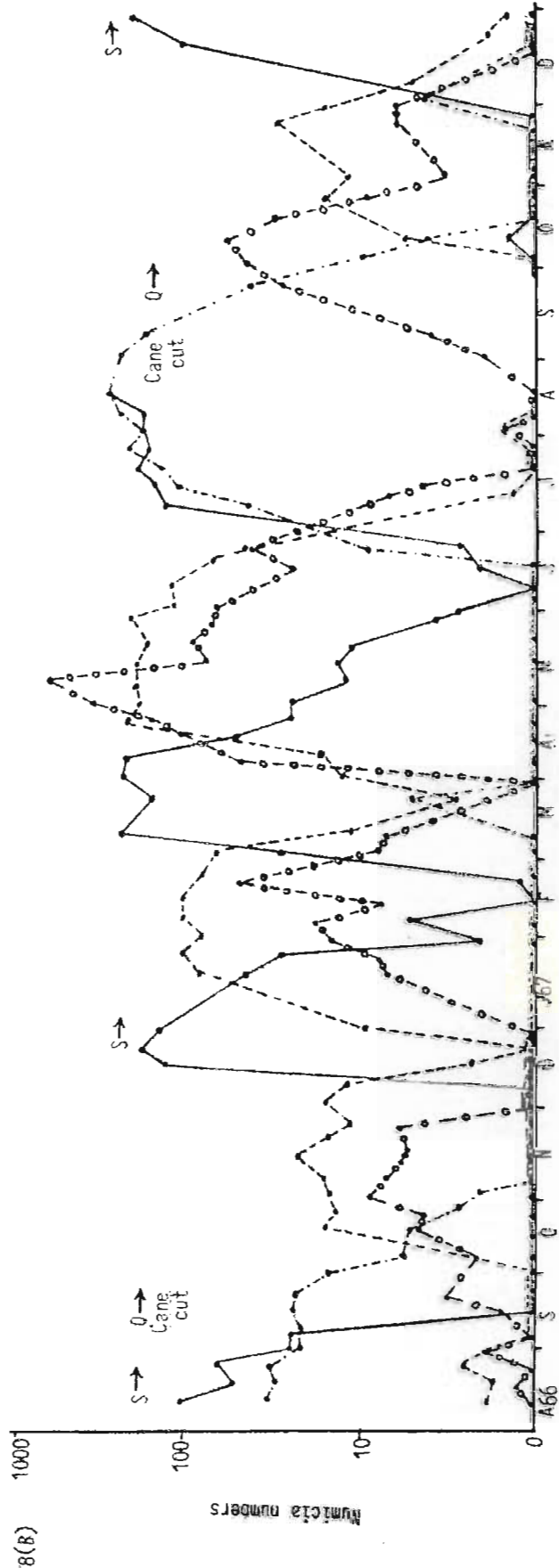
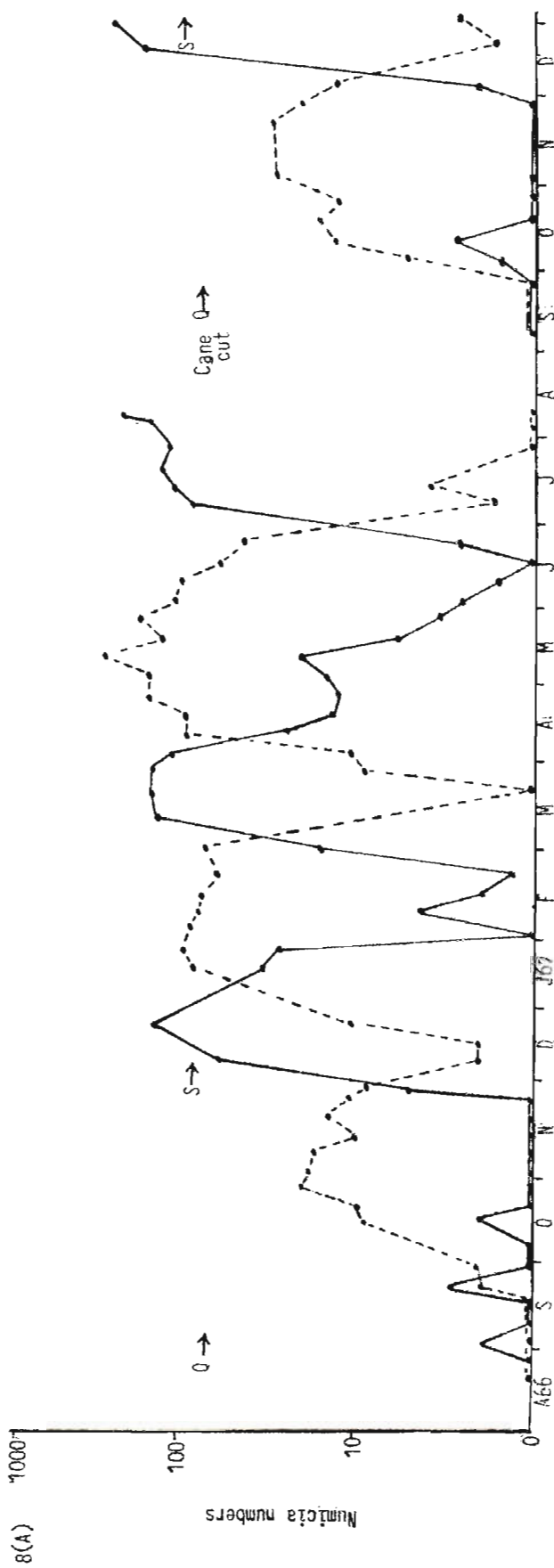


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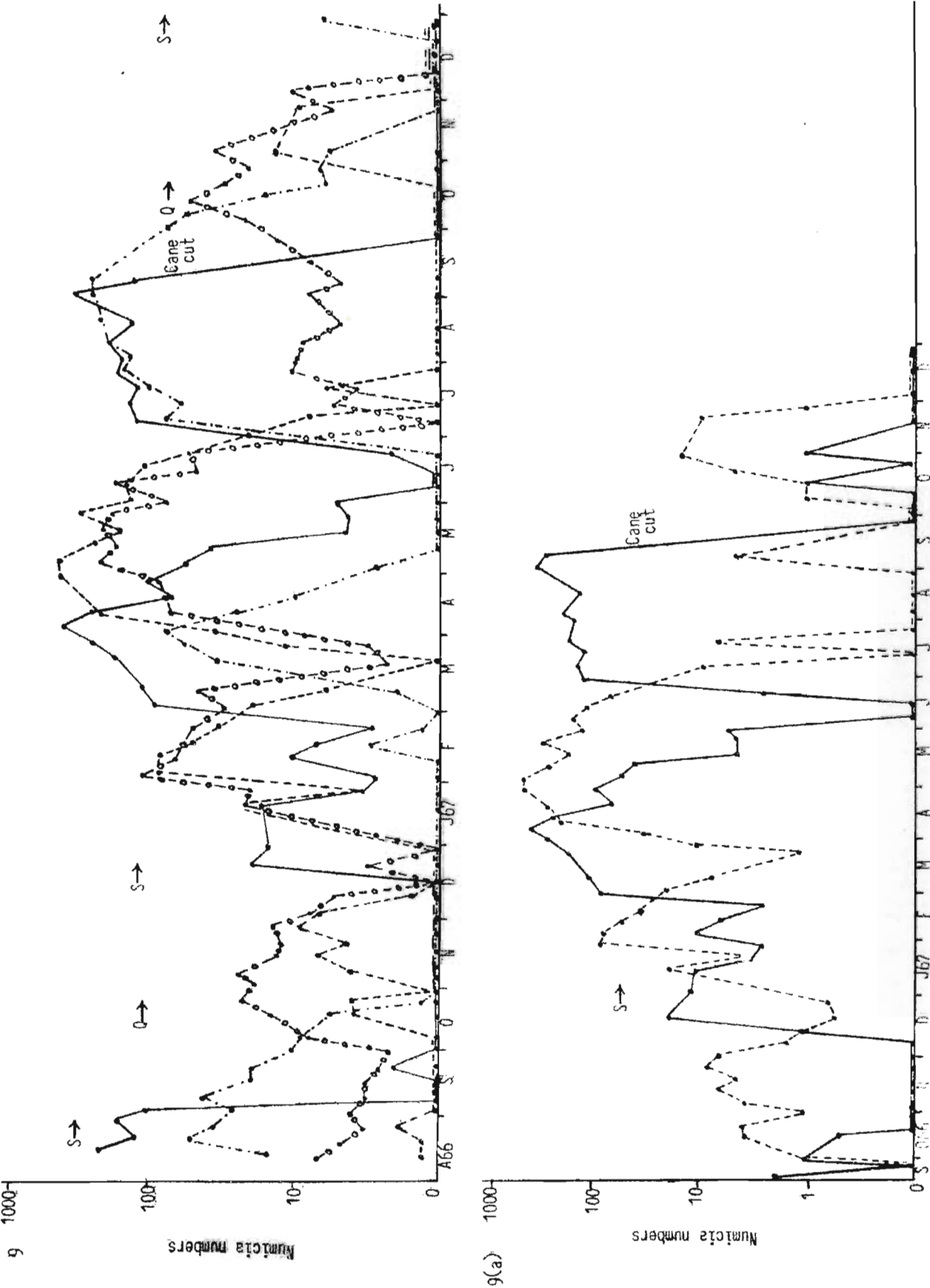


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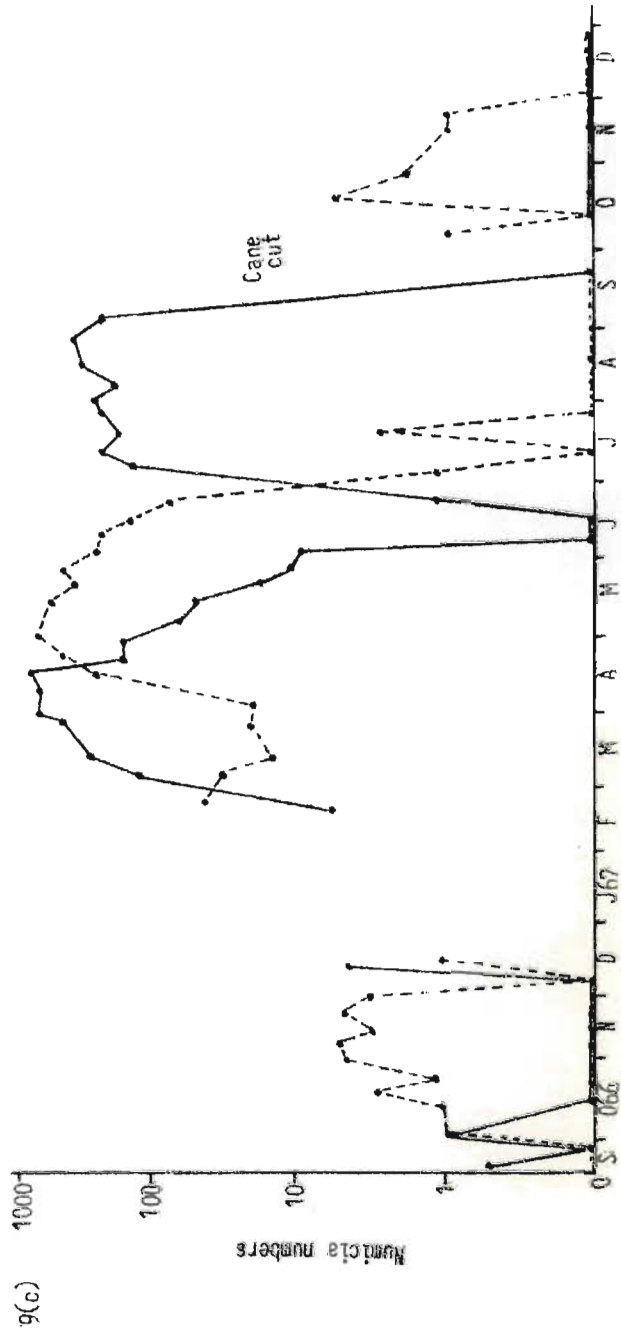
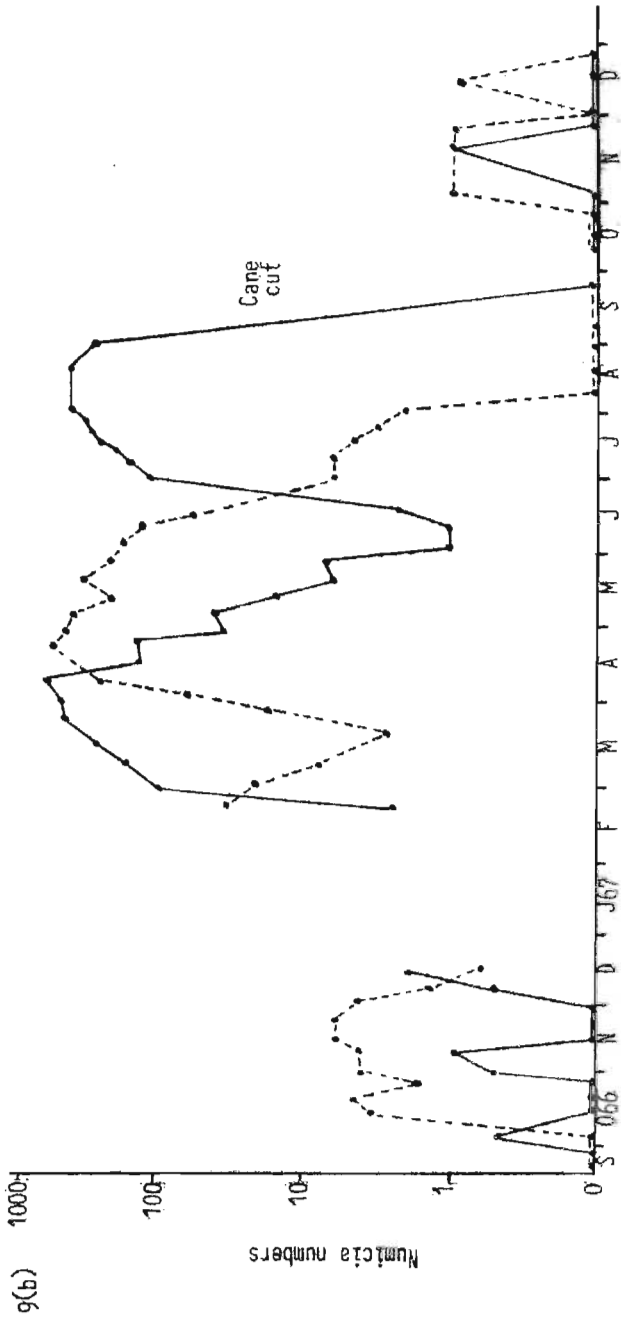
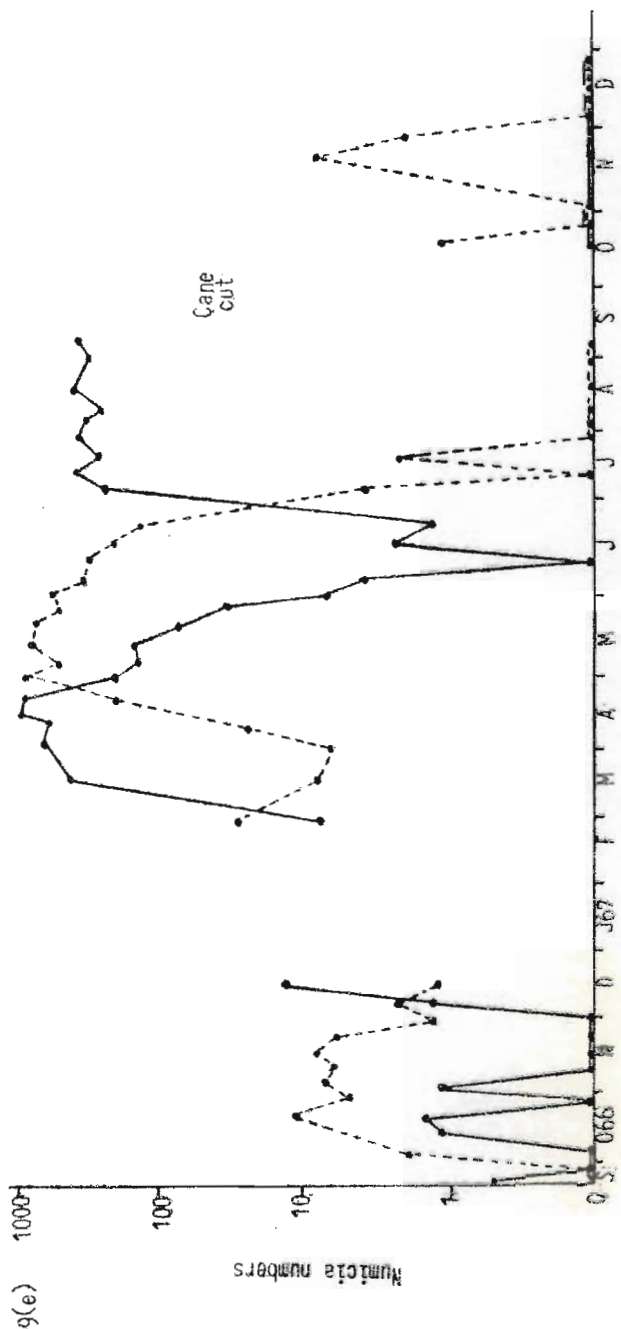
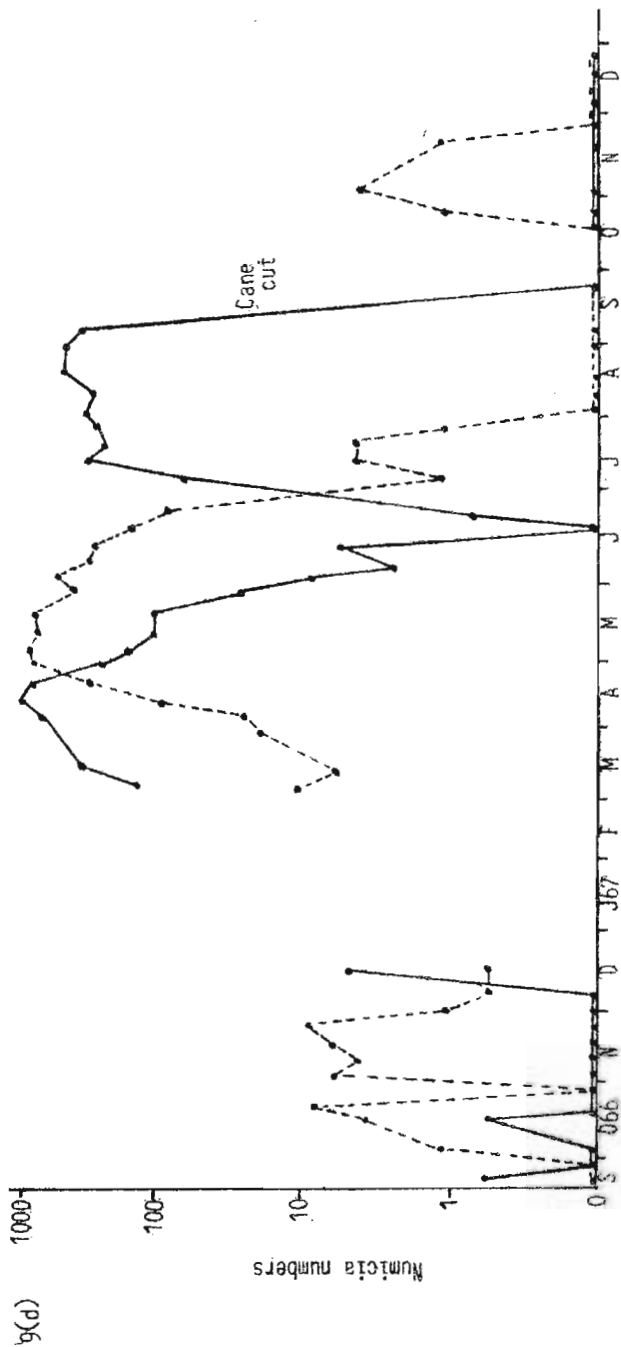


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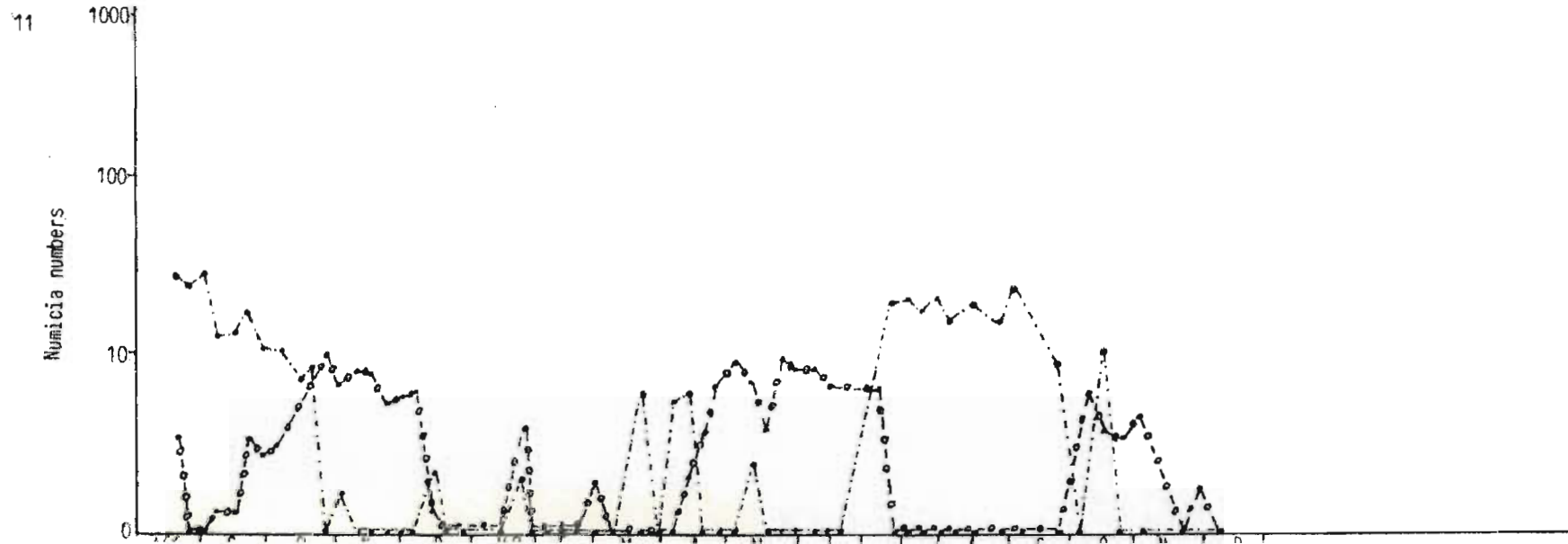
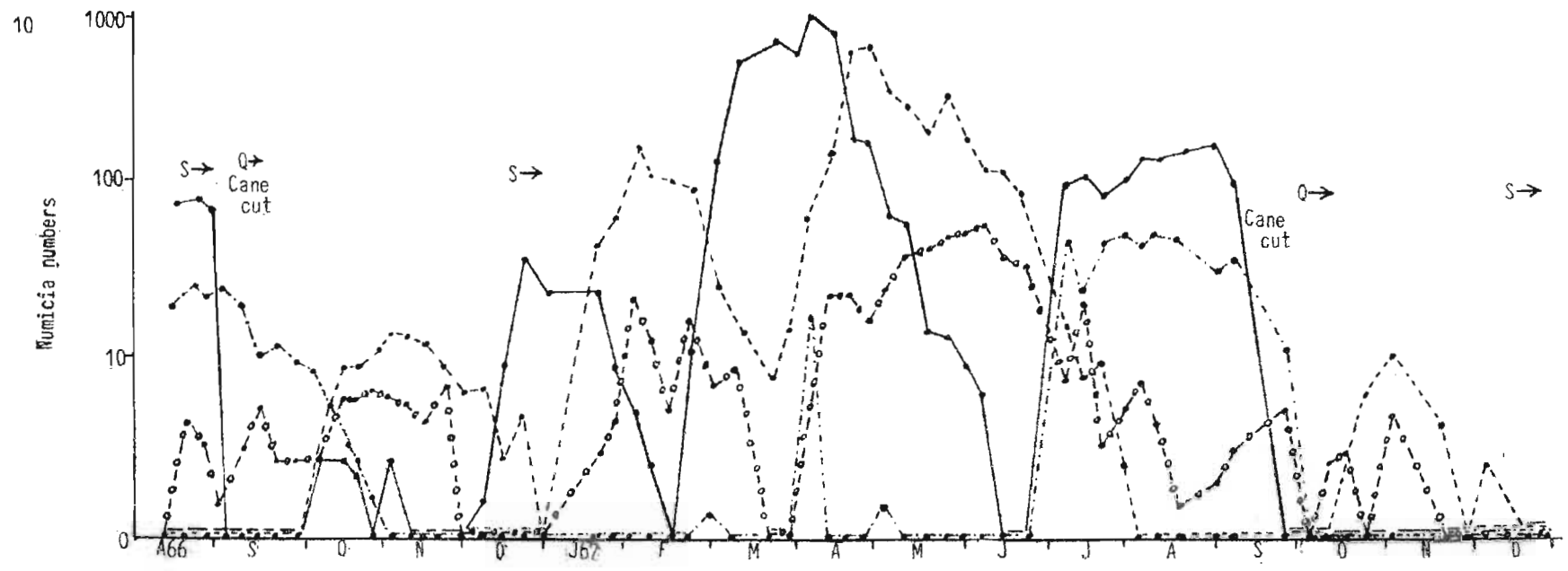
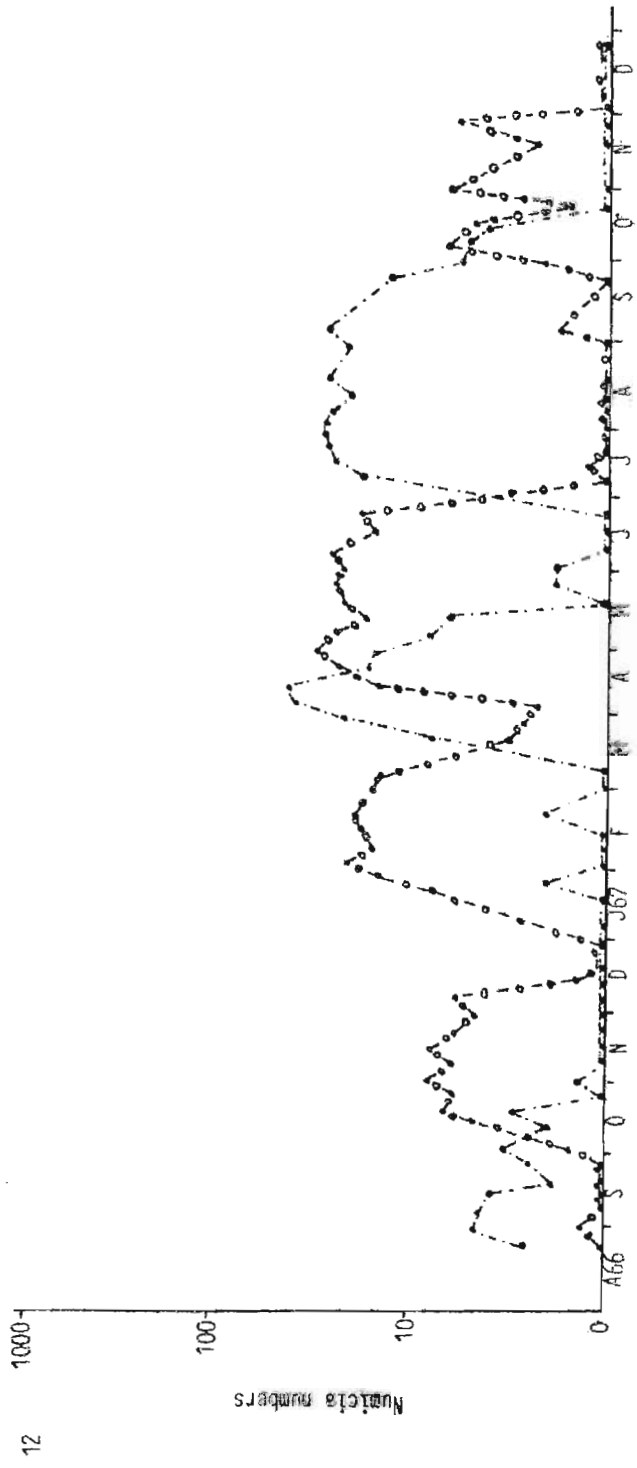


Fig. 27 (Continued).

Fig. 27 (Continued).



In October 1967 at site 2 burning of the grass was accompanied by numbers of adults in adjacent cane which were higher than might have been expected; and in March 1967 at site 5 the relatively small drop in adult numbers in cane following the peak could have been due to a boost from the adjacent cut grass.

The hazard of harvest was mentioned briefly when discussing carry over of numicia populations (3.6.1). This constitutes the temporary removal of the host plant with a complete alteration in environment and, when numicia is present in the nymphal stage it is virtually obliterated. From site sampling it was apparent that, following harvest, re-invasion by adults occurred and in some instances there was reason to believe that they may have come from adjacent grasses. Cane in site 8A was cut in August at a time when adults were all but absent. However, they appeared early in the ratoon and may have come from the adjacent grass, where nymphs had been plentiful. Similarly in site 8B cane was cut in September when nymph numbers were falling. Two weeks later adult numbers were up, and they too may have come from grasses, where nymph numbers had been quite high. Cane was harvested again the following August when nymphs were almost at their peak, and the subsequent adults in cane could have developed from nymphs in grass, for there would have been virtually no nymphs in the cane. Peak numbers in grass and cane in October and November 1967 were "out of phase" at site 8B, suggesting that adults may have moved from grass to cane. Cane was cut in August 1966 at site 9 when nymph numbers were high, and the subsequent adults in cane may have moved in from grass, where nymph numbers had been high; (the sampling error regarding quadrats in grass (3.7.1) should be borne in mind, for the discrepancy between nymphs and adults in grass was probably higher than the graph suggests).

3.7.1.2 Movement from cane to grasses

By the same reasoning as that stated in the previous section it should be possible from the figures to detect any marked adult movements from cane to adjacent grasses. However, the sampling error mentioned

in 3.7.1 must again be borne in mind; and in fact at every site there was at least one record of nymph numbers being lower than subsequent adult numbers.

On some occasions e.g. sites 4, 8 and 10, Jan. 67, the difference between numbers of adults and preceding nymphs in grasses was considered too great to be due only to sampling error, and the adults must therefore have flown in. There was however no great corresponding decrease in adult numbers in cane, and the increased population may have come from elsewhere in the grass. Similar cases are seen in site 5, May 67; site 9, Feb. 67; and site 10, but here between April and June there was a fall in numbers of adults in cane, while numbers in grass rose, suggesting a movement. At site 2 in November 1967 considerable numbers of adults were suddenly recorded on regenerating grasses following a burn which apparently annihilated all nymphs. These may have come from cane where adult numbers had been quite high. At site 3 in July 1967 nymphs appeared in regenerating grass after the previous grass had been cultivated out and the population destroyed; and it is quite possible that these hatched from eggs laid by some of the many adults present previously in the adjacent cane.

3.7.1.3 Movement from cane to cane

For the sites where more than one cane area was sampled i.e. sites 1, 4, 8 and 9, the figures do not suggest any marked movement, within the cane. The population curves at the different sampling positions correspond remarkably closely, suggesting that within these limitations at least, the population was very evenly distributed. It was unfortunate that the two sections of the field constituting the cane part of site 8 were each cut at a time when adults were almost entirely absent, so that no movement following burning and cutting could be detected.

3.7.1.4 Invasion of unpopulated areas

Mention has already been made of instances when adults appeared

in a sampling area where previously there had been no nymphs or only a few nymphs. This was noted in both cane and grasses, particularly after cutting of the grass or harvesting of the cane.

The only site where a plant crop was studied from time of planting was site 1, where, in addition to the perimeter, the field was sampled at 25 m intervals into the cane to a distance of 100 m. The first adult was recorded (on the perimeter) one week after the cane had sprouted. Nothing was then recorded for three weeks, when an adult was recorded at 75 m into the cane. Two weeks later adults were recorded at 50 m and 75 m. After a further two weeks they were recorded at all distances, and thereafter they became plentiful.

Notable instances of adults appearing on ratooning cane after harvest were: sites 3, Sep. 67; 4 and 8A, Oct. 67; 8B Oct. 66 and Oct. 67; 9 and 10, Oct. 66 and Oct. 67.

Similar instances in grasses were : sites 4, June 67; 5, April 67.

On occasions adults appeared in both media simultaneously after there had been very few nymphs e.g. sites 1 and 7, Jan. 67.

3.7.1.5 Survival of nymphs

No cases were seen of nymphs occurring in large numbers following burning and cutting. However, on two occasions nymphs were recorded on cane shortly after burning viz. sites 2, July 67; 9, Sep. 66.

3.7.1.6 Numicia numbers and cane age

In August 1966, when sampling of the various sites was started, the cane ranged in age from newly planted i.e. 0-month-old to 12 $\frac{1}{2}$ -month-old (Table 17). It was possible therefore to record numicia numbers for cane of varying ages.

Actual crop age was marked in on the graphs from which Fig. 27 was drawn, and numbers of nymphs and adults for each month were read off.

TABLE 18. Numicia incidence (%) and cane age during annual surveys 1964 - 1968.

Cane age	Year					Average
	1964	1965	1966	1967	1968	
0 - 3 months	35,7	52,4	31,6	16,7	23,7	32,0
4 - 6 "	58,5	58,1	43,2	65,6	55,6	56,2
7 - 9 "	70,4	65,5	53,9	60,2	61,8	62,4
10 - 12 "	72,7	51,5	61,6	50,0	63,6	59,9
13 - 15 "	69,8	50,0	66,7	59,1	62,5	61,6
16 - 18 "	74,2	24,2	70,6	56,5	51,2	55,4
Over 18 "	46,2	7,1	68,4	20,0	54,7	39,3

Figures taken were those corresponding to the fifteenth day of each month. For all sites except site 7 certain months were duplicated because during the 16-month sampling period most sites were harvested and ratooned.

There was no advantage in combining figures from the different sites, and in Fig. 28 population and cane age are shown separately for cane in each site. With large population fluctuations such as those in Fig 27, there is probably little to be gained by adjusting for the two sampling methods used. However, in preparing the figures from which Fig. 28 was drawn, a very rough adjustment was made by doubling figures obtained during quadrat sampling; it having been estimated that in cane of an age which may be sampled by both methods, quadrats gave approximately half the quantity obtained by shaking. Of the 330 figures used 102 are from quadrats.

Although there was a tendency for numicia numbers to increase with cane age, seasonal fluctuations precluded any strict linear relationship being established. There was an understandable tendency for very young cane to contain low numbers; this would have been influenced inter

Fig. 28

Numicia populations at different crop ages.

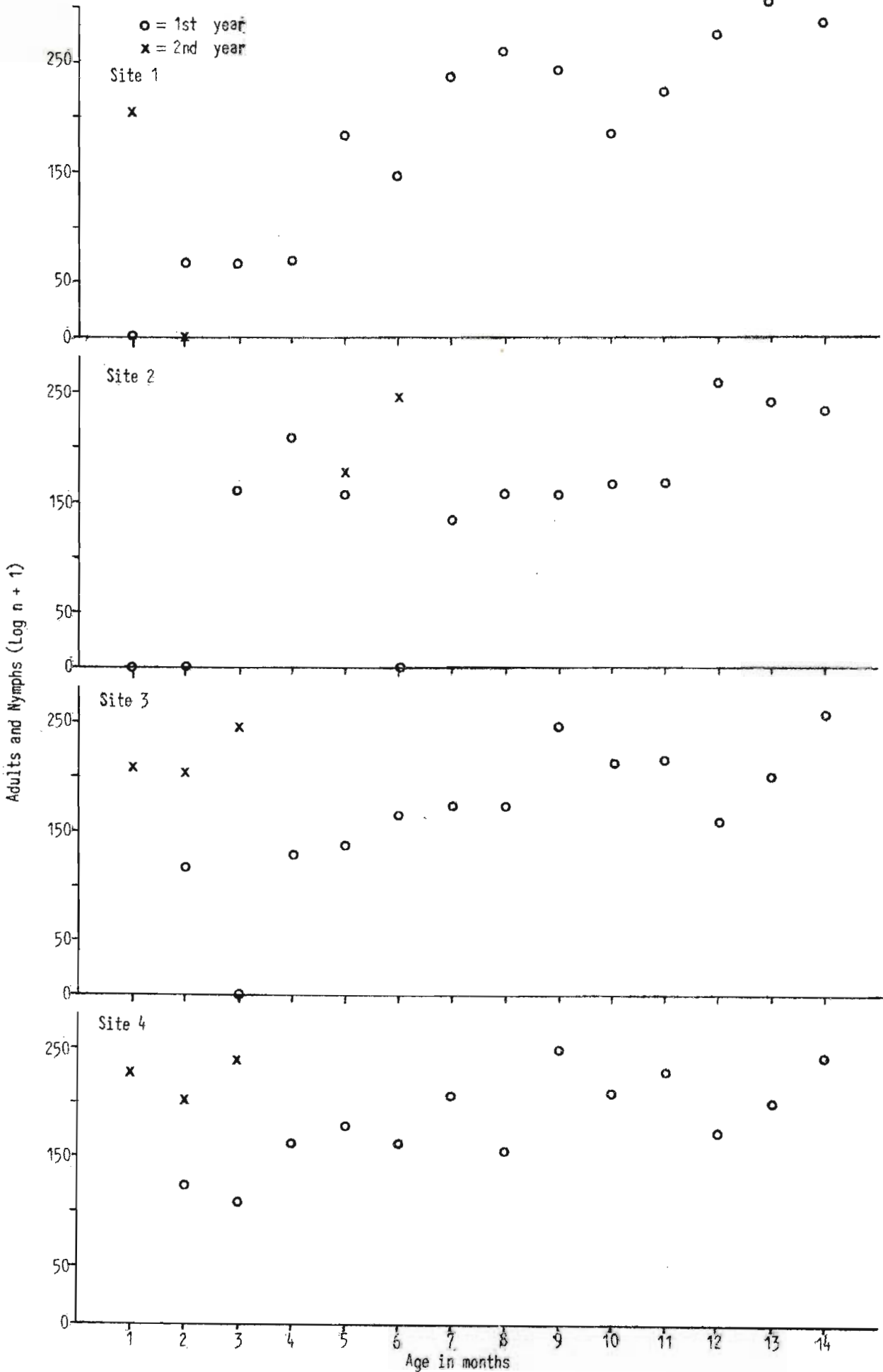


Fig. 28 (Continued)

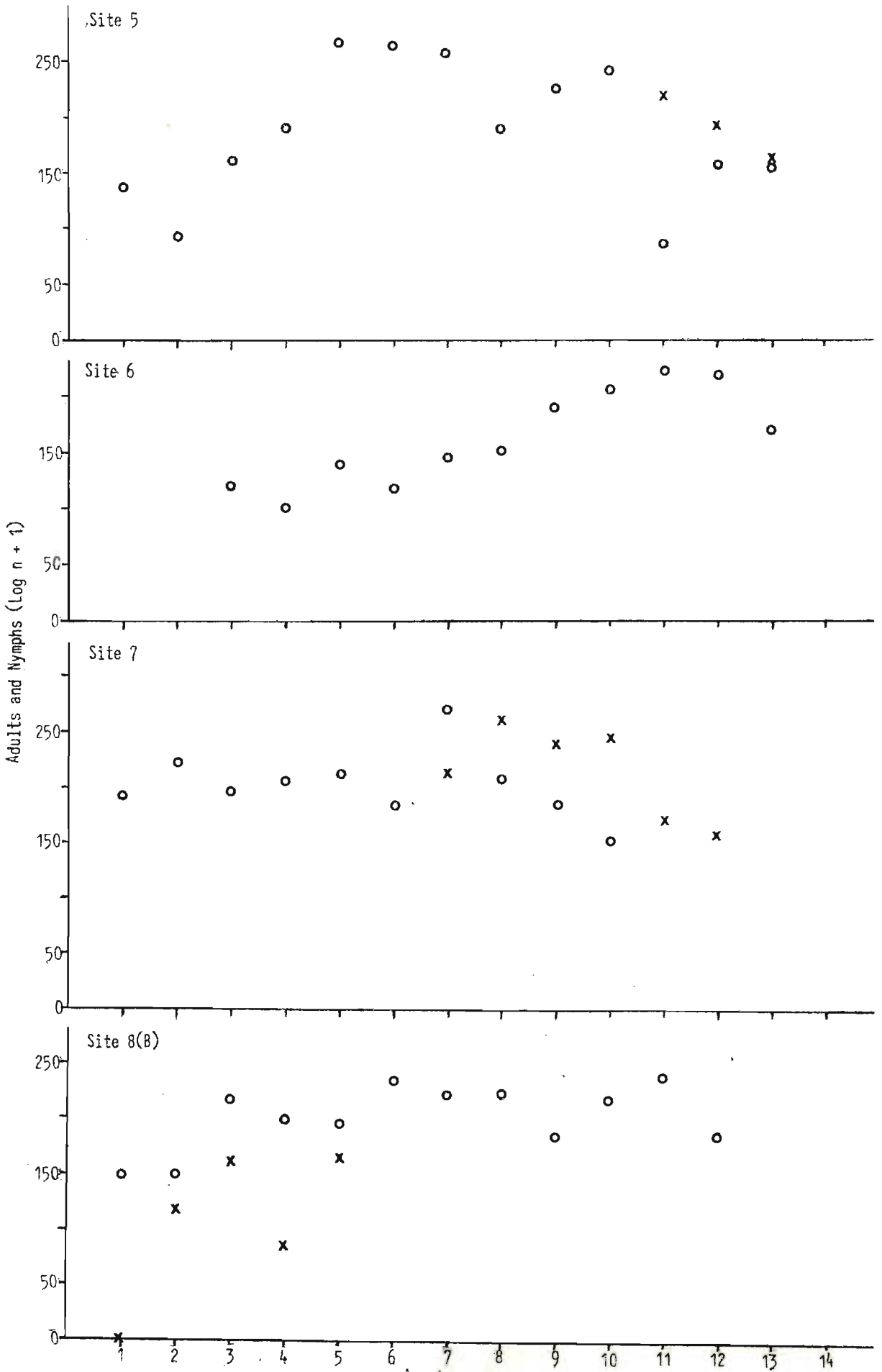
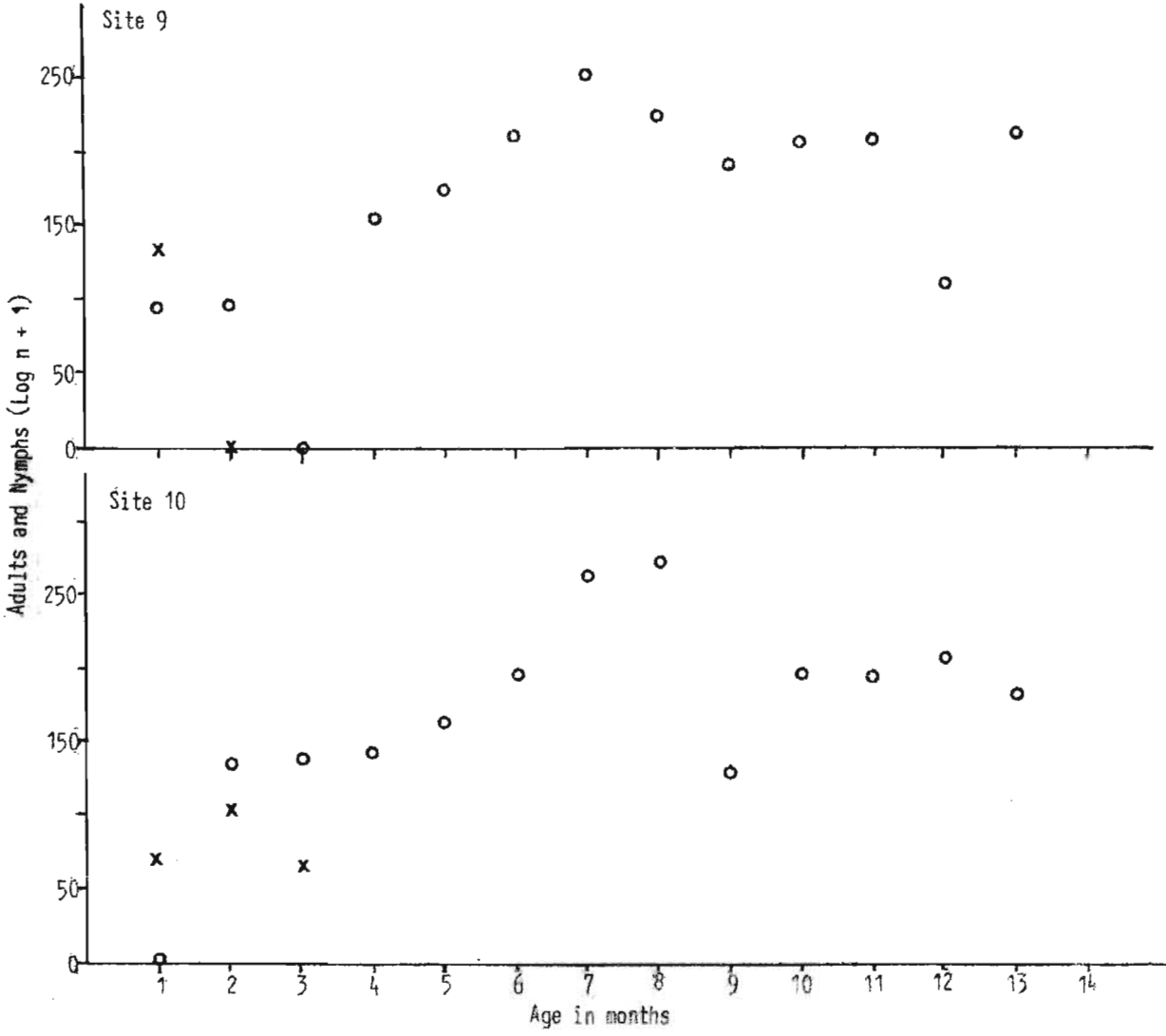


Fig. 28 (Continued)



alia by the occasions when cane was cut, and subsequently ratooned at a time when adults were absent or very scarce. However there were occasions when high numbers were recorded in young cane e.g. sites 3 and 4, Nov. 1967; and in those cases rate of survival into the following generation was high.

Highest numbers were recorded usually in cane aged five months or more, with highest numbers of all being recorded from 14-month-old cane. From this investigation it appeared that numbers tended to build up in suitable cane, and there were no grounds for assuming that very young or very old cane was immune from large populations.

It is appropriate to mention here further results obtained during the annual numicia survey, which was done throughout the S. African cane belt from 1963 to 1968 (1.3.1). Results of numicia incidence in cane of different ages are recorded in Table 18 (which shows incidence as a percentage of sites examined - not actual numbers obtained). The figures confirm that no age group was immune but that cane aged from seven to 15 months was favoured.

3.7.1.7 Initiation of infestation

It was evident that numicia adults could occur in large numbers on young ratooning cane, but that survival in the nymphal state from one crop to another was a rarity.

3.7.1.8 Synchrony

Synchrony of generations was maintained in grasses as well as in cane. This applied also to sites 11 and 12 which were grass communities remote from cane fields.

3.7.1.9 Discussion of experiment

Mention has been made of sampling errors which may have resulted in adult numbers appearing higher than those of the nymphs

Q = quadrat sampling; S = shake sampling; N = nymphs;
A = adults. Grasses always sampled with quadrats.

Site No.	October, 1966				February, 1967				May				October											
	Grass		Cane		Grass		Cane		Grass		Cane		Grass		Cane									
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A								
1	22	21	Q	0	Q	3	0	55	Q	9	S	36	90	370	S	210	S	400	480	450	S	1100	S	350
2	58	35	Q	16	Q	18	3	82	S	33	S	44	105	350	S	375	S	255	660	38	Q	270	Q	110
3	32	36	Q	16	Q	19	9	58	S	66	S	54	73	83	S	310	S	280	580	25	S	430	Q	205
4a	86	45	Q	12	Q	31	3	46	S	90	S	88	63	105	S	350	S	215	350	165	S	330	Q	225
4b			Q	14	Q	38			S	350	S	110			S	360	S	225			S	430	Q	110
5	11	5	S	73	S	23	0	3	S	24	S	76	0	310	S	480	S	510	150	23	S	420	S	75
6	22	20	Q	14	Q	18	3	35	S	36	S	80	14	155	S	200	S	210						
7	23	24	S	600	S	63	2	100	S	1	S	150	45	150	S	130	S	200	205	65	S	500	S	96
8a			Q	3	Q	20			S	125	S	90			S	135	S	235			S	180	Q	27
8b	33	9	S	90	Q	23	1	47	S	160	S	92	6	530	S	205	S	180	235	53	S	230	Q	28
9	47	23	S	170	Q	9	0	96	S	18	S	77	70	185	S	330	S	350	220	45	S	270	Q	14
10	22	6	S	70	Q	12	1	20	S	33	S	735	16	51	S	745	S	520	46	5	S	145	Q	10
11	61	17					3	4					10	15					60	9				
12	6	12					3	39					76	61					54	10				

dult nos.		higher		3/12		12/12		11/12		6/12		0/11		0/3	
oth	shaking	0/2				6/11				6/12					0/3
oth	quadrats	7/7				0/0				0/0					0/1
dults	shaking	0/0				1/1				0/0					0/0

from which they presumably developed. In Table 19 maximum numbers of nymphs and subsequent adults are shown for both grass and cane for the four periods of peak numbers which the experiment covered, and this discrepancy in numbers is evident. Routine population sampling for the same estate which was always done by shaking the cane, showed (with two exceptions) a nymphal mortality (Table 20).

TABLE 20 % mortality between numicia nymph and adult peaks for all fields sampled, Ubombo Ranches 1964 - 69 (figures to nearest five).

	February			May			October		
	nymph	adult	% mort- ality	nymph	adult	% mort- ality	nymph	adult	% mort- ality
1964				170	69	59	300	210	30
1965	75	40	47	110	110	0	1700	450	74
1966	490	350	29	270	190	33	450	80	82
1967	140	115	18	430	335	22	440	35	92
1968	90	75	17	285	170	40	130	10	92
1969	10	10	0	40	35	12	135	25	81

The discrepancy was particularly evident in grasses, which were sampled only by quadrats, and was undoubtedly due in large measure to sampling error. However, such an error may not have been the exclusive cause of the discrepancy.

Another possible explanation is that adult numbers could have been boosted by individuals flying in from elsewhere. When considering records for the various sites individually, the figures sometimes suggest that such a boost could have come from the adjacent medium; but this is not always the case, and on other occasions

numbers of adults in both media were higher than nymphs of the same generation even where all sampling was done by shaking. On several occasions, young ratooning or plant cane, from which nothing had been recorded since cutting, acquired adults which could not have developed in that field and must therefore have flown in. Likewise grass which had been unpopulated became inhabited by adults.

It is of interest that a fall in numbers between nymphs and adults of the same generation was most common and most striking in the period from August to November. During this period rain grown veld grasses are dry, and could produce few adults for migration into cane and surrounding green grasses. A similar, if less striking situation is seen in Table 20, the percentage mortality between nymphs and adults being generally higher for this period. Possibly there was more movement by adults during the summer period, and migration into cane from grasses occurred over considerable distances.

3.7.2 Experiment 2

Included here are three different sets of investigations which were carried out over much the same period (1966-67) and which involved shake sampling and quadrats applied in much the same manner as was done for Experiment 1. In essence these all concerned a rather more intensified look at numicia populations and their possible movement in cane and in grasses.

3.7.2.1 Fields Bakshee and Compound

There were two parts to this investigation.

Part a

Objective

To trace any adult movement from heavily infested nine-month-old cane to lightly infested four-month-old cane.

Procedure

The heavily infested field (Bakshee, Fig. 20) was separated

from the lightly infested one (Compound) by a 6m break. From 29 September 1966 until 28 December 1967 the fields were sampled on opposite sides of the break at approximately weekly intervals. Initially the field Compound was sampled also at 25 m intervals into the field, up to a distance of 200 m at first, and later to 150 m.

Results

Counts, to the nearest whole number, are shown in Table 21. When sampling started numicia were present in both fields and were mostly in the nymph stage, and there was no marked migration. By 15 October 1966 adult numbers in Compound were increasing, possibly as a result of newly emerged adults flying there from Bakshee. A sudden large increase in adult numbers in Compound was recorded on 2 November, but population was still of a low order and well below that in the adjacent cane. By December numbers in both fields were similar and remained so until Bakshee was harvested on 20 April 1967, when adult numbers in Compound increased (on 17 May. Unfortunately Compound was not sampled immediately after Bakshee was cut, so it cannot be said with certainty that the increase in numbers was a result of migration from the harvested field). After Compound was ploughed out, it was not sampled again for four and a half months, by which time adults were again present.

Part b

Objective

To investigate any numicia movement resulting from harvesting cane, or from changed state of grasses.

Procedure

Regular sampling was done in the field Bakshee (usually two different areas) before and after harvest, and also in grasses in the vicinity of an adjacent irrigation canal, and at another point on the opposite side of the field.

Date	Bakshee				Compound																Remarks (Q) = quadrats (S) = shakes
	5 m		5 m		25 m		50 m		75 m		100 m		125 m		150 m		175 m		200 m		
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	
9. 9.66	359	35	20	8	5	3	3	2	3	3	.										() Bakshee (Q) Compound
4.10	1222	87	17	10	15	10	10	5	2	12	5	5	5	3	0	5	7	0	0	2	
5.10	666	154	4	6	3	6	1	10	1	2	1	3	1	2	3	2	1	3	2	1	
7.10	1406	205	10	11	2	6	4	6	2	6	2	4	3	10	2	10	1	6			
5.10	339	260	3	17	2	19	1	16	2	17	3	11	1	15	2	11	1	12	2	8	
0.10	331	360	1	17	2	11	2	12	1	6	0	11	3	12	3	14	2	14	1	8	
7.10	210	740	1	18	1	12	0	12	1	14	1	13	0	15	1	13	1	9	1	12	
2.11	112	511	16	82																	(S) Compound
0.11	15	320	1	23																	
1.11	5	296	1	29																	
1.11	0	86	0	28	1	25	0	26	0	26	0	25	0	23	0	23					
1.11	1	81	0	27	0	11	1	1	1	14	0	11	0	9	1	11	0	8	0	10	
1.12	3	42	3	8	7	8	11	4	11	2	10	3	5	6	6	5					
1.12	25	20	23	3	24	5	41	3	44	3	51	2	33	2	34	4					
1.12	52	3	28	4	32	2	29	4	35	2	35	2	27	2	43	1					
1.12	14	4	24	3	21	1	15	2	26	4	28	1	29	3	34	3					
1. 1.67	34	13	19	17																	
1. 2	5	21	2	25																	
1. 2	2	31	2	20																	
2	2	22	2	37																	

TABLE 21. Nympha numbers per 10 m² at contact point between 2 fields (to nearest whole no.; N = nymphs, A = adults)

TABLE 21. (Continued).

Bakshee				Compound																Remarks (Q) = quadrats (S) = shakes	
5 m		5 m		25 m		50 m		75 m		100 m		125 m		150 m		175 m		200 m			
N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		
22. 2.67	0	28	3	23																	
1. 3	7	9	31	9																	
8. 3	31	8	58	18																	
22. 3	39	2	81	4																	
29. 3	33	3	65	7																	
4. 4	36	13	75	14																	
12. 4	8	27	14	68																	
19. 4	2	24	5	63																	Just before cutting Bakshee
20. 4	17	83																			Further up field
7. 5	0	52	5	122																	(Q) Bakshee
4. 5	0	90	3	197																	
1. 5	0	126	4	149																	
7. 6	0	109	4	106																	
4. 6	0	54	1	84																	
1. 6	0	71	1	57																	
1.11	0	48	0	14																	Compound ploughed out
3.11	0	24	0	25																	(Q) Bakshee (Q) Compound
5.12	32	18	0	9																	
3.12	212	7	0	1																	

Immediately before and after harvest the grass was sampled also at different distances from the harvested field in two directions (Table 22a).

Results

Counts (to the nearest whole number) are shown in Table 22. From Table 22a it can be seen that following burning and cutting of the cane, there was a consistent increase in adult numbers in adjacent grasses. This was greater than could be accounted for by normal metamorphosis, and it may be concluded that the adults came from the cane.

From Table 22b several noteworthy points arise.

It illustrates how nymphs may survive in a minimum of grass during the winter months provided the grass is not burnt e.g. 26 July to 25 September 1967. With the reappearance of green grass in November adults were again recorded with, in one area, an accompanying decrease in numbers in cane. Burning of the grass in late September was followed by a rise in adult numbers in cane; which may have been seasonal, or adults may have flown there from the grass. The generation synchrony was maintained.

3.7.2.2 Field Dlamini

Objective

To compare numicia populations in a cane field and in adjacent green grasses.

Procedure

Between May and December 1967 the cane field and adjacent grasses across an irrigation canal were sampled at approximately weekly intervals.

Results

These are summarised in Table 23.

TABLE 22. Numicia numbers per 10 m² in field Bakshee and in adjacent grasses before and after harvesting cane (to nearest whole number).

(a)

Date (1967)	Bak- shee		Grasses										N=nymphs
			Area 1 (towards mill)					Area 2 (over canal)					A=adults
			5 m		25 m		50 m		5 m		25 m		(Q)=quadrat.
			N	A	N	A	N	A	N	A	N	A	(S)=shaking
20.4 (S)	17	83	21	57	5	45	18	53	40	106	50	116	
26.4 (Q)	0	1	4	116	1	100	3	61	47	209	44	230	

(b)

Date (1967)	Bakshee opposite canal		Grass over canal		Bakshee opposite village		Grass near village		Remarks
	N	A	N	A	N	A	N	A	
20.4	17	83	40	106					(S) before cutting Bakshee
26.4	0	1	47	209					(Q) after "
3.5	0	52	3	18					
24.5	0	90	1	76	0	51	0	182	mixed green and dry grasses
31.5	0	126	1	95	0	63	0	142	grass drying off over canal
7.6	0	109	0	127	1	98	0	129	
14.6	0	54	0	26	0	41	0	35	
21.6	0	71	1	42	0	40	0	59	
6.7	46	3	42	1	50	7	67	4	(nymphs hatching)
19.7	49	2	97	1					
26.7	69	0	233	3	70	2	126	2	adjacent field reploughed
8.8	86	0	91	0	117	0	154	0	canal grass dry. Other mixed green-dry
31.8	156	1	143	0	156	1	194	0	
6.9	69	0	181	0	136	0	277	0	grass dry in both areas
25.9	60	1	4	0	101	6	130	1	" " " " "
3.10	10	11	0	0	52	18	0	0	grass burnt near village
10.10	42	20	0	0	98	34	0	0	
24.10	1	77	0	0	19	96	0	0	
2.11	0	87	1	4	4	51	3	22	green and dry grass patches
28.11	0	24	0	4	21	48	0	80	(S)
5.12	32	19	0	6	52	12	1	25	
28.12	132	2	0	0	211	7	2	0	

TABLE 23. Numicia numbers per 10 m² in field Dlamini and in adjacent grasses (to nearest whole number).

Date (1967)	Cane		Grass (across canal)		Remarks	
	nymphs	adults	nymphs	adults		
19.5	0	1124	4	671	(S) Dlamini 3	grass green
24.5	0	0	1	407	(Q) Dlamini 2	now " "
31.5	0	11	4	386	2 cane areas sampled	"
"	0	24				"
7.6	0	17	1	316		"
14.6	0	15	0	172		"
21.6	0	14	0	159		grass drying
6.7	0	1	147	13	nymphs hatching	"
19.7	0	1	226	27		"
26.7	0	0	217	3		almost dry
3.8	0	0	280	5		"
8.8	0	0	282	7		"
31.8	7	1	298	1		grass dry
6.9	8	0	488	3	2 cane areas sampled	"
6.9	19	0				
25.9	2	2	294	1		"
3.10	0	6	193	4		"
10.10	0	0	51	2		"
17.10	1	15	37	4		"
24.10	0	24	0	0		"
2.11	0	18	4	15		grass green and dry
21.11	0	20	0	8		" "
28.11	0	17	0	21		" "
5.12	23	8	2	29	(S)	" "
28.12	149	8	0	0		grass dry

There was no indication of survival of nymphs nor of adults in cane when quadrat sampling began on 24 May. However, adults appeared shortly afterwards, their appearance being accompanied by a drop in numbers in grasses. As grass became very dry, in October, there was a reduction in nymph numbers with no corresponding increase in adult numbers which did however increase in cane, suggesting a movement from grasses. However, the fate of the numerous nymphs, present in increasing numbers between early July and late September remains unexplained, for the subsequent increase in adult numbers in cane was not very great. Generation synchrony was evident.

3.7.2.3 Field Kayalihle

Objective

To compare numicia populations in cane and in adjacent grasses, and to note whether numbers in grasses varied between the field perimeter and at a distance of 25 m inwards.

Procedure

As before, but grasses were sampled where they bordered on the cane field and at points 25 m from the perimeter.

Results

These are summarised in Table 24.

The table shows, between April and June 1967 a fall in numbers of both nymphs and adults in cane and to some extent in grasses, suggesting that adults were moving out or dying. At that time of year adult mortality following oviposition is normal. Between September and October in grasses there was no rise in adult numbers corresponding with a fall in numbers of nymphs suggesting that they either died or moved to cane, where adult numbers did rise despite the fact that it had recently been burnt and nymphs were absent.

Table 24 shows that at the two points sampled, nymph figures were much the same, but that adult figures were higher farther into th

TABLE 24. Numicia numbers per 10 m² in field Kayalihle and in adjacent grasses on perimeter and 25 m farther in (to nearest whole number).

Date	Cane		Grass (perimeter)		Grass 20 m inwards		Remarks (Q)=quadrats (S)=shaking
	nymphs	adults	nymphs	adults	nymphs	adults	
29.10.66			1	0	1	1	
23.11			0	0	0	0	
22.2. 67			0	86			grass green
1. 3			0	63			grass green and dry mixed
8. 3			0	9			
22. 3			0	5			
29. 3			3	2			
4. 4			2	5			
12. 4			1	8			
19. 4			6	7			
26. 4	70	292	8	29	12	76	(S)
3. 5	55	212					
10. 5	9	192	3	27	2	50	
17. 5	25	191	1	22	2	29	
24. 5	8	222	0	27	1	51	
31. 5	5	131	1	23	1	29	
7. 6	2	117	0	30	1	20	
14. 6	1	94	0	22	0	27	
21. 6	2	65	1	22	4	21	
8. 7	86	6	35	4	37	4	adults dying; eggs hatching
12. 7	101	2	59	1	59	3	
19. 7	98	2	69	0	61	2	
26. 7	119	1	53	1	41	1	
3. 8	123	0	39	1	51	1	
8. 8	124	0	38	0	46	2	
17. 8	140	0	75	0	65	0	
31. 8	128	0	44	0	63	1	
6. 9	125	1	83	0	52	0	grass almost dry
25. 9			12	0	14	0	grass dry
3.10			8	0	2	0	cane burnt and harvested
17.10			0	0	1	0	
24.10	0	5	0	0			(Q)
2.11	1	8	0	0			
21.11	0	10	0	0	0	1	

TABLE 24. (Continued).

Date	Cane		Grass (perimeter)		Grass 20 m inwards		Remarks (Q)=quadrats (S)=shaking
	nymphs	adults	nymphs	adults	nymphs	adults	
28.11	0	3	0	0			
5.12	0	2	0	0			grass green and dry mixed
19.12	1	0	0	0	1	0	
28.12	0	0	0	0			

Adult nos on perimeter and 25 m into grassland:

S.E. of mean of differences (log. transformed data) = 0,036

t (23 D.F.) = 3,16**

adult numbers significantly higher 25 m into grassland.

3.7.3 Experiment 3

This and the next experiment were designed to investigate repopulation of a field following normal burning and cutting.

Procedure

In January 1968 the fields Spray G and Spray H were each divided into three sections. Three of the resulting plots were treated after harvest with dieldrin 18% emulsion at the rate of 3 litres to 600 litres water per hectare applied as an overall foliar spray. The other three plots were left untreated. A restricted area in each plot was sampled before treatment and periodically thereafter.

Results

Repopulation figures are summarised in Table 25.

From them it is apparent that a) adult numicia had already entered plots at the time of treatment and b) if treatment with dieldrin destroyed these, more flew in shortly afterwards, survived and produced viable eggs.

TABLE 25. Numicia numbers per 10 m² in treated and untreated plots in fields Spray G and H before and after treatment (to nearest whole number, quadrat sampling).

Date (1968)	Treated		Untreated		Remarks
	Nymphs	Adults	Nymphs	Adults	
12.1	0	8	1	15	before treatment
22.1	0	51	0	24	after treatment
7.2	0	63	0	39	
20.2	1	36	3	39	
11.3	143	16	139	20	
27.3	284	28	529	105	
3.4	332	66	492	96	

3.7.4 Experiment 4

Procedure

In the field Spray D shortly after harvest (1 August 1968) a 500 m transect from one edge of the field to another was sampled at 50 m intervals. Using a motorised suction sampler (3.2.2/b) this was done approximately monthly, sampling for 20 m at every 50 m point. The chosen transect consisted of one cane row and was altered slightly on each occasion, so that the identical row would not be sampled twice.

Results

These are summarised in Table 26.

One nymph, presumably a survivor, was recorded at the first sampling. A general increase in adult numbers was recorded after an adjacent field had been harvested in late September.

3.7.5 Experiment 5

Objective

To investigate whether the harvesting of a field which supported fair numbers of adult numicia resulted in a population

TABLE 26. Transects to investigate repopulation of field
Spray D by numicia (N = nymphs, A = adults).

Date	Numicia numbers at distances in metres																				Remarks		
	5		50		100		150		200		250		300		350		400		450			500	
	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
. 8.68														1									
. 8.68																							
. 9.68									1						1								Adjacent field cut from
.10.68	4		2		5		1		2		2		5		1		1						23.9 to 5.10
.11.68	1				1	1		1							2								Adjacent field cut from
.12.68													1										15.11 to 29.11
. 3.69			15		7		2		3		4		6		2								

Procedure

Fields sampled were Spray E, G, H and I which were being harvested during November and December 1966, a time when numicia were quite plentiful.

On 7 October a spot check was done by shake sampling Spray G and quadrat sampling Spray I, which had just been burnt. This showed the presence of reasonable adult numbers in mature cane and very few on the recently harvested field (Table 27). The main object of subsequent sampling was to record any increases in numicia numbers in the recently harvested fields I and E resulting from the current burning of fields G and H.

Before harvesting Spray H it was sampled in three positions and at the same time fields Spray E and I were sampled immediately opposite those positions and progressively inwards. Spray E and I were sampled again after harvesting Spray H (which was done in two stages).

Results

These are recorded in Table 27.

Spray G was harvested on 26 November. Numbers at position 1 in Spray I increased between 26 November (before Spray G was burnt) and 29 November, possibly as a result of disturbed adults flying in. However, at position 2 there was a decrease in numbers between 26 November and 1 December.

At position 1 in Spray I numbers were much the same at all sample points on 26 and 29 November, before the first section of Spray H was burnt; but afterwards on 30 November numbers in all positions had increased ($P < 0.05$). However at position 2 numbers in Spray I fell between the periods before and after the second section of Spray H was burnt (N.S.).

Numicia numbers per 10 m ² ; nearest whole number (nymphs absent in all young ratoons)											
Date	Field					Field					Remarks
	Spray G					Spray I					
	Nymph	Adult	5m	30m	60m	90m	120m	150m	180m	total	
7.10.66	390	72	1	2	2	1	0			6	a spot check
6.11.66	Spray H (top)					Spray I, position 1					a check before burning Spray G
	0	16	29	24	36	43	40	40	49	261	
	Spray H (bottom)					Spray I, position 2					
	0	30	17	18	18	19	21	31	34	158	" " " "
9.11.66	Spray H (top)					Spray I, position 1					before and after burning
	0	28	28	26	41	42	42	39	48	266	
0.11.66			34	49	47	54	56	67	51	358	Spray H (top)
1.12.66	Spray H (bottom)					Spray I, position 2					before and after burning
	0	21	15	14	19	20	21	38	25	152	
2.12.66			11	16	13	22	14	28	27	131	Spray H (bottom)
9.11.66	Spray H (top East)					Spray E, position 1					before and after burning
	0	27	0	0	0	0	0	0	0	0	
0.11.66			1	0	0	0	0	0	0	1	Spray H (top)
Averages			15,1	16,5	19,5	22,3	21,6	30,4	29,3		

TABLE 27. State of numicia in fields to be harvested and in adjacent young ratoons.

(Adult numbers in Spray I before and after burning Spray H: S.E. of mean difference = 3,73
t (6D.F.) = 3,49*)

In Spray E the change in population before and after burning was negligible.

In the young ratoons a tendency was apparent for numicia numbers to increase into the field.

On 29 November wind direction was towards Spray E parallel with the break between Spray H and I; on 1 December it was at right angles to this direction.

3.7.6 Experiment 6

Objective

To investigate pattern of distribution in a recently infested field.

Procedure

In April 1967 young adults were noted in a field of one-month-old plant cane (field Fireball) adjacent to a field of mature cane (Paddies South), which had been heavily infested during the previous generation. Between April and December quadrat samples were taken approximately weekly at 25m intervals into the young cane.

Results

There was a tendency for numbers to increase into the field (Fig. 29). In June nymphs of the following generation appeared and their numbers too reflected those of their parents; and this was true of the third generation as well. Over the entire period numbers fluctuated and dwindled although the field was never treated with insecticide.

3.7.7 Experiment 7

Objective

As most of the sampling in Experiment 6 was done to a distance of 50m only, it was decided to investigate invasion more thoroughly. An opportunity to do so arose when the field Mpembe was ploughed planed and prepared for a new irrigation system.

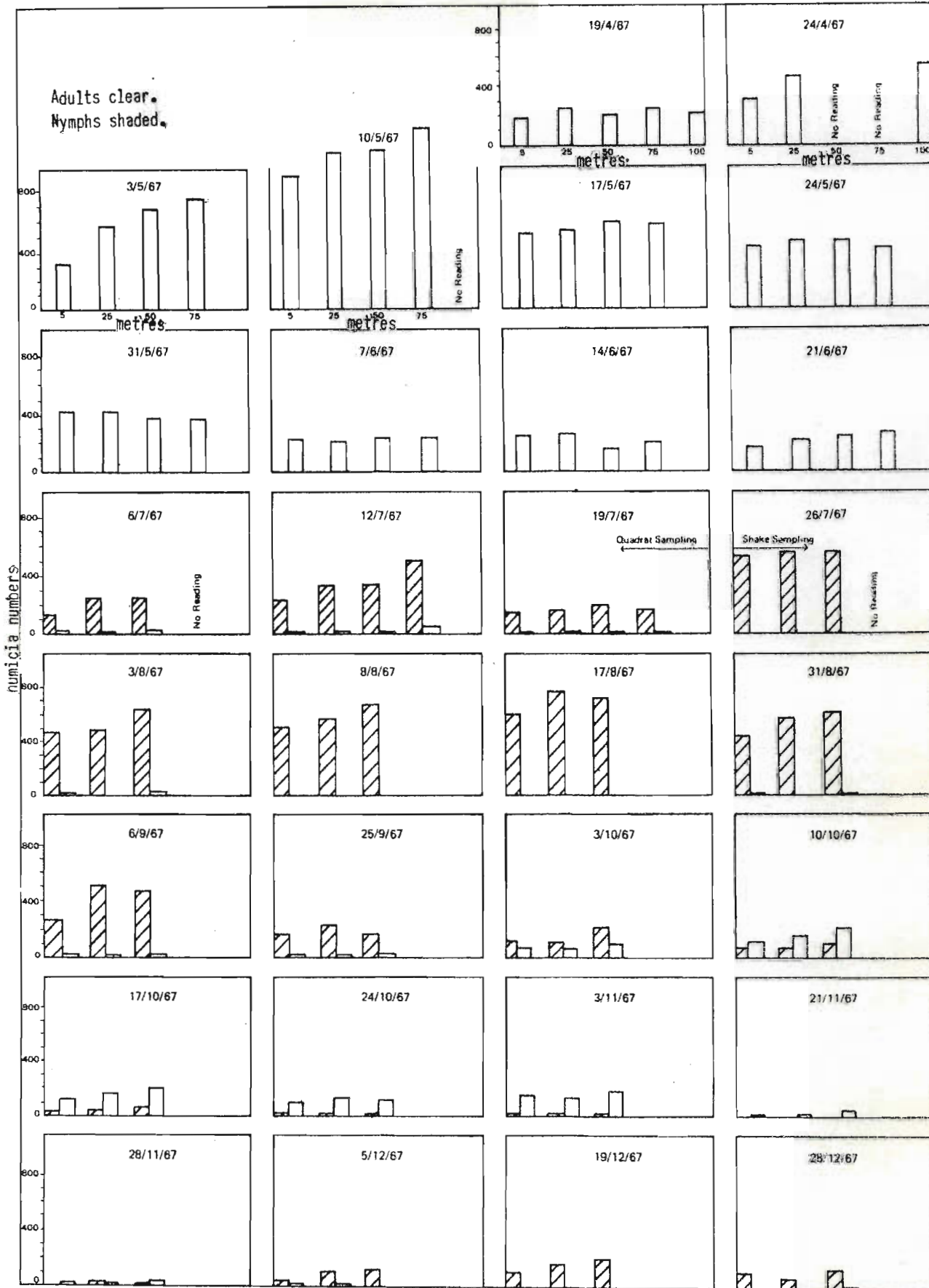


Fig. 29 Numicia numbers at different distances into a cane field.

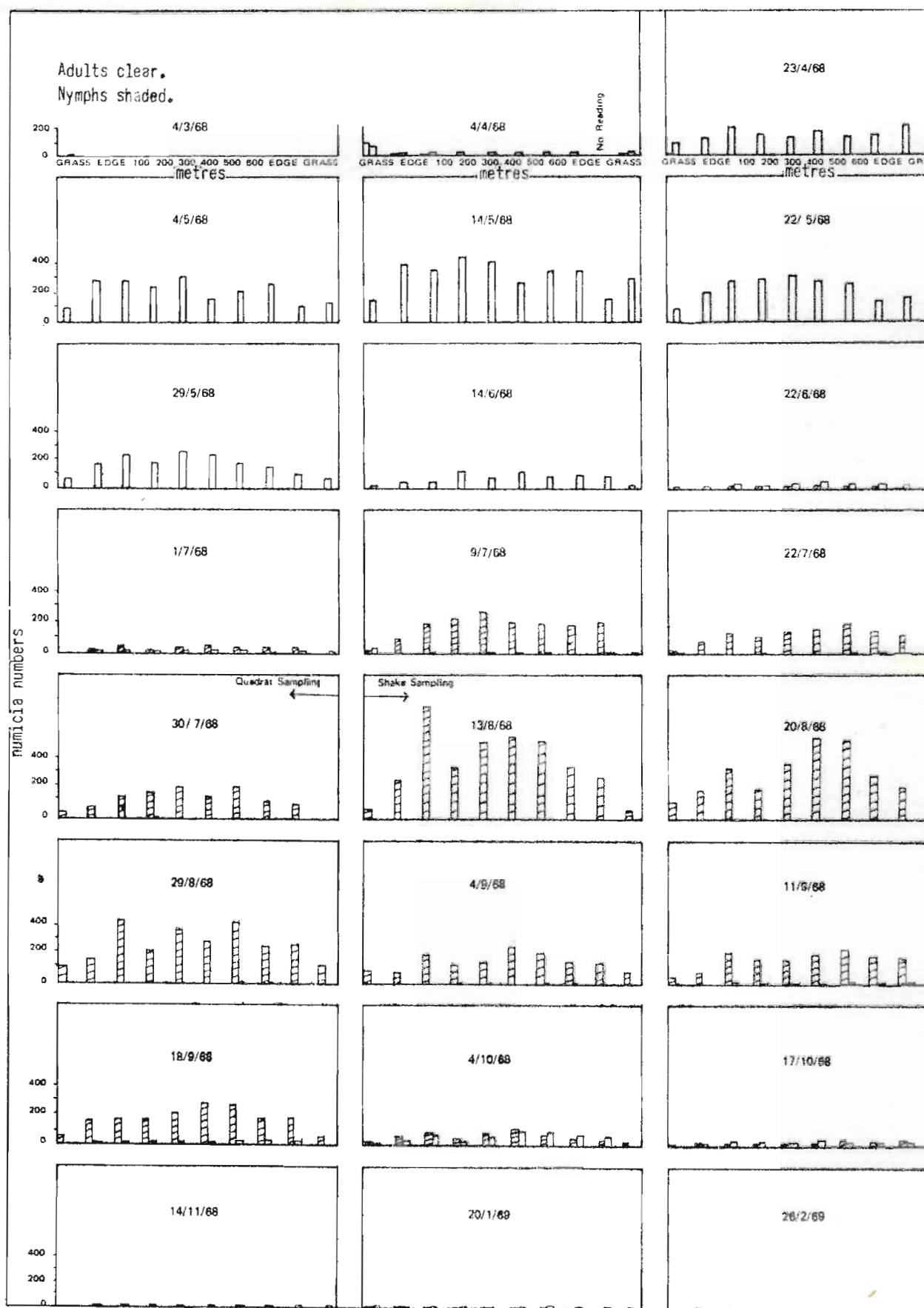


Fig. 30 Numicia numbers across a cane field and in adjoining grasses

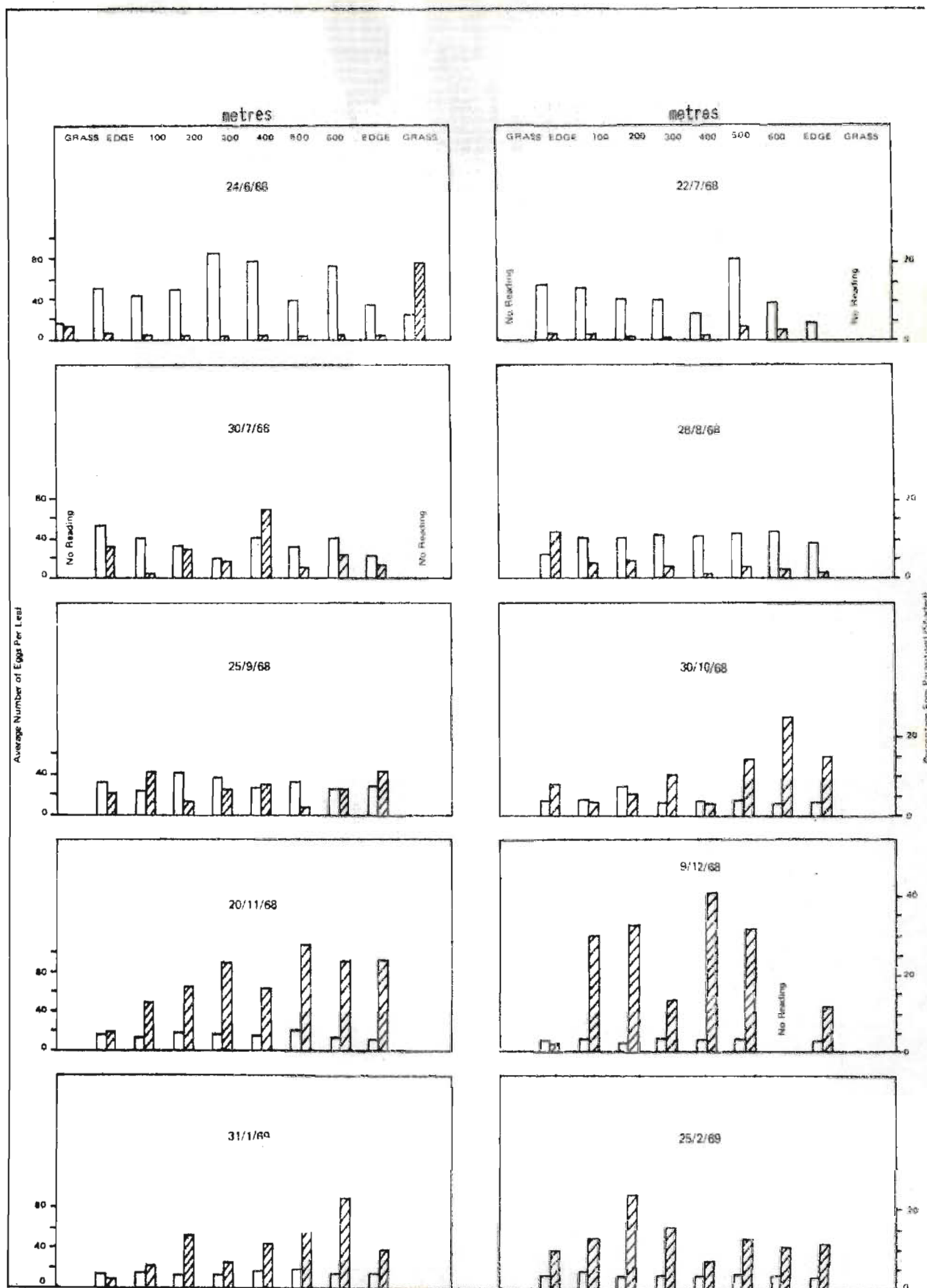


Fig. 31 Numbers of numicia eggs per leaf and percentage parasitised (in transects across a cane field).

Procedure

For seven months the field was bare of vegetation and during this time an occasional adult numicia was seen on it. The field was elongate in shape being about 700m across, and bounded along one side by a vleis and drainage system, and along part of the other by a grassy banked reservoir and non-irrigated grassland (Fig. 20).

From the 14 March 1968 when young shoots first appeared until April 1969 the field was sampled as frequently as possible. On each occasion a transect in approximately the same area was chosen. This ran from the reservoir bank through the field, and ended in the grass on the far side. The cane was sampled at each edge and at 100m intervals through the field. Quadrats were used until the cane became large enough to sample by shaking.

Over the same period and as frequently as opportunity offered, samples of leaves with eggs were collected from the same sampling points, including initially leaves of grass from the borders. Whenever possible 25 leaves with eggs were collected from each site, but seasonal egg scarcity sometimes prevented this. Eggs were subsequently counted in the laboratory and examined for parasites (3.10.2; 4.3.1.3).

Results

The first sampling produced no numicia in cane and very few in grasses (Fig. 30). Three weeks later adults began to appear throughout the cane field (also one or two nymphs which had probably hatched from eggs laid by migrants of the previous (February) generation).

By mid-May a distribution pattern was becoming apparent with larger numbers towards the centre of the field, a pattern which was maintained by subsequent generations.

Both the common egg parasites Ootetrastichus ?beatus and Oligosita sp. were present (4.3.1). Numbers of eggs per leaf and percentage eggs parasitised are shown in Fig. 31, where the combined effects of both parasites are considered.

In the first samples both parasite species were found in grasses, and in cane in the field centre as well as on the perimeter. At first Oligosita sp. was the more plentiful, but Ootetrastichus soon became equally so. From these figures no obvious pattern is apparent, but it is interesting how quickly and successfully the parasites, which are extremely delicate insects, found their hosts and became established throughout the field.

3.7.8 Experiment 8

Objectives

To investigate further the movements of adult numicia from older to younger cane, noting in particular: a) whether there was a predominance of one sex; b) whether females flew only at a certain stage of egg maturity; c) whether there were any differences in numbers, sex ratio or state of maturity at different distances from the old cane (from which the adults were assumed to have come, since there was no other older cane or green grass in the immediate vicinity).

Procedure

In October and November 1968 another field of young ratooning cane (Boundary North) was sampled at different distances from mature adjacent cane (Rossland) which had supported reasonably large populations of numicia in the previous generation.

The old cane was sampled at its perimeter and the young cane both at its perimeter and at intervals into the field to a maximum distance of 375m. Two transects were sampled on the 30 October; six including the previous two on the 6 November; and four of these were repeated on the 20 November. All transects started at

points along an access road separating the two fields, the two most distant starting points being about 1 km apart.

Sampling was done exclusively with a motorised suction sampler (3.2.2/b). At each point the sampler was operated for 30 seconds along the top of one row at walking speed, and for a further 30 seconds in the opposite direction along the top of another row.

All numicia collected were preserved in a mixture of alcohol and glycerine and were returned to the Experiment Station for counting, sexing and dissecting. All females were dissected and the numbers of eggs counted. The only eggs included were those which were mature or very nearly mature. Females without such eggs were classified as immature or empty, the latter being those which had expelled their eggs.

The period covered by the sampling included a time of peak adult numbers and activity, although on the occasion of the first sampling numbers were still relatively low.

3.7.8.1 Results

In considering the results the situation was summarised as follows: 1) combining all distances into the cane on each occasion (Table 28); 2) combining available transects for each occasion and showing each distance into the cane separately (Table 29). For 30 October only one of the two transects is shown because different distance intervals were used in each transect, and combining them added nothing to the information gained.

From Table 28 the following points may be noted.

- a. Both sexes were common throughout the period of sampling. This shows that the flight of young adults is not confined to females only, and suggests that mating can occur after flying. From similar sampling on another estate (Mhlume) and from field observation, females are known to mate also in the cane in which they developed.

TABLE 28. State of numicia (total of all distances) on each sampling date.

Date (1968)	Males	Females	Total	% Female	% im- mature female	% empty female	Eggs per female of remainder	Eggs pe female (total)
30.10	28	34	62	54,8	88,2	0,0	16,2	1,9
6.11	401	460	861	53,4	31,3	4,8	20,7	13,3
20.11	374	209	583	35,8	22,9	12,4	21,6	13,9

b. Females will fly when eggs are still immature.

c. As was to be expected, percentage of immature females fell, while that of those which had expelled their eggs rose.

d. At the last sampling total numbers of males were considerably higher than females; previously their numbers had been much the same. This could have been caused by female mortality following oviposition i.e. one sex living longer than the other.

e. Mature females contained an average of 19,5 eggs. This is considerably lower than the figure of 28,2 obtained from insectary reared material (Harris, 1968; 2.20). The highest number of eggs recorded in this experiment was 49, compared with 162 found in an insectary reared female.

From Table 29 the following points may be noted:

(i) Only in the last sampling was there a trend for numbers of both males and females to increase into the field. The lengths of the transects represented less than a third of the total field width, and sampling was not done beyond the distances shown for fear of encountering influences from other fields; so it is not known whether the trend continued.

(ii) Apart from a slight trend for the percentage of females to increase into the field, the situation at each distance sampled was much the same.

TABLE 29. State of numicia at different distances into cane on each sampling date.

Date (1968)	Distance into cane m	Numicia								
		M*	F*	Nymph	Total	% F*	% immature F*	% empty F*	No. eggs per F* of remainder	No. eggs per total
30.10	Edge tall	?	?	6	9	-	-			
Total of 1 transect	" short	0	1	0	1	100,0	100,0	0,0	0,0	0,0
	75	10	6	0	16	37,5	100,0	0,0	0,0	0,0
	150	4	3	0	7	42,8	100,0	0,0	0,0	0,0
	225	4	4	0	8	50,0	100,0	0,0	0,0	0,0
	300	5	3	0	8	37,5	66,6	0,0	25,0	8,3
	375	2	3	0	5	60,0	100,0	0,0	0,0	0,0
		25	20							
6.11	Edge tall	2	12	1	15	85,7	100,0	0,0	0,0	0,0
Total of 6 transects	" short	88	53	0	141	37,5	43,4	3,7	19,2	10,9
	50	89	100	1	190	52,9	36,0	2,0	20,1	12,5
	100	89	81	0	170	47,6	24,6	7,4	21,2	14,5
	150	75	113	1	189	60,1	25,6	6,2	21,6	14,7
	200	58	101	0	159	63,6	25,7	4,9	20,7	14,4
		401	460							
20.11	Edge tall	3	1	0	4	25,0	100,0	0,0	0,0	0,0
Total of 4 transects	" short	69	20	0	89	22,4	35,0	15,0	19,7	9,6
	50	73	40	0	113	35,3	20,0	2,5	21,8	16,9
	100	84	49	0	133	36,8	18,3	16,4	22,7	14,9
	150	90	62	0	152	40,7	30,6	6,5	19,7	12,5
	200	55	37	0	92	40,2	10,8	27,0	23,3	14,5
		374	209							

On the first occasion most females were immature at all distances, showing that before oviposition they may fly quite a long way i.e. at least 400m. At all distances numbers of eggs per female remained moderately constant.

(iii) The occasional record of a young nymph in the young cane was of interest. These were almost certainly survivors from the previous generation (3.6.1).

No true internal or external parasites of adults or nymphs were ever encountered, but on one occasion an Epipyropid moth larva was noted on an adult (4.3.4).

3.7.9 Further notes on population distribution within a field

Positions on the leaf which were adopted by insectary reared nymphs and adults are discussed in 2.23. The scope for similar intensive studies in the field was limited, but the few observations made and supported by figures are listed below.

3.7.10 Distribution on sunny and shady sides of a cane break

Where the direction of a cane break was such that one side was predominantly shady and one sunny, the impression was sometimes gained that numicia were more plentiful on the shady side. This was investigated on two occasions.

a. Eggs

At Mhlume in August 1964 100 leaves were collected respectively from sunny and shady sides of a cane break. Those without eggs were discarded, and the numbers of eggs per leaf for the remainder were recorded, (60 leaves from the shady side, 52 from the sunny side). Average numbers of eggs per leaf were 42,8 from the shady side and 30,0 from the sunny side ($P < 0,05$) (Table 30).

b. Nymphs

At Ubombo Ranches in May 1968, using a motorised suction sampler collections were made of nymphs and adults from shady and

sunny sides of a cane break (field Nyoni). Collection was done between 10 a.m. and 12 noon, each sample being taken over a distance of 40 paces. Eight samples were taken on each side of the break.

TABLE 30. Positions of numicia eggs on normal green cane leaves, and relative egg numbers on sunny and shady sides of a cane break.

	Sunny side	Shady side
Total leaves sampled	52,0	60,0
% midrib distal to eggs	26,7 (12,0 - 45,0)	23,0 (6,5 - 43,2)
% " proximal " eggs	69,3 (49,3 - 93,3)	71,3 (42,9 - 89,2)
Av. nos eggs per leaf	30,0	42,8

Egg numbers: S.E. of difference of means = 5,7

$t(110 \text{ D.F.}) = 2,25^*$

Average number of nymphs per sample were 3,13 from the shady side and 1,25 from the sunny side ($P < 0,05$).

c. Adults

Sampling was as for nymphs.

Average numbers of adults per sample were 14,63 from the shady side and 9,75 from the sunny side ($P < 0,01$).

3.7.11 Distribution at different levels

In March 1968 non-replicated collections were made with the motorised suction sampler in fields Nyoni and Sangweni, sweeping the cane at a level of 1m and 3m above the ground. In each position in each field sampling was done for a period of two minutes. Numbers collected were as follows:

Field Nyoni; high level	2094 nymphs	21 adults
low level	3839 "	57 "

Field Sangweni; high level 520 nymphs 10 adults
 low level 1012 " 24 "

This comparison was never repeated nor extended, but a variation of this sort could be influenced by time of day. These counts were made during the late morning.

3.7.12 Distribution over a large field

Further information on distribution within a field was obtained from pre-treatment nymph and adult counts which were made before an insecticide trial in field Spray C (Table 31; Fig. 51). There was a tendency for numbers to decrease towards the estate boundary. The reason for this is not certain but it may have been associated with the dry state of the veld grasses at that time. In contrast, the vegetation in the direction of increasing numbers was either irrigated cane or permanently green grass.

TABLE 31. Numicia numbers (adults and nymphs) in plots of Spray C before insecticide trial (See Fig. 51).

Plot	ML	ED5	C	ED3	MD	ED5	C	MD	ML	ED3
Position 1	22	12	47	51	46	36	45	58	129	85
" 2	10	62	44	18	47	76	39	96	53	54
Plot	ED5	MD	ED3	ML	C	C	ML	ED3	MD	ED5
Position 1	48	3	20	58	80	66	84	57	69	101
" 2	28	53	73	60	75	88	59	61	60	47
Total	108	130	184	187	248	266	227	272	311	287

3.7.13 General discussion of numicia population distribution and movement

From the foregoing experiments and observations several conclusions may be drawn.

The synchrony of generations was evident under a wide variety

of circumstances and was not influenced by locality, plant species or state of host plant, nor by population size.

Spread of infestation was mainly by adults of both sexes flying from older cane into younger ratoons or plant cane. Females so doing were sometimes too immature to oviposit immediately, and travelled at least 400m into young cane before ovipositing. However there was no evidence of a mass or directional migration in response to any stimulus. The greater difference in numbers between nymphs and subsequent adults of the winter generation (August to November) did suggest that adult movement might be greater and more extensive in the summer months, but there has been no convincing evidence to prove this. There was evidence that a movement of adults from older to younger cane might be encouraged if infested cane were burnt and harvested when adults were present; but such a movement did not necessarily accompany harvest. There was evidence of adult movement from grass communities to cane and vice-versa. Adults often appeared in previously barren cane fields, and less frequently in previously barren grasslands.

Nymphs were never numerous following burning and harvesting, but it was evident that occasionally nymphs did survive the ecological hazard of harvest and became established on the young ratoons. It was possible that eggs occasionally survived also.

There was a tendency for numicia numbers to increase with cane age, but both small and large numbers were found in cane of all ages.

It was found that numicia populations could survive in winter even in very "dry" grass communities, provided the grass was not burnt.

A tendency was detected for numicia numbers to be lower near the perimeter of a cane field or grass community than farther in. Where sampling was done right across a field numbers tended to be

higher in the field centre, possibly as a result of migrating adults from both sides accumulating there.

Hymenopterous egg parasites occurred in a "new" cane field about two months after their host had become established.

The large numicia numbers frequently recorded from grasses near cane fields are considered to be a result of numicia having become established in epidemic numbers in intensively cultivated sugarcane. During this investigation spot checks were periodically made in green grass communities a matter of ten or more kilometres from the nearest infested sugarcane, and numicia were only occasionally found, and never in numbers larger than one or two per quadrat.

3.8 The progress of an untreated outbreak

During the early stages of this investigation growers were very quick to use insecticide, feeling understandably that if they did not, the infestation might be progressive and that their entire crop would be ruined. Once it had been established that useful natural enemies were present the dangers of unnecessary insecticide use were stressed, and the management of Ubombo Ranches courageously agreed to leave untreated a badly infested field so that the progress of the infestation could be followed (Carnegie, 1966).

In April 1965 numicia adults and nymphs suddenly became very numerous in four fields in particular (Compound, Cascade, Mhlosinga, Spray C). Compound (four-month-old furrow-irrigated NCo 310) was left untreated, but the other three were aerially dusted with 5% mercaptothion at 45 kg per hectare. During the subsequent life of the crop (about 14 months) Compound was visited monthly and a number of observations made and samples taken. (Biological control aspects of this infestation received particular attention and are discussed in detail in 4.3.1.3, and will only be outlined here).

Sampling for eggs, nymphs and adults was done throughout the period of study and the results are shown in Figs 32 - 35 and Figs 38 - 42. When sampling began numbers of eggs, nymphs and adults were already decreasing, and subsequent peaks of the various stages became progressively lower. It is interesting to compare figures for nymphs and adults for the two treated fields for which they are available (Figs 32 and 34). Following treatment there was an immediate fall in numbers, but subsequent numbers of nymphs and adults were high, exceptionally so in the field Mhlosinga, and this was continued even into the following generation. The fields were treated at the worst possible time i.e. when egg numbers were high and those of nymphs and adults quite low, and there was no follow-up second treatment. The temptation is to blame the upsurge on destruction of natural enemies by insecticide, but this must be done with caution. For two of the three treated fields (Mhlosinga and Spray C) figures are available for egg parasitism over the period May to December 1965. Sampling, which was approximately weekly was done on the same day in all three fields and there are valid grounds for making comparisons, although one of the two treated fields was of a different variety (Mhlosinga : NCo 376) and both were spray irrigated as opposed to furrow irrigated. However, all three fields contained large numbers of numicia and did not differ markedly in any obvious way. In both treated fields subsequent egg parasitism was lower than in the untreated field ($P < 0,01$), particularly so in the case of Mhlosinga (Fig. 35). But there were on the estate two other comparable fields which were not treated (Mpembe and Road) both of which contained large numicia numbers over the same period; and although Road had had a higher degree of parasitism even than Compound (N.S.) parasitism in Mpembe was significantly lower ($P < 0,01$) (Appendix X). There are no other comparable fields for which records were kept.

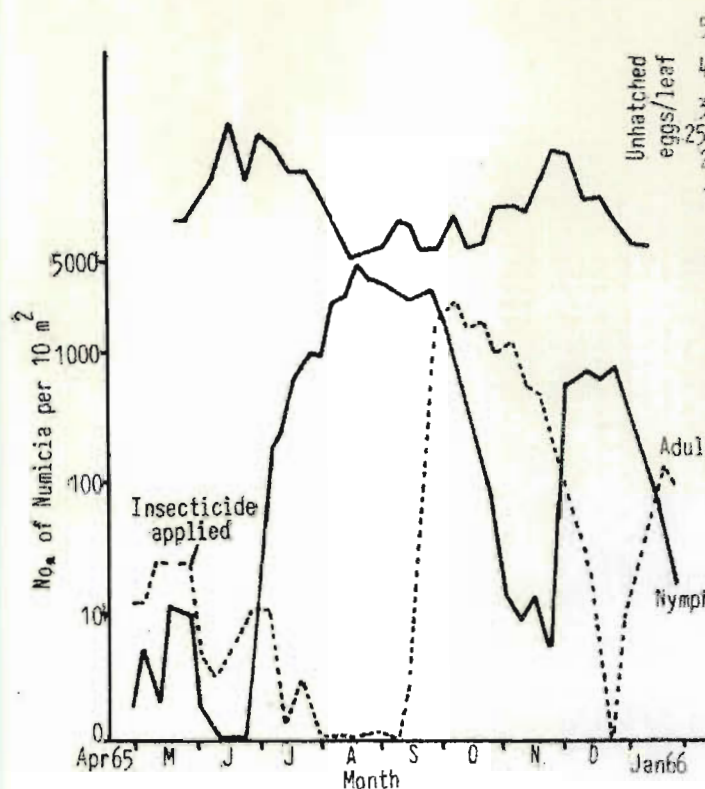


Fig. 32

Numicia populations in an insecticide treated cane field (Mhlosinga).

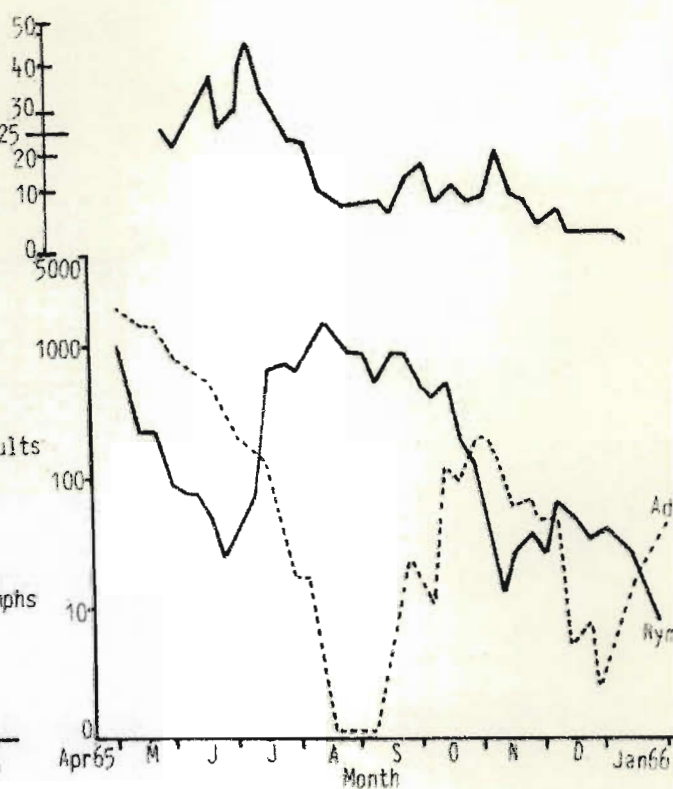


Fig. 33

Numicia populations in an untreated cane field (Compound).

Furthermore, the greatest differences in parasitism rates occurred in the latter half of the year, several months after insecticide treatment.

In the untreated field there appeared to be a general build up of predaceous insects and spiders, and from September onwards a more thorough sampling for nymphs and adults was done as follows: a plastic canopy was placed over four stools of cane at a time in the form of a tent. Ground sheets were placed under this and insecticide fumigant tablets ignited within it. After a suitable period everything which fell was collected and preserved for later examination. This was done five times in the untreated field and on three occasions was duplicated in the treated field. Intensity of sampling was very low but results are worth recording, and are summarised in Table 32.

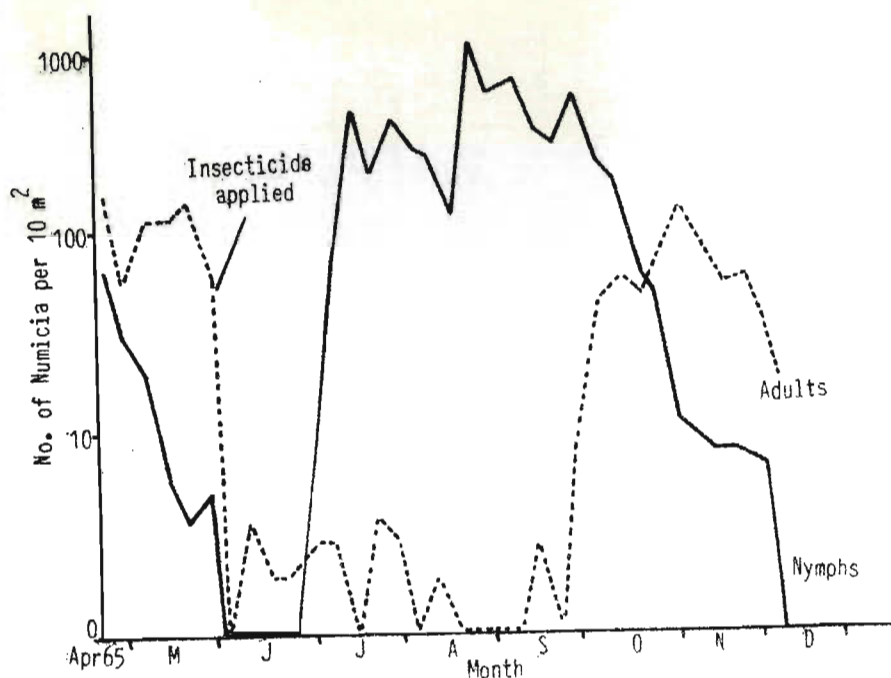


Fig. 34 Numicia populations in an insecticide-treated cane field (Spray C).

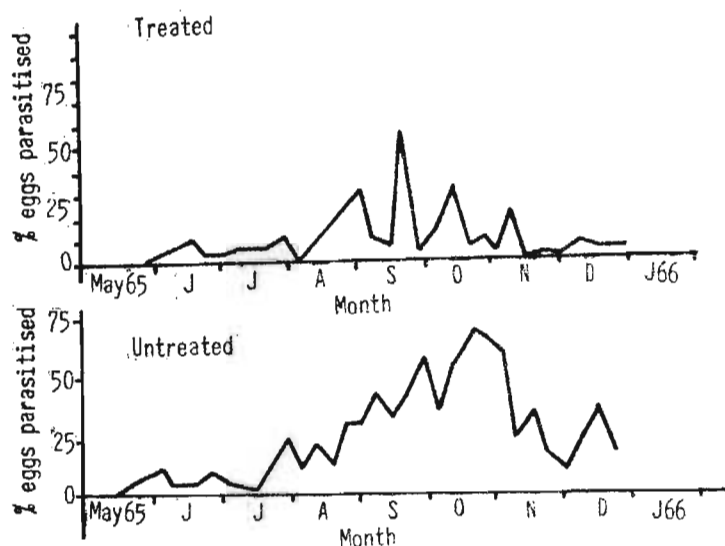


Fig. 35. Numicia egg parasitism in an insecticide-treated and an untreated cane field (Mhlosinga and Compound respectively).

In the untreated field, while numicia numbers remained high so did numbers of other arthropods, and the action of predators must have contributed to the gradual fall in numicia numbers. In the dusted field numbers of arthropods other than numicia were proportionately lower, but they were present in numbers similar to those in the untreated field.

TABLE 32. Average numbers of arthropods collected by fumigating cane (3 to 4 stools at a time in an untreated field (Compound) and a field treated with mercaptothion 5% dust (Mhlosinga).

	Date	Numicia	Spiders & predaceous mites	Coccin- ellidae	Dryin- idae	Other insects	% other insects	% predators
Untreated	15. 9.65	101,0	6,0	0,0	0,5	135,0	47,8	16,3
	12.10.65	116,0	38,0	2,0	0,0	103,0	40,6	15,8
	15.11.65	31,4	25,7	0,0	0,3	78,0	57,6	19,0
	15.12.65	4,0	13,0	0,5	1,0	36,0	92,6	22,2
	18. 1.66	4,0	2,0	0,0	0,0	15,5	72,1	9,3
Treated	12.10.65	2440,5	53,5	10,0	0,5	100,0	3,8	2,4
	15.11.65	92,2	21,6	7,0	0,0	64,3	34,6	15,4
	18. 1.66	16,0	17,0	0,0	0,0	10,0	23,3	39,6

3.8.1 Effects on the crop

During the winter months the general appearance of the untreated field was very poor indeed. Leaves turned yellow and there was very heavy trashing and poor growth; but by October signs of recovery were apparent. The field was due to be harvested in December, but was left until the following April, when it yielded much the same as the previous ratoon had done (7.15 tons cane/hectare month), i.e. much as would have been expected of it the previous December had there been no numicia infestation. The loss could therefore be assessed in terms of four months growth wasted.

3.9 Alternate host plants

The natural host plants of numicia are a wide variety of grasses. Indeed, it appears that any grass which is sufficiently robust to accommodate eggs and withstand the feeding of nymphs and adults may serve as a host plant. An interesting contrast was noted with the introduced Delphacid Perkinsiella saccharicida Kirk., the ecology of which was investigated at the same time as the numicia investigation. Perkinsiella was not recorded from grasses, except very rarely and then only in close proximity to cane, from which it appeared to have strayed. Numicia however was found on most grasses which grew in the vicinity of infested areas and was often present as eggs, nymphs and adults, and in large numbers.

In Table 33 are listed a number of host plants from which numicia was recorded and the list is not regarded as exhaustive. The presence of nymphs is the best indication of compatibility between insect and host plant, because adults could have flown to the alternate host, and eggs could have been laid fortuitously. Nymphs were encountered on many of the alternate hosts, which were simply noted in the course of the investigation, no deliberate survey ever being made or insectary tests carried out.

TABLE 33 Recorded alternate host plants of numiwa.

Host plant	Egg = E	Nymph = N	Adult = A
<u>Brachiaria brizantha</u>	E	N	A
<u>Urochloa mosambicensis</u>	E	N	A
" <u>panicoides</u>	E		A
<u>Chloris pycnothrix</u>	E	N	A
" <u>virgata</u>	E	N	A
<u>Cymbopogon validus</u>	E	N	A
<u>Cynodon dactylon</u>			A
<u>Dactyloctenium australe</u>	E		A
<u>Digitaria sanguinalis</u>	E		A
" <u>swazilandensis</u>	E		A
<u>Diplachne eleusine</u>	E		A
<u>Echinochloa crusgalli</u>	E	N	A
<u>Enneapogon cenchroides</u>	E		A
<u>Eragrostis curvula</u>	E	N	A
<u>Ischaemum arcuatum</u>	E		A
" <u>brachyatherum</u>			A
<u>Panicum deustum</u>	E	N	A
" <u>glabrescens</u>	E	N	A
" <u>laevifolium</u>	E	N	A
" <u>maximum</u>	E	N	A
" <u>repens</u>	E		A
<u>Paspalum urvillei</u>	E	N	A
<u>Pennisetum clandestinum</u>	E	N	A
" <u>thunbergii</u>	E	N	A
<u>Phragmites communis</u>	E		A
<u>Rhynchelytrum repens</u>	E	N	A
<u>Setaria chevalieri</u>	E	N	A
" <u>nigrirostris</u>	E	N	A
" <u>verticillata</u>	E		A
<u>Sorghum verticilliflorum</u>	E	N	A
<u>Stenotaphrum secundatum</u>			A
<u>Urochloa mosambicensis</u>	E	N	A
" <u>panicoides</u>	E		A
<u>Zea mays</u>	E		A

TABLE 33 (Continued).

Host plant	Egg = E	Nymph = N	Adult = A
<u>Cyperus sexangularis</u>	E	N	A
<u>Amarantus hibridus</u>	E		A
<u>Commelina benghalensis</u>	E		A
<u>Sonchus oleraceus</u>	E		A

In the more robust grasses e.g. Sorghum verticilliflorum, Cymbopogon validus eggs were frequently laid in leaf midribs as in cane, but in grasses with smaller leaves eggs were inserted in inflorescence culms e.g. Rhynchelytrum repens, or in leaf bases e.g. Pennisetum clandestinum (Fig. 15). In grasses numicia were seen feeding on leaves or at leaf bases.

In a small maize field at Mhlume a number of leaves of young maize plants contained eggs and it was noted that distal to the egg batch the leaf had become russet coloured and mis-shapen. On another occasion at Pongola considerable numbers of adults were found in a maize field adjacent to commercial cane apparently feeding on the plants. However there has been no record of numicia having caused economic damage to maize.

3.10 Numicia numbers and cane variety

Just as any sufficiently robust grass species seems able to serve as host plant to numicia, so also has the insect been found in all local field-grown cane varieties. Various growers have expressed the opinion that not only are certain varieties more susceptible to numicia damage, but that some varieties actually support larger populations than others. The investigations described below showed that significant differences sometimes existed, although the reasons for them were not obvious (Carnegie, 1972a).

3.10.1 Assessment of populations in variety trials : Ubombo Ranches

The nine varieties concerned were contained in a variety trial of 10-month-old plant cane distributed in randomised blocks of four replicates (Table 35). The trial had been well grown under conditions of spray irrigation, and its purpose was to investigate the agronomic merits of the various varieties under local conditions. Included in the trial were NCo 376 and NCo 310, the two most popular varieties grown commercially on the estate.

In March 1966 it was noted that numicia eggs, nymphs and adults were fairly plentiful throughout the trial area, and the opportunity was taken of sampling all plots to see whether insect numbers varied with variety. The trial was sampled in March and again in May 1966.

Individual plots were sufficiently large (1750 m^2) to constitute potential ecological units while the entire experimental area was not so large as to prevent movement of adult insects from any one variety to another, should there be a marked preference. It was considered that any differential ability to survive and mature on certain varieties would be revealed especially by egg and nymph population numbers.

Sampling procedure

Eggs

Twenty egg-bearing leaves from each plot were examined in the laboratory.

Leaves were collected by two teams of three people who walked side by side, plot by plot, along interrows for an entire block. Every three paces a lowest, non-selected green leaf was plucked, providing a total for each plot of approximately 99 leaves, which were made up to 100 by one of the samplers. Occasionally where the cane had become badly lodged (i.e. fallen over but still growing) deviation from the interrow was inevitable, and on one occasion the full 100 leaves were not collected.

At the end of each plot any leaves without eggs were discarded and the remainder returned to the laboratory for egg examination. From a subsample of twenty leaves the following statistics were recorded:

a) percentage leaves with eggs b) total egg numbers c) numbers of eggs per leaf d) percentage eggs hatched and unhatched e) percentage viable eggs f) percentage eggs parasitised g) which parasite (Oligosita or Ootetrastichus) was responsible h) percentage eggs degenerated.

The last category included all eggs which would not hatch through causes other than parasitisation e.g. fungus attack, dehydration.

For the second sampling separate records were kept of egg numbers in leaves collected by different individuals, for it was conceivable that as a result of leaves at different heights containing different numbers of eggs, a sampling error could occur (3.7.11). It was felt that an individual's interpretation of "lowest green leaf" could vary and possibly be influenced by his height. Results showed that with one team the tallest individual collected most eggs, but with the other the tallest member collected fewest; and figures for all individuals suggested that any such sampling error was negligible.

Nymphs and adults

Populations were assessed by shake sampling (3.2.2/c) using one square metre in two corresponding positions in each plot. In both March and May sampling for nymphs and adults was done immediately before egg sampling, two individuals sampling every plot of a replicate.

3.10.2 Results

The samples taken in March and May are referred to as sample 1 and sample 2 respectively.

Nymphs and adults

At the time of sample 1 most active numicia were in the late nymphal stage and numbers were quite high. By the time sample 2 was taken the next generation was present, but at a much lower population level and

most insects were in the adult stage (Table 34). There had been no insecticidal treatment either in this field or in surrounding fields and numbers must have dwindled through natural causes.

Any nymphs recorded could be assumed to have developed in that particular plot, and an examination was made of nymphal numbers for sample 1. Total numbers are shown in descending order in Table 34, and total numbers per plot are shown, as they occurred in the experiment plan, in Table 35.

TABLE 34. Total numbers sampled for unhatched eggs, nymphs and adults in Ubombo Ranches variety trial.

Variety	Unhatched eggs sample		Nymphs sample		Adults sample		Total sample		Grand Total
	1	2	1	2	1	2	1	2	
NCo 310	787	1618	623	24	78	123	1488	1765	6506
CB 38/22	704	1588	470	22	88	157	1262	1767	6058
CB 36/14	692	1772	428	13	48	146	1168	1931	6198
NCo 334	545	1858	423	19	49	194	1017	2071	6176
N 51/539	535	1864	386	14	49	139	970	2017	5974
N 50/211	862	1927	386	19	55	126	1303	2072	6750
N 53/216	1083	1252	340	25	50	104	1473	1381	5708
NCo 376	682	1538	331	13	35	122	1048	1673	5442
N51/168	609	1627	256	18	44	130	909	1775	5368
Total	6499	15044	3643	167	496	1241	10638	16452	54180

From this table it can be seen that overall differences between varieties existed ($P < 0.05$). Highest numbers were recorded in the variety NCo 310. Two replicates of this variety (plots 17 and 25) were in an area of relatively high concentration, although the other two plots were away from it, one of them at the other end of the trial.

TABLE 35. Total numicia nymphs per plot at sample 1, as they occurred in experimental area; means of log. transformed data

	Rep. 1	Rep. 2	Rep. 3	Rep. 4
1	N51/539 108	10 N51/168 40	19 N53/216 106	28 NCo 310 150
2	N50/211 64	11 NCo 376 67	20 CB38/22 82	29 NCo 376 96
3	CB36/14 66	12 NCo 334 101	21 NCo 376 98	30 CB36/14 115
4	N53/216 68	13 N53/216 67	22 N50/211 96	31 NCo 334 72
5	NCo 310 105	14 CB36/14 75	23 N51/168 78	32 N51/539 75
6	N51/168 69	15 N50/211 97	24 NCo 334 167	33 N51/168 69
7	CB38/22 168	16 CB38/22 105	25 NCo 310 147	34 N53/216 99
8	NCo 334 83	17 NCo 310 221	26 CB36/14 172	35 N50/211 129
9	NCo 376 70	18 N51/539 114	27 N51/539 89	36 CB38/22 115

TABLE 35. (Continued).

<u>Variety</u>	<u>Means</u> (nymphs/plot)
NCo 310	1,18
CB38/22	1,05
CB36/14	1,00
NCo 334	1,00
N51/539	0,98
N50/211	0,97
N53/216	0,92
NCo 376	0,91
N51/168	0,79

S.E. (diff. of 2 means) = 0,09

L.S.D. (0,05) = 0,18

(0,01) = 0,25

Further tests on differences in nymph numbers between individual varieties showed the following:

- a. NCo 310 contained significantly higher numbers of nymphs than N51/539, N53/216, NCo 376 and N51/168 ($P < 0,05$).
- b. The variety N51/168 contained significantly fewer nymphs than the varieties N51/539, CB36/14, NCo 334, CB38/22 and NCo 310 ($P < 0,05$).

Eggs

Following examination of eggs in leaves returned to the laboratory, figures for various categories into which the eggs had been classified were analysed.

The two conditions considered most likely to influence oviposition or hatching by numicia or by its egg parasites are midrib hardness and hairiness, both of which vary to some extent between varieties. No quantitative rating for these factors exists, and the comments included

below are based on observation and on the assumption that a variety with a hard stalk will also have a hard midrib. At both samplings large numbers of eggs were encountered and in the following assessment of the various categories the results of the two samplings will be considered together. In the tables figures for sample 1 are recorded in descending numerical order.

Percentage leaves with eggs (Table 36).

No strong relationship to texture was apparent although at the second sampling the percentage of leaves with eggs was somewhat higher in the hairier varieties. The order was not constant but at both samplings the varieties N53/216 and N51/168 rated high and low respectively ($P < 0,01$ in sample 1; $P < 0,05$ in sample 2).

TABLE 36. Cane leaf texture and % leaves containing numicia eggs.

Variety	texture		% leaves with eggs	
	hardness	hairiness	Sample 1	Sample 2
N 50/211	quite hard	scanty	63,2	47,0
N 53/216	medium	hairy	53,5	62,3
NCo 376	"	medium	51,5	63,0
N51/539	quite hard	scanty	48,8	48,5
NCo 310	medium	"	48,0	43,2
CB36/14	quite hard	scanty-medium	46,8	39,0
CB38/22	"	hairy	38,5	54,3
N51/168	medium	scanty	35,5	44,5
NCo 334	"	hairy	29,5	49,5
S.E.	5,9 F test***		7,2 F test*	
L.S.D. (0,05)	12,1		15,0	
(0,01)	16,5		20,3	

Numbers of eggs (total of hatched and unhatched) per leaf (Table 37).

Within samples there was considerable variation, and there was no evidence of any constant trend between the two samplings.

TABLE 37. Number of eggs (hatched and unhatched) per leaf.

Variety	Egg numbers	
	Sample 1	Sample 2
N53/216	22,2	20,9
NCo 376	17,9	20,7
NCo 310	17,7	23,6
N50/211	17,0	25,7
CB36/14	16,6	23,7
N51/539	15,5	25,5
CB38/22	15,3	23,3
N51/168	13,9	23,3
NCo 334	12,5	25,9
S.E.	3,8 F N.S.	6,1 F N.S.
L.S.D. (0,05)	7,9	12,5
(0,01)	10,8	16,9

Total numbers of unhatched eggs (Table 38)

It is conceivable that hatching might be delayed in certain varieties, but no such trends were evident. With the exception of N50/211 which contained high numbers of unhatched eggs on both occasions, the varieties harbouring highest numbers at the first sampling ($P < 0,01$) were among the lowest at the second sampling, notably N53/216.

Percentage of eggs hatched (Table 39).

On both occasions fewest hatched eggs were recorded from N50/211. Otherwise there was no trend. In fact, with three exceptions, the rating per variety at sample 2 was in the reverse order to sample 1.

Midrib texture could conceivably affect hatching or hatching rate, but there is no evidence that it did so.

TABLE 38. Total numbers of unhatched eggs.

Variety	Egg numbers	
	Sample 1	Sample 2
N53/216	1083	1252
N50/211	862	1927
NC _o 310	787	1618
CB38/22	704	1588
CB36/14	692	1772
NC _o 376	682	1538
N51/168	609	1627
NC _o 334	545	1858
N51/539	535	1864
S.E.	40,0 F**	113,9 F N.S.
L.S.D. (0,05)	82,6	235,2
(0,01)	111,9	318,7

TABLE 39. Percentage eggs hatched

Variety	% eggs	
	Sample 1	Sample 2
CB36/14	58,3	7,1
N51/539	56,5	8,7
NC _o 376	51,8	7,1
NC _o 334	47,0	11,4
N51/168	45,5	13,9
CB38/22	43,6	14,2
NC _o 310	42,2	15,3
N53/216	38,1	25,8
N50/211	35,9	6,3
S.E.	7,7 F N.S.	3,4 F*
L.S.D. 0,05	15,8	10,0
0,01	21,4	13,6

Percentage of viable eggs (Table 40).

On both occasions most viable eggs (i.e. undamaged and not parasitised) were found in N51/168, and fewest in N50/211, with N51/539 containing second fewest on both occasions. Otherwise no trend could be detected. The difference between numbers in N50/211 and N51/168 was greater in sample 1 ($P < 0,01$) than in sample 2 ($P < 0,05$). It is conceivable that texture could prevent the entry of parasite eggs or of fungi, but textural characteristics of these two varieties are not markedly different.

TABLE 40. Percentage viable eggs

Variety	% eggs	
	Sample 1	Sample 2
N51/168	78,6	86,6
N53/216	68,4	78,6
NCo 334	64,8	78,3
CB38/22	56,6	82,8
NCo 310	55,9	83,8
CB36/14	47,4	82,3
NCo 376	47,0	82,1
N51/539	45,9	75,8
N50/211	42,8	74,5
S.E.	11,0 F*	6,1 F N.S.
L.S.D. (0,05)	22,8	12,7
(0,01)	30,9	17,2

Percentage of eggs parasitised (Table 41)

Numbers shown are relative to total eggs because O. beatus frequently destroys more than one host egg (4.3.1.1). Figures for Oligosita in sample 2 are not shown. They were so low, including many zeros, as to be almost worthless. Also, some of the examination and

interpretation was done by an inexperienced person, whose figures were consistently aberrant and had to be rejected. Both parasites, with O. beatus numbers predominant, were found in all varieties although not in all plots, but there were no overall significant differences. The tendency for both samples to have higher numbers of O. beatus in the same varieties is of interest, and N50/211 had highest numbers of both parasites in all cases with numbers in N51/168 consistently low.

TABLE 41. Percentage eggs parasitised.

Variety	Parasite nos (relative to total eggs)		
	Sample 1		Sample 2
	<u>O. beatus</u>	<u>Oligosita</u>	<u>O. beatus</u>
N50/211	11,8	1,5	7,7
NCo 376	10,3	0,7	6,4
CB36/14	9,0	0,8	6,5
NCo 334	7,4	0,4	5,5
NCo 310	7,4	1,2	4,6
N51/539	6,7	0,8	6,4
CB38/22	5,9	0,9	3,6
N53/216	5,8	0,1	4,4
N51/168	3,7	0,8	3,4
S.E.	2,3 F N.S.	0,8 F N.S.	1,7 F N.S.
L.S.D. (0,05)	4,8	1,6	3,5
(0,01	6,5	2,1	4,6

Percentage of eggs degenerated (Table 42).

In this category were included all unhatched eggs which had degenerated through causes other than obvious parasitism e.g. by

fungal infection or desiccation. A factor common to both samples was that NCo 376 rated lowest; but within replicates there was such variation (C.V. 137% and 85%) that no conclusion could be drawn.

TABLE 42. Percentage eggs degenerated.

Variety	% eggs	
	Sample 1	Sample 2
N53/216	4,90	1,28
N50/211	3,16	1,36
NCo 310	2,22	1,11
CB 38/22	2,18	2,92
N51/539	1,92	4,09
N51/168	1,27	1,19
NCo 334	1,18	3,96
CB36/14	0,95	0,95
NCo 376	0,80	0,62
S.E.	2,1 F N.S.	1,3 F N.S.
L.S.D. (0,05)	4,3	2,7
(0,01)	5,8	3,6

Total numbers at each sampling (Table 43).

An examination of total numbers per variety at the time of each sampling showed that there was a general increase in population. For each sample, mean numbers of unhatched eggs per plot were added to mean numbers of adults and nymphs per shake sample (to the nearest whole number), this being considered as a fair reflection of total population. The magnitude of population increase varied between varieties from 3,1% in N53/216 to 158,5% in N51/539, and none of the factors considered in the analysis of

this experiment offered a satisfactory explanation. Obvious factors to consider are failure of eggs to hatch through parasitism or degeneration, egg viability and leaf texture. However, examination of the two "extreme" varieties mentioned shows the following:

- (i) N53/216, which had most eggs at sample 1, had fewest eggs and lowest population increase at sample 2 (Table 34 and 43)
- (ii) N51/539, which had fewest eggs at sample 1 had highest population increase at sample 2 and second highest egg numbers
- (iii) N53/216 had the second highest number of viable eggs at sample 1
- (iv) N51/539 had the second lowest number of viable eggs at sample 1.
- (v) N53/216 had the second lowest number of parasitised eggs at sample 1
- (vi) N53/216 had the highest percentage of degenerated eggs at sample 1 but this was only 4.9%, which could not have accounted for so poor an increase in numbers compared with other varieties
- (vii) Regarding texture, N53/216 was rated of medium hardness but hairy; although the fact that at sample 2 it contained least unhatched eggs suggests that hatching had not been impeded
- (viii) N51/539 was rated quite hard and of scant hairiness, which could possibly have favoured population increase.

Nitrogen level and numicia fecundity have been associated (Harris, 1968; 2.20); but the relative nitrogen rating for these varieties bears no relation to population figures. (The ratings shown in Table 43 are agronomic data from a variety trial at Pongola).

When totals for unhatched eggs, nymphs and adults for both samples were considered, the differences between varieties were not significant (Table 34).

3.10.3 Assessment of populations in variety trial : Pongola

Further figures for numicia and egg parasite numbers and varieties were obtained during 1967 from a variety trial at the Pongola

TABLE 43. Total numicia numbers at each sampling i.e. eggs per 20 leaves + mean nymph and adult numbers per plot; also nitrogen rating from third leaf analyses.

Variety	Total		Difference ($T_2 - T_1$)	%	Nitrogen rating
	Sample 1	Sample 2			
N51/539	188	486	298	158,5	1,82
NCo 334	195	491	296	151,7	1,84
N51/168	190	425	235	123,7	2,02
CB36/14	233	463	230	98,7	1,97
N50/211	271	500	229	84,5	2,08
CB38/22	246	420	174	70,7	1,84
NCo 376	215	362	147	68,4	2,12
NCo 310	285	423	138	48,4	2,06
N53/216	319	329	10	3,1	2,02

In anticipation of a possible build-up of numicia within the trial plots, samples of leaves with eggs from the plant crop were taken periodically during the year and forwarded to the Experiment Station for examination.

3.10.4 Results

Results for the ten varieties represented are summarised in Table 44.

With numbers of eggs per leaf (which may be considered as representative of numicia population) overall differences between varieties were detected ($P < 0,05$).

No significant differences were noted for parasite numbers.

3.10.5 Further records of numicia numbers and cane variety

a. Numicia surveys

Numicia surveys which were carried out annually throughout the cane belt have already been mentioned (1.3.1; 3.3; Dick, 1967).

TABLE 44. Populations of numicia and egg parasites in 10 sugarcane varieties at Pongola.

Variety	Category		
	Eggs (total) per leaf	<u>O. beatus</u> numbers ⁽¹⁾	<u>Oligosita</u> numbers ⁽¹⁾
NCo 310	49,7	0,8	0,8
CB38/22	57,5	0,8	0,6
CB36/14	66,9	1,5	0,7
NCo 334	44,1	0,9	1,2
N51/539	42,0	1,2	2,0
N50/211	47,8	2,1	1,1
NCo 376	51,9	1,7	0,6
N51/168	44,4	1,1	0,7
N55/805	61,2	0,9	0,9
NCo 293	46,5	0,6	0,8
F test	*	N.S.	N.S.
S.E.	7,0	0,5	0,6
L.S.D. (0,05)	14,4	1,0	1,2
	(0,01) 19,5	1,4	1,7

(1) $\frac{\text{total parasites} \times 100}{\text{total eggs}}$

Of the varieties encountered, five were inspected in a sufficiently large number of sites for comparisons to be made (Table 45).

There was a slightly but consistently higher incidence in N50/211 than in NCo 310. Incidence in NCo 376 was regularly slightly lower than in NCo 310. The lower incidence in the other two varieties may have been associated with the environments in which they were commonly grown. NCo 293 occurs most frequently in high altitude areas and NCo 382 in sandy fields. Numicia is not common in high

altitude areas nor in the rather poor cane found in sandy areas.

TABLE 45. Numicia incidence encountered in 5 cane varieties during surveys. Figures represent % occurrence.

Variety	Year					Average
	1964	1965	1966	1967	1968	
N50/211	70,2	60,7	75,0	66,7	75,6	68,6
NCo 310	69,7	58,3	62,4	58,9	62,4	63,5
NCo 376	67,7	49,6	53,6	58,9	62,0	57,0
NCo 382	60,9	35,1	40,6	40,0	51,7	45,5
NCo 293	24,5	29,0	48,5	37,5	36,7	34,0

b. Insecticide trial

A further item of information on incidence with varieties was obtained incidentally during an investigation of insecticide effects on certain cane insects (Dick and Thomson, 1969). More numicia eggs were present in NCo 376 than in NCo 339 ($P < 0,05$) (Appendix XI).

3.10.6 Discussion of numicia incidence and cane variety

From the figures obtained there was no striking and consistent evidence of any particular variety attracting or supporting larger numbers of numicia than the others. All varieties under consideration were suitable host plants with no marked differences in suitability.

It is interesting that in sample 1 of the Swaziland trial a significant difference ($P < 0,05$) between nymph numbers was detected between varieties which included NCo 310 and NCo 376, the two most popular varieties grown in S. Africa and Swaziland. (During the year covering this investigation Ubombo Ranches had for a number of agronom

reasons been changing from NCo 310 to NCo 376). It has often been noted by field personnel that under what appear to be similar numicia infestations the variety NCo 310 suffers more visibly than NCo 376; so possibly in such cases higher numbers have actually been present in NCo 310. For the set of figures under discussion only the variety N51/168 contained fewer numicia nymphs than NCo 376. None of the other varieties in the trials is grown extensively in areas where numicia is a problem. In the course of numicia surveys throughout cane growing areas, incidence in NCo 376 was regularly slightly lower than in NCo 310.

Why larger numbers of numicia nymphs should occur in certain varieties is not clear, neither does consideration of the egg data offer an explanation. By the time sample 2 was completed the differences between numbers of nymphs and adults in the different varieties had become far less marked.

There was some structural variation between varieties regarding leaf texture and surface type (hardness, hairiness) which could conceivably have influenced oviposition, hatching or parasitisation; but no consistent relationship could be established.

In the Swaziland trial the only other categories in which significant differences between varieties were found, were the percentages of leaves with eggs and the number of unhatched eggs per plot. Of these, the former might be considered as a reflection of numicia population; but, with the exception of the variety N51/168 the rating was at variance with the number of nymphs per square metre.

Regarding numbers of unhatched eggs, it is conceivable that hatching might be delayed in certain varieties. However, with the exception of the variety N50/211, which contained high numbers of unhatched eggs in both sample 1 and sample 2 (N.S.), the varieties harbouring highest numbers in sample 1 were among the lowest in sample 2, notably N53/216. In sample 1 and in the Pongola trial, the

varieties NCo 334 and N51/539 were rated lowest, but this was contradicted by sample 2 where they were among the highest rated (N.S.).

No significant differences were detected in sample 2, but its results did if anything tend to gainsay those of sample 1. When totals of the two samples of unhatched eggs, nymphs and adults (which may be regarded as representative of population) were considered together, differences between varieties were not significant.

There was no evidence that cane variety influenced the numbers nor the activities of the two common hymenopterous egg parasites.

It was concluded that although significant differences in numicia numbers on different cane varieties were detected, they were neither striking nor consistent, and cannot be considered of practical importance.

3.11 Relation between individual field records and numicia numbers

From 1964 until 1970 regular field population counts were made at Ubombo Ranches Swaziland (3.4.1; Fig. 23).

For each year there existed also comprehensive estate records which included for each field the following information:

- a. crop i.e. plant crop to fifth ratoon
- b. Variety: mostly NCo 376 or NCo 310
- c. Irrigation type: overhead or furrow
- d. Month of harvest
- e. Yield (i) cane weight
(ii) sucrose content

From population counts it was possible to differentiate between different generations, and within them to record both a peak in numbers and a mean.

Although this mass of information had not been obtained with statistical analysis in mind it was considered worth while to investigate whether any relationship could be established between population numbers and any of the factors listed above. The picture was complicated by the fact that over the years the management of the estate had been following a programme which favoured replanting with NCo 376 and establishing an overhead irrigation system.

Therefore each of the 82 fields for which records existed was considered separately, and its characteristics and population figures extracted.

A comparison of four particular fields, which were selected because they were similar in respects other than their population figures, had indicated that yield in metric tons cane per hectare month was 1,06 metric tons higher in fields of low infestation than in heavily infested fields (Appendix XIIa). There then followed a comprehensive analysis the results of which are summarised in Appendix XIIb. These computerised results were received too late to be included in the main body of this dissertation, but in essence they are as follows:

- a. There was no significant evidence of an association between numicia numbers and the following three factors: (i) variety (ii) irrigation type (iii) crop.
- b. For the November-January generation no significant association between numicia numbers and cane yield was detected. However, for the February-May and June-October generations a significant association was detected ($P < 0,01$ and $0,05$ respectively), indicating a loss in yield of up to 12 metric tons per hectare.

CHAPTER 4

NATURAL CONTROL OF NUMICIA POPULATIONS

4.1 Introduction

In theory numicia population numbers may be controlled a) naturally e.g. ecologically, climatically, biologically, b) by applied methods e.g. crop management, introduced biological agents, or by insecticides. An investigation showed that a number of natural factors played a part in restricting field populations of numicia, and that applied (non-chemical) methods showed promise where naturally occurring agents were inadequate. (Insecticides are discussed in Chapter 5).

4.2 Natural non-biological controlling factors4.2.1 Ecological factors

Although eggs and adults have occasionally been seen in dicotyledonous weeds the species seems to be restricted mainly to monocotyledons and especially to grasses (Table 33).

Where numicia occurs in natural grasslands, numbers would normally be greatly reduced by seasonal winter burning which would allow the persistence of green grass only in moist areas, such as occur along the edges of water courses. In summer rainfall areas the drying of grasses in winter, even without burning would be sufficient to restrict numbers, for no evidence for an egg diapause has been found. A spring and summer generation would then spread into the new seasonal grasses from the overwintering green areas.

When numicia is in the egg or nymphal stages any sudden destruction of the host plant will reduce populations drastically, although some eggs, or even nymphs may survive long enough to benefit from the regenerating grass (3.6.1/a).

The time of year at which grasses become dry can be of

importance to survival, for if drying occurs when the insect is in an immobile or semi-mobile stage i.e. as egg or nymph it cannot survive; whereas adults can move to greener areas. Such variation has been noted in Swaziland, where in February one year the grasses surrounding a sugar estate became too dry to support numicia, whilst in other years late summer rains kept the grasses green until May and June.

Mention should be made of flooding, which could conceivably account for reduction in numicia numbers in riverine and vlei grasses under circumstances of prolonged submergence; but it could never be an important factor. It has been noted that where cane fields are furrow irrigated numicia falling into the water do not swim but float on the surface and, when opportunity offers, climb out apparently undamaged.

4.2.2 Climatic factors

No figures exist for reduction in numicia population numbers as a direct result of climatic factors, although probable effects of violent weather conditions are easy to visualise. The early nymphal instars are particularly vulnerable especially immediately after hatching, at which stage, if shaken from cane leaves on to the bare ground of the interrows, they may well die before regaining the growing leaves. Violent wind especially when accompanied by rain, can adversely affect cane, causing lodging even in the middle of cane fields. Many numicia could be killed by such conditions especially if they occurred at a vulnerable stage of the life cycle. Such storms (which occur in the cane growing areas of Swaziland) would probably affect numicia populations more adversely in cane fields than in grasses, where dislodged individuals could regain the host plant more easily. Such climatic factors probably contribute to the discrepancy between numbers of nymph and subsequent adult populations (Table 20).

Field temperatures probably have no direct influence on survival. *Numicia* thrive in shade temperatures of 40°C and more. In a refrigerator all stages could survive a temperature of 10°C for at least two hours, and eggs would hatch even after a week at such temperatures. During conditions of normal radiation frost in a cane field, ground temperature fell to 0°C for ten minutes, and the corresponding temperature 1m above ground measured 3.5°C (Glover, unpublished Report, Exp. Stn, Mount Edgecombe).

4.2.3 Factors within the cane plant

Mention must be made of such factors as the fate of eggs laid in leaves which become dry. Although the eggs may survive and hatch, the resulting nymphs may die if they cannot reach green leaves almost immediately (2.1). Such a cause could be partly density dependent, for under a heavy infestation leaves become dry abnormally quickly.

4.3 Biological factors

Not surprisingly *numicia*, being an indigenous insect, is attacked by a number of naturally occurring biological agents which include other insects, mites, spiders, birds and fungi. In the notes which follow, various agents are considered in order of apparent importance.

4.3.1 Hymenopterous parasites

Two egg parasites, Ootetrastichus ?beatus Perkins (Eulophidae) and Oligosita sp. (Trichogrammatidae) have been reared from egg material collected in many parts of the cane belt. At least two Dryinid parasites attack nymphs and adults. Lestodryinus sp. and Dryinus (possibly erraticus Turner) have been identified. Since 1962 the impression has been gained that in recent years Dryinids have become less common.

4.3.1.1 Ootetrastichus ?beatus

When submitted for identification O. beatus (Fig 36; Plate 1

was determined with caution, because males were present which is unusual, the species being generally regarded as parthenogenetic. It was identified by Dr B.D. Burks of the U.S. National Museum, Washington.

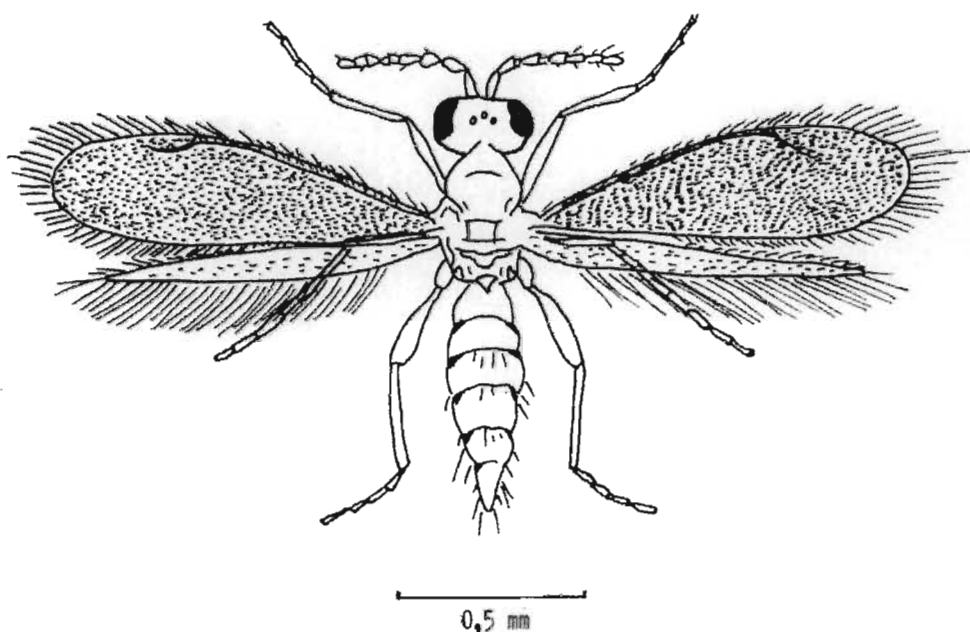


Fig. 36 Ootetrastichus ?beatus Perkins, adult female
(after Swezey, 1936).

This was the most effective parasite encountered and was found to be present throughout the cane belt. However, it was not found during early visits to the Malelane and Komatipoort areas of the eastern Transvaal made in 1965 to 1968 (although over that period as cane cultivation expanded both numicia and the egg parasite Oligosita sp. were becoming more plentiful and widespread (4.3.1.7/f)).

O. beatus has a particularly high potential because although only one egg is deposited in the host egg, the developing parasite larva may account for up to seven or eight host eggs.

Ovipositing females were observed in the field. The adult insect would follow a row of numicia eggs touching the opercula with its antennae. Eventually (possibly because a suitable egg had been detected) it would move to the opposite side of the midrib and oviposit into the rounded end of the host egg through the plant tissue. The female would pass repeatedly to and fro from one side of the midrib to the other between ovipositing. Detailed studies of development were not made, but in the course of examining many hundreds of numicia eggs the parasite was continually encountered, and the life cycle is similar to that described for other members of this genus (Williams, 1957). The larva develops to the final instar within the numicia egg, consuming its contents. It then leaves the chorion of the host egg and burrows along the midrib tissue. If it encounters no further eggs it will eventually pupate, sometimes burrowing several centimetres before doing so. Usually it encounters adjacent host eggs and for a period becomes predaceous, consuming up to six or seven more host eggs before pupating within the leaf tissue. The emerging adult then bites its way out, usually through the upper leaf epidermis, and frequently through a hole already made by an earlier maturing parasite. Among the same egg batch, parasites in various stages of development are found, the stage of any individual being determined by the amount of food encountered. Consequently there is considerable variation in adult size, the developing larva growing considerably after leaving the original host egg.

In the course of its burrowing the larva will eat host eggs containing its own developing siblings. Williams (1957) noted that the larva of O. pallidipes Perkins fed on pupae of its own species but no case of this was noted with O. beatus, neither was it seen feeding on eggs of any species other than numicia. In the course of this work O. pallidipes was reared from eggs of Perkinsiella

saccharicida Kirk. but the two species of Ootetrastichus were apparently specific to their respective hosts. Williams (loc. cit.) points out that within one larval instar Ootetrastichus may be parasitic, predaceous and cannibalistic.

Parthenogenesis appeared to be normal, although males were encountered.

Its potential efficiency as a biological control agent is perhaps lessened by its cannibalistic tendencies, but it was found (at least in inland areas) to be generally more effective than the other egg parasite, Oligosita sp. (4.3.1.3).

4.3.1.2 Oligosita sp.

This minute Trichogrammatid (Fig. 37; Plate 19) has been reared from numicia eggs collected throughout the cane belt, and was always present when heavy infestations occurred. It is a new species and will be named O. numiciae by Dr G. Viggiani of the Institute of Agricultural Entomology, Portici, Naples. It was identified to genus by Dr D.P. Annecke, of the Plant Protection Research Institute, Pretoria.

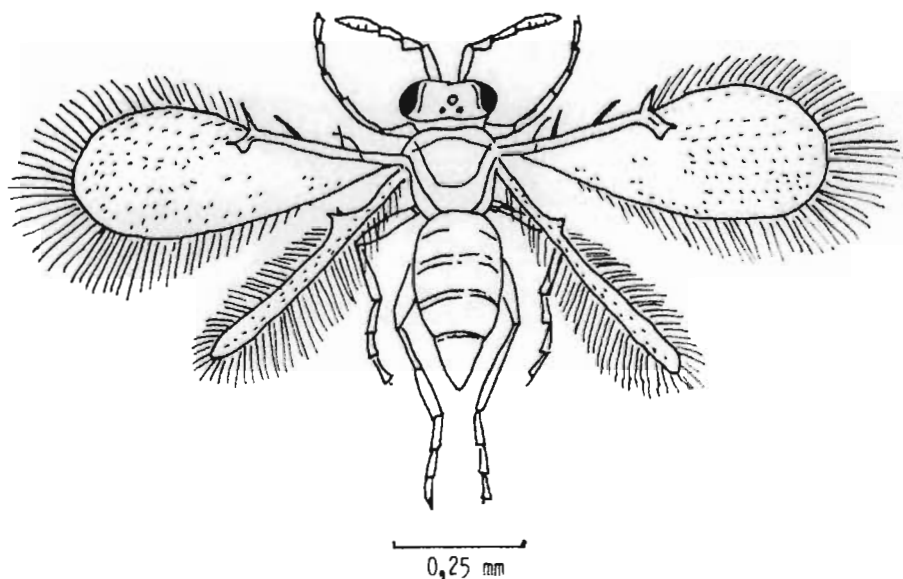


Fig. 37

Oligosita sp. adult female

Females were observed running up and down numicia egg batches, touching the opercula with their antennae. They oviposited mainly by penetrating the leaf tissue immediately adjacent to the operculum, but on one occasion a female was seen trying to oviposit through the operculum, which it was unable to penetrate. During the act of oviposition the antennae were held still and pointed downwards towards the leaf surface.

The parasite egg is inserted into the host egg, and the resulting larva completes its development inside it. Within a few days of parasitisation the host egg darkens and the puncture mark is often conspicuous. By the time pupation occurs the host egg becomes completely black and opaque, and the enclosed parasite can be seen only when the egg is cut open. The resulting adult bites its way out through the end opposite the operculum and through the tissue of the upper leaf lamina, each parasite leaving by a separate hole.

4.3.1.3 The relative merits of *O. beatus* and *Oligosita* sp. as biological control agents

Between May 1965 and May 1966 an opportunity was offered of assessing the merits of these two parasites in the field (Carnegie, 1972b). This arose when the management of Ubombo Ranches Swaziland agreed to leave untreated one field of heavily infested cane so that the course of the infestation could be followed (3.8).

Materials and method

The field concerned was Compound (45 hectares of NCo 310, Fig 20) and each month when the field was visited samples were taken of various plant media containing eggs. These included: a) green cane leaves collected non-systematically throughout the field b) green cane leaves collected in the immediate vicinity of a patch of the sedge *Cyperus sexangularis* c) dry cane leaves (trash) from the lower stems, collected non-systematically throughout the field d) leaves and e) stems of the grass *Panicum maximum* f) leaves and g) stems of the grass *Pennisetum*

thunbergii h) leaves of Kikuyu grass Pennisetum clandestinum i) stems of the grass Rhynchelytrum repens and j) stems of the sedge Cyperus sexangularis.

All the grasses were collected in breaks within the infested field, and the sedge was collected from a patch which grew within two or three metres of the cane in a drainage line between two sections of the field. In grass stems eggs were usually found immediately below the inflorescence in the culm. In the sedge they were inserted in the ridges of the stem which is hexagonal in cross section (Fig. 15). In all leaves they were inserted in midribs. A sample of dry cane leaves was included to see how long eggs would survive in trash, which is abnormally heavy in an infested field. Eggs were found in all media on most occasions, but there were occasional blanks.

In addition to the above sampling cane leaves were sampled on most occasions from various other fields on the estate, and samples of leaves and stems of Panicum maximum were taken from the vicinity of another, uninfested field in the Usutu river area several kilometres from the field under investigation.

All plant tissue sampled was placed in polythene packets and returned, chilled in an insulated box with dry ice, to Mount Edgecombe for laboratory investigation. Using a binocular microscope plant tissue was dissected to expose any numicia eggs which were classified as follows: i) hatched ii) unhatched iii) viable iv) parasitised v) numbers present of O. beatus and vi) Oligosita sp. vii) numbers of dead parasites viii) numbers of eggs degenerated through causes other than parasitisation.

Category vii was of little quantitative value since by the time examination took place, cause of death could not be determined with certainty. It was included because in the course of examining eggs in cane leaves the impression had been gained that Oligosita sp. in particular sometimes died in the adult stage, purely as a result of its inability to

bite its way through the midrib tissue. However, in the course of chilling, partial drying and general handling, considerable numbers of parasite larvae and adults died, although examination showed no obvious cause of death, which would probably not have occurred had the material remained in the field. There was insufficient valid evidence for associating conclusively such parasite death with plant media, but points of interest were noted (Appendix XIV).

Category viii included eggs which were possibly infertile, or which had shrivelled up without hatching, become desiccated, or degenerated as a result of fungus attack.

In addition to the samples taken during monthly visits weekly sampling of cane in this field was done by the estate, and any leaves containing eggs were sent to Mount Edgecombe for examination, and were treated in the same manner as the other samples.

4.3.1.4 Results

a. Parasite numbers (Fig. 38 a - k (i))

In the following discussion absolute parasite numbers are not used unless so stated. This is because the numbers of grass leaves sampled on each occasion were not constant, neither were the numbers of numicia eggs contained within them nor within cane leaves. Therefore a factor has been used to relate parasite numbers to the total numbers of eggs (hatched and unhatched) present. For each parasite species total numbers were multiplied by 100 and divided by the total number of eggs. For Oligosita sp. this figure is the same as the per cent host eggs parasitised; but for O. beatus it differs from the percentage of eggs parasitised because one parasite usually destroys more than one egg. In each case figures for total parasites rather than living parasites only were used, because as stated earlier, cause of parasite death was not always "natural".

Fig. 38 Egg parasite numbers and per cent parasitism in various media; Ubombo Ranches 1965 - 66.

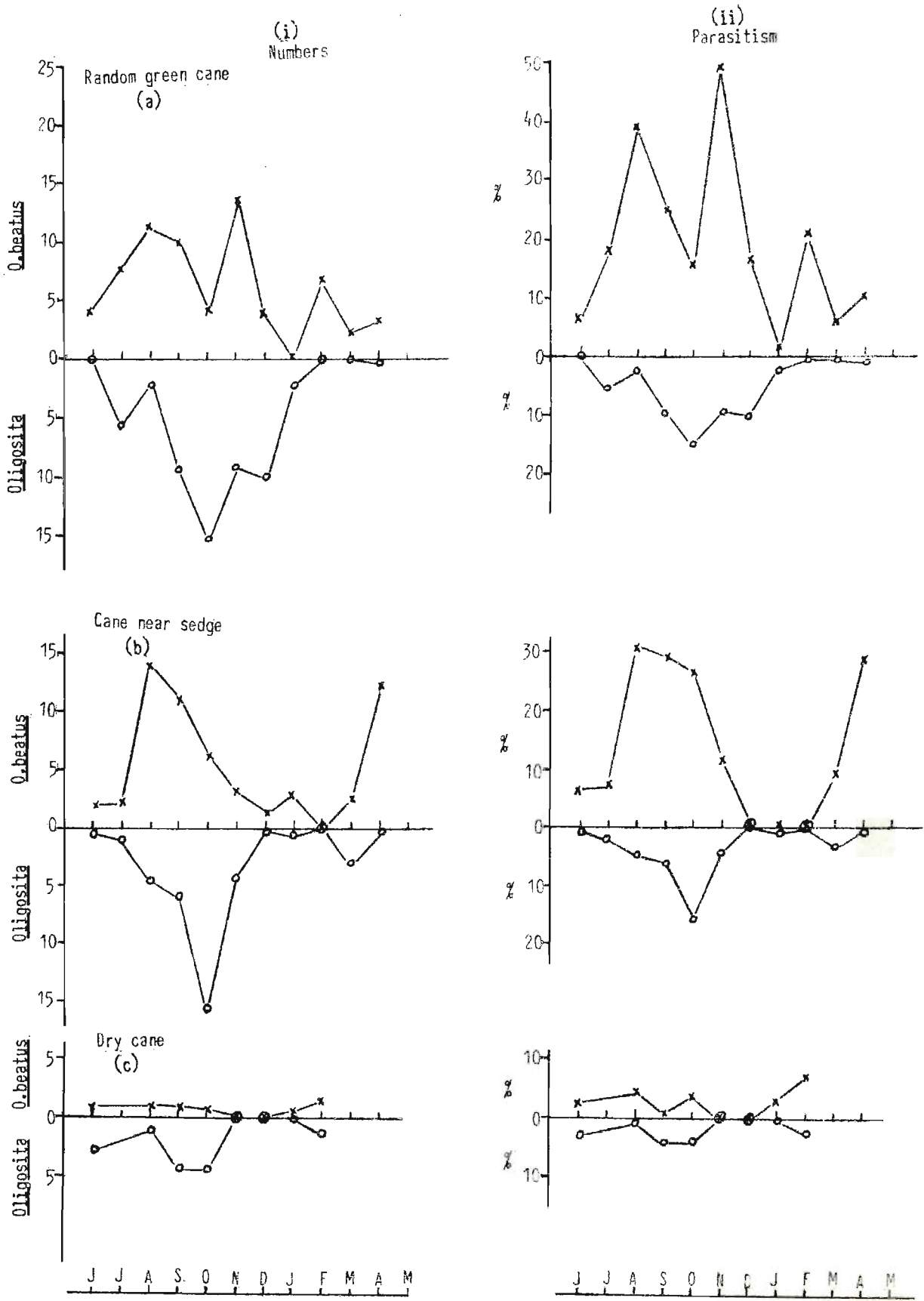


Fig. 38 (Continued).

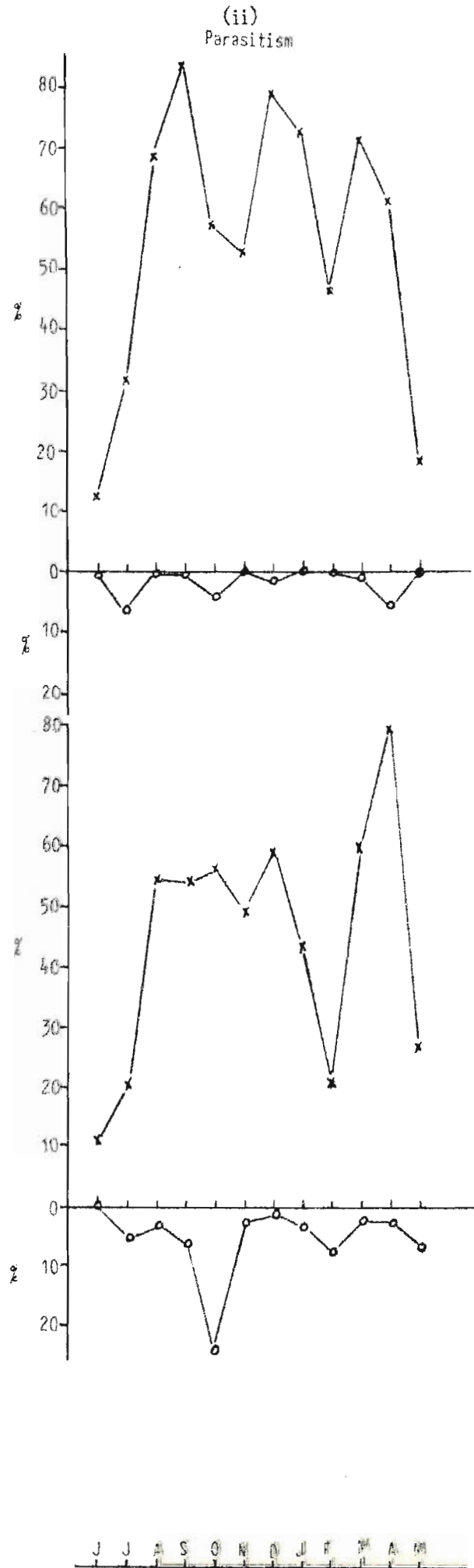
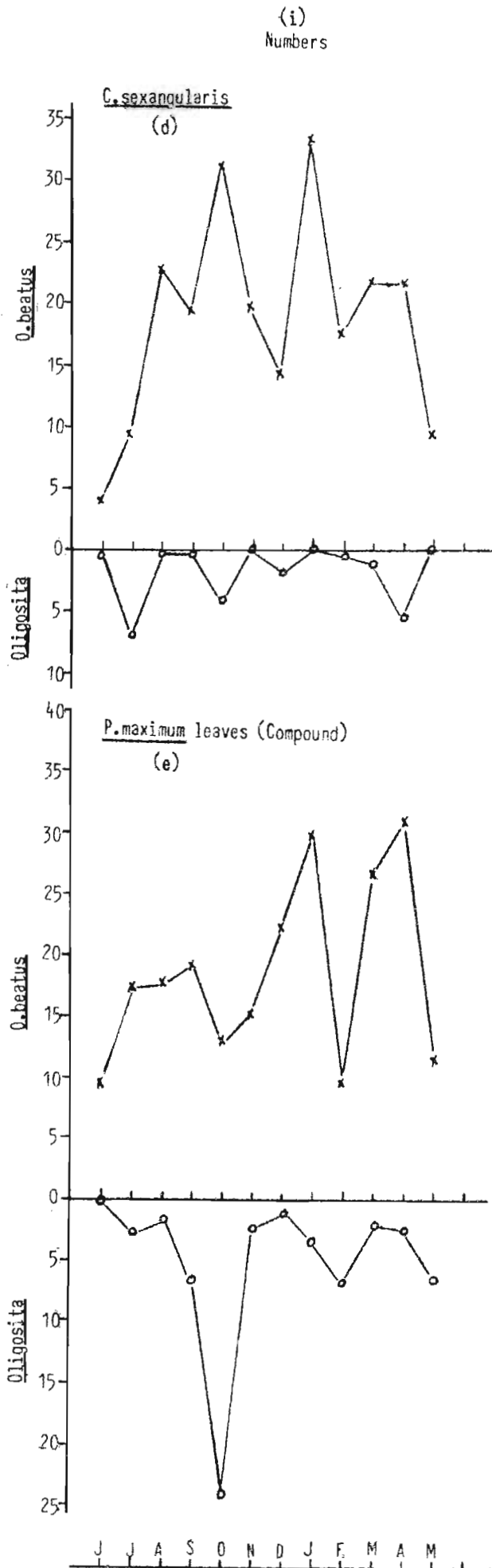


Fig. 38. (Continued)

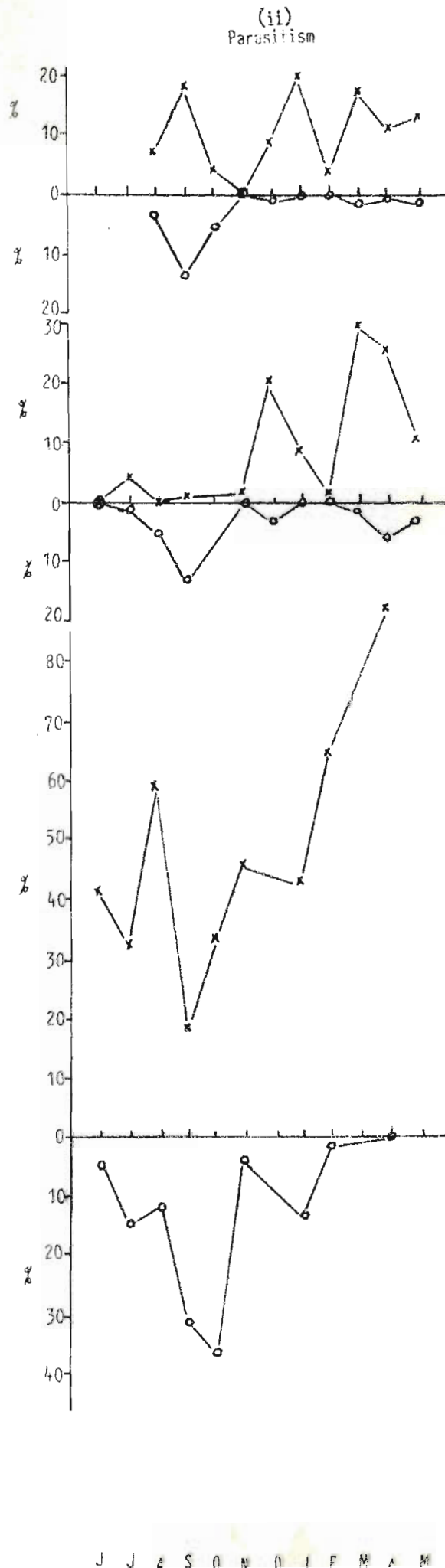
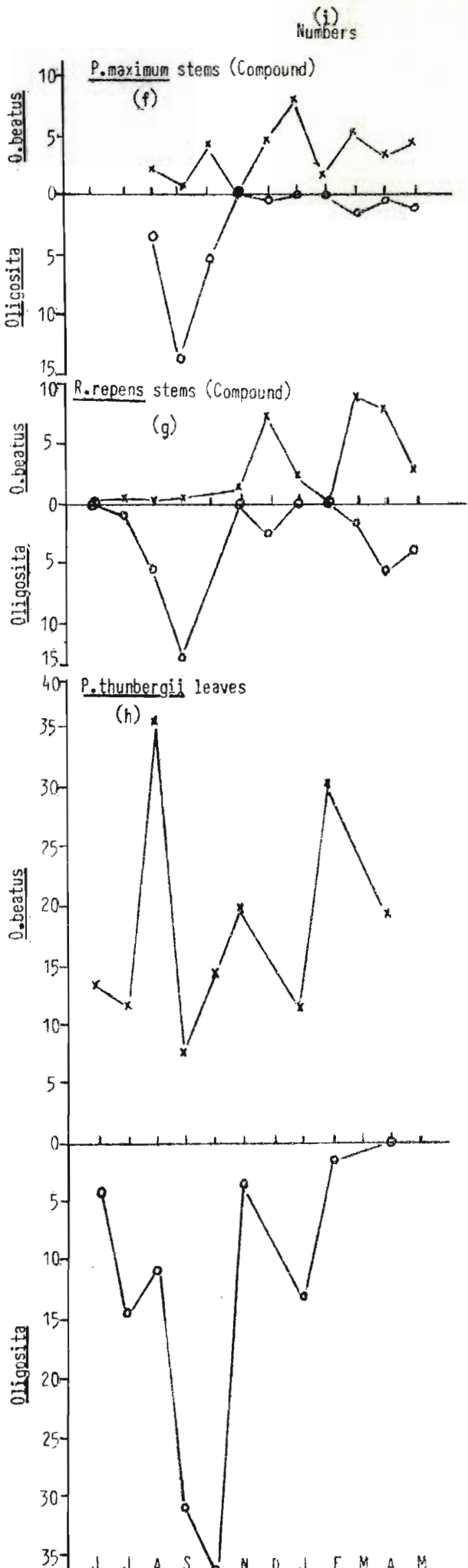
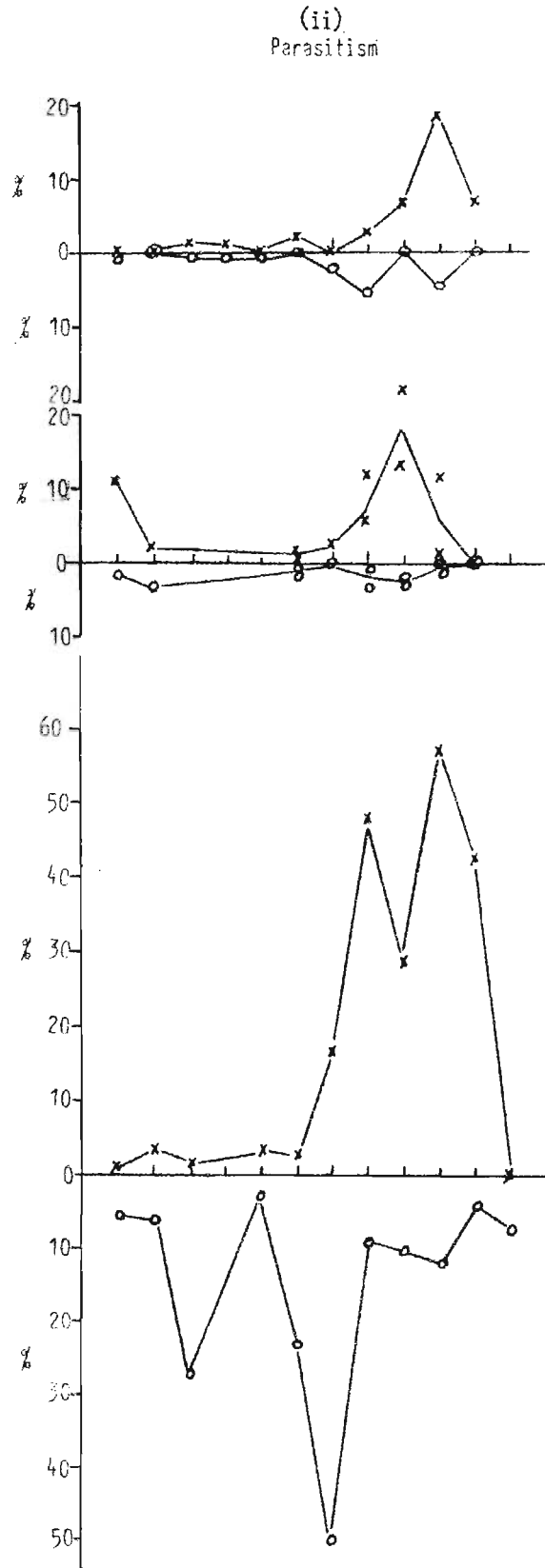
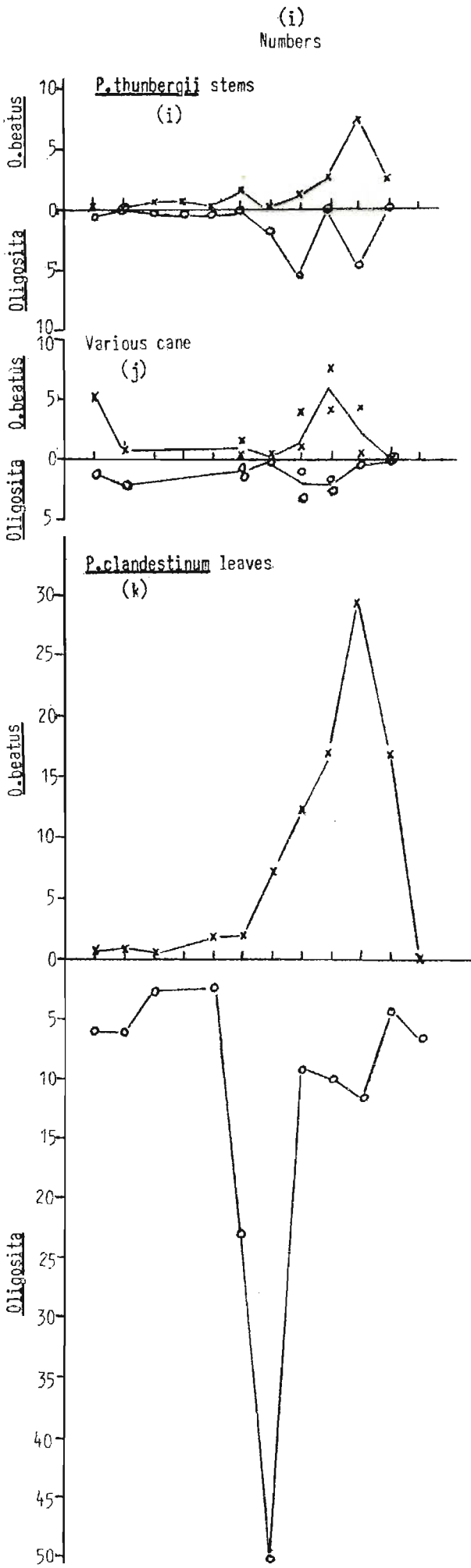


Fig. 38. (Continued)



From both the monthly and the weekly (estate) sampling it was evident that in green cane there was a build-up in numbers of both parasites towards October and November (Figs. 38a and 39 respectively). Subsequently numbers of both parasites fell, increasing slightly again before the field was harvested the following year.

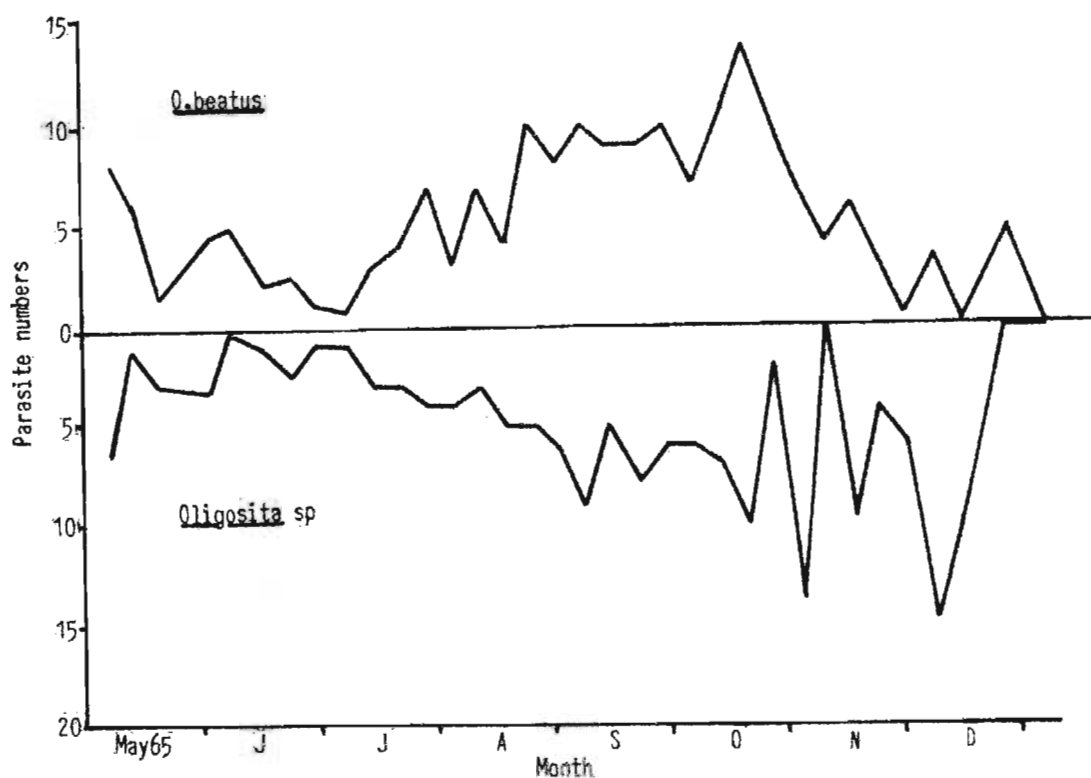


Fig. 39 Parasite numbers in untreated green cane (field Compound, Ubombo Ranches' sampling 1965).

A comparison of figures for parasite numbers with figures for host populations (Fig. 33) shows that this increase in numbers was accompanied by a decrease in numbers of unhatched eggs until September, when numbers increased again until November. The corresponding decrease in per cent viable eggs was even more marked (Fig. 40a).

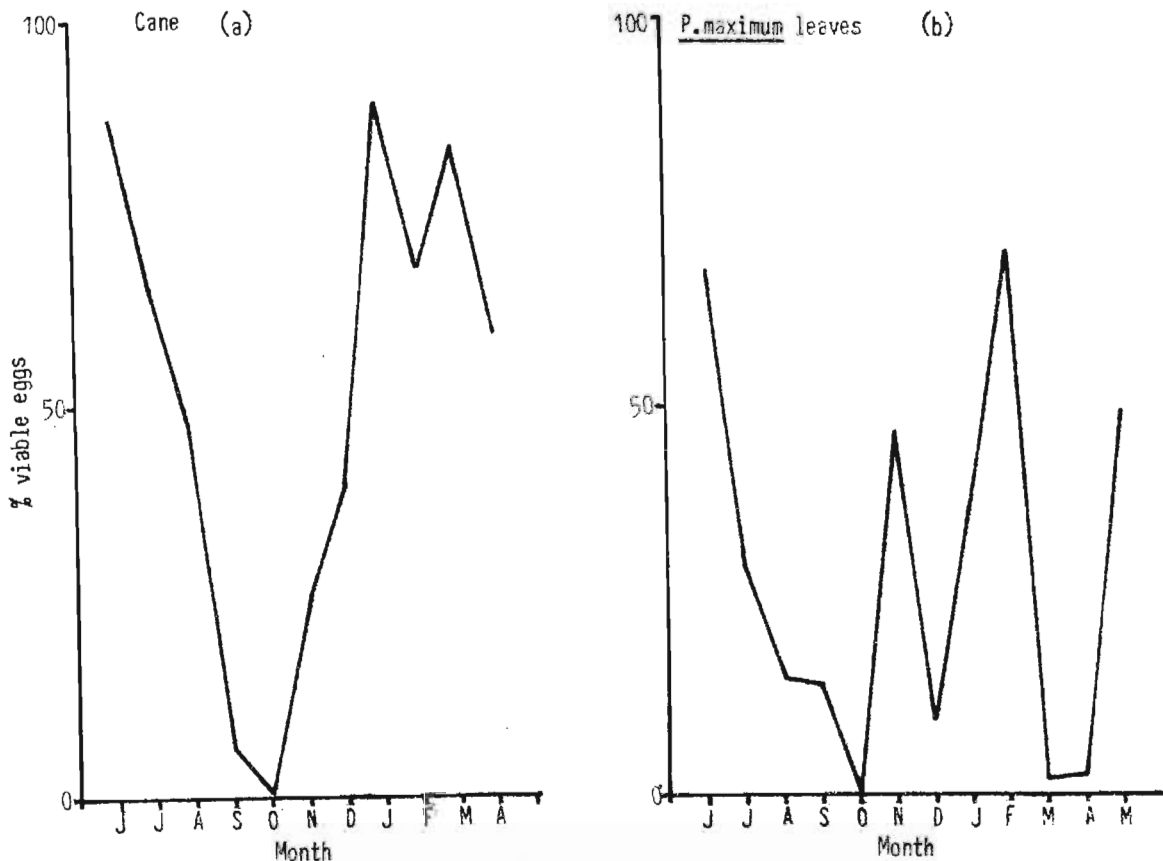


Fig. 40 Per cent viable numicia eggs in green cane and in grass leaves (Ubombo Ranches 1965-66).

A similar pattern was recorded for green cane growing on the field edge near the patch of sedge, although numbers of O. beatus fell steeply between September and December (Fig. 38b).

In dry cane leaves (Fig. 38c) numbers of both parasites were generally lower. Larger numbers of Oligosita were recorded and showed to a lesser degree the same rise and fall as was recorded in green cane. When collected these leaves had been dry for a matter of weeks, and it was surprising to find that on some occasions many unhatched eggs within the midribs were unaffected. The relatively lower numbers of O. beatus recorded may have been due to mortality resulting from the predaceous habit of the larva, once it leaves the host's egg, rendering it more vulnerable to desiccation. Percentage of dead parasites was generally higher in dry cane

than in other media (Appendix XIV).

An examination of parasite numbers in grasses produced several interesting and striking comparisons, showing higher numbers (especially of O. beatus) in leaves than in stems.

Panicum maximum was probably the most common grass weed on the estate, being available for sampling in cane breaks and reaching luxuriant pure stands wherever irrigation run-off occurred on land adjacent to fields and in the vicinity of natural waterways. Numbers of Oligosita in P. maximum leaves were of the same order as in green cane, but numbers of O. beatus were much higher (Fig. 38). A seasonal pattern similar to that in cane was recorded.

Far fewer of both species were recorded from P. maximum stems and the seasonal pattern was less well defined (Fig. 38f).

The situation in leaves of the grass Pennisetum thunbergii was similar, but Oligosita was more plentiful than in P. maximum, although there is no obvious explanation for this (Fig. 38h). A similar seasonal pattern again occurred for Oligosita but not for O. beatus, numbers of which were relatively low from September to January. Numbers of both parasites were very much lower in stems, where a slight increase was recorded towards the end of the sampling period.

In the grass Pennisetum clandestinum ("Kikuyu") eggs were found only in the leaves, where they were inserted in the lower midrib in the region of the sheath (Fig. 15c). This grass was common along the edges of waterways and on the banks of irrigation reservoirs where it served to bind the soil. A rather different seasonal pattern was noted for O. beatus where a very striking peak was reached in March, falling to zero two months later (Fig. 38k). Numbers of Oligosita were higher even than in P. thunbergii, reaching the highest peak recorded for either parasite in any medium. A possible explanation for the relatively high numbers of Oligosita in both this grass and in P. thunbergii could lie in the rather lawn like habit

of the two species and the soft texture of their leaves. Oligosita is a very small insect and probably a weak flier. Observed females sought their host eggs by running over the leaf surfaces, and in doing so they would experience less impediment in a closely knit habitat than they would in the sort of habitat presented by taller grasses.

With Rhynchelytrum repens numicia eggs were found only in stems, the narrowness of the leaves possibly precluding oviposition in their midribs. Numbers of both species were slightly more plentiful than in other grass stems examined, and the seasonal pattern was rather similar to that recorded for stems of P. maximum (Fig. 38g).

The large sedge Cyperus sexangularis was common in natural waterways and small vleis between cane fields. No numicia eggs were found in its involucre bracts but they were common in stems, and numbers of O. beatus recorded were particularly high (Fig. 38d), and remained at a relatively high level throughout the period of study. However, numbers of Oligosita were low, being comparable with those found in grass stems.

For general comparison numbers of both parasites are shown for eggs in leaves of green cane collected on each occasion from a number of non-epidemic fields on the estate (Fig 38j). Throughout the period they remained low, reaching a slight peak between January and March.

Ratios for absolute numbers of the two parasites in various media are shown in Table 46. In only two media viz. the sedge Cyperus sexangularis and the grass Panicum maximum in the epidemic area were numbers of O. beatus very much higher than those of Oligosita. Numbers were lower in three media (including P. maximum distant from the infested field). In the remainder differences varied from nil to 60%.

TABLE 46. Aspects of numicia egg parasitism and degeneration in different plant media

Plant medium	<u>O. beatus/Oligosita</u>		Eggs parasitised by (%)		Nos eggs degenerated (%)
	Parasite ratio	Parasitism ratio	<u>O. beatus</u>	<u>Oligosita</u>	
Green cane (random)	1,1	3,9	19,1	4,9	2,5
Green cane (near <u>Cyperus</u>)	1,6	4,2	13,6	3,2	3,6
Green cane (misc)	1,4	5,7	6,5	1,1	1,5
Dry cane	0,3	1,5	2,7	1,8	5,0
<u>P. maximum</u> leaves (Compound)	5,3	8,9	39,7	4,5	13,3
<u>P. maximum</u> leaves (Usutu)	0,7	1,9	18,1	9,4	19,9
<u>P. maximum</u> stems (Compound)	1,1	4,1	10,3	2,5	14,5
<u>P. maximum</u> stems (Usutu)	1,2	3,2	1,7	0,5	27,6
<u>P. thunbergii</u> leaves	1,3	3,7	37,0	12,8	15,6
<u>P. thunbergii</u> stems	1,1	2,9	3,5	1,2	11,1
<u>P. clandestinum</u> leaves	0,5	1,2	17,1	14,0	18,4
<u>R. repens</u> stems	1,0	3,1	8,4	2,7	14,9
<u>C. sexangularis</u> stems	8,8	31,3	54,5	1,8	9,6

b. Parasitism (Fig. 38(ii))

For Oligosita, where each developing larva destroyed only one host egg, figures are the same as for parasite numbers; but for O. beatus they are always higher sometimes very much so (see also Fig. 41 and Table 46). In Fig. 41 figures for parasitism by each species are compared, those for O. beatus being arranged in descending order, each column representing

a mean for the entire period of study. Even where parasite numbers approximated or where those for O. beatus were lower, parasitism by O. beatus was still higher e.g. random green cane, stems of P. thunbergii, P. maximum, R. repens and leaves of P. clandestinum respectively (Table 46).

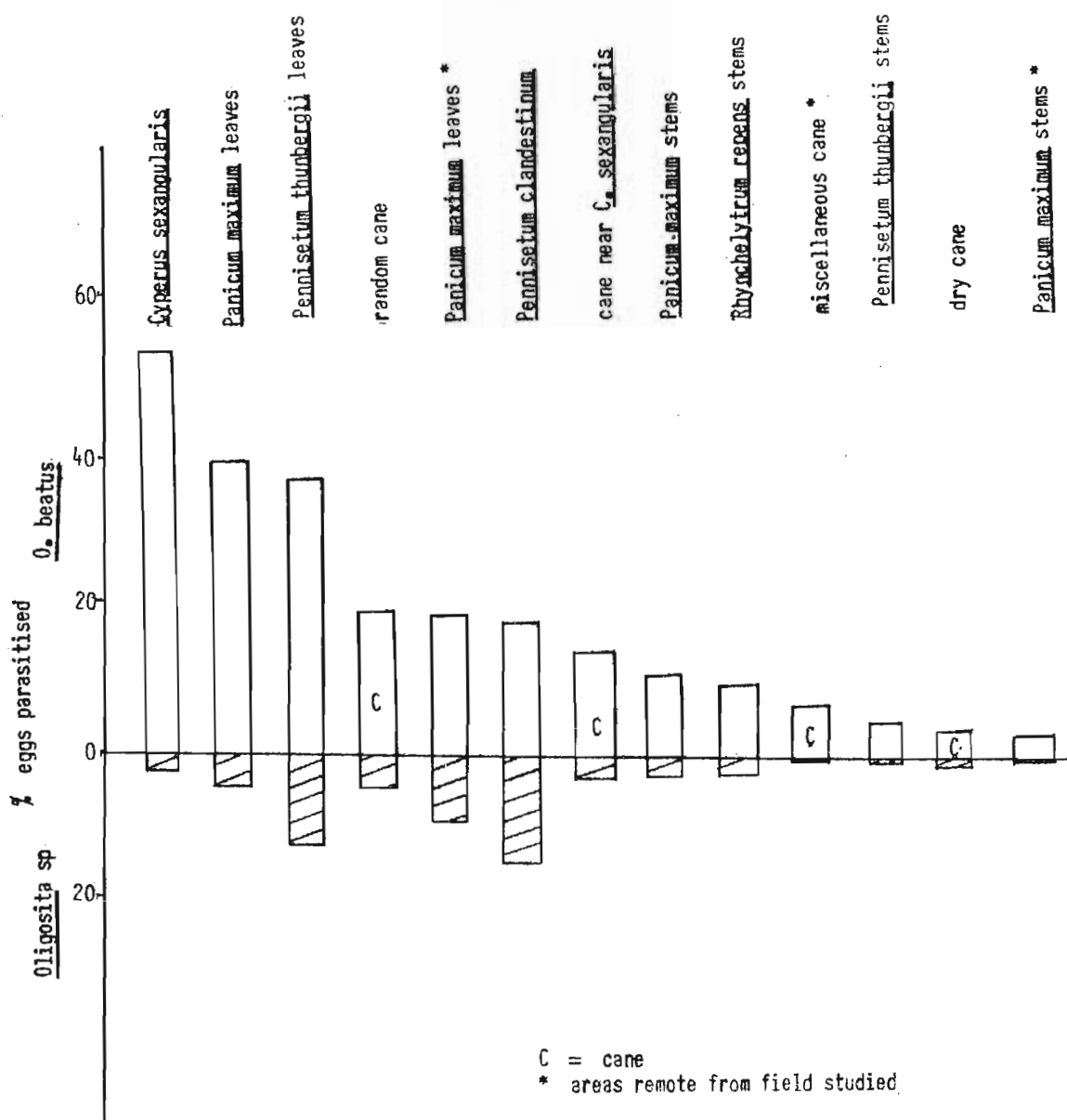


Fig. 41 Per cent parasitism of numicia eggs by each egg parasite in various plant media.

This is again reflected in figures obtained from the weekly cane sampling done in this field by the estate and submitted to the Experiment Station (Figs. 39 and 42).

Numicia eggs in an early stage of parasitisation by Oligosita must occasionally be eaten by the wandering O. beatus larva, although this was never noted in the case of eggs which had already darkened as a result of parasitisation.

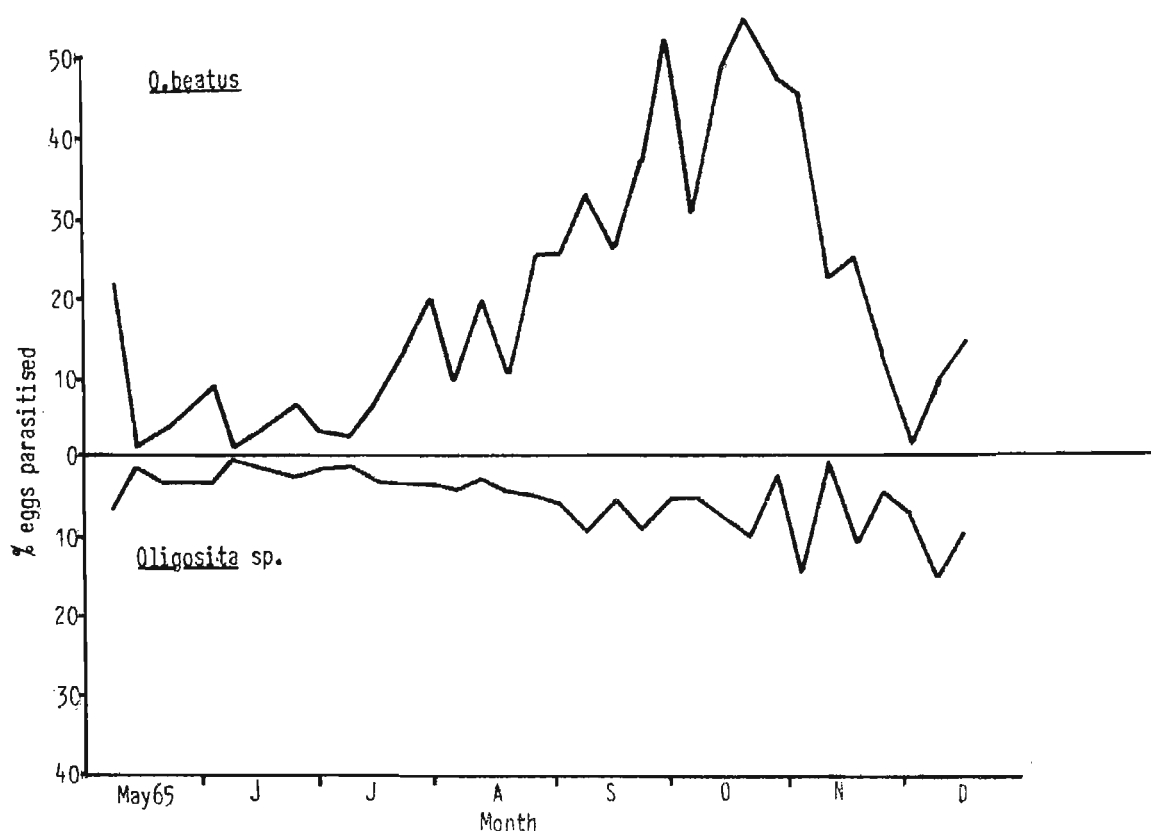


Fig. 42 Per cent parasitism of numicia eggs by each parasite in untreated green cane (field Compound; Ubombo Ranches' sampling).

This complication which would mask to some degree the efficiency of O. beatus as a controlling agent was not fully investigated. However, from the results recorded it can be seen that of the two egg parasites O. beatus was very much

more efficient as a natural controlling agent.

4.3.1.5 A comparison, in the different media, of factors causing egg degeneration

It is interesting to note the results of parasitism and of degeneration from other causes in the various plant media. Figures for combined parasitism are shown in decending order in Fig. 43, and below each column is shown the percentage of eggs in that medium which had degenerated through causes other than insect parasitism. In addition using the results of each month's sampling (over an 11 month period) as a replicate, an analysis of variance was done for the four categories and eight host plant media shown in Table 47. (There is a discrepancy between figures used in the analysis of variance (means) and those used for Figs. 41 and 43. This is because

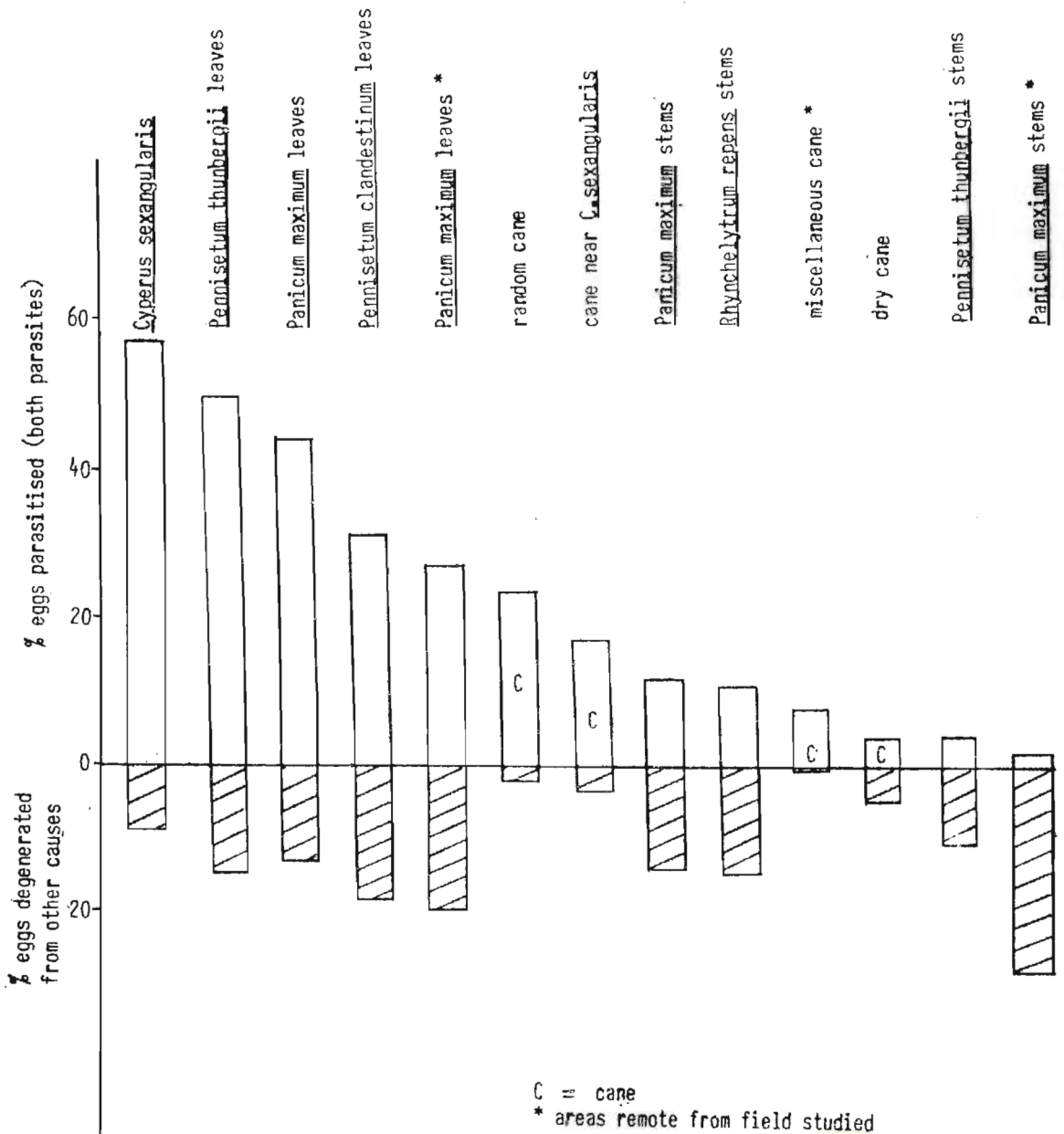


Fig. 43 Per cent parasitism of numicia eggs (both parasites combined) and

the analysis of variance figures are for an eleven month period, whereas those for the histograms are means of 14 readings taken over a 13 month period in some cases e.g. P. maximum leaves and stems, and only eight readings in others e.g. dry cane).

TABLE 47. Mortality of numicia eggs in sugarcane and in 7 adjacent indigenous host plants, (transformed data in brackets).

Plant medium	% eggs destroyed by <u>Oligosita</u> sp. (= numbers of <u>Oligosita</u>) (4.3.1.4/a)		% eggs destroyed by <u>Ootetrastichus</u> <u>O. beatus</u>		Numbers of <u>O. beatus</u>		% eggs degenerated through other causes	
Sugarcane	4,93	(0,57)	19,06	(1,14)	6,02	(0,76)	2,48	(0,36)
<u>P. maximum</u> leaves	5,04	(0,65)	46,97	(1,64)	19,02	(1,27)	13,68	(1,08)
" stems	2,11	(0,33)	6,62	(0,84)	2,86	(0,55)	14,00	(1,10)
<u>P. thunbergii</u> leaves	13,15	(0,93)	48,51	(1,70)	12,78	(0,94)	15,93	(1,12)
" stems	1,25	(0,23)	3,55	(0,44)	2,95	(0,35)	11,08	(1,04)
<u>P. clandestinum</u> leaves	16,18	(0,13)	20,54	(1,01)	7,17	(0,64)	19,79	(1,21)
<u>R. repens</u> stems	3,47	(0,43)	8,63	(0,69)	3,61	(0,44)	16,15	(1,17)
<u>C. sexangularis</u> stems	1,92	(0,35)	53,66	(1,69)	18,26	(1,23)	8,34	(0,83)
S.E.		0,16		0,15		0,17		0,14
L.S.D. (0,05)		0,32		0,31		0,34		0,28
(0,01)		0,43		0,41		0,45		0,38

a. Oligosita sp.

Percentages of eggs destroyed were higher in leaves of indigenous hosts than in stems. For the two grasses for which both leaf and stem samples were available (P. maximum and P. thunbergii) the differences were significant ($P < 0,05$; $0,01$ respectively). Numbers destroyed were

significantly higher in leaves of P. thunbergii and P. clandestinum than in cane leaves ($P < 0,05$; $0,01$ respectively).

b. O. beatus

With one exception, percentages of eggs destroyed in leaves of indigenous hosts and in cane leaves were higher than in stems, the difference being significant for P. maximum and P. thunbergii ($P < 0,01$). The exception was the stems of the sedge Cyperus sexangularis, where percentage of eggs destroyed was higher than in any other medium. The percentages of eggs destroyed in leaves of P. maximum and P. thunbergii were significantly higher than those destroyed in cane leaves or in leaves of Pennisetum clandestinum ($P < 0,01$).

c. Other causes of degeneration

In all cases figures for indigenous host plants were significantly higher than for sugarcane ($P < 0,01$).

4.3.1.6 Discussion

In the host plants examined egg mortality was generally lower in sugarcane than in indigenous hosts which may well be a reason for numicia having become a pest of sugarcane. Where mortality was due to parasite activity eggs in grass stems suffered less than those in grass leaves; but where it was due to "other causes" mortality was relatively high in both leaves and stems.

In the course of examining thousands of eggs in the various host media the impression was gained that the midribs of sugarcane leaves provide an ideal oviposition medium. Moist but robust, the tissue provided protection from both desiccation and wasp parasites. Even in trash, eggs remained viable long after the leaves had become dry. None of the indigenous hosts studied had these qualities. A measure of protection from parasites was afforded by grass stems which were hard in texture, but their hollow structure offered little protection from desiccation. Grass leaves were flimsy

by comparison. The spongy nature of the sedge studied offered some protection from desiccation, but eggs in it were heavily attacked by the Eulophid parasite.

Another possible factor influencing the level of parasitisation in sugarcane compared with other host plants could have been growth habit. In the lower lying more compact circumstances of a grass community the minute and delicate egg parasites may have been better able to find their host eggs than among the more widely separated leaves of a field of sugar cane.

From the results obtained in this experiment O. beatus appeared to be a more efficient controlling factor than Oligosita. Its numbers were generally higher, and it destroyed more host eggs per parasite.

An apparent inverse relationship between parasitism and other causes of degeneration (detectable in Fig. 43) was in most cases probably due to errors of interpretation. Parasitism by either wasp species was in its later stages easily distinguishable, as was simple desiccation (found frequently in grass stems). However in some cases the cause of abnormal egg development may have been misdiagnosed.

4.3.1.7 Distribution of the two egg parasites O. beatus and Oligosita sp.

Both parasites have been recorded from cane leaf material collected throughout sugarcane areas of South African and Swaziland. However from numerous records obtained from the examination of numicia eggs in leaf samples it is apparent that Oligosita was far more numerous on the Natal south coast than was O. beatus. The latter was however generally more numerous in records made from Swaziland cane leaf material, where it was shown to be the more useful of the two parasites.

As illustration of relative abundance records from 13 localities may be cited as examples, and compared with the situation at the Swaziland estate mentioned earlier (Ubombo Ranches).

a. Illovo Sugar Estates

A coastal section of this estate was visited and sampled regularly between June 1965 and July 1969 (3.4.3). Egg sampling, which was done at approximately fortnightly intervals, was concentrated in fields within 1 km of the mill (usually field 23, which had in 1962 supported sufficiently large numbers of numicia to warrant chemical control measures to be taken). Throughout the sampling period the field was of mixed varieties (NCo 310 and NCo 376) of ratoon cane. Although nymphs and adults were scarce (Fig. 25) between 20 and 40 egg-bearing leaves could usually be obtained as samples, and from these the state of eggs on each occasion was recorded. At each sampling an average number of 480,9 eggs were examined and categorised as before (3.10.2; 4.3.1.3). Leaves were sampled by two to five individuals, and considerable searching was often necessary before an adequate sample was obtained. On occasions when the field had recently been harvested, eggs were sought in adjacent or neighbouring fields.

Relative numbers of the two parasites, (expressed as before in relation to total egg numbers (4.3.1.4/a) are shown in Fig. 44a; (see also Table 48). In the figure the points represent mean numbers for any particular month, for which one to three readings were usually taken, sampling being done fortnightly whenever possible.

The most striking feature of Fig. 44a is the relatively large numbers of Oligosita, compared with the nearly equal numbers of each parasite found in the epidemic Swaziland field discussed in the previous section (4.3.1.4; Fig. 39; Table 46). There, O. beatus outnumbered Oligosita by 1,4 : 1, whereas at Illovo Oligosita outnumbered O. beatus 28,7 : 1 (absolute numbers).

For further and fairer comparison with Illovo, figures were used from non-epidemic fields at Ubombo Ranches, Swaziland. Over the period June 1965 to April 1968 regular samples of egg-bearing leaves had been received for examination from Ubombo Ranches. From the numerous

records available figures were extracted for fields of the same varieties as those in the Illovo fields, and which had been sampled at approximately the same time, and which provided approximately the same numbers of eggs; (average numbers were 476,8 Ubombo Ranches; 480,9 Illovo). No records for the epidemic field discussed in 4.3.1.3 - 4.3.1.6 were included. For each estate 67 samples were included, (Fig. 44 a and b).

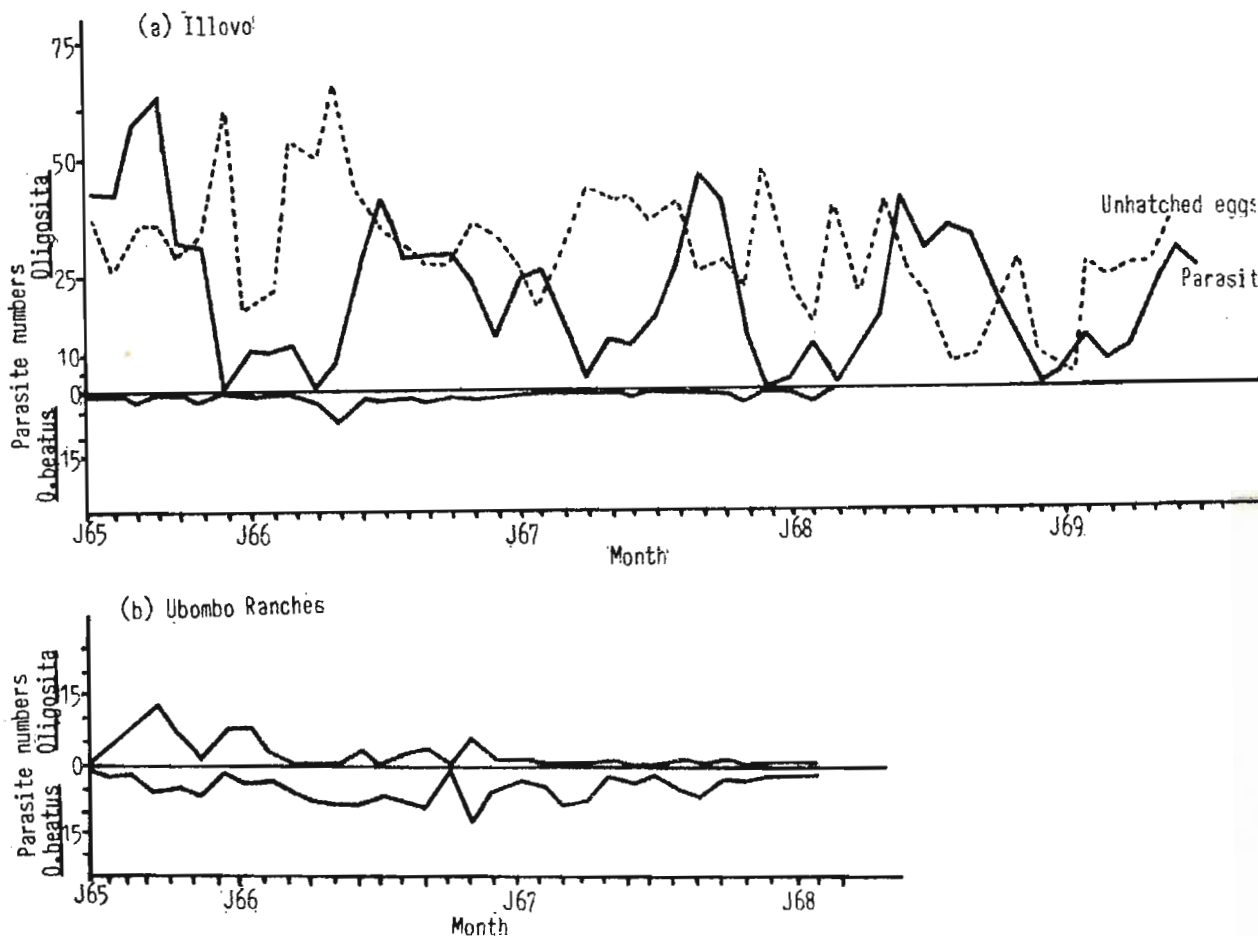


Fig. 44 a. Relative numbers of two numicia egg parasites and numbers of unhatched eggs at Illovo, 1965-69.
 b. Relative numbers of the two parasites at Ubombo Ranches Swaziland, 1965-68.

Other comparisons were made. In the course of numicia investigations eggs from cane leaves, collected in a variety of localities were examined. Sometimes e.g. Pongola, Paddock and Compensation this was a systematic or routine practice associated with some definite objective.

TABLE 48. *Numicia* egg parasitism records for various localities in the cane belt : 1965-69. Results of subsequent spot-checks are shown below main table.

Date	Locality	No. of samples	Total eggs	Parasite numbers (relative to eggs)		Ratio <u>O. beatus</u> / <u>Oligosita</u> (absolute nos)	
				<u>O. beatus</u>	<u>Oligosita</u>		
6.65 - 7.69	Illovo	96	50244	0,7	21,3	1,0	28,7
6.65 - 4.66	Compensation	12	3858	0,3	17,8	1,0	51,6
7.66	Amanzimtoti	1	414	0,2	19,1	1,0	79,0
6.68	Tongaat	3	514	0,0	45,4	0,0	45,4
6.66 - 6.69	Paddock	24	28402	2,1	1,7	1,0	1,0
5.65 - 6.67	Pongola Settlement	37	29606	1,3	5,1	1,0	4,0
6.67 - 2.68	Pongola Field Station	49	53136	1,2	0,9	1,4	1,0
2.66	Big Bend Estate (S)	1	1480	4,7	0,7	7,7	1,0
2.66 - 6.66	Crookes Plantations (S)	2	3346	8,4	0,3	26,9	1,0
4.66 - 4.67	Tambankulu (S)	2	1937	4,4	2,9	1,6	1,0
6.67 - 4.68	S.I.S. (S)	5	3433	6,1	1,8	2,8	1,0
? .65 - 4.69	Mhlume (S)	6	3308	3,4	1,4	1,4	1,0
6.65 - 6.68	Ubombo Ranches (S)	67	31948	4,2	2,5	2,0	1,0
29.4.71	<u>Tytthus</u> Exp. 1 Insectary	5	2208	0,5	25,0	1,0	46,0
14.9.71	Paddock	1	1862	1,3	28,2	1,0	21,0
6.12.71	Ubombo Ranches (S)	1	738	14,7	1,0	15,6	1,0
10.10.72	" " (S)	1	296	8,4	0,3	25,0	1,0

(S) = Swaziland

At the Pongola Field Station for instance, during 1967 and 1968 egg-bearing leaves from a variety trial were collected and examined in order to anticipate any potentially damaging build up of nymphs and adults (3.10.3). At Paddock and Compensation (and at Illovo) eggs, nymphs and adults were sampled periodically to see if populations followed the same trends as in Swaziland. At other places eggs were collected on any occasion when a visit (requested or otherwise) was made, simply as a check e.g. Pongola settlement, Swazi Irrigation Scheme. Samples of the latter category tended to be small, but are included with others in Table 48 because they are interesting even if not of great significance. Of the former category Illovo has already been mentioned; but four other places from which a number of samples were examined deserve individual mention.

b. Pongola Field Station

This 80-hectare farm was established on virgin soil by the S.A.S.A. Experiment Station in 1966, and was situated on the western boundary of the Pongola settlement. *Numicia* has never been a serious problem on the station but early in 1967 it was noted and, for reasons of agronomic experimentation it was important that its presence should in no way interfere with current projects. Therefore a periodic check was kept throughout that growing season.

c. Pongola Settlement

Owing to the various insecticide campaigns and experimentation conducted in this area, especially in the early days of *numicia* control (5.2), Pongola was considered unsuitable for "pure" research work on *numicia*. It was feared that any projects might be interrupted by further insecticide application, or their results be obscured by an unnatural biological state. However, a periodic check on numbers of eggs, nymphs and adults was made, especially during the years when numbers were relatively high.

d. Compensation

One field on one farm was visited approximately monthly over a 12-month period to see if population trends were comparable with those in northern inland areas. These visits were discontinued when the field was harvested because numbers (of nymphs and adults especially) were considered too low to justify the exercise.

e. Paddock

In 1966 the attention of the Experiment Station was drawn to a farm at Paddock, where considerable numbers of numicia had been noted in a field of NCo 376 (3.4.3). There exist monthly population records (with some blanks) from June 1966 until June 1969.

From the records listed in Table 48 it becomes apparent that O. beatus was predominant in inland areas, and Oligosita very much more predominant on the coast. Paddock, where numbers of each parasite species approximated very closely is not far inland, but differs from coastal areas in having higher altitude and rainfall, but lower temperatures and slower growth rate.

In 4.3.1.3 - 4.3.1.6 it was shown that at Ubombo Ranches, where parasitism in cane and grasses was investigated, O. beatus was the more efficient of the two parasites although they were present in much the same numbers. Obviously this is not necessarily the case throughout the cane belt, as is adequately exemplified by the Illovo results. Why there should be this variation, determined apparently by locality, is not certain. The fact of O. beatus being a predator in its later instars may be a factor. For some reason it may be better adapted to the inland and northern areas where its relatively large numbers and predaceous habit prevent Oligosita developing its maximum potential as a controlling factor. The predaceous larval stage must account for some eggs at least which are in an early stage of parasitisation by Oligosita. Possibly in a coastal area such as Illovo O. beatus is for some reason less well adapted to its habitat, and its

numbers never become sufficiently high to mask the controlling potential of Oligosita. However, a recent spot check done at Paddock in 1971 showed a marked predominance of Oligosita (Table 48).

It is felt that other possible causes of apparent variation in parasite numbers, such as subjective interpretation of egg state or cane variety can be discarded. In all cases egg examination was done by well trained staff whose work was checked, or by two entomologists, and the parasite species present, where parasitisation could be detected at all was obvious. In one variety trial (3.10.2) results obtained by one newly recruited staff member were rejected because they were consistently at variance with the rest of the team, but this was the only case where there was doubt. Since 1967 almost all egg examination was done by the same person on each occasion. Regarding varieties, the most commonly grown ones were NCo 376 and NCo 310, and almost all samples were from one or the other of these. Analyses of variety trials (3.10) suggest some variation in numbers between varieties but nothing at a level of significance sufficient to influence these results.

A further point of interest is that O. beatus appears to be predominant in the more recent cane growing areas. At coastal places such as Illovo and Compensation cane has been grown for at least 120 years, and even at the Pongola Settlement it has been grown for nearly 20 years; but Ubombo Ranches and other Swaziland estates have been growing cane for only about 14 years. The Pongola Field Station, where O. beatus numbers were relatively high was first planted to cane in 1966.

The presence of a secondary parasite could throw light on the situation, but none has been recorded here although Perkins (1912) mentions them occurring in Hawaii. Writing of Eulophinae (as opposed to Tetrastichinae) he states "...Clostercerus javanus belongs to the former, and I suspect that it is hyperparasitic, attacking.... parasites belonging to the genus Ootetrastichus". Writing of the Tetrastichinae he continues "The members

of this family were supposed by the late Dr. Ashmead to be hyperparasites, but it is now known that many are primary parasites". Since Perkins worked on O. beatus for "seven or eight years" and "bred generation after generation for long periods of time", there can be little doubt that the species is a primary parasite.

f. Eastern Transvaal

The position in the eastern Transvaal (Malelane and Komatipoort areas) deserves separate consideration because commercial cane production began there only at about the time when the numicia investigation began (1964-1965). Only limited time could be allocated to the area, but occasional visits were made and samples taken, the results of which are worth recording (Table 49). Until 1969 numicia was by no means plentiful in the area and

TABLE 49. Numicia egg parasitism in E. Transvaal (Malelane and Komatipoort).

Date	Total eggs	Total <u>O. beatus</u>	Total <u>Oligosita</u>	Parasite numbers relative to eggs		% eggs parasitised
				<u>O. beatus</u>	<u>Oligosita</u>	
10. 6.65	603	0	167	0,0	27,6	27,6
8. 2.66	383	0	66	0,0	17,2	17,2
9. 2	146	0	0	0,0	0,0	0,0
9. 2	220	0	0	0,0	0,0	0,0
14. 2.67	192	0	17	0,0	8,9	8,9
14. 2	294	0	13	0,0	4,4	4,4
15. 2	241	0	12	0,0	5,0	5,0
12. 1.68	336	1 (?)	105	0,3	31,4	32,4
5. 6.	1364	0	128	0,0	9,4	9,4
5. 6	9980	0	748	0,0	7,5	7,5
25. 6	2597	0	339	0,0	13,1	13,1
25. 9	1555	2	266	0,1	17,1	17,6
12.12	2321	10	267	0,4	11,5	13,2
18. 3.69	1184	16	1	8,7	0,5	24,5
19. 3	55	2	5	3,6	9,1	16,4
29. 4	1707	35	8	2,1	0,5	6,6
30. 9.71	760	0	25	0,0	3,3	3,3

leaves with eggs were difficult to find. When the area was first visited in June 1965 eggs were found only at Riverside (near Malelane) in non-commercial cane which had been growing there for some years. No O. beatus was recorded, but Oligosita was present. Subsequent visits revealed the presence of Oligosita only, until January 1968 when one unconfirmed O. beatus was recorded. This was one of 106 parasites recorded from a sample of 336 eggs, the others all being Oligosita. In the course of three subsequent visits only Oligosita was recorded, and in fair numbers. It was then decided to introduce O. beatus from another part of the cane belt where it was plentiful. This was done in June 1968 by placing several hundred leaves containing parasitised eggs in one section of a Komatipoort field where eggs were plentiful. A check done at the same time revealed no O. beatus to be present already.

The site was visited three months later and from 1555 eggs examined two O. beatus were recorded compared with 266 Oligosita. Subsequently O. beatus has been common on that estate and on neighbouring farms. There is little reason to believe that it would not eventually have appeared, but the deliberate introduction (which was largely a "public relations propaganda" move) may have accelerated things.

4.3.1.8 Corresponding numbers of parasite and host

An examination of Fig. 44a reveals the presence of a "rhythm" to the fluctuations. Each year, numbers of Oligosita were high between about August and October. There was also a peak, but at a lower level about February each year. In December and March-April each year numbers were very low. This rhythm was reminiscent of the regular fluctuations found in numbers of nymphs and adults (Fig. 23) and the possibility of it being host-dependent was investigated.

Figures for numbers of unhatched eggs per leaf which were obtained at the same time as parasite figures, were plotted on the same graph, and are shown in the figure by the broken line. The relationship

to O.beatus numbers is not strongly marked, but the relationship to Oligosita numbers is and shows a very typical predator-prey relationship (Huffaker et al., 1963; Clark, et al., 1967). When numbers of unhatched eggs were high, numbers of Oligosita increased to a maximum, and then decreased again as a result of prey scarcity. When unhatched eggs were again able to increase in number, the cycle was repeated. Unhatched eggs were taken as representative of host numbers, but the same pattern held for total eggs, because most eggs sampled were unhatched.

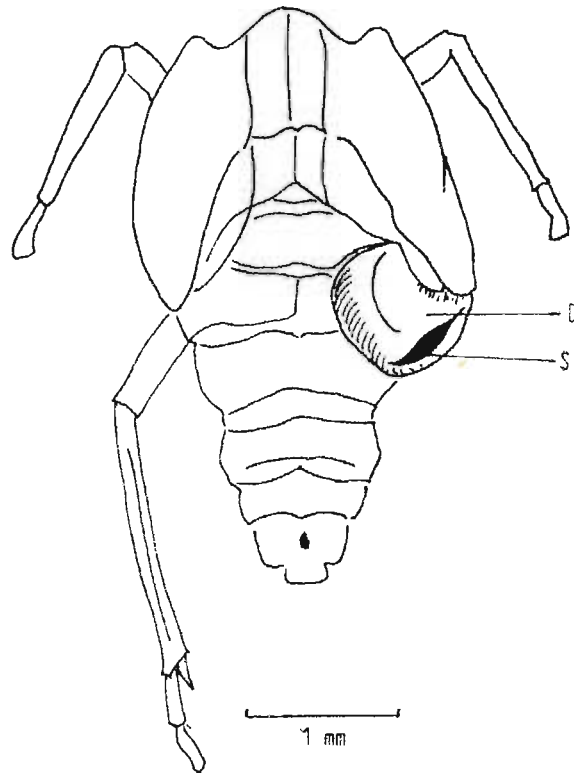
If parasitism figures for other estates are treated similarly the same pattern can be seen, but it is particularly well marked in the case of Illovo. If the line for unhatched eggs is superimposed on that for Oligosita and then advanced approximately two months, the two lines fit very closely indeed.

4.3.1.9 Dryinidae

Two Dryinid parasites of numicia have been identified by the British museum (det. Z. Boucek). Females of this family have characteristic chelate foretarsi and are frequently apterous. They are characteristically internally parasitic upon homopterous nymphs, especially those of Fulgorinae, Cercopidae, Membracidae and Jassidae.

Parasitised numicia became conspicuous when a gall-like cyst formed by the parasitic larva protruded from their abdomens (Fig. 45). This cyst is apparently developed from the moulted larval skins (Imms, 1964) and in some species several may be present in one host, although with numicia only one cyst per host was noted.

The parasite inserts her egg into the host and after a variable period the larval sac becomes visible externally (Perkins, 1905). The mature larva leaves the host at about the time of death and pupates externally.



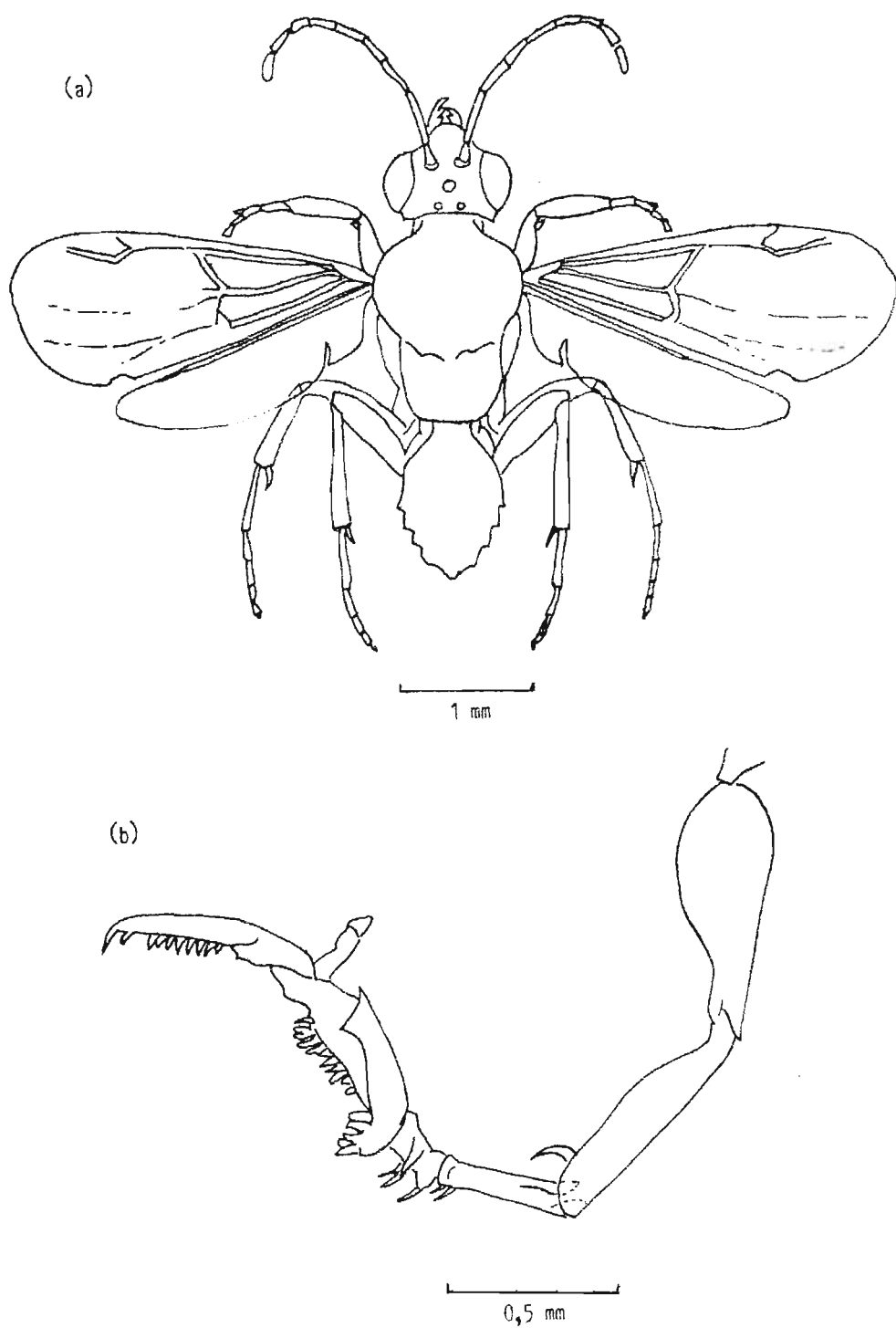
D = Dryinid larval protrusion
 S = split through which mature
 Dryinid larva leaves host

Fig. 45 Dryinid larval protrusion from 5th instar numicia nymph.

4.3.1.10 Dryinus sp. (possibly erraticus Turner)

This species (Fig. 46) was occasionally noted in the northern inland areas but was noted in particular abundance, especially on one occasion (December 1968) at Paddock on the south coast. It was inadvertently introduced from Paddock into the Mount Edgecombe insectary and became abundant in one type 1 cage there.

Both sexes are winged and black but are considerably different in appearance and were thought initially to comprise two species. They were both very active in insectary cultures, moving mainly by walking, and jerking both their wings and antennae as they did so.



.g. 46. Dryinus sp. (possibly D. erraticus Turner) (fam. Dryinidae)
 (a) adult male (b) foreleg of female showing chelate tarsus.

Oviposition in numicia nymphs was noted on several occasions and, while perhaps a less dramatic spectacle than that described for Echthrodelpax fairchildii Perkins by Perkins (1905) it was certainly a very violent and deliberate operation. When a large nymph was seized it would usually hop away taking the attached wasp with it and both would roll over the soil on the cage floor, the wasp clasping the nymph with mandibles and forelegs, while curving the abdomen into a suitable position for inserting its egg between sclerites. When released the nymph might take several minutes before recovering sufficiently to hop or crawl to its host plant.

When a small nymph was seized the wasp adopted a curious position on the vertical leaf, its dorsum facing the leaf surface to which it remained attached by its second and third pairs of legs. The nymph was held between forelegs and mandibles and the egg inserted by manoeuvring the ovipositor into a suitable position. When the operation was complete the nymph was simply dropped. Perkins (loc cit.) noted that on some occasions leaf-hopper nymphs were deliberately replaced on leaves.

Affected host insects developed a typical protrusion from the integument, the affected area becoming black in colour. Eventually, in the distal end of the protrusion there occurred a split, through which the mature larva left the host to pupate under a layer of web on the host plant surface. These Dryinid larvae apparently left the host insect as it died; although Perkins states that with Perkinsiella saccharicida and Echthrodelpax fairchildii the hosts might die either before or some time after the parasites left, death being preceded by a period of "sluggishness" during which the feeding parasite might be seen through the split in the integument. This, Perkins considered "one of the most repulsive sights that natural history can afford". He found that once the host had died, feeding by the parasite became indiscriminate, and it underwent a colour change accompanied by rapid growth.

With seven observed Dryinus sp. the pupal periods lasted from 16 to 37 days, with an average period of 25,5 days.

The fact that both sexes were present in approximately equal numbers suggests that sexual reproduction was normal although copulation was never observed. However, some Dryinids are normally parthenogenetic (Swezey, 1936) and this may have held for Dryinus sp.

No secondary parasites were recorded. Indeed, in the large insectary culture of numicia the unimpeded controlling effects of Dryinus sp. were very evident, and it is very likely that in the field secondary parasites occur.

Only nymphs were noted carrying Dryinus sp. larvae, although the other Dryinid encountered was noted on both nymphs and adults. For a winged species this aspect is less important, but for an apterous species parasitism of immature individuals only must greatly hinder the spread of the parasite.

4.3.1.11 Lestodryinus sp.

The impression was gained that from about 1963 to 1965 when numicia first received attention, this parasite was more plentiful than subsequently; although it has been encountered throughout the period of investigation, especially in the northern areas. (The highest rate of numicia parasitism by Dryinids recorded was about 50% (Dick, pers. comm.)). This occurred about 2 months after the major insecticide campaign at Pongola (5.2), and it was suggested that destruction of secondary parasites may have resulted in such high numbers). An Encyrtid secondary parasite, Cheiloneurus sp. was common and was frequently reared from Dryinid pupae, and it was assumed that its activities suppressed the potential value of its Dryinid host. There was no marked increase in numbers of Lestodryinus as numicia numbers increased (Table 32), and it was not considered to be of much practical importance, nor deserving of detailed investigation.

Numicia adults and nymphs which were parasitised by Lestodryinus carried a conspicuous external protrusion of the same colour as the host. Individuals from which the material was identified were reared from parasitised nymphs and adults collected in the field and returned to the Experiment Station. On leaving the host, the active caterpillar-like Dryinid larva would travel some distance and pupate on a piece of leaf beneath a thin web cover.

4.3.2 Acarina

In the insectary two Tetranychid species, Oligonychus saccharinus Baker and Pritchard and O. grypus B. and R, affected numicia by competing for the host plant and defiling its leaves, but these species were never noted in large numbers in the field.

A large red predaceous mite Anystis baccharum (Linn.) was sometimes very plentiful in Swaziland, especially when numicia numbers were high.

Mites of this family (Anystidae) are, according to Baker and Wharton (1959), characteristically fast moving and predaceous on other mites and small insects found on growing plants. Not usually abundant, they do occasionally occur in large numbers and all developmental stages are similar.

In Swaziland cane fields where numicia infestation was heavy, large numbers of A. baccharum were often encountered. When disturbed they would run rapidly over the plant surface. Very frequently they were found next to batches of unhatched numicia eggs, as if in preparation for feeding on the hatching nymphs. Small red spheres, possibly their eggs, were also found near numicia egg batches. Cannibalism was noted on one occasion.

Although they were seen feeding on first instar numicia nymphs in the field, it was a far less common occurrence than might have been expected considering the large numbers of mites present, and the fact that there was little else to eat besides the abundant numicia nymphs. Also,

eat them. However, the fact that they were often plentiful and were observed eating numicia nymphs, is perhaps sufficient evidence for regarding them as a controlling factor of some importance.

4.3.3 Araneida

Spiders were plentiful where there was a build up in numicia numbers (Table 32), and both nymphs and adults were seen caught in their webs. No figures were obtained for the relative importance of different species, but where adult numicia were numerous spiders must have had some restricting influence on numbers and on movement.

4.3.4 Epipyropidae

An Epipyropid moth was occasionally noted in very large numbers in Swaziland and Pongola (Plates 20-25). It is probably a new species of Epipyrops, possibly a new genus (Davis, Smithsonian Institute, Washington, pers. comm.).

This most interesting lepidopterous family was designated from Epipyrops anomala, which was discovered in Hong Kong by Bowring (1850) and described by Westwood (1876). In discussing the biology of E. anomala, Marshall (1970) states that little has been added to the knowledge of the biology of Epipyropidae since Dyar (1902) and Perkins (1905). More recently further interesting points have arisen concerning their silk production (Marshall and Lewis, 1972).

When associated with numicia Epipyrops sp. became particularly obvious in its later instars when it would protrude dorsally between the wings on the dorsum of the host (Plate 20).

These "passenger-parasites" as they became commonly known, were noted on several occasions when infestations of numicia were very heavy, and they appeared to be density dependent. Like the Dryinids they seemed to be more common during the early days of the numicia problem i.e. 1963-1965, but the species was not investigated at the time. (At the height of an outbreak at Tambankulu in 1963 it was estimated that 60% of numicia adults captured were carrying Epipyropid - an estimate which could have been biased owing to the Epipyropid

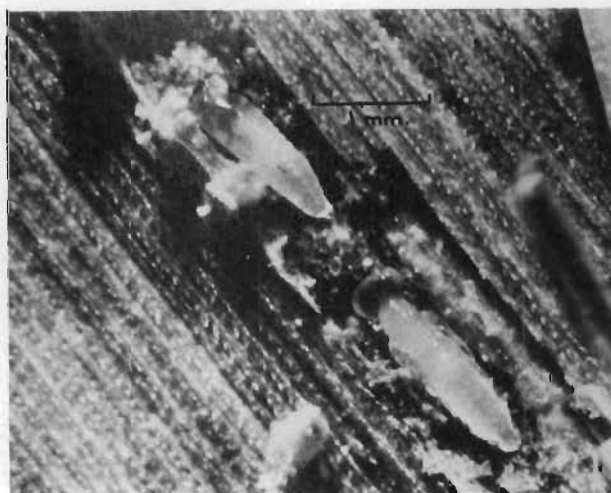


Plate 18 – *Ootetrastichus ?beatus* Perkins.
Larva and pupa in cane leaf midrib.

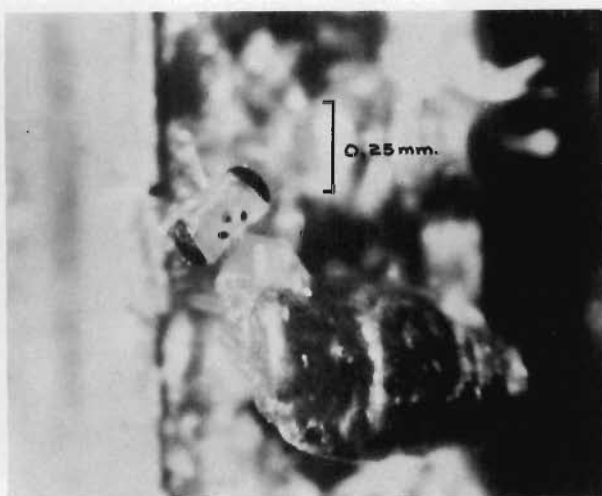


Plate 19 – *Oligosita* sp. adult emerging from numicia egg

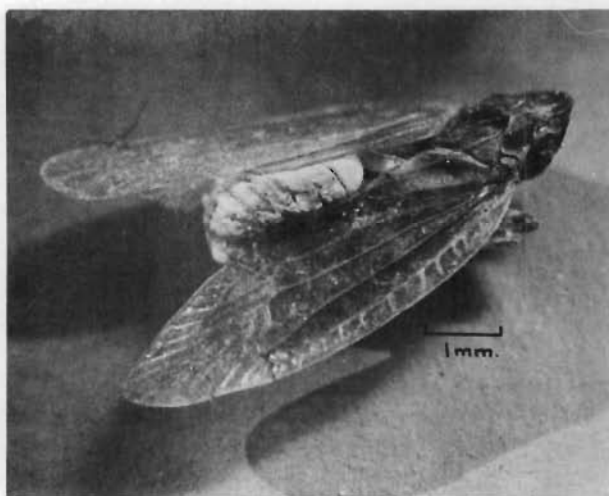


Plate 20 – *Epipyrops* larva on numicia adult



Plate 21 – *Epipyrops* larva ventral aspect

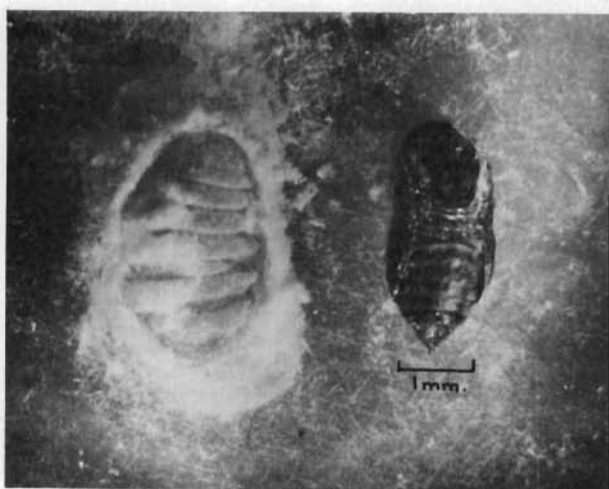


Plate 22 – *Epipyrops* pupating larva and
pupa exposed from cocoon

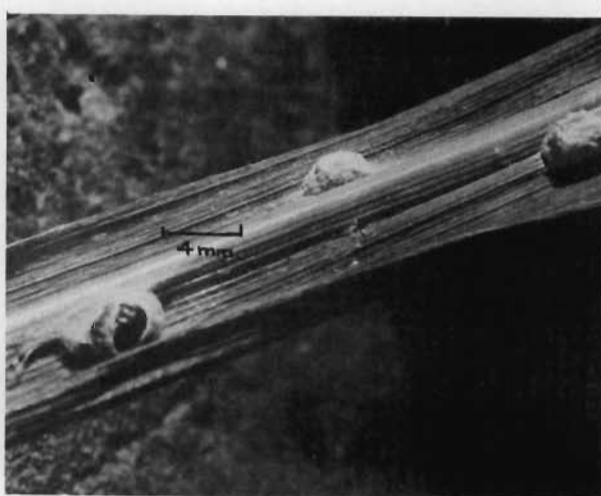


Plate 23 – *Epipyrops* cocoons on a cane leaf

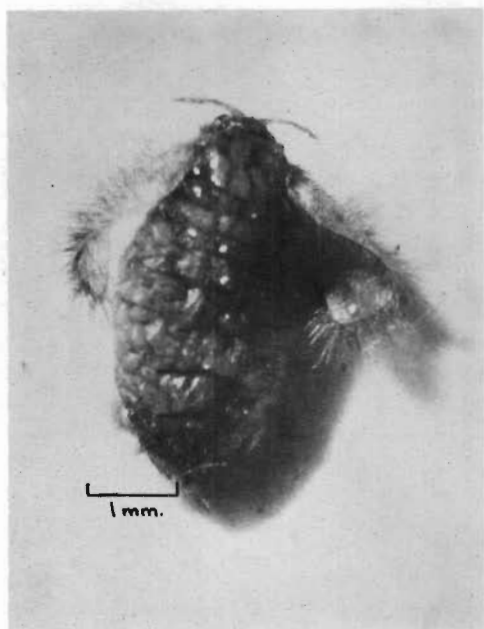


Plate 24 — *Epipyrops* adult female

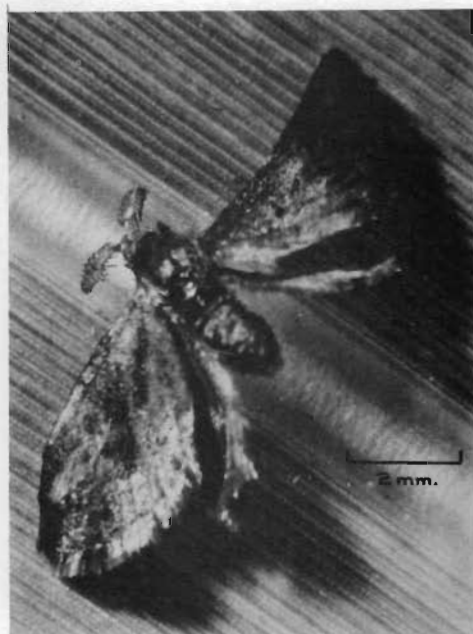


Plate 25 — *Epipyrops* adult male

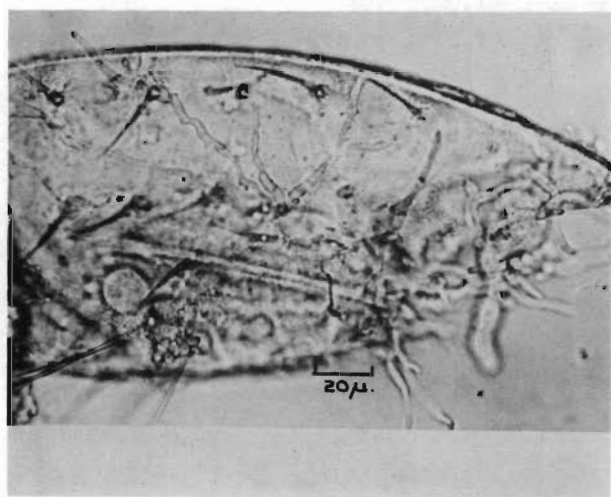


Plate 26 — *Entomophthora* mycelium and zygospores in numicia body tissue.

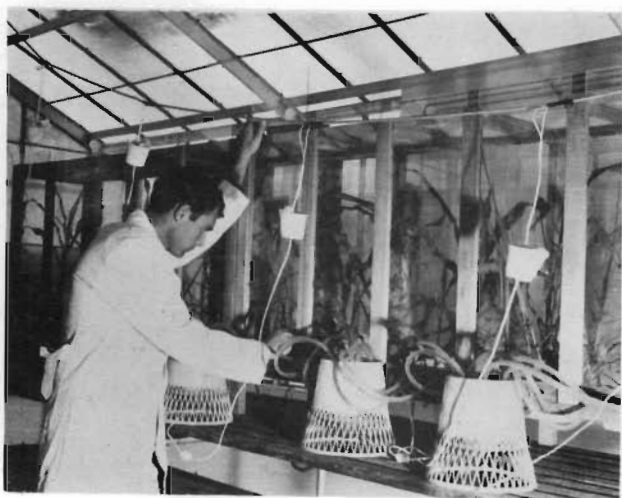


Plate 27 —
Insectary cages for rearing *Tytthus* spp.

Since 1965 when a small outbreak was seen at Tambankulu Swaziland, only one moderate sized population of Epipyropids was noted - at Mhlume in April 1967. Apart from those two occasions, the writer has seen the insect once only, when a single specimen was collected during an investigation of numicia movement (3.7.8.1). That it should be density dependent is understandable since the female, being brachypterous, would be unable to follow her host. Although large numbers of eggs are produced, chances of hatching larvae finding a host could be very slight.

The nature of the first stage larva was never determined (neither was it for E. anomala by Marshall (1971, pers. comm.)). It must be very active and is possibly triungulate in form.

The smallest larvae of Epipyrops sp. seen were without any waxy covering and were attached to numicia adults under the wing. No larvae were seen attached to nymphs; but had they been attached, they would presumably have become dislodged at ecdysis.

Later stage larvae are ovate in shape and flattened ventrally (Plate 21). They have a sclerotised head capsule with conspicuous but small black eyes, and legs and prolegs are quite well developed. There is a silky waxy mat of varying thickness covering the lateral and dorsal body wall, and this increases in density as the larva matures. (The large spinneret as mentioned by Marshall for E. anomala was not noted; but material for examination was limited since it was required for rearing adults and parasites). As larvae matured they became positioned on the dorsal surface of the abdomen, frequently tending towards one side, where they were covered by one wing. Sometimes they stretched diagonally over the dorsal surface, with head directed posteriorly and curved ventrally over the posterior abdomen.

Mature larvae left the host insect and moved actively over the leaf surface on which they would eventually pupate, spinning copiously until they were enclosed in a semi-spherical ball of waxy threads (Plates 22 and 23). Within this covering was enclosed a typical

lepidopterous pupa. The only pupal period recorded was 10 days, after which the adult moth emerged through one end of the silky pupal case.

There was very marked sexual dimorphism, the male being a small attractive grey moth about 5 mm long with a wing span of 12 mm, and pinnate antennae; and the female being a small sedentary oval insect with non-functional wings and inconspicuous antennae (Plates 24 and 25).

When they emerged females voided a mass of eggs over the leaf surface, but no larvae were reared from them.

It was thought at first that the Epipyropid larvae were almost entirely passengers on numicia, possibly feeding on waxy exudations. The possibility of their feeding on honeydew was discounted, because it was not appreciated until later in these investigations that numicia is a producer of honeydew. Examination of a host from which the Epipyropid larva had been removed revealed a marked concavity of the dorsal abdominal sclerites, giving them an emaciated appearance. Also, pieces of cuticle appeared to be missing, but no obvious access to the host's interior could be discerned, although in places a darkening of the cuticle suggestive of wounds was seen.

It was concluded that although the Epipyropid undoubtedly hampered the activities of its host, it probably did not kill it, nor was there evidence that it precluded copulation or oviposition.

Recently Marshall (1970) was able to discern in the Fulgoroid host of E. anomala, conspicuous wounds, through which the Epipyropid fed on both the blood and even sub-cuticular fat body. He noted also that the gut was remarkably modified compared with the gut of phytophagous larval Lepidoptera, and that host blood appeared to be stored in the stomach. His conclusion was that E. anomala is a true parasite; and the same may well be true of the Epipyrops species associated with numicia. Were both sexes active fliers it would possibly be a more common and useful controlling agent than it is.

Two Encyrtid parasites were reared from Epipyrops sp. They

were Chelloneurus sp. and Ooencyrtus sp., both identified by Dr G.J. Kerrich of the British Museum.

4.3.5 Coccinellidae

Ladybird beetles and lacewings deserve mention because they were seen feeding on numicia on occasions, although they are not assumed to be of great importance as natural control factors.

On one occasion (October 1964) the beetle Chilomenes quadrilineatus Muls. was very plentiful in a heavily infested field at Mhlume. This beetle is commonly found in cane fields associated with colonies of the aphid Melanaphis sacchari on which it feeds, and since in this particular field aphids could not be found it was felt that the beetles might be eating numicia. In the course of sampling it was noted that a beetle larva fed readily on a nymph which had been dislodged from the plant and had fallen on to the sampling sheet. However, observation on material returned to the laboratory was not encouraging. The adult beetles and larvae both appeared eager to feed on numicia nymphs but were obviously repelled from any direction of approach by the nymphs' waxy strands (2.12), and the predator appeared unable to seize and hold its prey.

At Ubombo Ranches (June 1965) a larva of Cydonia propinqua Muls. was noted eating an adult numicia. This was an isolated case, and occurred at a time when numicia were very numerous.

The ability of numicia to move rapidly if disturbed and the protective function of the nymph's waxy strands probably prevents many from falling victim to ladybird beetles. However, it is possible that under certain circumstances, for example during hours of darkness or under cold conditions, the predator is more active than its prey and may be of some value in control.

4.3.6 Chrysopidae

On one occasion (Ubombo Ranches, June 1965) a lacewing larva was noted with numicia exuviae covering its back, and was cultured with

numicia nymphs; but no adult was reared and it can be considered of very little importance.

4.3.7 Unidentified egg predator

It was quite common to encounter leaves from which a row of eggs together with midrib tissue had been removed. The predator was never identified, but Tettigoniids were sometimes present under such circumstances and were therefore suspect, although they could not be made to feed on the eggs in the insectary.

4.3.8 Birds

Swallows have been observed swooping to and fro over fields heavily infested with numicia, and cane growers have drawn attention to their possible potential as a controlling factor. However, it is considered more likely that they were feeding on other insects such as emerging Diptera, which are known to be plentiful in cane fields (Table 32; 5.4).

Small flocks of "white eyes" (Zosterops pallidus, Z. senegalensis) were noted hopping about actively in cane which supported large numicia infestations, but because of current foot-and-mouth disease regulations it was not possible to examine stomach contents. They may well have fed on numicia, but may also have been attracted by honeydew from aphids and mealybugs.

4.3.9 Fungi

Dramatic attacks by fungi have been recorded, but are not considered of very great importance since such phenomena are still uncontrollable.

In the course of this investigation three outstanding cases of numicia infestations being controlled by fungi were seen. In May 1966 at Big Bend Estate Swaziland, numerous nymphs and adults were found dead and dying, and attached to leaves by fungal hyphae. Specimens were returned to the Experiment Station where the microbiologist identified Entomophthora as the most important genus involved.

The other two main fungal outbreaks were in May 1968 in two adjacent and one distant field at Ubombo Ranches, Swaziland (fields Nyoni, Sangweni, Thekwane). Nymphs and adults were again found dying, dead, desiccated and adhering to leaves. This was of particular interest because it occurred soon after the management had, albeit dubiously, taken the Experiment Station's advice not to treat the three fields with insecticide. The infestation was rapidly and effectively controlled.

No such fungal outbreaks were ever seen in the course of numerous and regular visits to the coastal areas of Natal, where the more humid conditions might be considered even better suited to fungus propogation. However, Bayer (1964; Cedara unpublished report) records that during early March 1964 at Illovo "mortality due to a fungous disease was high. In a sample of 80 adults, 18 females and 15 males died from fungus infection within four days of collection". He does not state whether the fungus was identified. It is interesting that the available records are all for the latter part of the hot rainy season and concerned relatively dense numicia populations; (at no time since mid-1964 would it have been easy to collect 80 adult numicia at Illovo).

The temptation to experiment with microorganisms for purposes of field control (Roth, 1967) is understandable and a further examination of the microorganisms involved in the Swaziland fields is of interest. The following account is a condensation of the paper cited above.

Using both living and dead numicia collected from infected fields, fungal cultures on various media were established.

Apparently healthy numicia were found to be contaminated with many different types of saprophytic fungi, many of which are found also on plants and in soil. Many non-pathogenic bacteria too were found. None of these could be associated with the state of health of the specimens, but cultures obtained from external and internal parts of dead and dying insects yielded several fungal species which were not present in cultures

derived from healthy specimens.

Using 56 dead or dying numicia and 20 healthy specimens, 10 culture plates were inoculated with each, giving a total of 760 plates for contamination studies. Eight parasites were listed (Table 50).

TABLE 50. Parasitic microorganisms associated with numicia.

Parasite	Contamination from:			
	Healthy insects		Diseased insects	
	No. of culture plates	%	No. of culture plates	%
<u>Beauveria bassiana</u>	3	1,5	94	16,8
<u>Microsporium</u> sp.	0	0,0	58	10,4
<u>Fusarium semitectum</u>	7	3,5	172	31,5
<u>Dactylium fusarioides</u>	0	0,0	35	6,2
<u>Fusarium poae</u>	0	0,0	126	22,5
Entomophthoraceae	0	0,0	542	96,6
<u>Mucor</u> sp.	2	1,0	314	56,0
Nematodes	0	0,0	69	12,2
Total no. of plates	200		560	

Of the eight listed parasites only three were found in cultures derived from healthy insects, in which they were present in only a few cases. Particularly high were numbers of a fungus of the Entomophthoraceae (not found in healthy specimens), and of Mucor sp. (found to a limited extent in healthy insects also).

To determine what parts of the insects were infected healthy and diseased adults were compared. Stained microtomed sections showed no evidence of fungal growth on bodies of freshly killed healthy insects. However, when healthy numicia were placed with ones which had died of fungus

disease they became infected, apparently by crawling over the bodies of the dead ones which were covered with abundant conidia. The infection was not evident to the naked eye; but through a microscope an internal fungal mycelium was discernable, with hyphae protruding through the external membrane. The mycelium may eventually extend throughout the body tissue with production of zygospores (Plate 26).

An account such as the above immediately fires the enthusiasm of a cane grower, who insists that it should be a simple task to breed up appropriate spores and feed them into irrigation water wherever numicia is a threat or a problem. Enthusiasm was similarly fired as long ago as the eighteenth century (DeBach, 1964; Ordish, 1967); but in the history of applied biological control using microbial agents, disappointments have outweighed the not inconsiderable successes. This is not the place to summarise achievements and failures in this type of biological control, a subject which has been well covered by such publications as those cited above, and more recently by Burges and Hussey (1971). However, a few points concerning numicia and microorganisms are worth mentioning.

Numicia is indigenous, as are the organisms mentioned above. Where a numicia outbreak occurs fungi are very probably present, but optimum conditions are required to effect propagation and biological control. That those arise only infrequently under natural conditions is evident from the few naturally occurring incidents cited above. The possibility of creating optimum conditions artificially and economically should not perhaps be discounted, but one tends to be sceptical. Important factors to be considered are: temperature and humidity which affect both host and pathogen; weather conditions; population density of host; micro-habitat of pathogen and host; resistance of host; virulence of fungus; saturation point of pathogen in environment; ease of artificial propagation and distribution; time of application; ability of fungus to survive and spread; effect of pathogen on other biological control agents; economic value.

It is perhaps significant to mention that since April 1968 a further field outbreak of pathogens has been awaited, so that the matter may be further investigated!

4.3.10 Other factors in natural biological control

Two other factors deserve mention.

During examination of numicia eggs and recording their condition, a category was reserved for those unhatched eggs which had "degenerated through causes other than parasitism" (note also Metcalfe's (1971) "egg mortality factor"). Although this category probably included some parasitised eggs in which the parasites had died, many appeared also to have suffered from fungal or bacterial infection which could not be identified nor specified. The possibility has been mentioned also (Simmonds, 1964; unpublished report) of numicia eggs being "stung" (possibly for parasite feeding purposes) without being parasitised; although no evidence for this has been found.

In 1965 during the rather intensive study of a heavily infested field at Ubombo Ranches Swaziland (3.8) adults were often noted with malformed or crumpled wings. This occurred during August and September when insect numbers were very high (Fig 32). Their state resembled that of newly emerged adults with unexpanded wings, but it was noted that in many cases the wings never expanded, and females with crumpled wings were seen ovipositing. Such a deformity could have an indirect controlling effect through the enforced restriction in the insects' effective range.

4.4 Applied biological control

Before discussing applied methods of biological control against numicia it may be pertinent briefly to put the problems into perspective.

A mass of literature exists covering both theoretical and practical aspects of applied biological control of insects. Representative modern works include a comprehensive book edited by DeBach (1964) and at a more popular level, one by Ordish (1967). The former has been used extensively

during the present investigation.

Although each case of biological control must be considered on its merits, the advantages of island (or "ecological island") conditions have often been stressed. Also, applied biological control is more likely to succeed when the host plant or pest or both are exotic; under which circumstances a suitable predator or parasite may be sought in the pest's country of origin, collected, reared in quantity, screened for possible harmful effects, and released among its original host in new surroundings.

The contingency regarding numicia does not conform to the above, for there is no suggestion of the southern African cane belt being an ecological island, numicia is an indigenous pest and sugarcane, although an exotic crop, resembles very closely the grasses amongst which it is cultivated. In grasses adequate natural control already existed. In sugarcane however, although the same natural enemies were present, they were unable to maintain a numicia population level sufficiently low to reduce it permanently to non-pest proportions. Immediately the problem was appreciated it was realised that although control with insecticide dust was satisfactory, it should be regarded only as an emergency measure, and that other control measures should be investigated. What was required was an agent which would augment existing biological control to such an extent that damage to cane would cease to be of economic importance; i.e. numicia having become a pest as a result of a change in environment, an attempt should be made to achieve a state of equilibrium in the new environment.

With the limited knowledge of numicia available at that time (1964) consideration was given to related pests of sugarcane in other countries and to any achievements in controlling them biologically. Account was taken of similarities in biology and habit rather than of taxonomy, for no other record could then be found of a Tropicuchid achieving pest status, neither is much recorded of the biology of this family (1.1). Records from the British Museum and from Kawanda Research

Station Uganda, of Numicia insignis Dist. occurring in East Africa raised some hope, until it was learned that the same species was recorded from Pietermaritzburg in 1917 (Table 1), suggesting that any potentially useful parasite would already be present in Natal. Of the other Numicia species recorded in Table 1, nothing is known regarding their biology, and it was felt that a field investigation in the remote places concerned, was not at that stage justified.

An obvious candidate for trial was the Mirid egg predator Tytthus mundulus (Breddin) (Fig 47), and from 1965 to 1970 a great deal of time and money was spent in attempts to establish the species in South Africa (Carnegie and Harris, 1969). The story is one of failure, but the project raised many points of interest and is considered worth recording in some detail.

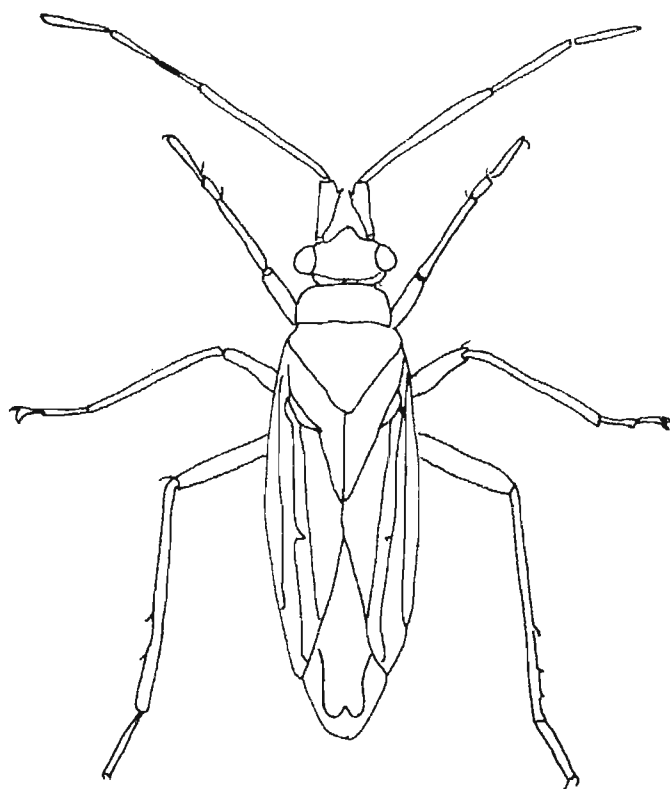


Fig. 47 The egg predator Tytthus mundulus (Breddin) (fam. Miridae)
(after Szwed, 1936)

4.4.1 The introduction of Mirid egg predators

The Miridae, a family of sucking bugs, include a number of species which feed on the eggs of other insects and some of them have been used as biological control agents against insect pests of agricultural crops.

One of the most notable, Tytthus mundulus (Bredd.) (formerly Cyrtorhinus mundulus, has been used successfully in several countries against the sugarcane leafhopper Perkinsiella saccharicida Kirk. T. mundulus was first encountered by Muir, an entomologist from Hawaii, who visited Australia in 1919 to collect a wasp parasite Drypta sp. to be used against P. saccharicida. His mission failed, but in Queensland he collected T. mundulus, some living specimens of which he conveyed successfully to Hawaii, where it showed great promise (Muir, 1920, 1924; Swezey, 1936). For the next 20 years Hawaiian literature mentions repeatedly the status of T. mundulus which became established as the most successful controlling agent of the leafhopper. It has been used successfully in Fiji against Perkinsiella vitiensis Kirk. (Lever, 1945) and was introduced successfully into Mauritius against P. saccharicida (Williams, 1958).

Introductions of Tytthus have not always been successful and in Jamaica, where it was introduced against the West Indian canefly Saccharosydne saccharivora it failed to become permanently established, although an alternate host Peregrinus maidis (Ashm.) was present.

The canefly and the sugarcane leafhopper are both Delphacids and it was perhaps optimistic to think that Tytthus might be successfully introduced into South Africa against numicia. The experiment was however considered worth trying, partly because in pilot experiments small consignments of Tytthus from Mauritius were found, in confinement to eat numicia eggs and even a nymph. Also there is in South African sugarcane the leafhopper P. saccharicida, an insect which is at present economically unimportant but which is of great potential importance since it is a vector

recorded in South Africa, but it is present in many sugar growing countries including Madagascar.

The history of Tytthus introductions shows that most success has been achieved where it has been introduced in the egg stage or as an entire colony (Bianchi, pers. comm.; Williams, 1958; Muir, 1921). For egg introductions the alternate host Peregrinus maidis has been used. Sections of maize or sugarcane tissue containing Tytthus eggs were sent to the country of introduction, where the eggs and young nymphs were released as quickly as possible. In Mauritius about 24 000 nymphs, from eggs which hatched on their way from Hawaii were released at several sites. Most of these colonies died out, but they became established at one site where 15 000 were liberated (Williams, loc.cit.). Establishment was rapid and two years later the insect was noted in places remote from those in which it had been released. The story for Hawaii was similar, although whole colonies were introduced and it was actually reared there in an insectary for some time after it had become established in the field.

In South Africa plant quarantine regulations forbade the introduction of Tytthus in the egg stage regardless of the country of origin. This was a source of great disappointment for it was appreciated that for successful establishment the release of large numbers was essential, and it was considered a reasonably straight forward operation for someone in Hawaii or Mauritius (both of which countries had offered to help) to rear Tytthus under carefully quarantined conditions, and to consign to South Africa by air freight sections of disease-free maize containing eggs. (Neither country has Fiji disease).

The approved alternative was to collect nymphs and adults in the country of origin, and to air-freight them with sections of maize stalk for quarantining in Pretoria, after which they could be forwarded to Mount Edgecombe for release.

Early consignments, of which there were several in the years

1965-67 (all from Mauritius) included nymphs and adults. On each occasion regulations required that these be quarantined in Pretoria, which resulted in postal delays and excessive handling of the insects in an uncongenial climate, and only a small proportion of those sent reached the Experiment Station at Mount Edgecome in a healthy state.

The first consignment was received in early May 1965 and was met in Pretoria by the writer equipped with leaves containing eggs of both numicia and P. saccharicida. These were to serve as food material once the egg-containing plant matter which had accompanied them from Mauritius had been discarded (as required by regulations). Of 180 Tytthus sent from Mauritius only $\frac{3}{4}$ reached Pretoria alive. When presented with leaves containing eggs they showed interest in the batches but seemed unable to eat them unless the eggs were exposed from the leaf tissue, when they ate those of both numicia and Perkinsiella. Despite careful handling only two survivors (both male) reached Mount Edgecombe, where they lived for three weeks on exposed numicia eggs.

Later in May a further 80 specimens were received. Of these, 20 were kept at Mount Edgecombe and the remainder released on to cane infested with both numicia and Perkinsiella at Pongola. By the time Pongola was reached there were only 25 survivors.

Nothing more was received until December 1965 when, from a consignment of 140 Tytthus 25 survivors reached Pongola, where the species was again released. A further five or six individuals in varying states of deterioration, were placed on growing cane in the Mount Edgecombe insectary.

Subsequent searching at release sites failed to reveal any Tytthus, and it was decided to request no further consignments from Mauritius until a new insectary at Mount Edgecombe was completed and adequate cultures of maize, with the alternate host insect Peregrinus maidis were available.

Such an opportunity arose in August 1967 when large numbers of Tytthus became available in one area of Mauritius, and approximately 250 (adults and nymphs) were dispatched. Of these about 50% survived the journey to Mount Edgecombe. Approximately 30 individuals were placed in large test tubes with eggs of Perkinsiella or with eggs and nymphs of numicia. About 100 individuals were placed also in large insectary cages, where they were given a choice of food consisting of eggs and nymphs of P. maidis in living maize, numicia eggs and nymphs on cane leaves, and Perkinsiella eggs and nymphs in cane leaves and stems. None was released in the field. The culture survived for about one month, during which time the following notes were made:

Immediately after being placed in insectary cages Tytthus adults sucked droplets of water or honeydew. One attempted to pierce a dead Peregrinus nymph and one oviposited in a maize stalk. Others were seen apparently feeding on Peregrinus eggs in maize stalks and on Perkinsiella eggs in cane stalks.

One adult in a test tube fed on a numicia nymph, the operation taking about 30 minutes and ending with Tytthus discarding the empty skin. In insectary cages, feeding on eggs of Peregrinus and Perkinsiella continued, and there was some oviposition. Several Tytthus eggs were found in oviposition punctures of Perkinsiella.

Another Tytthus adult was seen eating a numicia nymph. Tytthus had oviposited only in leaves supplied when the insects originally arrived and eggs were nearly all in old oviposition punctures, 16 being in those of numicia.

These Tytthus eggs hatched and the nymphs apparently ate Peregrinus eggs. However, no further eggs hatched and the cultures were considered to have died out.

In 1968 the Plant Protection Research Institute in Pretoria agreed that if a suitable member of staff of the Experiment Station went to

Mauritius to collect and dispatch Tytthus, he could be responsible there for quarantine facilities. This arrangement had the advantage that consignments no longer required quarantining en route and could reach Mount Edgecombe undisturbed within eight hours of being dispatched. However, it was now required that adults only could be sent and that there could be included no food material. Advantage was taken of this concession as follows:

4.4.2 Materials and methods used for large scale Mirid introductions

An entomologist went to Mauritius in January 1969, and with the help of Mr J.R. Williams, Chief Entomologist of the Sugar Industries Research Institute, and locally recruited assistants managed to collect, screen and dispatch nearly 6 000 Tytthus adults. In Mauritius there are three similar species (T. mundulus, T. parviceps and Cyrtorhinus lividipennis) the adults of which are very similar in appearance, and all three were collected in the field. Although all three species had been offered by Mauritius and T. parviceps had been recommended by the Commonwealth Institute of Biological Control, T. mundulus was the main subject since it had been most successful elsewhere. Therefore in the course of laboratory screening for unwanted insects, the other species were rejected.

When Mauritius was visited T. mundulus was scarce on sugarcane, which was largely at an early stage of growth. It was however plentiful in certain maize fields and as many as 13 adults could be found on one plant. During three weeks collecting, using aspirators, approximately 13 000 T. mundulus adults were captured, and survivors were carefully screened in the laboratory, resulting in 5764 being sent to South Africa in five separate consignments.

For consignment the insects were placed in plastic ventilated containers of about 1 litre capacity. These in turn were enclosed in cardboard boxes and conveyed in the air crew's cabin of a regular flight. In the first two consignments many Tytthus died, apparently from desiccation

(90% and 70% respectively). In subsequent consignments wet cotton wool was placed between the plastic sides of containers and an organdie sleeve on wire mesh within it which contained the insects, reducing mortality almost to nil.

Approximately 3000 living specimens were received at Mount Edgecombe, most of which were placed on insectary cultures of maize which supported Peregrinus maidis. A few were released directly on to caged field maize plants which supported large populations of P. maidis.

Cultures of field-collected P. maidis were established on maize in cages as illustrated in Plate 27. The cultures had to be continuous so that Peregrinus and its predator could be reared progressively from one generation to the next. This was done by using cages which could be subdivided into separate adjacent compartments, each having removable trays of maize plants. Cultures could be started in one compartment and when the plants in it degenerated, fresh ones could be placed in the adjoining compartment and the intervening glass partition could be removed. The insects would infest the new plants while the older ones degenerated, and there would then be present both young and old material. It was intended that large numbers should be reared for field releases en masse.

Cultures were maintained at temperatures and relative humidities ranging between 25° and 30° C., and 80% and 100% R.H. respectively. Electric fans housed in waste paper baskets blew an air stream via flexible tubes through the cultures to prevent misting of the glass sides.

Throughout the year, as a source of fresh Peregrinus material for starting or augmenting cultures, successive crops of infested maize were grown at Mount Edgecombe in adjoining fields, about one eighth hectare at a time. When a field was ploughed stalks were taken from it and placed in an adjoining field of younger maize.

4.4.3 Results

Initially chances of survival seemed good. Adults fed readily

It was at this stage that it became apparent that more than one species were present, for some nymphs were green whereas T. mundulus nymphs are red. The green nymphs were placed in separate cultures, and when adults appeared they were sent to the Commonwealth Institute of Entomology who identified them as T. parviceps (Reuter).

Tytthus mundulus

Despite the large numbers of T. mundulus originally placed in cultures, they did not produce the overwhelming numbers one might have expected. Over the course of four generations their numbers dwindled to practically nothing and they finally died out completely (Fig. 48).

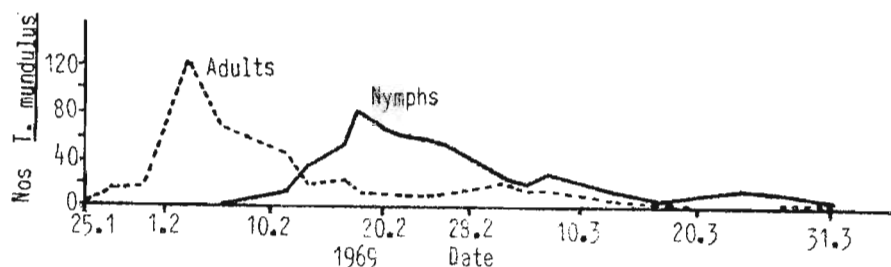


Fig. 48 Insectary populations of Tytthus mundulus; Jan- March 1969

Food was plentiful and conditions of temperature and humidity were carefully controlled. Specimens in the cultures were either active, robust and apparently healthy, or else dead; there were no half measures, with no signs of ill health, pathogenic infection or any other form of adversity. There was an occasional flush in numbers when eggs hatched, but eggs were not produced in the sort of numbers expected from so many adults, and nymphal mortality was unexpectedly high.

Any defects in rearing methods are made harder to pin-point since numbers of T. parviceps, which cannot have originated from more than three or four individuals, increased satisfactorily. Both species had identical treatment in identical cages in the same insectary. Reasons for the fall in numbers of T. mundulus may be subtle, such as inability under artificial conditions to find a mate, or for mating to occur only at a certain age, but no mention of such an impediment was encountered in available literature. Verma (1955) states that T. mundulus preferred to oviposit in old plants, and that eggs laid in young maize came to nothing. In Mount Edgecombe cultures, old tissue as well as young was available, and age of plant could hardly therefore have been the reason for their failure to multiply.

T. parviceps

When it seemed that T. parviceps was a comparatively easy insect to rear in the insectary, it was decided to salvage everything possible from the operation by continuing rearing that species and at the same time investigating its merits as a controlling factor. In the insectary it became the subject of observation and some experimentation, and planned field releases were attempted.

When it became apparent that its numbers were increasing, figures for insectary counts were separated for the two species and each was recorded separately. Figures for T. parviceps are shown in Fig. 49. The figure,

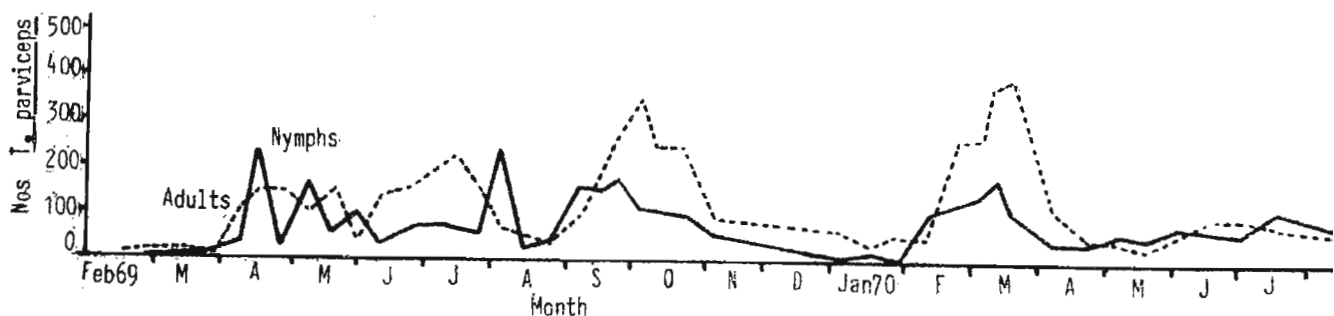


Fig. 49 Insectary populations of Tytthus parviceps; Feb. 1969 - Aug. 1970.

which shows both crests and troughs, does not represent the full potential of the insect for two main reasons: (a) insectary and cage accommodation was inadequate, and (b) adults (especially gravid females) were being removed periodically and placed in gauzed field cages enclosing maize plants which were heavily infested with P. maidis. These cages which measured approximately 3m x 3m x 1½m were portable and could be moved to suitable sites.

Such field cages were used on field maize at Mount Edgecombe whenever sufficiently high numbers of P. maidis had been established. In addition, at the Pongola Field Station maize was established in close association with cane, and large numbers of P. maidis, sometimes augmented from elsewhere were encouraged to develop upon it. This was then caged within structures such as those described above, and T. parviceps adults and nymphs from the Mount Edgecombe insectary were placed within them for a week before the cages were removed.

4.4.4 Notes on feeding habits of T. parviceps.

A number of small scale insectary experiments were conducted with T. parviceps to investigate its potential as a predator. These were not replicated, and it is appreciated that the Mirid might have behaved differently under field conditions. However, some interesting observations were made which are considered worth recording.

4.4.4.1 Experiment 1

From Illovo Sugar Estates, 120 leaves containing numicia eggs were collected. Of these, 60 were isolated and placed standing in a beaker of water as a control. Four lots of 15 were similarly placed in beakers of water and enclosed in insectary cages containing populations of T. parviceps. After five days all leaves were removed and the state of the eggs determined. It was felt that were there any marked feeding on numicia eggs the numbers of viable eggs (i.e. unhatched, unparasitised and healthy) would be noticeably greater in controls than in eggs exposed

to T. parviceps.

Results

Differences were not marked. An average number of 186,7 viable eggs were recorded from exposed beakers, and 219,8 viable eggs from the control, and there was no evidence of predation.

4.4.4.2 Experiment 2

Two type 3 cages (2.4) were used to enclose growing cane leaves. Cage A contained two first instar numicia nymphs; Cage B contained two first instar nymphs and a batch of numicia eggs. Into each cage was placed one Tytthus parviceps adult and notes were made each day regarding its behaviour.

Results

Cage A. During the first 12 days the nymphs moved very little, but Tytthus moved all over the cage, ignoring the nymphs. After 12 days a further T. parviceps adult was added. After 21 days both T. parviceps died and were survived by both nymphs.

Cage B. The numicia nymphs moved very little and were undisturbed by Tytthus, which moved about sporadically but was seen only once on the egg batch. Towards the end of the observation period Tytthus became visibly thinner but remained active. After 23 days Tytthus escaped from the cage. The nymphs were untouched, and examination of the egg batch showed that they were all hatched (and had presumably been so since the start of the experiment).

It was concluded that Tytthus will not readily eat numicia nymphs, and will live for considerable periods without animal prey. It may have fed upon honeydew or even leaf tissue, but this is considered unlikely for it was under continual observation and there was no indication that it did so.

4.4.4.3 Experiment 3

This experiment concerned numerous observations of Tytthus parviceps when it was given access to numicia eggs. Extensive notes were

made, and only a summary is given here. In all cases leaves used were field collected and already contained numicia eggs. Seven type 3 cages were placed over egg batches, and the lower end of the cut leaves were placed between two pieces of plastic foam in polythene bags containing water. These bags, which served as a vase were tied at the top around the leaf. The cages were then placed so that they could be observed through a rotating stereoscopic microscope (Plate 7). In some cages the eggs had been exposed or partly exposed from the leaf tissue with a scalpel. Into each cage were placed T. parviceps nymphs or adults. Wherever possible any activity and probing by Tytthus was identified with specific eggs which were subsequently examined and their state noted. These were found to be either normal unhatched, hatched, parasitised, spherical but empty or flattened; those of the last two categories were considered to have been sucked by Tytthus.

Results

Both nymph and adult T. parviceps showed obvious interest in numicia egg batches, especially where eggs had been exposed from leaf tissue. For long periods on end (30 minutes and probably more) they would move up and down egg batches probing with the proboscis which was inserted into cracks in the leaf tissue and into empty hatched eggs. Two nymphs which were observed probing exposed numicia eggs were unable to penetrate the chorion, although their proboscides dented the egg surface and even curved slightly. One nymph sucked an egg when it penetrated it through a slit in the leaf midrib (which may have offered support for the proboscis).

On one exposed egg batch the stillness of an adult which was apparently feeding, contrasted markedly with the agitation of others which were restlessly probing. Subsequent examinations showed that only two eggs were flattened and that most of the batch were unaffected.

In the course of several weeks observation involving hundreds of eggs, 26 eggs of those exposed were probably eaten, although some may have become flattened through other causes. Of the unexposed eggs not

more than five were eaten, and there is some doubt attached to that figure for the original state of the enclosed egg could never be determined with certainty.

4.4.4.4 Further observations

Four adult T. parviceps were introduced using an open ended glass specimen tube into a type 2 cage in which there was a culture of numicia eggs, nymphs and adults (2.3). They remained inactive in the tube for an unexpectedly long time, the last one not leaving the tube until the following day. One Tytthus adult approached a dead numicia adult male, lying on the cage and grappled with it for 15 minutes until deliberately disturbed. Its motive was uncertain, but it could not have fed on the numicia which was desiccated. Another Tytthus slowly climbed a leaf until after about 30 minutes it reached a colony of numicia eggs, nymphs and adults; but it showed no interest and descended the leaf again. There was no evidence that any numicia were eaten, and the four Tytthus eventually died.

In the same culture, 25 days after the original four Tytthus were introduced, another adult was noted which apparently found its own way in, having escaped from another culture. It was seen for several days remaining mainly between two contiguous leaves, but subsequently it disappeared and was not seen again.

4.4.4.5 Conclusions from T. parviceps feeding experiments

- a. The Mirid was attracted to numicia eggs, especially when these were exposed from the leaf tissue.
- b. They could penetrate numicia eggs only with difficulty, even when these were exposed from the leaf tissue.
- c. They could not penetrate unexposed eggs (i.e. where only the operculum protruded from the leaf) except perhaps occasionally e.g. through a slit in the midrib.
- d. Tytthus usually died soon after isolation with numicia colonies; but on one occasion lived for 32 days apparently without feeding.

4.4.4.6 Discussion of *Tytthus* spp. experiments

Although insectary cultures of *T. parviceps* were maintained without great difficulty for more than 18 months it was decided to terminate the project. This was partly because the observations described above cast considerable doubt on its merits as a controlling factor for cane pest species, and also because information obtained from literature substantiated this doubt.

Simmonds (pers. comm.) stated that during an outbreak of the West Indian cane fly (*S. saccharivora*) in Florida *T. parviceps*, which is indigenous to central America had been present, but that its effects as a controlling agent had not been notable. And Metcalfe (pers. comm.) and Frank (1971) found that although *T. parviceps* was present in Jamaica, it always seemed to disappear when most needed. Carvalho and Southwood (1955) suggest that *T. parviceps* is very much a cosmopolitan species, having been recorded from the following places : Egypt, St. Vincent, Seychelles, Rodriguez, Paraguay, Florida, East and West Africa, Morocco, Gigepio, Italy, South Africa (Cape Province), St. Helena, St. Thomas, Virgin, San Domingo, Cuba, Puerto Rico, Venezuela.

Then, in the course of collecting with a suction sampler at Pongola and Mhlume two Mirids were taken and sent to the British Museum for identification. They were identified as being probably *T. parviceps*, but there was an element of uncertainty since females only were present. It was remotely possible that the Pongola record could have been a recovery from field released material, but certainly not the Mhlume record.

It seemed therefore that an attempt was perhaps being made to rear a fairly useless insect which was already present!

Regarding *T. mundulus* the situation is different because its merits as a controlling factor for *Perkinsiella saccharicida* are beyond dispute, and there was reason to believe that it might well contribute towards the biological control of numicia also. The few specimens which

reached Mount Edgecombe alive were too precious to be used for observation and experimentation; but two numicia nymphs were seen being eaten, and it is possible that under field conditions the predator might effectively account for many numicia eggs in grasses even if the relatively tough texture of cane made penetration difficult.

The numicia problem is at present in abeyance (1972) and the urgency for control measures has passed - at least temporarily. Other problems are now receiving priority attention. However, should there be an alarming recrudescence or should Fiji disease ever threaten the industry, the introduction of T. mundulus might well be reconsidered; in which case it would be essential to obtain authority to introduce it in the egg stage, and in very large numbers.

4.4.5 Other introductions worth considering

While numicia outbreaks remain small and restricted no further introductions are warranted. However, there are certain other biological control agents which should be borne in mind.

It was mentioned earlier that the local Ootetrastichus ?beatus Perkins was identified with some caution since males were present, and males were hitherto unknown. It is possible that an entirely parthenogenetic strain, such as that which apparently exists in Hawaii, might if introduced prove to be a more efficient parasite than the local one.

Metcalf (pers. comm.) states that a British Honduras strain of Tetrastichus sp. introduced into Jamaica was showing much greater promise as a controlling agent of cane fly than was the local species. Such a species might be worth trying against numicia.

The insect collection at the Sugar Industries Research Institute, Mauritius, includes an unidentified species of Numicia, very similar in size and general appearance to N. viridis. It was collected in Madagascar on sugarcane and, although it has never been recorded in pest proportions, it might well have an effective parasite suitable for trial against N. viridis.

(A very similar specimen, N. dorsalis Jac., is represented in the Tananarive Museum, Madagascar, but its host plant is not recorded).

4.5 Management practices

Under the broad heading of this chapter mention must be made of management aspects which in essence concern ecological factors.

4.5.1 Alternate grass hosts

It appears that most indigenous grasses are capable of acting as host plants for numicia (3.9). Theoretically their presence in the vicinity of cane fields could be either advantageous or detrimental. A comparison of cane and grass communities was made in 3.7; but it could be argued that numicia populations could build up in grasses in the wet summer months, and when the grasses begin to dry off in late summer, the young adults of the April-May generation might move into cane fields and start an infestation. However, since egg parasitism has been shown to be generally higher in grasses than in cane, it could be argued also that the presence of grass communities in association with cane is beneficial, since such communities serve as a reservoir for parasites. In practice, permanently green grass communities always exist where cane is grown under irrigation, and some grass hosts are deliberately cultivated on canal banks and reservoir walls to prevent erosion. Nevertheless, the burning of adjacent grasses when numicia adults are present should be avoided, although to do so when nymphs and eggs only are present could be advantageous.

4.5.2 Cane harvesting

In inland irrigated areas (i.e. areas where numicia is most troublesome) cane fields are burnt before the cane is cut. The cutting season, which is determined by the period when mills are operating, usually extends from about mid-April until mid-December, a period which will normally include two adult peak periods viz. April-May and October-November (Fig. 23). Of the three peak periods which occur, these two produce higher numbers than the February peak.

Burning and cutting a field at a time when most numicia are in the egg and nymphal stages will virtually annihilate an infestation, and the danger of a carry over to the following ratoon by eggs or nymphs is considered to be remote (3.6.1/a). However, burning a field which contains many adults may cause them to move into another field and thus spread the infestation (3.7.5).

It would be advisable therefore to adjust harvesting programmes so that affected fields may be cut at the most appropriate times. Which is not always practicable, because heavy infestations frequently occur in cane aged from five to nine months, at which age the weight and sucrose yields are poor.

4.6 Discussion of natural control

Natural controlling factors, both ecological and biological were recognised. In grasslands the most important ecological factors were seasonal drying off of the host plant, and even burning in the summer rainfall areas (which are the areas where numicia has been most troublesome). Destruction of the host plant when numicia is in the egg or nymphal stage means the virtual destruction of the population present, and under natural conditions the insect would survive the dry winter months only in small areas of permanently green grass. In cane a similar controlling factor was seen in the form of harvest, which would often occur when numicia was present in the egg or nymphal stage. Flooding similarly must occasionally affect populations in grassland, but cannot be considered important. The tie up between the above factors and management practices is worth consideration, for sometimes a harvesting schedule might be advantageously altered to enable a heavily infested field of mature cane to be prematurely harvested.

Since numicia is an indigenous insect it is understandable that a number of biological controlling agents were identified. Most important among these were two hymenopterous egg parasites, of which the Eulophid Ootetrastichus ?beatus Perkins appeared to be the more important since each

parasite larva would account for up to seven host eggs. However, although the Trichogrammatid Oligosita sp. accounted for only one host egg per parasite larva, it was the more common of the two in coastal areas, which are the older cane growing areas and are those in which numicia is far less of a problem. Parasitism by these two insects was shown to be heavier in grasses than in cane, which could well be an important contributing factor to numicia having become a pest of sugarcane.

Two Dryinid parasites, Lestodryinus sp. and Dryinus sp. were frequently noted, but their controlling effect appeared to be lessened by the activities of secondary parasites (Cheiloneurus sp. and Ooencyrtus sp.).

Although spiders were sometimes present in large numbers in infested fields, insect predators were not conspicuous. This may have been because during daylight hours at least, numicia are quite active insects, and hop away readily if disturbed. The Coccinellid beetles Chilomenes quadrilineatus Muls. and Cydonia propinqua Muls. were on isolated occasions associated with heavy numicia populations, but were not commonly found in infested cane fields. An unidentified lacewing larva was also suspected on one occasion of feeding on numicia.

Although sporadic in appearance, small birds must occasionally account for some numicia, but did not appear to be an important controlling factor..

Heavy outbreaks were occasionally brought under control by the action of parasitic fungi, notably Entomophthora sp., which was recorded only towards the end of the rainy season.

An attempt was made at introducing and establishing Mirid egg predators from Mauritius. Tytthus mundulus Breddin and T. parviceps (Reuter) were introduced, but only the latter showed promise of becoming established, and there was reason to believe that not only was it of little potential use, but that the species might well be established in the cane belt already. The former showed some promise as a predator of eggs of both numicia and Perkinsiella saccharicida Kirk.

slowly dwindled in numbers until the species apparently died out completely. Should numicia again become a problem, or should Fiji disease, of which P. saccharicida is a vector be recorded in South African cane, a further attempt at introducing T. mundulus might be made. However, it would probably not be worth doing so unless permission could be obtained to introduce very large numbers of eggs, rather than nymphs or adults.

At the time of writing there is no reason to believe that natural control has failed. The outbreak years were from 1962, with occasional very localised minor outbreaks occurring until February 1971. The indications are that in recent years natural controlling factors have improved, for insecticide use has been negligible and yet there has been a general fall in numicia population numbers. Recent spot-checks have indicated an improvement in egg parasitism (Table 48), and it is possible that the egg parasites have become better adapted both to finding and penetrating their host egg in cane fields. However with other similar insects e.g. the West Indian canefly, Saccharosydne saccharivora, long periods have elapsed between outbreaks (Metcalf, 1971) and it is quite possible that numicia will again become a problem (1.3.2).

CHAPTER 5

CHEMICAL CONTROL

5.1 Introduction

Once the broader aspects of the numicia problem had been appreciated and an emergency method of insecticidal control established, carefully planned insecticide trials were conducted. These are discussed in detail later in this chapter and have been summarised by Carnegie (1971b).

5.2 Early insecticide trials

Mention must first be made of the earlier small scale trials, hastily designed to investigate the merits of various insecticides, formulations and application methods (Dick, 1963; Anon., 1964).

In August 1962 a small scale trial was conducted in Swaziland.

Treatments were:

- a. Mercaptothion (as malathion) 5% dust, applied at between 34 and 45 kg per hectare.
- b. Carbaryl (as Sevin) 10% dust, applied at between 34 and 45 kg per hectare.
- c. BHC 5% dust applied at between 34 and 45 kg per hectare
- d. Dimethoate (as Rogor E) 40% emulsion, applied at approximately 2,3 kg active ingredient in 400 litres water per hectare
- e. A mixture containing chlorinated camphene (as Toxaphene) 40% and DDT 20%, at approximately 2,3 kg a.i. in 400 l water per hectare.

All treatments were applied from the ground using portable motorised equipment which could be adapted to deliver either dusts or sprays.

It was noted that the dusting powders gave far better penetration of the dense cane foliage than did the sprays, an impression which was later confirmed during aerial application of mercaptothion. Wettable powder adhered to the upper parts of the plants and missed numicia populations,

which concentrate on lower surfaces of leaves (2.23.1). Dusts formed a cloud which penetrated right down to the ground and covered all exposed surfaces. (This observation was confirmed by the complete failure of the first commercial treatment at Tambankulu, Swaziland, where against the advice of the Experiment Station, a wettable powder was used. Subsequent dusting was successful).

Although the conditions of the trial did not enable accurate mortality counts to be made it was apparent that mercaptothion 5% dust had produced a satisfactory kill, and that it was the treatment to take effect most rapidly. When examined three days later mercaptothion-treated plots still appeared to show the best results.

In May 1963 at Pongola an insecticide test was conducted on one of the most heavily infested farms. Mercaptothion was applied by helicopter as a fog, generated by hot exhaust gas passing through solution in "Diesoline". Extensive mortality counts were not made, but both penetration of foliage and insect mortality were considered satisfactory and several other farms were treated by the same method. However, under commercial conditions the result proved to be very erratic. Because of the low density of the fog this treatment was particularly sensitive to air movement including moderate to strong winds and rising air currents, and fogging could therefore be effectively carried out only early in the morning.

Being heavier, the dust was less easily dispersed by air movement. Aircraft were able to allow for slight drift due to moderate wind (up to about 10 k.p.h.) and it was claimed that better distribution was often obtained under these conditions than in a flat calm. In a moderate wind dust was released to windward of the target area and the subsequent lateral drift resulted in the cane being effectively covered with dust.

In October 1963 at Pongola the following dusts were tested against numicia: mercaptothion 2% and 5%; dieldrin 1%; DDT 10%; carbaryl 5%; "toxaphene" 10%; BHC 5%. All were applied at a rate of 45 kg per hectare

using a small hand-operated duster. A very patchy insect distribution precluded accurate mortality figures being obtained, but the following information did emerge: The 2% mercaptothion was less effective than the 5%; after 24 hours many numicia were still alive on cane stools treated with dieldrin, DDT and toxaphene; fairly satisfactory kills followed treatment with carbaryl, BHC and the 5% mercaptothion.

In January 1964 at Illovo three tests were carried out. In the first of these, 5% formulations of mercaptothion and carbaryl dusting powders were each applied by aircraft to individual areas of two hectares, at a rate of approximately 45 kg per hectare. In each treatment 10 metre-square plastic mortality sheets were scattered throughout the area. Relative effectiveness was assessed by counting dead insects on the sheets, each of which was regarded as a replicate. Counts were made at intervals of 3, 6, 24 and 48 hours after treatment. Almost all insects were nymphs in the first instar. Cumulative totals for each replicate and means for each treatment are shown in Table 51. After 48 hours living nymphs were still evident in the area treated with carbaryl.

Since in this trial there was some doubt as to the accuracy of dosage rates, a Swaziland estate (Ubombo Ranches) who were at that period treating some of their fields commercially, were asked to conduct a similar test over a larger area; which they did and produced the information recorded in Table 52. A 5% dust formulation of each insecticide was used and applied at a rate of 33,5 kg per hectare. (A rate of 40 kg per hectare was intended but an error occurred and the actual amount applied was calculated by subtraction). The action of mercaptothion was evidently superior to that of carbaryl.

Later in January they conducted a second trial. Using a hand operated blower in young cane, 5% dust formulations of the following insecticides were used: mercaptothion, BHC, carbaryl and endosulfan (as Thiodan) all applied at approximately 45 kg per hectare to well grown 5-month-old cane

TABLE 51. Numicia mortality counts following aerial spraying with 2 chemicals (Illovo).

Treatment	Repli- cate	Mortality counts (nymphs)			
		No. of hours following treatment			
		3	6	24	48
Mercaptothion 5% dust	1	175	325	426	466
	2	365	624	764	775
	3	281	356	402	413
	4	110	160	168	183
	5	195	259	307	312
	6	139	168	174	180
	7	161	205	212	219
	8	120	132	141	143
	9	90	101	106	107
Total		1636	2330	2700	2798
Mean ⁽¹⁾		181,9	258,9	300,1	310,9
Carbaryl 5% dust	1	9	21	93	125
	2	11	65	163	208
	3	6	14	61	90
	4	7	19	93	110
	5	27	98	235	255
	6	8	32	105	135
	7	10	30	146	171
	8	32	62	191	203
	9	16	77	245	271
	10	6	18	106	118
Total		132	436	1438	1686
Mean		13,2	43,6	143,8	168,6

(1) One replicate destroyed by pigs.

TABLE 52. Numicia mortality counts following aerial spraying with 2 chemicals (Ubombo Ranches).

Nos on mortality sheets after 24 hrs						
Mercaptothion 5% dust			Carbaryl 5% dust			
Dead *		Dead		Alive		
Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	
29	4	12	12	1	0	
30	4	10	8	1	0	
105	3	11	19	7	8	
31	9	7	30	10	3	
21	5	3	4	11	10	
14	4	7	12	6	3	
33	13	8	12	13	5	
154	22	5	12	13	5	
25	3	4	8	7	4	
48	7	0	2	1	1	
Total	490	74	67	119	70	39
Mean	49,0	7,4	6,7	11,9	7,0	3,9

* no living insects recovered

Numbers of dead insects per square metre 24 hours after treatment are shown in Table 53. Mercaptothion again showed up well. (The poor results given by endosulfan are surprising considering the results obtained with it in 1966 and 1967 (5.3.2; 5.3.3)).

In May and June 1964 at Illovo, a BHC powder containing 3,5% gamma isomer was included in two small scale tests. In the first test insecticides used were: 3,5% gamma BHC made up in powder of 3 degrees of fineness; 5% endosulfan; 5% fenthion (as Lebaycid); 2,5% trichlorphon (as Dipterex); 5% mercaptothion; and a mixture containing 10% "toxaphene" and 5% DDT. All were applied with a hand operated duster at 45 kg per hectare. Mortality counts were made at regular intervals for eight days, and cumulative total

mortalities are shown in Table 54.

TABLE 53. Numicia mortality counts following hand dusting with 4 chemicals (Ubombo Ranches).

Mortality after 24 hours					
Mercaptothion		Endosulfan		Carbaryl	BHC
Nymphs	Adults	Nymphs	Nymphs	Nymphs	Nymphs
28	1	2		3	0
7		0		2	0
28		2		3	19
7		0		3	2
20		0		12	5
26		0		1	0
91		0		10	3
34		20		1	0
Total	241	1	24	35	29
Mean	30,1	0,1	3,0	4,4	3,6

TABLE 54. Numicia mortality counts following hand dusting with 8 formulations (Illovo).

Mortality after 8 days (cumulative counts)								
BHC 1	BHC 2	BHC 3	Endo- sulfan	DDT + Toxaphene	Trichlor- phon	Mercapto- thion	Fenthion	
10	15	11	11	19	16	15	26	
8	33	12	27	5	21	10	50	
19	26	20	27	22	27	20	23	
17	7	29	11	6	12	29	33	
23	31	13	17	25	20	42	35	
Total	77	112	85	77	96	116	167	
Mean	15,4	22,4	17,0	18,6	15,4	19,2	23,2	33,4

A few days later the experiment was repeated, omitting two of the BHC powders and the mixture of DDT with "toxaphene". The remaining treatments were replicated eight times. Cumulative total mortalities six days after treatment are shown in Table 55. Once again most dead insects were recovered from the mercaptothion treated plots, but fenthion again did well (a result not convincingly confirmed in a trial in 1966; 5.3.1.2).

TABLE 55. *Numicia* mortality counts following hand dusting with 5 formulations (Illovo).

Mortality after 6 days				
BHC 2	Endosulfan	Trichlorphon	Mercaptothion	Fenthion
5	5	2	7	6
5	1	1	9	7
3	2	3	13	11
9	6	2	15	14
19	3	7	5	3
6	5	8	5	5
4	5	4	8	7
6	9	7	7	8
Total 57	36	34	69	61
Mean 7,1	4,5	4,2	8,6	7,6

These small scale trials left the impression that mercaptothion 5% dust applied at 45 kg to the hectare gave as satisfactory a control as anything else tried. By this time it had been established that certain useful hymenopterous parasites of *numicia* existed (4.3.1), and the non-persistence of mercaptothion was therefore an additional advantage. Other advantages were the high LD50, the low cost, and the fact that dust formulations by their billowing effect made better contact with *numicia* than other formulations. Therefore, where chemical control methods were

considered necessary this procedure became a standard recommendation.

Shortly after this last trial, numicia became the subject of a more intensive investigation, which soon produced evidence that insecticidal control should be regarded as a last resort, for it could aggravate a situation. It was noted that in some cases, especially where a field was dusted once only, dusting was followed by increases in numbers of the Delphacid Perkinsiella saccharicida and of the aphid Melanaphis sacchari. In other cases, where timing of application had been poor there followed a marked increase of numicia itself (3.8).

5.3 More recent insecticide trials

During 1966 and 1967 there followed statistically planned insecticide trials, designed to assess the relative merits of various chemicals and formulations against numicia and its natural enemies, taking into consideration the economics of the operations. It was hoped also that some knowledge of crop loss would be gained. By this time a synchrony of generations had been recognised (3.5) and for various agronomic reasons the trials were aimed at the May and October generations, treating where possible at a time when fewest unhatched eggs were present, with the insects largely in the transitional stage from large nymphs to adult. The trials were conducted at Ubombo Ranches, Swaziland.

Materials and methods

In all cases a standard fixed wing Piper Pawnee crop spraying aircraft was used, with any necessary modifications being made according to formulations and volumes required. Treatments were applied in the early morning when atmospheric conditions were optimum. Despite large plot sizes and generous guard plots between treatments there occurred some insecticide drift, which is reflected in the results. In each case mercaptothion 5% dust was included as a standard, and in only one trial was the cane dusted twice, as would be recommended in practice.

Nymph and adult populations were assessed by shake sampling

(3.2.2/c). In addition to this sampling, which was done before and after treatment, metre square plastic sheets were placed in the interrows before treatment, and from them mortality counts were made.

Egg sampling was done by the method described in 3.2.1.

The following trials are most conveniently considered as three different sets.

5.3.1 Set A

Objectives

- a. To investigate the effects of two insecticides on numicia populations and on its egg parasites. The previous year it had been noted that in a field near the experimental site (Mhlosinga, near Station respectively) dusting once with mercaptothion 5% against numicia in the presence of unhatched eggs had been followed by a striking increase in numbers of the following generation (3.8; Fig. 32).
- b. To assess the effects of numicia on cane yield.

Treatments and dosages

1. Controls

2 and 3 Aerial applications at the rate of 45 kg per ha of the following:

- (i) Mercaptothion (as Malathion) 5% dust, (2,2 kg a.i. per ha)
- (ii) Fenthion (as Lebaycid) 2½% dust; (1,1 kg a.i./ha)

Both chemicals were applied from a height of 1m above the cane.

Experimental area

A 40 ha field of 6-month-old spray irrigated cane was used (Fig. 50). The field consisted of three sections, separated by two roadways. Each section was divided by 3m irrigation breaks into blocks which served as individual plots. This set of trials is best considered as two separate experiments.

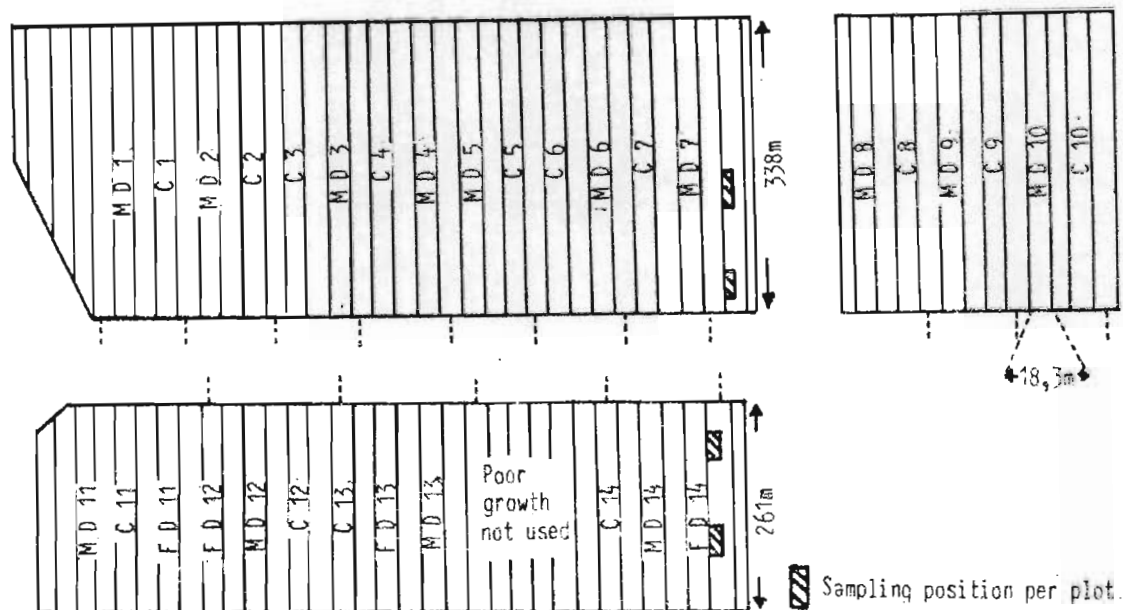


Fig. 50 Insecticide trial Set A : experimental area.

5.3.1.1 Experiment 1 : mercaptothion and control

Design

Randomised block with 10 replications of each treatment.

Variety NCo 310 or 4 replicates; NCo 376 on 6 replicates.

Plot details

Plots consisted of 0,61 ha each (18,3m x approx. 338m). Treatment plots were separated by a single guard plot of the same size, the intended functions of which were:

- to minimise the possibility of insecticide drift into the controls and
- to act as a barrier against reinvasion by numicia from controls into treated plots, since 5 to 10m of the guard plots also received insecticide.

5.3.1.2 Experiment 2 : mercaptothion fenthion and control

Design

Randomised block with 4 replications of each treatment.

Variety NCo 310 on 3 replications; NCo 376 on 1 replication.

Plots consisted of 0,46 ha each (18,3m x approx 261m) and the layout was as for Experiment 1. Use of fenthion was subordinate to the main trial, but was considered worth investigating, if only for its effects on parasitic wasps.

Procedure

The trial was treated on the 10 March and 25 May. (On the second occasion two fenthion plots were left untreated because insufficient insecticide was available).

Pre-treatment sampling was done the day before treatment, and post-treatment sampling was repeated three times for nymphs and adults and twice for eggs before the field was harvested in October 1966.

Results

Experiment 1

Mercaptothion 5% dust gave satisfactory control (Table 56).

TABLE 56. Mortality counts for numicia (nymphs and adults) and other insects following 2 aerial applications of mercaptothion.

Treatment	Average no. per m ²	
	Numicia	Other insects
Mercaptothion 5% dust, 1st application 10.3.66	76,9	115,1
Control	8,8	12,1
Mercaptothion 5% dust, 2nd application 25.5.66	5,2	22,2
Control	0,4	3,1

There was no suggestion of a subsequent increase in numicia populations following dusting. In all cases numbers declined until the following summer generation when a seasonal increase was recorded (Table 57). In

TABLE 57. Numicia numbers (nymphs and adults) in experimental area before and after aerial application of mercaptothion.

Treatment	Average no. per m ²			
	Before 1st appl.	Before 2nd appl.	After 2nd appl.	
	9.3.66	24.5.66	8.6.66	11.10.66
Mercaptothion 5% dust	79,0	15,8	5,4	14,6
Control	68,4	15,2	8,9	12,6

March and May 1966 the average numbers in 14 other fields on the estate (10 m² sampled per field) were 19,7 and 19,6 per square metre respectively. No significant decrease in egg parasitism was recorded for treated plots (Table 58). Plot yields showed no significant differences between treatments (Table 59).

TABLE 58. State of numicia eggs in leaves sampled from experimental area.

Treatment	Of 100 leaves sampled per plot		
	% leaves with eggs	Av. eggs/leaf (leaves with eggs only)	% eggs parasitised
Mercaptothion 5% dust before 1st appl. 9.3.66	74,2	21,4	29,4
Control	69,5	25,8	35,0
Mercaptothion 5% dust before 2nd appl. 24.5.66	61,6	22,7	21,4
Control	61,3	26,7	22,9
Mercaptothion 5% dust after 2nd appl. 31.8.66	20,5	18,7	24,0
Control	27,3	17,9	18,5

TABLE 59.

Plot yields from Experiment 1

Treatment	Average yield in tons cane/ha.		
	NCo 376	NCo 310	Mean
Mercaptothion 5% dust	116,5	80,2	101,9
Control	107,5	79,3	96,3
Difference	9,0	0,9	5,6
S.E.	6,6	8,1	5,1

Differences not significant

Experiment 2

There was an indication that mercaptothion gave better control than fenthion (Table 60). No subsequent increase in numbers resulting from treatment was recorded (Table 61). No significant decrease in egg

TABLE 60. Mortality counts for numicia (nymphs and adults) and all other insects following 2 aerial applications of mercaptothion and fenthion.

Treatment	Average no. per m ²	
	Numicia	Other insects
Mercaptothion 5% dust after 1st appl. 10.3.66	58,0	140,5
Fenthion 2½% dust after 1st appl. 10.3.66	34,2	55,8
Control	no figures available	
Mercaptothion 5% dust after 2nd appl. 25.5.66	6,5	12,8
Fenthion ⁽¹⁾ 2½% dust after 2nd appl. 25.5.66	1,0	6,0
Control	0,5	1,5

(1) Data from 2 plots only.

TABLE 61. Numicia numbers (nymphs and adults) in experimental area before and after aerial application of mercaptothion and fenthion.

Treatment	Average no. per m ²			
	Before 1st appl.	Before 2nd appl.	After 2nd appl.	
	9.3.66	24.5.66	8.6.66	11.10.66
Mercaptothion 5% dust	81,6	11,3	2,9	15,1
Fenthion 2½% dust	74,8	14,1	7,9	10,3
Control	76,7	13,5	8,1	11,6

parasitism was recorded for treated plots (Table 62). Plot yields showed no significant differences between treatments (Table 63).

TABLE 62. State of numicia eggs in leaves sampled from experimental area.

Treatment	Of 100 leaves sampled per plot		
	% leaves with eggs	Av.eggs per leaf (1)	% eggs parasitised
Mercaptothion 5% dust before 1st appl. 9.3.66	70,2	24,1	29,7
Fenthion 2½% dust before 1st appl. 9.3.66	65,0	20,3	28,6
Control	69,5	19,5	33,8
Mercaptothion before 2nd appl. 24.5.66	50,5	17,8	17,8
Fenthion before 2nd appl. 24.5.66	50,2	22,7	33,0
Control	52,0	23,0	15,1
Mercaptothion after 2nd appl. 31.8.66	16,5	15,6	14,3
Fenthion after 2nd appl. 31.8.66	10,2	14,5	11,1
Control	16,5	17,9	16,8

(1) Only leaves with eggs included

TABLE 63.

Plot yields from Experiment 2

Treatment	Average yield in tons cane per ha	
	Means of 4 reps	Means of 2 reps
Mercaptothion 5% dust	99,0	96,1
Fenthion 2½% dust	108,6	107,1
Control	106,4	102,6

S.E. of treatment means = 1,56

Differences not significant

5.3.2 Set BObjectives

To investigate the effects of two formulations of two insecticides on numicia and on its egg parasites.

Treatment and dosages

a. Controls

b. Mercaptothion (as Malathion 93%) ultra low volume concentrate at 0,7 litres per hectare without dilution (0,8 kg a.i. per ha). Applied at 2,5 kg/cm² pressure, flying 4m above the cane.

c. Mercaptothion (as Malathion) 5% dust at 45 kg/ha (2,2 kg a.i./ha).

d. Endosulfan (as Thiodan) 3% dust at 28 kg/ha (0,84 kg a.i./ha)

e. Endosulfan (as Thiodan) 5% dust at 28 kg/ha (1,4 kg a.i./ha)

Treatments c, d and e were applied from a height of 1m above the crop.

A 45 ha field of spray irrigated, 10-month-old cane of variety NCo 310 was used (Spray C). This was in the form of one rectangular block, subdivided by 3m irrigation breaks into sub-blocks, 20 of which served as plots (Fig. 51).

Design

An incomplete latin square with 4 replicates of each treatment

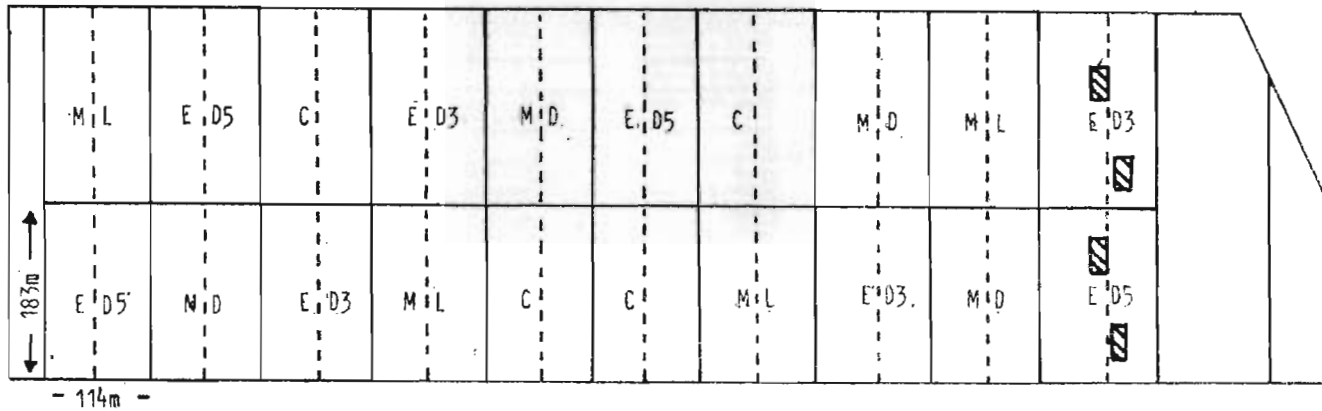


Fig. 51 Insecticide trial Set B : experimental area.

and for the gradual decrease in numicia numbers towards one end of the field as shown by pre-treatment sampling (Table 31).

Plot details

Each plot covered an area $114\text{m} \times 183\text{m}$ and consisted of two parallel half blocks, separated by a 3m irrigation break.

Procedure

Pre-treatment sampling was as before, but six metre-square mortality sheets per plot were used instead of two. Treatment was on the 13 October, and the following day all dead insects on the mortality sheets were collected.

The first shake sampling following treatment was done after four days and since all numicia collected were alive they were regarded as survivors. Shake sampling was done in undisturbed cane within a few metres of the original sampling positions. The afternoon following treatment many dead numicia were noted in the breaks and floating in irrigation run-off water, but were not noted subsequently. Shake sampling was repeated periodically up to 44 days after treatment. Egg sampling was repeated after 18 and 30 days.

Results

The only evidence of significant differences among treatments was that of lower mortality (from dead insects collected on sheets) in the control compared with treated plots, and a lower mortality from endosulfan 3% dust compared with endosulfan 5% dust (Table 64).

TABLE 64. Mortality counts for numicia (nymphs and adults) following aerial application of mercaptothion and endosulfan (Set B).

Treatment		Log. of average no. per m ²
Mercaptothion 93% ULV concentrate		2,12
"	5% dust	2,08
Endosulfan	3% "	1,96
"	5% "	2,34
Control		1,49

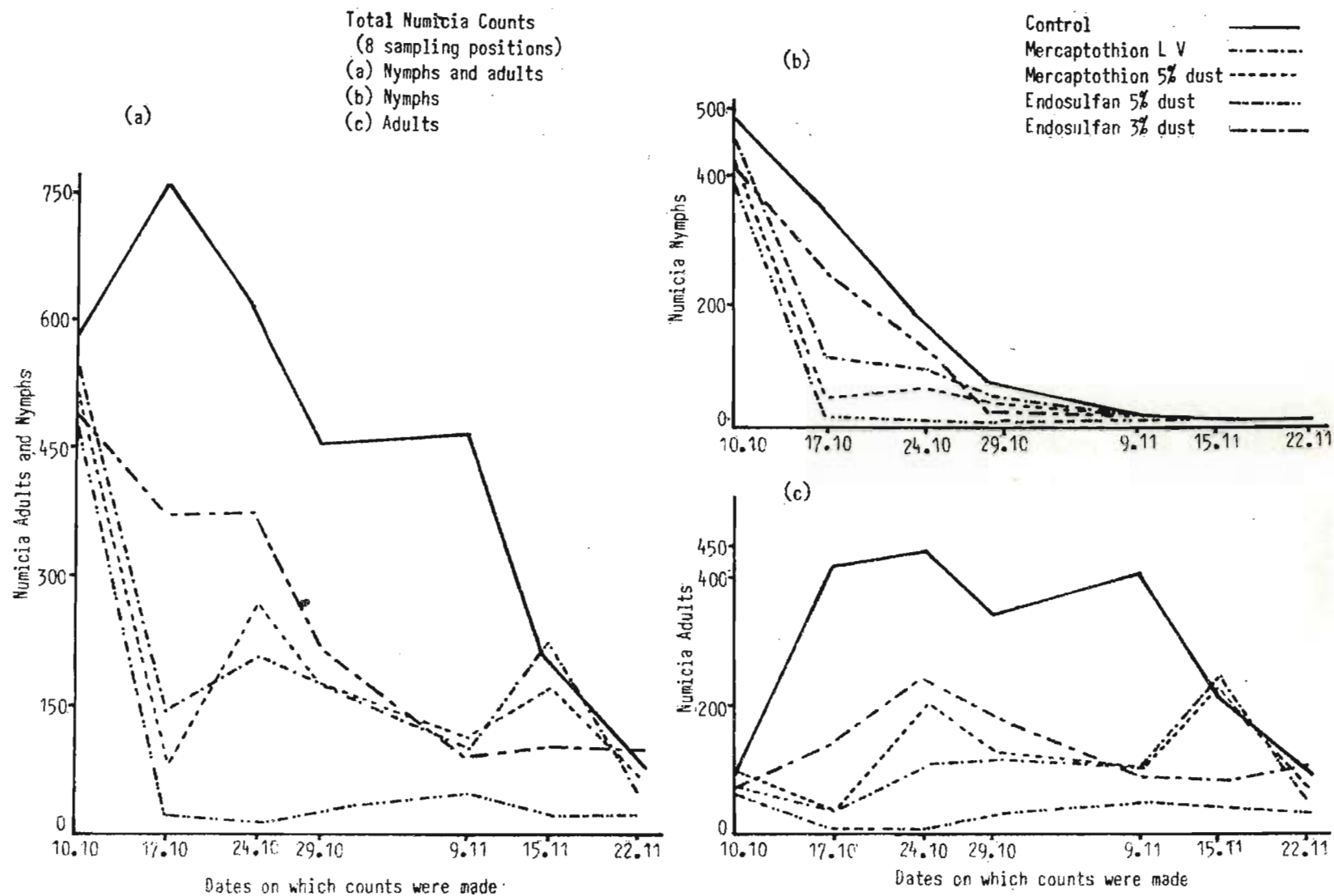
S.E. treatment mean = 0,079

L.S.D. (0,05) = 0,31

L.S.D. (0,01) = 0,51

Shake count results obtained after 24 October (Fig. 52) were not included in the analysis because of a normal seasonal decrease in population numbers as nymphs matured into adults, which laid eggs and died. Analysis of counts made on 17 October showed significantly lower numbers compared with control for mercaptothion 5% dust, and endosulfan 5% dust treatments respectively ($P < 0,05$). The reduction in numbers due to treatment with mercaptothion low volume was very nearly significant, but the reduction in numbers from use of endosulfan 3% dust was not. Of all treatments endosulfan 5% dust was the most effective. Similar trends were evident with counts made on the 24 October, although only endosulfan

Fig. 52 Insecticide trial Set B : numicia population counts before and after treatments.



5% dust caused a statistically significant reduction in numbers when compared with the control. No significant association with pre-treatment counts could be shown.

The period between treatments and harvest was too short for any definite conclusions to be drawn on the effect of these insecticides on egg parasitism.

5.3.3 Set C

Objectives

To investigate two formulations of two insecticides on populations of numicia noting any differences in "knock-down" effects.

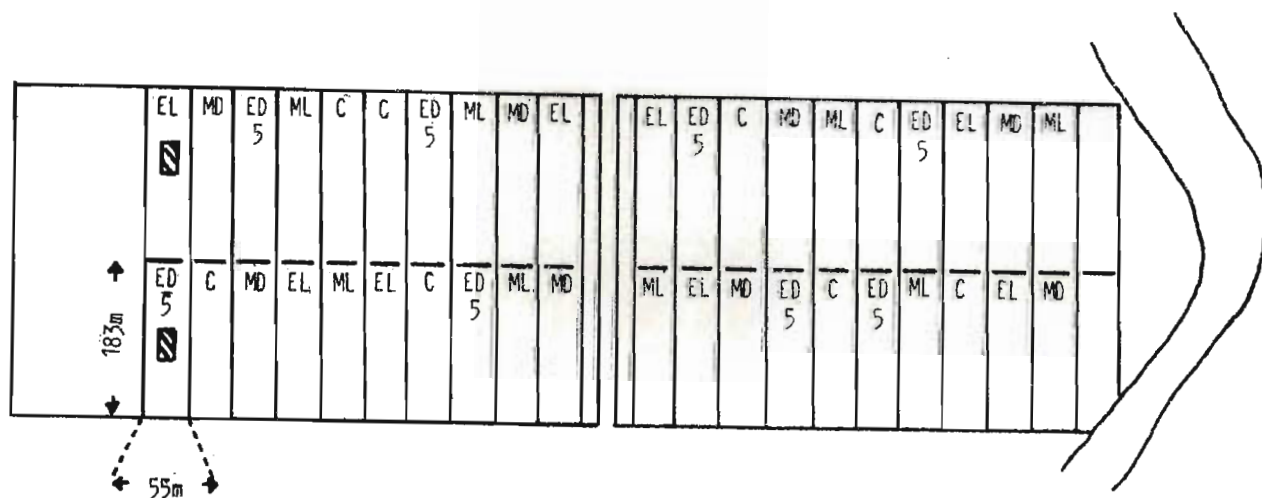
Treatments and dosages

- Controls
- Mercaptothion (as Malathion) ultra low volume concentrate at 0,45 litres/ha without dilution (1,3 kg a.i./ha)
- Mercaptothion (as Malathion) 5% dust at 45 kg/ha (2,2 kg a.i./ha)
- Endosulfan (as Thiodan) 5% dust at 33,6 kg/ha (1,7 kg a.i./ha).

Treatments b and d were applied from a height of 2,5m for the outer two swaths, and six metres for the control swath. Treatments c and e were applied from a height of 1,5m.

Experimental area

A 46 hectare field of spray irrigated, 9-month-old cane of variety NCo 376 was used. Field lay out was as shown in Fig. 53.



Design

An incomplete latin square with eight replications of each treatment.

Plot details

Each plot covered an area of 185m x 55m, the width embracing three irrigation units, the centre one of which included a sampling area 20m long.

Procedure

Pre-treatment samplings of two square metres per plot were made, and five mortality sheets were placed in each plot.

The trial was treated on 13 September. Twenty-four hours after treatment all numicia on mortality sheets were counted and removed. Further counts were made after 48 hours and after five days. Scarcity of endosulfan LV permitted only four replicates to be treated. Shake sampling was repeated periodically after treatment.

Results

When assessed from counts of dead insects on sheets (Table 65) effective control was achieved by the insecticides. These results show no

TABLE 65. Mortality counts for numicia (nymphs and adults) following aerial application of mercaptothion and endosulfan (Set C).

Treatment	Average no. per m ² after			
	24 hr	48 hr	5 days	Total
Mercaptothion 5% dust	44,1	11,5	5,0	60,6
" ULV	45,2	20,5	13,6	79,3
Endosulfan 5% dust	24,9	38,6	6,0	69,5
" LV	40,7	14,9	1,0	56,6
Control	5,5	5,6	0,7	11,8

Figures are averages for 5 replications per plot.

significant differences among the insecticides in their effectiveness. Shake sampling was started 12 days after treatments and continued at approximately weekly intervals for two months. Results are shown in Fig. 54. (The figure also shows a decrease in numicia numbers for the

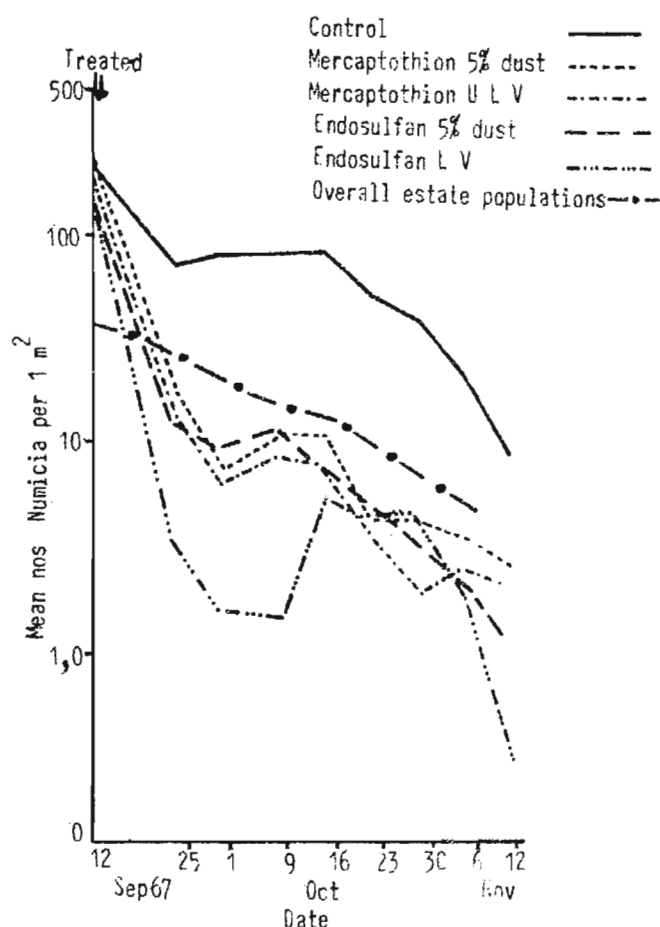


Fig. 54 Insecticide trial Set C : numbers of living numicia (nymphs and adults) collected from experimental plots, and mean estate populations for the same period.

whole estate. The means are of 10 shake samples for 20-25 fields on each sampling date). Fig. 54 has a logarithmic vertical axis. An analysis of numicia numbers obtained from sampling on 25 September 1967 showed significantly fewer survivors in mercaptothion treated plots than in the controls ($P < 0.01$). Numbers in endosulfan treated plots showed

a reduction when compared with mercaptothion treated plots ($P < 0.01$). The low volume treatment appeared to be more effective than the dusts, the endosulfan treatment being most effective of all. There was an indication also that repopulation began approximately two weeks after treatment, at which time metamorphosis to the adult state had started.

5.4 Discussion of chemical control of numicia

Numicia was found to be readily susceptible to the more commonly used insecticides. However, during early campaigns against it, it was apparent that dusts were more effective than wettable powders, presumably because the billowing effects of dusts enabled them to reach the insects, which are found more commonly on the lower leaf surfaces (2.23.1). With this in mind and the fact that infestations of the insect are accompanied by a build up of natural enemies, including two useful wasp parasites, it was decided to test two potentially suitable non-persistent insecticides and formulations. It was found that low volume formulations were equally effective or more effective than dusts, and that endosulfan, which has a reputation for being relatively harmless to certain beneficial insects was more effective than other insecticides tested.

It was not possible to study the effects of the various treatments on the natural enemies of numicia, but it was found that egg parasitism persisted even where mercaptothion had been used. Lack of significant differences in egg parasitism among the different treatments was interesting. Whether this was due to survival or repopulation is uncertain; but it was subsequently noted that when numicia adults invaded a newly planted cane field their egg parasites appeared, even several hundred metres from surrounding cane and grasses, within nine weeks (3.7.7). In these trials there was always untreated cane within a few metres of treated plots.

No satisfactory estimate of crop loss was possible from insecticide trials, partly because infestations studied were not of an order likely to cause extensive damage, and partly because plots which were

placed sufficiently close to eliminate agronomic variables were subject to insecticide drift effects. Observation of affected sugar estates has suggested that there is considerable crop loss (3.8.1; Appendix XIIa).

The rather high numbers of insects sometimes collected from control plots (Table 56) suggests that insecticide drift occurred. It is possible also that some dusted insects, perhaps disturbed by the operation, flew as far as the control plots before dying.

Insects other than numicia which were collected on mortality sheets were not fully classified, but they consisted mainly of small Diptera, Lepidoptera, Homoptera and Orthoptera. The only other pest species collected was Perkinsiella saccharicida, but in small numbers. Towards the end of the year the lower figures obtained in Set A, both for percentage leaves with eggs and for average numbers of eggs per leaf, were a reflection of the general decrease in numicia numbers in that field.

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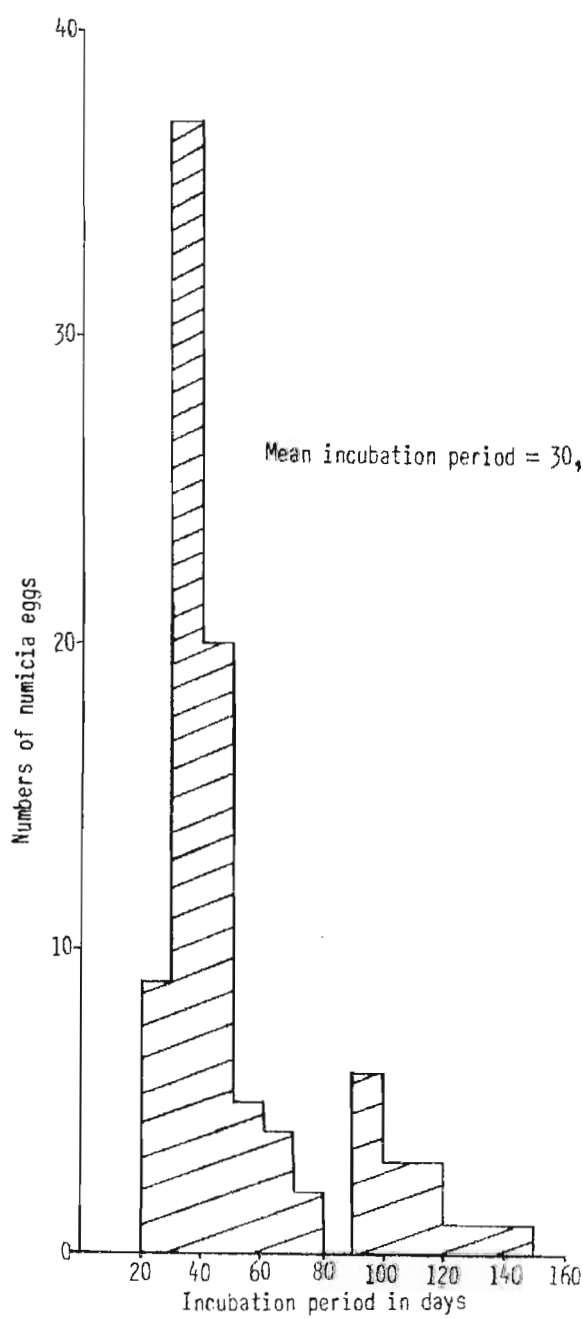
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APPENDIX I

Numicia egg incubation periods; insectary records



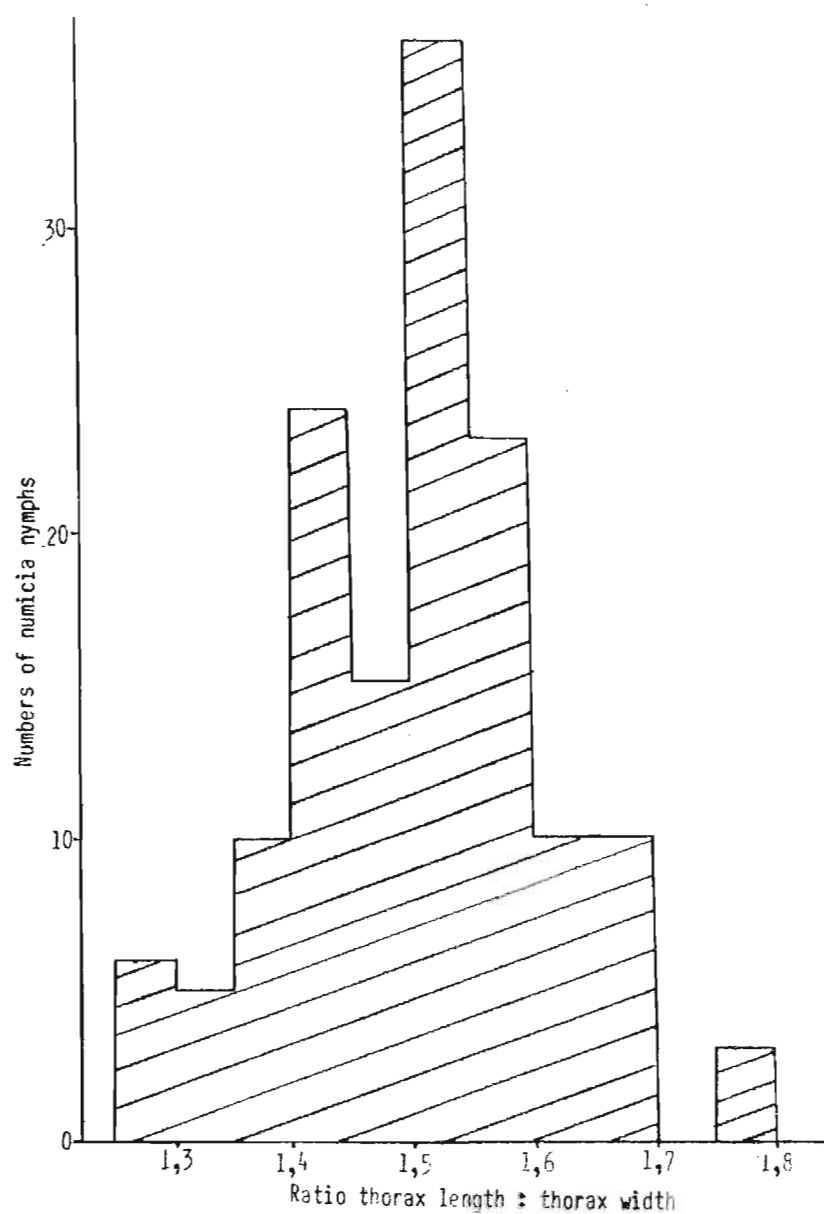
APPENDIX II

Numicia egg hatching times : insectary records

Date	Culture No.	Time
29. 6.66	Harris' record	a.m.
"	"	"
"	"	"
"	"	"
14. 4.70	5	p.m.
28. 5	1	a.m.
30. 5	5	"
5. 6	2	"
6. 6	2	"
8. 6	2	"
"	6	"
10. 6	2	"
10. 6	8	"
"	"	"
"	11	"
11. 6	11	"
"	"	"
13. 6	2	"
"	"	"
14. 6	2	"
"	"	"
16. 6	4	"
"	"	"
21. 6	2	"
"	"	"
"	"	"

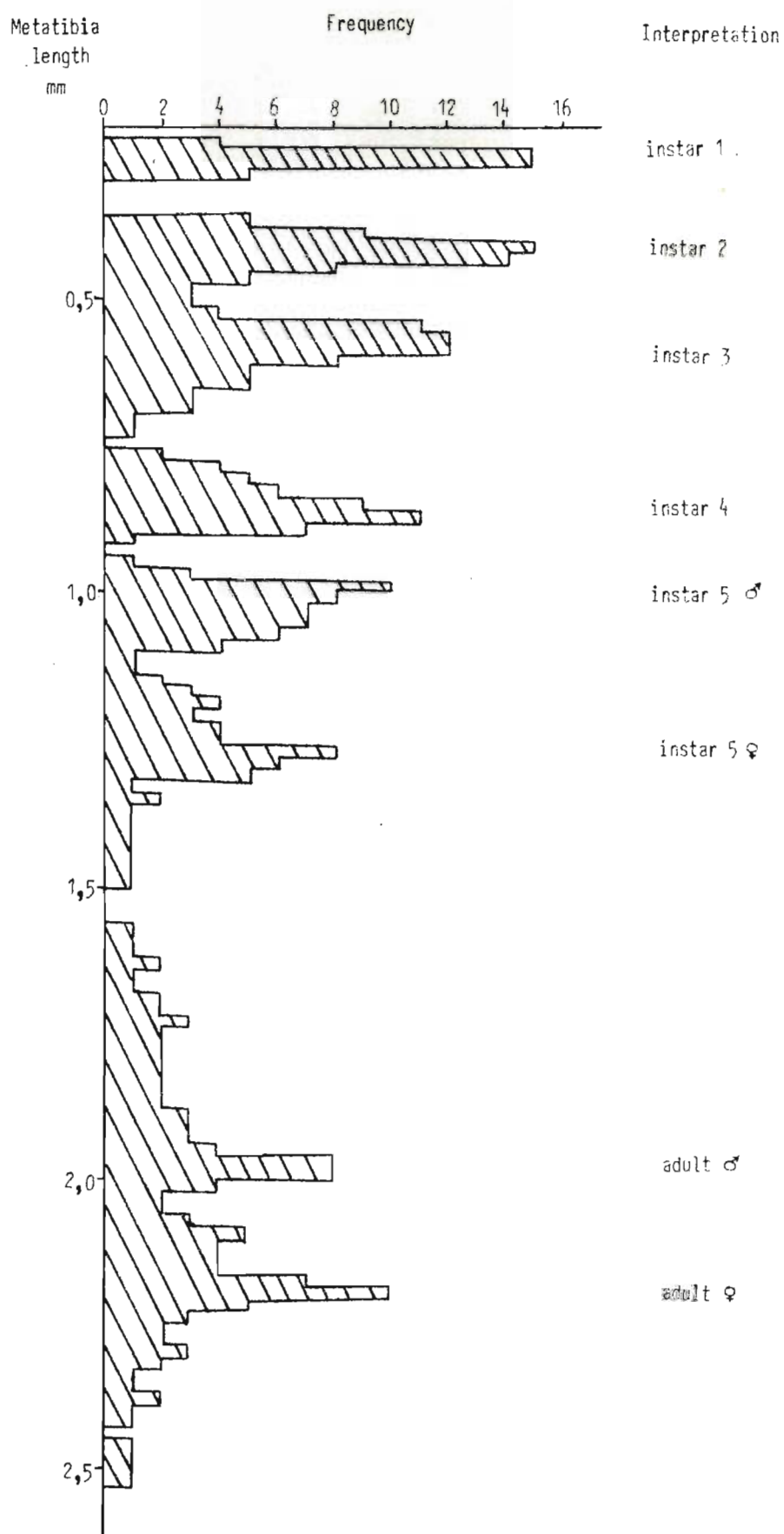
APPENDIX III

Ratio of thorax length to width of 142 numicia nymphs (mainly first instar, but including a few second instar nymphs). The absence of two obvious and approximately equal peaks suggests that there was no sexual dimorphism regarding thoracic dimensions.



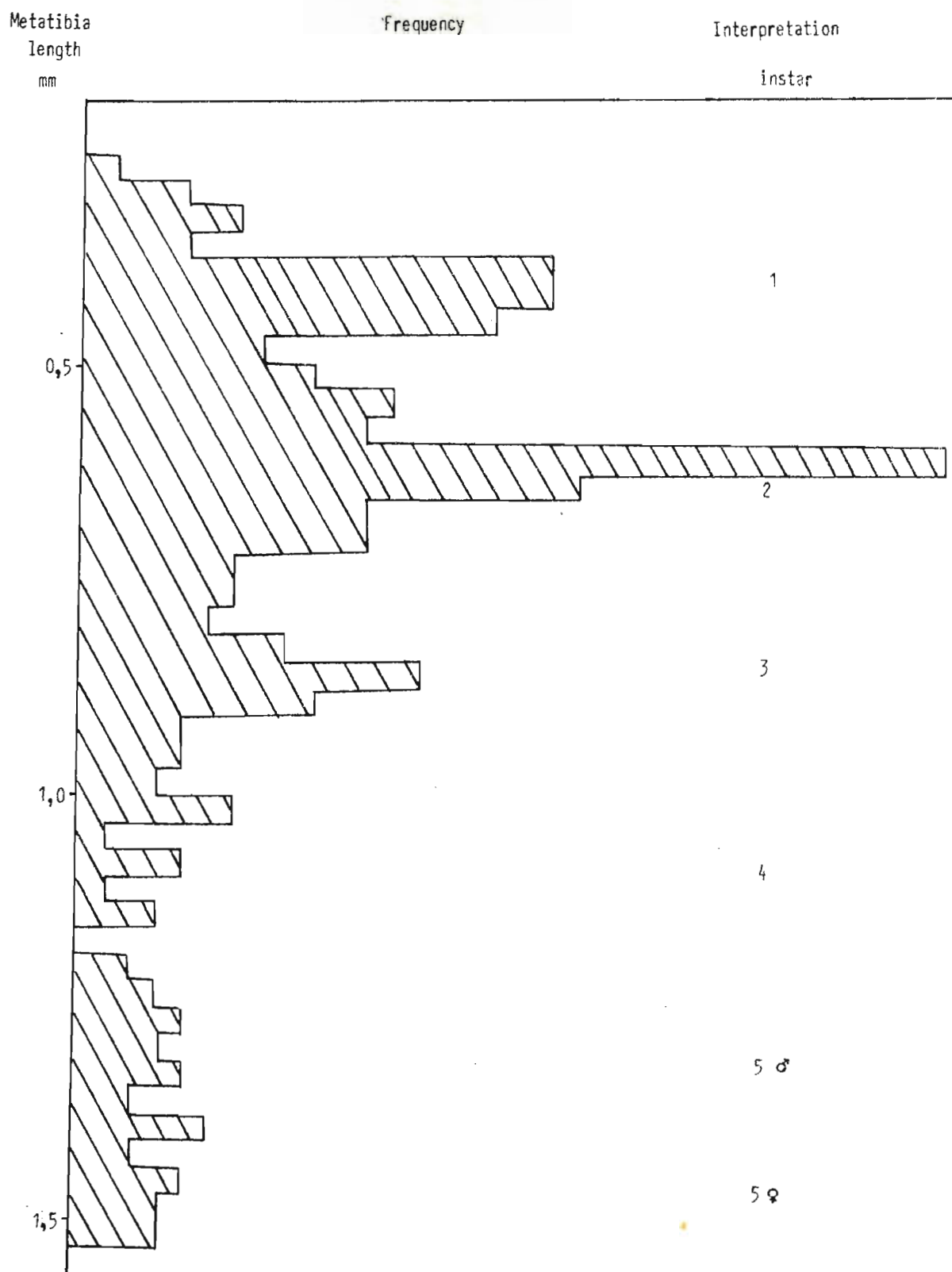
APPENDIX IVa

Metatibia lengths measured from numicia exuviae



APPENDIX IVb

Metatibia lengths measured from living nymphs



Numicia moulting times : insectary records

Date	Culture No.	Nymph or Adult	Time (approx).	Date	Culture No.	Nymph or Adult	Time (approx).
5.6.70	1	N	a.m.	11.8.70	11	N	3.30 p.m.
8.6	2	"	"	12.8	4	"	a.m.
"	5	"	"	"	11	"	"
12.6	6	"	"	"	8	A	"
17.6	8	"	"	14.8	5	N	"
19.6	1	A	p.m.	"	12	"	9.15 a.m.
20.6	2	N	a.m.	"	12	"	11.15 a.m.
23.6	12	"	p.m.	"	8	A	11.00 a.m.
24.6	13	"	a.m.	16.8	13	N	8.00 a.m.
25.6	13	"	"	17.8	11	"	8-8.30 a.m.
30.6	10	"	"	"	"	"	a.m.
2.7	8	"	"	"	"	"	"
"	11	"	"	"	13	A	9.30 a.m.
5.7	12	"	"	18.8	11	N	a.m.
11.7	13	"	"	19.8	4	"	"
12.7	13	"	"	20.8	8	A	8.30 a.m.
14.7	2	"	"	21.8	5	N	7.30 a.m.
"	6	"	"	"	12	A	"
15.7	4	"	"	24.8	5	"	a.m.
20.7	12	"	"	25.8	12	N	11.30 a.m.
21.7	13	"	"	"	2	"	"
22.7	12	"	"	"	13	A	"
"	10	"	"	"	11	"	11.45 a.m.
23.7	12	"	"	26.8	2	N	7.30 a.m.
"	13	"	"	"	12	"	a.m.
29.7	13	"	11 p.m.	"	6	A	7.30 a.m.
"	11	"	p.m.	27.8	11	N	11.00 a.m.
30.7	11	"	a.m.	"	11	"	11.15 a.m.
2.8	12	"	p.m.	"	11	"	11.30 a.m.
4.8	8	A	a.m.	"	14	"	1.30 p.m.
6.8	10	"	"	28.8	11	"	8.00 a.m.
"	12	N	"	"	4	"	3.30 p.m.
"	13	"	"	29.8	5	"	8.00 a.m.
7.8	10	A	"	1.9	6	"	a.m.
"	11	N	"	5.9	5	A	"
9.8	11	"	"	9.9	11	N	6.00 a.m.
10.8	12	"	p.m.	9.9	2	"	8.00 a.m.
"	8	A	"	10.9	4	"	10.00 a.m.
11.8	11	N	a.m.	"	2	"	9.00 a.m.
"	8	A	"	"	"	"	"

APPENDIX VINumicia adult sex ratios from field collections

Total	Male	Female	Mean difference
	2231	1852	25,27

S.E. of mean difference = 19,28

t (14 D.F.) = 1,31 N.S.

APPENDIX VII

Daily numicia counts in roof area of insectary
type 1 cage.

Total adults			
a.m.	noon	p.m.	noon
231	154	246	146

$$\chi^2 = \frac{2(38,5)^2}{192,5}$$

$$= 15,4 ***$$

$$\chi^2 = \frac{2(50)^2}{196}$$

$$= 25,5 ***$$

APPENDIX VIIIaPosition of numicia on cane leaves in insectary cultures

Upper surface			Lower surface			
Nymphs	Adults	Total	Nymphs	Adults	Total	
96	0	96	481	0	481	no adults
10	0	10	0	18	18	
174	122	296	380	140	520	
0	133	133	2	9	11	
80	39	119	392	107	499	
69	0	69	452	77	529	
23	10	33	243	156	399	
192	10	202	582	37	619	
16	0	16	78	0	78	no adults
0	11	11	0	128	128	no nymphs
532	59	591	1260	182	1442	
0	104	104	0	32	32	no nymphs
101	0	101	252	0	252	no adults
71	2	73	417	27	444	
9	2	11	159	0	159	
130	12	142	250	0	250	
1503	504	2007	4948	913	5861	

Nymphs

$$\text{Pooled } \chi^2 = 2 \frac{(1722^2)}{3226}$$

D.F.

$$= 1838,4 \quad 1 \quad P < 0,001$$

$$\text{Total } \chi^2 = 2012,0 \quad 12 \quad "$$

$$\text{Heterogeneity } \chi^2 = 174,6 \quad 11 \quad "$$

Adults

$$\text{Pooled } \chi^2 = 2 \frac{(204,5^2)}{708,5}$$

D.F.

$$= 118,1 \quad 1 \quad P < 0,001$$

$$\text{Total } \chi^2 = 566,9 \quad 9 \quad "$$

$$\text{Heterogeneity } \chi^2 = 448,8 \quad 8 \quad "$$

Direction faced by numicia on cane leaves in insectary cultures

Upward facing			Downward facing			Horizontal			
Nymphs	Adults	Total	Nymphs	Adults	Total	Nymphs	Adults	Total	
479	0	479	72	0	72	26	0	26	no adults
7	13	20	2	5	7	1	0	1	
435	196	631	91	50	141	28	16	44	
1	104	105	0	33	33	1	3	4	
371	90	461	93	51	144	8	5	13	
380	56	436	123	19	142	18	2	20	
224	105	329	41	56	97	1	5	6	
572	43	615	138	4	142	64	0	64	
66	0	66	25	0	25	3	0	3	no adults
0	88	88	0	47	47	0	5	5	no nymphs
1346	154	1500	364	70	434	82	17	99	
0	110	110	0	11	11	0	15	15	no nymphs
313	0	313	34	0	34	6	0	6	no adults
445	23	468	32	6	38	11	0	11	
138	2	140	30	0	30	0	0	0	
221	8	229	129	7	136	25	0	25	
4998	992	5990	1174	359	1533	274	68	342	

Nymphs facing up or down

$$\text{Pooled } \chi^2 = \frac{2(1912^2)}{3086}$$

D.F.

$$= 2369,2 \quad 1 \quad P < 0,001$$

$$\text{Total } \chi^2 = 2476,6 \quad 12 \quad "$$

$$\text{Heterogeneity } \chi^2 = 107,4 \quad 11 \quad "$$

Adults facing up or down

$$\text{Pooled } \chi^2 = \frac{2(316,5^2)}{675,5}$$

D.F.

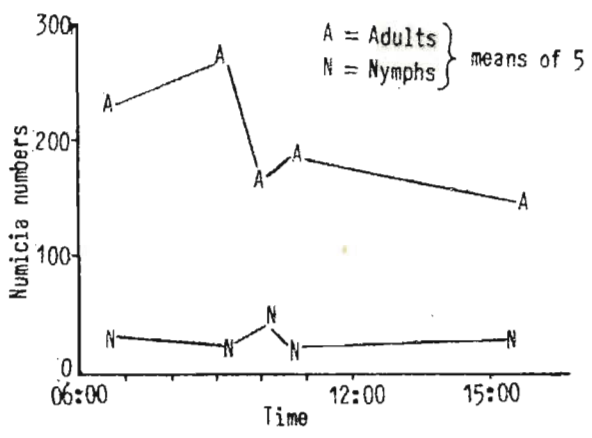
$$= 296,6 \quad 1 \quad P < 0,001$$

$$\text{Total } \chi^2 = 239,1 \quad 11 \quad "$$

$$\text{Heterogeneity } \chi^2 = 32,5 \quad 10 \quad "$$

APPENDIX IXa

Numbers of numicia sampled, by shaking cane, at
different times of day; Ubombo Ranches



APPENDIX IXb

Variation in numicia numbers recorded by 3 samplers
(shaking cane); Ubombo Ranches.

i) Nymphs

		Area				
		1	2	3	4	5
Sampler 1		16	12	21	9	16
Sampler 2		15	9	20	15	17
Sampler 3		11	38	27	21	8
<u>Mean counts</u> (log. transformed data)						
1	1,1527			F		N.S.
2	1,1675			S.E. diff. of means	0,13	
3	<u>1,2555</u>			L.S.D. (0,05)		0,30
Mean	1,1919			(0,01)		0,44

ii) Adults

		Area				
		1	2	3	4	5
Sampler 1		107	153	93	97	80
Sampler 2		121	120	80	94	73
Sampler 3		84	133	59	69	64
<u>Mean counts</u> (log. transformed data)						
1	2,0153			F		**
2	1,9803			S.E. diff. of means	0,03	
3	1,8928			L.S.D. (0,05)		0,07
Mean	1,9628			(0,01)		0,09

APPENDIX X

Numicia egg parasitism (% eggs parasitised) in insecticide-treated and in untreated fields

Treated fields : Mhlosinga, Spray C

Untreated " : Compound, Mpembe, Road

1. Compound and Mhlosinga

Total (32 samplings)	Compound	Mhlosinga	Mean difference
	827,81	331,71	15,503
S.E. of mean difference = 3,46			
t (31 D.F.) = 4,48**			

The greater percentage parasitism in the untreated field was highly significant

2. Compound and Spray C

Total (26 samplings)	Compound	Spray C	Mean difference
	626,86	409,84	8,35
S.E. of mean difference = 2,68			
t (25 D.F.) = 3,12 **			

The greater percentage parasitism in the untreated field was highly significant.

3. Compound and Mpembe

Total (25 samplings)	Compound	Mpembe	Mean difference
	592,10	336,76	10,22
S.E. of mean difference = 3,37			
t (24 D.F.) = 3,03 **			

The greater percentage parasitism in Compound was highly significant despite the fact that neither field was treated.

4. Compound and Road

Total (30 samplings)	Compound	Road	Mean difference
	754,34	969,40	7,17
S.E. of mean difference = 4,14			
t (29 D.F.) = 1,73 N.S.			

In these two untreated fields the percentage parasitism in Road was higher than in Compound, but the difference was not significant.

APPENDIX XI

Effects on numicia eggs in cane treated weekly
with dimethoate at 0,46 litres a.i. per hectare

Variety	Untreated			Treated		
	Total	Parasitised	% parasitised	Total	Parasitised	% parasitised
NCo376 3541		1475	41,6	1308	388	29,7
NCo339 1866		787	42,2	610	219	35,9
Total 5407		2262	41,8	1918	607	31,7

Comparison of yields (in tons cane per hectare-month) from cane fields at Ubombo Ranches, similar in respects other than infestation level.

High infestation				Low infestation			
Field	Peak (x1000 nymphs)	Date	Yield (TPHM)	Field	Peak (x1000 nymphs)	Date	Yield (TPHM)
Mhlosinga B	4,2	8.65	6,00	Spray A	0,7	3.66	6,90
				End C	0,06	10.66	5,91
				Banana	(no record)		<u>7,41</u>
				Total			20,22
				Mean			6,74
Station	3,2	1.66	9,18	Cascade	0,9	9.66	9,72
				Speculation 5	0,08	9.66	11,20
				Spray E	(no record)		9,65
				Boundary N	"		<u>9,65</u>
				Total			40,22
Cascade 2A	7,0	8.65	6,32	Spray A	0,7	3.66	7,41
				End C	0,06	10.66	5,91
				Circle E	0,07	6.65	9,61
				Boundary W	(no record)		8,62
				First Lines A	"		7,24
Compound N	1,6	8.65	6,88	" " B	"		<u>7,19</u>
				Total			45,98
				Mean			7,66
				Spray D	1,2	9.65	8,06
				Mpembe	2,1	-	7,91
				Vubu A	0,1	-	13,26
				Swamp	(no record)		6,20
				Mamba	"		6,68
				Quarry	"		8,40
				Hollander N	"		7,19
				Mbogodo 1	"		<u>7,46</u>
				Total			65,16
				Mean			8,15

Difference between means from fields of
high and low infestations

= 1,06 metric tons per hectare-
month.

Results of analysis of numicia population level and agronomic field data; Ubombo Ranches, 1964-69. (Summary only; full details of computerised analysis are filed at the Mount Edgecombe Experiment Station).

Multiple regression analysis

Objectives

- a. To test whether variety, crop or irrigation type have any influence on numicia numbers
- b. To test whether numicia numbers have any effect on cane yield

Data

Nymph numbers only were used, because heaviest feeding occurs in this stage, and movement by nymphs is negligible.

Numbers used consisted of counts obtained from estate sampling from 1964 to 1969 at Ubombo Ranches, Swaziland.

Counts were classified into three generations: (i) November to January (ii) February to May (iii) June to October.

Estate records of tons cane per acre, cane age, month of harvest, crop (plant, first ratoon, etc), variety, irrigation type (overhead or surface), section of estate, year of recordings were associated with numicia counts from the fields sampled.

All fields were not represented in each year or sampled for each generation.

A total of 164 crops are represented in the data, i.e. 98 crops with generation 1, 105 with generation 2, and 135 with generation 3. (Some crops included more than one generation).

Model

a. Factors affecting numicia numbers

The model included terms for:

- (i) Years 1964 - 68
- (ii) Estate sections 1-7
- (iii) Variety a) other vs NCo 376 + NCo 310

b) NCo 376 vs NCo 310

(iv) Irrigation: sprinkler vs surface

(v) Crop: plant vs ratoon

The purpose of having terms for years and sections was to remove unwanted variation arising from these sources.

The regression model was fitted to both mean and peak numicia numbers for each generation.

Numicia numbers were transformed to $\log(\text{number} + 1)$.

Results

	Variety		Irrigation	Crop
	(376+310-others)	(310-376)	(spray-surface)	(plant-ratoon)
Gen. 1				
Peak	$-0,120 \pm 0,065$	$0,047 \pm 0,091$	$0,086 \pm 0,099$	$0,068 \pm 0,108$
Mean	$-0,133 \pm 0,057$	$0,023 \pm 0,080$	$0,058 \pm 0,087$	$0,060 \pm 0,094$
Gen. 2				
Peak	$0,013 \pm 0,047$	$0,006 \pm 0,067$	$-0,062 \pm 0,075$	$-0,017 \pm 0,073$
Mean	$0,035 \pm 0,043$	$0,051 \pm 0,061$	$0,023 \pm 0,069$	$0,054 \pm 0,066$
Gen. 3				
Peak	$0,097 \pm 0,057$	$0,045 \pm 0,083$	$0,000 \pm 0,100$	$0,002 \pm 0,091$
Mean	$0,082 \pm 0,053$	$0,022 \pm 0,076$	$0,013 \pm 0,092$	$-0,019 \pm 0,084$

There is no significant evidence that any of the above factors are associated with numicia numbers.

b. Effect of numicia numbers on cane yield

Yield was measured as tons cane per acre.

The model included terms for:

(i) Potential production for the period of growth. This was a summation of the potential evapo-transpiration for the months during which the crop grew. (Average monthly E_t for the northern inland irrigated areas was taken from Experiment Station records).

(ii) Years 1965 - 68

(iii) Estate sections 1 - 7

(iv) Variety a) other vs NCo 376 + NCo 310

b) NCo 376 vs NCo 310

- (v) Irrigation type
- (vi) Crop: plant, 1st, 2nd, 3rd, 4th, 5th-plus ratoons
- (vii) Numicia numbers, transformed to $\log(\text{number} + 1)$.

The inclusion of terms other than numicia numbers was to eliminate from yield data possible variation arising from these sources

Results

	Regression coefficient	S.E.	t value
Generation 1 Peak	1,68	$\pm 1,20$	1,40
Mean	1,03	$\pm 1,37$	0,75
Generation 2 Peak	-4,70**	$\pm 1,48$	3,19
Mean	-5,31**	$\pm 1,60$	3,32
Generation 3 Peak	-2,09*	$\pm 0,98$	2,13
Mean	-2,21*	$\pm 1,05$	2,09

For generation 1 there was no evidence that an increase in numicia numbers was associated with a depression in yield.

However, for generations 2 and 3 evidence of a trend for lower yield with increased numicia numbers was significant ($P < 0,01$ and $0,05$ respectively).

A check on this result was done by estimating the simple regression of yield in tons cane per acre on $\log(\text{number} + 1)$ for each year, using mean numbers for generation 2:

Year	Mean log	Mean t.c.a.	Correl. coeff.	Regr. coeff.
1965	1,01	58,4	0,05	$2,4 \pm$
1966	1,84	53,5	-0,48	$-8,2 \pm$
1967	1,74	50,3	0,14	$2,5 \pm$
1968	1,76	45,3	-0,55	$-9,1 \pm$

The results do not indicate any inadequacy in the multiple regression model.

APPENDIX XIII

Annual numicia survey; incidence by topography, irrigation, crop.

% sites positive	1963	1964	1965	1966	1967	1968	Average	t test
Topography								
Alluvial flats	37,5	79,4	73,3	57,1	66,7	70,2	64,0	
Other	22,9	61,8	43,0	56,8	56,3	53,7	49,1	N.S.
Irrigation								
Irrigated	36,1	81,2	68,9	67,7	79,0	68,2	66,9	
Non-irrigated	22,8	56,6	42,1	51,4	53,2	48,0	45,7	P < 0,05
Crop								
Plant	-	70,0	53,8	50,0	67,9	52,8	58,9	
Ratoon	-	61,6	50,9	59,5	53,2	63,1	57,7	N.S.

Percentage dead egg parasites from nympha eggs in different plant media 1965-1966 (*Ootetrastichus beatus* and *Oligosita* sp. combined, except for March and April 1966).

Medium	June '65	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '66	Feb.	March		April		Mean (June-Feb)
										<i>O.beatus</i>	<i>Oligosita</i>	<i>O.beatus</i>	<i>Oligosita</i>	
Dry cane	6,6	-	60,0	51,6	81,3	-	-	100,0	75,0	-	-	-	-	62,4
<i>O.sexangularis</i>	0,0	0,0	34,5	19,7	25,5	31,3	30,6	46,4	20,0	47,5	100,0	64,1	100,0	23,1
<i>P.thunbergii</i> leaves	0,0	0,8	50,9	14,2	9,1	9,8	-	77,8	21,8	-	-	35,7	-	23,0
Green cane	8,1	7,9	3,6	34,1	74,2	36,4	15,4	14,3	8,0	80,0	-	0,0	0,0	22,4
<i>P.maximum</i> leaves	3,8	3,1	24,0	46,2	35,3	0,0	45,0	16,7	4,0	79,7	100,0	40,5	100,0	19,8
<i>P.maximum</i> stems	-	0,0	22,4	42,1	20,0	-	4,2	16,7	0,0	9,4	0,0	54,5	100,0	15,0
<i>P.thunbergii</i> stems	0,0	-	0,0	14,3	50,0	0,0	0,0	40,0	0,0	65,3	0,0	37,5	-	13,0
<i>R.repens</i> stems	0,0	20,0	4,5	41,9	-	0,0	0,0	15,4	0,0	23,2	0,0	48,5	34,8	10,2
<i>P.clandestinum</i> leaves	4,9	0,0	0,9	-	0,0	1,5	8,6	11,7	1,8	25,3	22,6	75,0	84,6	3,7
Mean	2,9	4,5	22,3	33,0	36,9	11,3	14,8	37,7	14,5					

= no parasitism or no figure available).

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