IMPLEMENTATION AND TECHNIQUES OF INSECT PEST MANAGEMENT OF SUGARCANE IN OKINAWA

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Introduction

History of systematic cane cultivation dates back to the 1640s in Okinawa. Like the logistic growth of human pupulation, the acreage of sugarcane at first slowly increased from 290 to 19,000 ha during a long period of *ca.* 3 centuries when an Okinawan variety called YOMITANZAN was allowed to grow only in a few restricted villages of Okinawa Is. until 1888. Thereafter the restriction was lifted and extensive cultivation could take place in other Okinawan islands such as Miyako and Ishigaki.

Several improved varieties were introduced from Taiwan to Okinawa in the 1910 - 20s. Among those, POJ 2725 was recommended for cultivation. POJ 2725 replaced YOMITANZAN by 1934 and POJ cultivation lasted until the late 1950s. Both YOMITANZAN and POJ were poor ratooners. Spring planting and annual renewal tended to prevail when YOMITANZAN was cultivated. POJ was available both for spring and summer plantings. Summer cane which takes 1.5 years for maturation was higher in yield than spring cane which matures after one year growth. Summer cane could hardly ratoon after the harvest but spring cane was able to ratoon only once. The spring-summer cane ratio was about 1:2 for POJ. Thus the standing plant types or age structure of cane at the time of harvest were somewhat diversified for POJ as they included immature summer cane (0.5-year old), mature spring cane (1-year old), mature summer cane (1.5-year old) and mature ratoon cane of spring cane origin (2-year old). However, remarkable increase in cane acreage did not occur when POJ was cultivated.

After World War II, cane breeders strove to select high yielding varieties with high sucrose content and high capacity of ratooning. NCo 310 was one of such varieties introduced from Taiwan to Okinawa in the 1950s. NCo 310 had replaced POJ 2725 by the end of the 1950s and its acreage rapidly increased to reach the peak of 30,000 ha in 1965. NCo 310 was a good ratooner irrespective of the two-season plantings. Moreover, the yield of summer cane was much higher than that of spring cane. Consequently, the spring-summer cane ratio increased to 1:5 on an average. Thus the age structure in NCo shifted to a much higher age group (ratoon cane) with plants more than 4-year old being common.

It is now recognized that unexpected outbreaks of some economically important pests of cane have been increasing with the cultivation of NCo (Ito, 1976; Azuma, 1977; Hokyo and Nagamine, 1978). Especially, infestation by some soil insect pests such as the wire worm, *Melanotus tamusyensis*, and the white grub, *Anomala albopilosa*, is severe in the remote islands of Okinawa Prefecture such as Minami-Daito Is., Ishigaki Is. and Miyako Is., as well as in a few restricted areas of the central and northern parts of Okinawa Is. Thus the NCo system of cultivation can not be carried out adequately without sound management of artificial and natural environmental components that influence the level of pest abundance.

Implementation and techniques

1 Dynamics and management of ratoon culture

Fig. 1 shows the trends of cane acreage in the five districts of Okinawa based on the Prefectural statistics of cane production from 1965-66 to 1978-79. The five districts cover about 90% of the total

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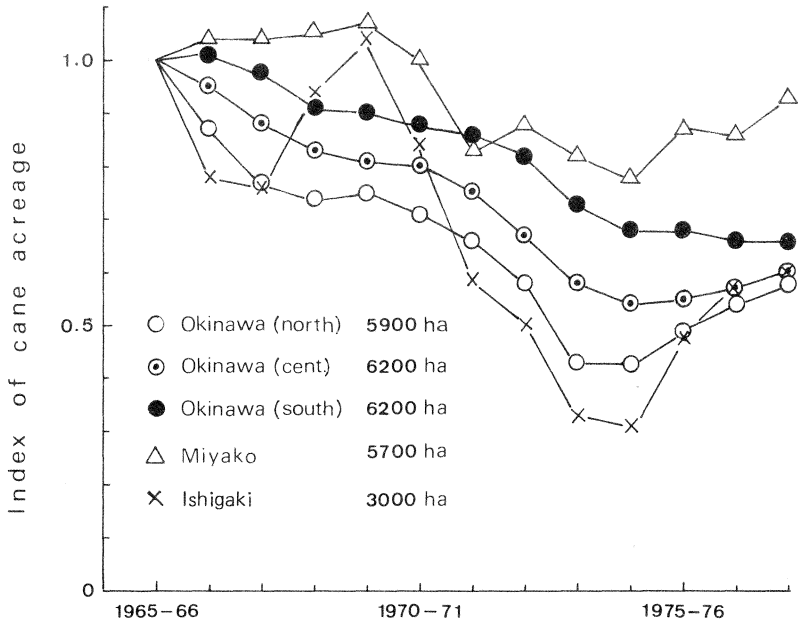

Fig. 1 Trends of cane acreage in the five districts of Okinawa from 1965-66 to 1978-79

acreage of cane in Okinawa.

After the peak of total acreage was reached in 1965-66, followed a phase of decline lasting until 1974-75. Such a decline was mainly caused by the high economic growth of mainland Japan which led to the extensive use of a vast area of the agricultural land of Okinawa. Thereafter there was a slow recovery largely due to the fact that other crops such as pumpkin, cabbage, haricot bean, etc., were being grown for export to the mainland, as well as for sericulture and stock farming.

The central and southern parts of Okinawa Is. are lowland districts where heavy clay soil called 'djagaru' is abundantly distributed. As 'djagaru' is moderately alkaline and has high water holding capacity, this soil is best for cane cultivation. The northern part of Okinawa Is. is a highland district with numerous mountains. There red soil called 'kunigami-maji' is abundantly distributed. However, 'kunigami-maji' shows variations in physical and chemical properties. The water holding capacity is generally low and the acidity ranges from weak to strong. On mountain slope and table land, pine-apple, fruit trees and rice are grown by preference. Cane is extensively grown in lowland areas. It is interesting to note that Ishigaki Is., which is located far to the south-west of Okinawa Is., has many characteristics similar to those of the northern part of Okinawa Is. Miyako Is. which is situated beside Ishigaki Is. is a flat island. There another kind of red soil called 'shimajiri-maji' is abundantly distributed. This soil is weakly alkaline to neutral. All the soils in Okinawa have a very low content of humus, which is commonly seen in tropical and subtropical areas. Consequently, the ratoon culture of NCo 310 has been sustained by the abundant use of chemical fertilizers.

Fig. 2 shows the mean annual percentages of the four types of standing cane at the time of harvest and their standard deviations throughout the same years. The percentage of ratoon cane is high in the central and southern part of Okinawa Is., viz. 76-79%, but it decreases to 67% in the northern parts of Okinawa Is., being 52% in Miyako Is. and 39% in Ishigaki Is. These differences are probably due to the differences in soil fertility among the five districts. However, the composition of

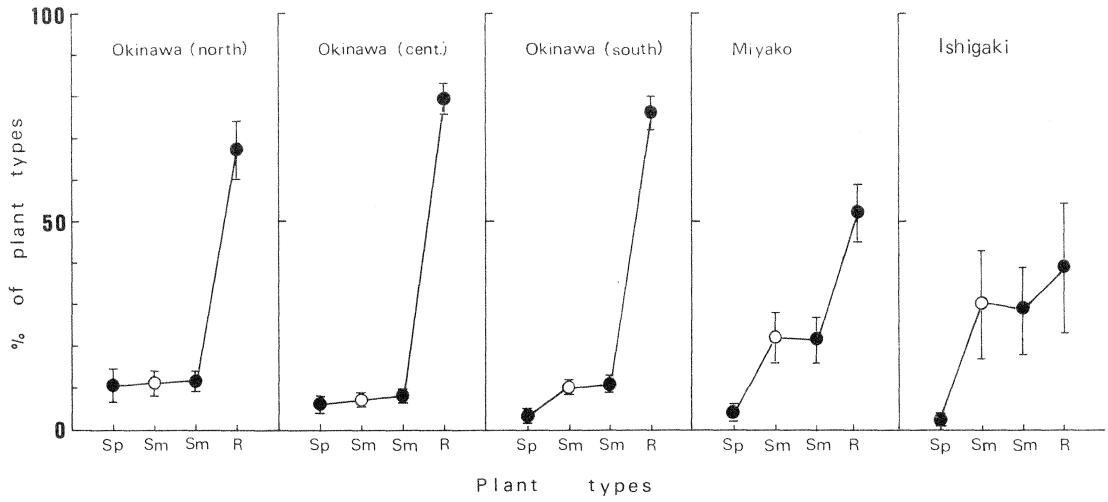

Fig. 2 Mean annual percentage of 4 types of standing cane at the time of harvest in the five districts of Okinawa
The mean percentages shown by the smeared circles correspond to the spring (Sp), summer (Sm) and rotoon (R) canes already mature for harvesting in the current year. The open circles correspond to the immature summer cane to be harvested in the next year.

the standing cane types greatly fluctuates within the years in Miyako Is. and especially in Ishigaki Is. as indicated by the high values of standard deviation. Thus some factors other than soil fertility are also important. Such differences in stability of the cane type composition are indicated in Fig. 3 where the annual changes in percentage of the acreage harvested are listed for each district. The remaining percentage, viz. 100 - percentage harvested, corresponds to the summer cane planted in the previous year.

It is apparent from Fig. 3 that about 90% of the total acreage is constantly harvested each year in the three parts of Okinawa Is., but only 77 and 70% are harvested on an average in Miyako Is. and Ishigaki Is. Such a low efficiency of cane production in the two islands is primarily due to the occurrence of abnormal ratooning of summer cane which began to be visible from 1974 onward and is caused by the severe infestation by soil insect pests. The recent infestation by soil insect pests is especially severe in Ishigaki Is. where the spring-summer cane ratio (1:17 on an average) is very high compared to that in Miyako Is. (1:6 on an average). The ratoon culture which predominates in summer cane is especially favourable for the development of soil insect pests in 'maji' soil areas (Hokyo, 1979 and in press; Nagamine, in press). In this connection, it is noteworthy that in the northern part of Okinawa Is. the spring-summer cane ratio is near 1:1. Among the differences in the spring-summer cane ratio, such factors as scale of farming, multiple land use in relation to rotation of cane and other crops, water availability (irrigation), degree of mechanization, local climate, etc. should be taken into account.

Fig. 4 shows the mean annual yields and their standard deviations for spring, summer and ratoon canes respectively in the five districts. When the yield of summer cane was divided into 1.5 years of the growth period the difference in yield did not appear to be remarkable between spring and summer canes in each district. The superiority in yield of ratoon cane to spring and summer canes is apparent in the three districts of Okinawa Is., but is less evident in Miyako Is. and especially in Ishigaki Is. because of the 30-40% reduction of yields in each crop type on an average and the great fluctua-

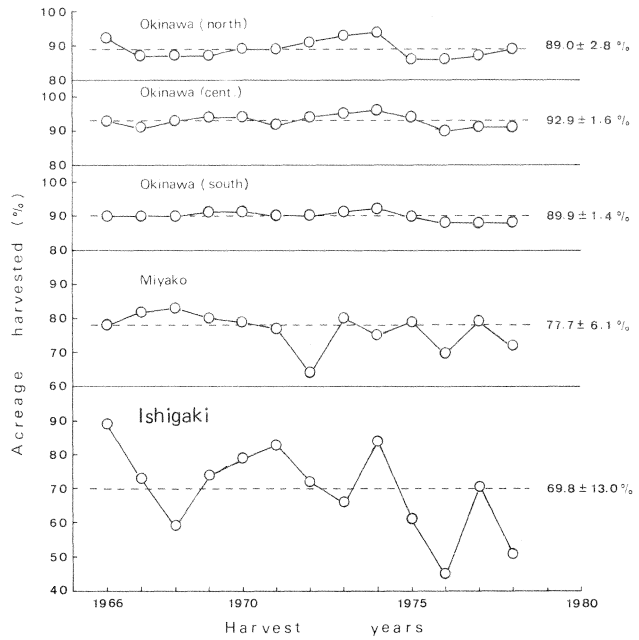

Fig. 3 Annual trends in percentage of cane acreage harvested in the five districts of Okinawa

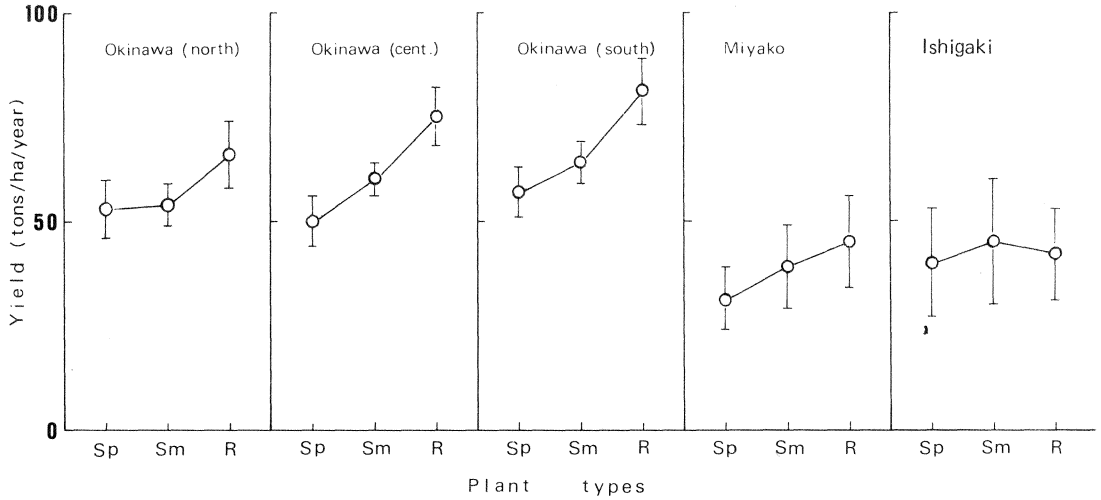

Fig. 4 Mean annual yields of spring (Sp), summer (Sm) and ratoon (R) canes per ha in the five districts of Okinawa
The yield of summer cane is divided into 1.5 years of the growth period

tions in their yield compared to those in Okinawa Is. The poor irrigation during drought periods as well as the severe infestation by soil insect pests observed recently is probably the main cause of such low productivity in the two islands. Therefore, improvement of the high spring-summer cane ratio combined with the establishment of an efficient irrigation system is a prerequisite in these islands.

2 Wild host plant

Miscanthus and *Imperata* grasses in the natural vegetation seem to play an important role in the population dynamics of many insect pests of cane in Okinawa. A typical example is based on studies on the ecology and population dynamics of the small cicada, *Mogannia minuta*, which have been carried out since the 1960s (Azuma, 1969, 1977; Ito and Nagamine, 1974, 1978; Nagamine, Teruya and Ito, 1976; Murai, Nagamine and Ito, 1975; Nagamine and Teruya, 1976).

This insect was first observed in Ishigaki Is. in 1913. However, during the cultivation of YOMITANZAN and of POJ no conspicuous invasion of this cicada into cane fields could be detected probably because of good management of the wild host vegetation for use in roofing and fuel and of effective predation by ants, spiders and birds. When NCo began to be cultivated cane fields were established within the natural habitat of this insect. Also management of the wild host vegetation became poor due to modernization of life. The cicada's population began to increase in cane fields from 1963 onward and the population reached an epidemic level in 1969. Azuma (1969) who surveyed the infested areas in Miyako Is. and Ishigaki Is. in April-May, 1969 reported that the population density inclusive of exuviae of emerged adults and nymphs of 1st and 2nd year classes varied from 3 to 1,093 per m^2 (average 375) in Ishigaki, and from 26 to 476 (average 253) in Miyako Is. The population density was especially high in ratoon cane fields.

Almost at the same time, the cicada's population also reached an epidemic level in a fairly restricted area, Chinen village, in the southern part of Okinawa Is. and extensive population surveys have been made since 1972. Fig. 5 shows the annual trends of mean densities of emerged adults per m^2 in several of the ratoon cane fields and the *Miscanthus* patches in the outbreak area. Although the two kinds of survey sites were moderately distant from each other, one cannot rule out the possibility of some population exchange between the two kinds of habitats (Murai, *et al.*, 1975). It appears that the two populations of cicada are experiencing a phase of decline. The decrease in the *Miscanthus* population of cicada is partly due to the large destruction of *Miscanthus* vegetation by the establishment of a golf course, and that of the cane population of cicada by the increasing renewal of older ratoon fields. Under such circumstances, natural enemies may operate more effectively.

The ratoon culture based on summer cane is especially favourable for the population build-up of the cicada because the overwintered summer cane provides suitable oviposition sites (leaves) for the adults which emerge from March to July with a peak from April to May. The same considerations apply to other soil insect pests such as wire worms and white grubs, and to the diaspid scale, *Aulacapsis takarai*.

3 Varietal resistance

Some subtle or conspicuous differences in the plant morphology such as opening degree of leaf sheaths, degree of natural defoliation or trashing, stem hardiness, etc., would have a considerable effect on the abundance of some economically important pests of cane (cf. Azuma, 1977). Here only two examples are presented.

The diaspid scale, *Aulacapsis takarai*, is a species peculiar to Okinawa whose natural habitat is preferably *Miscanthus* and *Arundo* grasses. The infestation of the cane field was first recognized over ca. 60 ha of cane (NCo 310) acreage in a restricted area of Miyako Is. in November, 1961. Now this scale is parasitizing cane as far as Ishigaki Is. and Okinawa Is. However, the population is most abundant in Miyako Is. and the near-by islands, Irabu Is. and Tarama Is. When the cultivation of NCo 310 was spread, another variety NCo 376 was introduced from South Africa in 1961. Several years after the introduction cultivation of NCo 376 began to spread to a few small islands such as Irabu Is.,

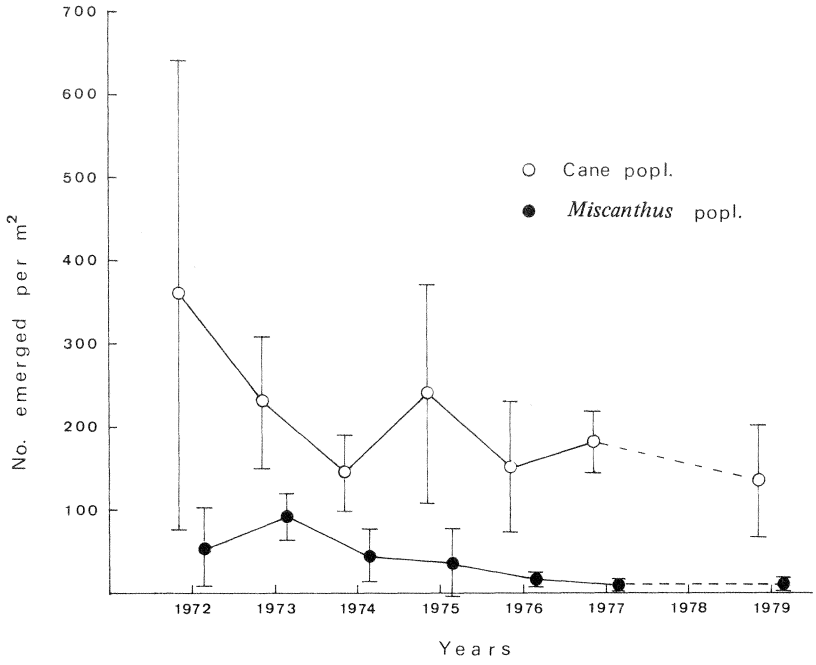

Fig. 5 Change of annual mean densities of emerged adults of *Mogannia minuta* in the ratoon cane fields and *Miscanthus* patches in Chinen village
Each solid bar shows 90% confidence limit of the mean density (Nagamine, unpublished data).

Minami-Daito Is., Ie Is. and Kume Is., and also to some areas of the northern part of Okinawa Is. NCo 310 and 376 are now equally grown in Irabu Is. of Miyako province, and field resistance against the scale infestation is clearly different in the two varieties: NCo 376 is much more heavily parasitized by the scale than NCo 310. Although the two varieties are not conducive to natural trashing, NCo 376 is a little more difficult to trash than NCo 310. Such a subtle difference would greatly affect the continuous population growth of the scale from the base to the top of cane nodes. Thus artificial trashing is highly effective to control the scale population.

The superiority of NCo 310 to 376 with regard to *A. takarai* is reversed in the case of the oriental chinch bug, *Cavelerius saccharivorus*, which has become the most pandemic species in Okinawa after its accidental introduction from Taiwan to Okinawa in the 1910s. In Minami-Daito Is. where monoculture of NCo 310 lasted until the early 1970s, severe yellowing of young cane leaves caused by gregarious sucking of the 1st generation nymphs used to be visible in May over a wide acreage of summer and ratoon canes. After the spread of NCo 376 which now covers about 80% of the total acreage, such a phenomenon could hardly be detected. The opening angle of leaf sheaths of NCo 376 is narrower than that of NCo 310, which would limit the number of suitable interstices between stems and leaf sheaths which the insects select to live in. Leaf-burning at the time of harvest is widely practised in this island where mechanization is the most prevalent in Okinawa. This practice is also effective in controlling the overwintering population (Tamaki and Takara, 1979).

4 Loss assessment and use of insecticides

About one half of the total amount of insecticides has been allocated to the control of the oriental chinch bug since 1964. Fujisaki, one of the authors of this paper, has begun to study the effect of ear-

ly damage (leaf yellowing) on the final yield of cane since last year (1979). The study now under way indicates that the extensive use of insecticides (granular types of Sumithion) against this insect is uneconomical because severe yellowing of young cane leaves in the unsprayed plot can be treated by the vigorous compensating growth of cane plant in which the density dependent dispersal (emigration) of adults (Murai, 1975; 1977) is also playing an important role. It can be assumed that the economic threshold density may be much higher than expected judging from the apparent damage.

Azuma (1969) mentioned that the epidemic density of *M. minuta* observed in Ishigaki Is. and Miyako Is. would cause the abnormal ratooning of sugar cane after harvest. However, his assertion must be tested because such an abnormal ratooning of cane has not been recurrent in the outbreak area of Chinen village of Okinawa Is. It is certain that the abnormal ratooning of cane prevailing in these islands could be caused by far lower densities of wire worms and white grubs than the epidemic densities of cicada (Hokyo, 1979 and in press). To prevent the severe infestation of underground buds and roots by these two soil insect pests, soil applications of some organophoshorus insecticides are needed at the time when new cane sets are planted and during the younger nymphal stages of these insect pests.

Summary

It was emphasized in this paper that the ratoon culture of cane which predominates in summer planting is the major cause of severe infestation by some economically important pests of cane in Okinawa. Implementation and techniques concerning the improvement of such practice of cane cultivation were discussed in relation to artificial and natural environmental components that influence the level of pest abundance.

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Discussion

Ohgushi, R. (Japan): Could you tell me how many species of soil insects are known to attack sugar cane in Okinawa? Can you distinguish the lesions produced by the respective agents?

Answer: Nineteen species of white grubs belonging to Cetoniidae (2 spp.), Rutelidae (8 spp.), Melolonthidae (7 spp.) and Dynastidae (2 spp.), one species of wire worm (*Melanotus tamusyensis*) and the small cicada *Mogannia minuta* have so far been listed as the soil insect pests of cane. Of these, the rutelid grub *Anomala albopilosa* and the wire worm *M. tamusyensis* are both commonly seen in many islands of Okinawa and are the most important agents of abnormal ratooning in cane stubbles. The injury of cane plants caused by the two species is to some extent specific depending on their different life cycles and feeding habit, their density and the growing stage of the cane plants.

Sogawa, K. (Japan): Could you give some information about the mechanism of varietal resistance in sugar cane?

Answer: Very little is known in this regard. Varietal resistance is often ascribed to morphological mechanisms. The possibility of the existence of a genetical or physiological basis has not yet been investigated.

Hidaka, T. (Japan): Is there any difference in the insect pest species attacking sugar cane between the various islands of Okinawa?

Answer: This problem has not been investigated yet.