CORDYCEPS SP. AN IMPORTANT ENTOMOPATHOGENIC FUNGUS OF CICADA NYMPHS AT RAMU, PAPUA NEW GUINEA.

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ABSTRACT:

Nymphs of the cicadid Baeturia papuensis *and* B. valida *have become pests of commercial sugarcane at Ramu Sugar estate, Papua New Guinea. Field observations made in 1989-92 showed that the first monsoon rains in October/November significantly ($p < 0.001$) enhanced mortality by a pathogenic fungus,* Cordyceps *sp. Mortalities of 5th instar nymphs in the field ranged from 2-67%, 0-80% and 0-50% in 1990, 1991 and 1992, respectively. Attempts to artificially innoculate planting furrows with ground cadavers infected with* Cordyceps *sp. are also discussed.*

Keywords: *Cicadas,* Baeturia papuensis, B. valida, Cordyceps *sp., sugarcane.*

INTRODUCTION

The cicadids, *Baeturia papuensis* de Boer and *B. valida* Blote (Homoptera: Tibicinidae) (identified by A.J. deBoer) have become serious pests of commercial sugarcane (hybrids of *Saccharum* spp.) at Ramu Sugar estate, Papua New Guinea (PNG) (Kuniata & Nagaraja 1992; Kuniata & Sweet 1991). The first outbreak was observed in late 1988 where cicadid damage has since been a severe problem (Ramu Sugar Ltd., unpublished reports). At Ramu, as elsewhere, cicadid damage to sugarcane as a result of nymphs feeding on the roots caused either the failure of the infested plants to ratoon (regrowth after harvest) or the subsequent ratoon shoots to die when about 30 cm high (Wilson 1960, Chandler 1981). Yield losses have not yet been accurately quantified but it is known that this pest has caused annual reduction in cane stool population of 4-10 percent (Kuniata & Nagaraja 1992).

Control of cicada nymphs with insecticides has been shown to be ineffective (Wilson 1969, Chandler 1981, L.S. Kuniata, unpublished data). Indeed such treatments often caused much worse infestations than in their absence (Chandler 1981).

More than 28 species of *Cordyceps* have been recorded from Papua New Guinea in a very wide range of hosts (Kobayasi & Schimizu 1976, Shaw 1984) with *C. ctenocephala* H. Sydow, *C. prolifera* Y. Kobayasi and *C. sinclairii* Y. Kobayasi found attacking cicada nymphs (Kobayasi and Schimizu 1976). The entomopathogenic fungus found in the nymphs *B. papuensis* and *B. valida* at Ramu Sugar estate was identified by Dr H.C. Evans (IIBC, UK) as *Cordyceps* sp. suggesting that this might be a new species. Seasonal occurences of this pathogen has not been studied and therefore these studies were initiated. Artificial innoculation of planting furrows with ground *Cordyceps* sp. cadavers were also attempted.

MATERIALS AND METHODS

Cicada nymphs infected with *Cordyceps* sp. can be identified in the field by the external outgrowth of the synnemata. Dead nymphs without these were taken to the laboratory and placed in containers of heat-treated soil and observed for synnemata production. The various instar nymphs collected were separated by the size of the front femur (Kuniata & Nagaraja 1992).

Field Survey

Field observations were made between October

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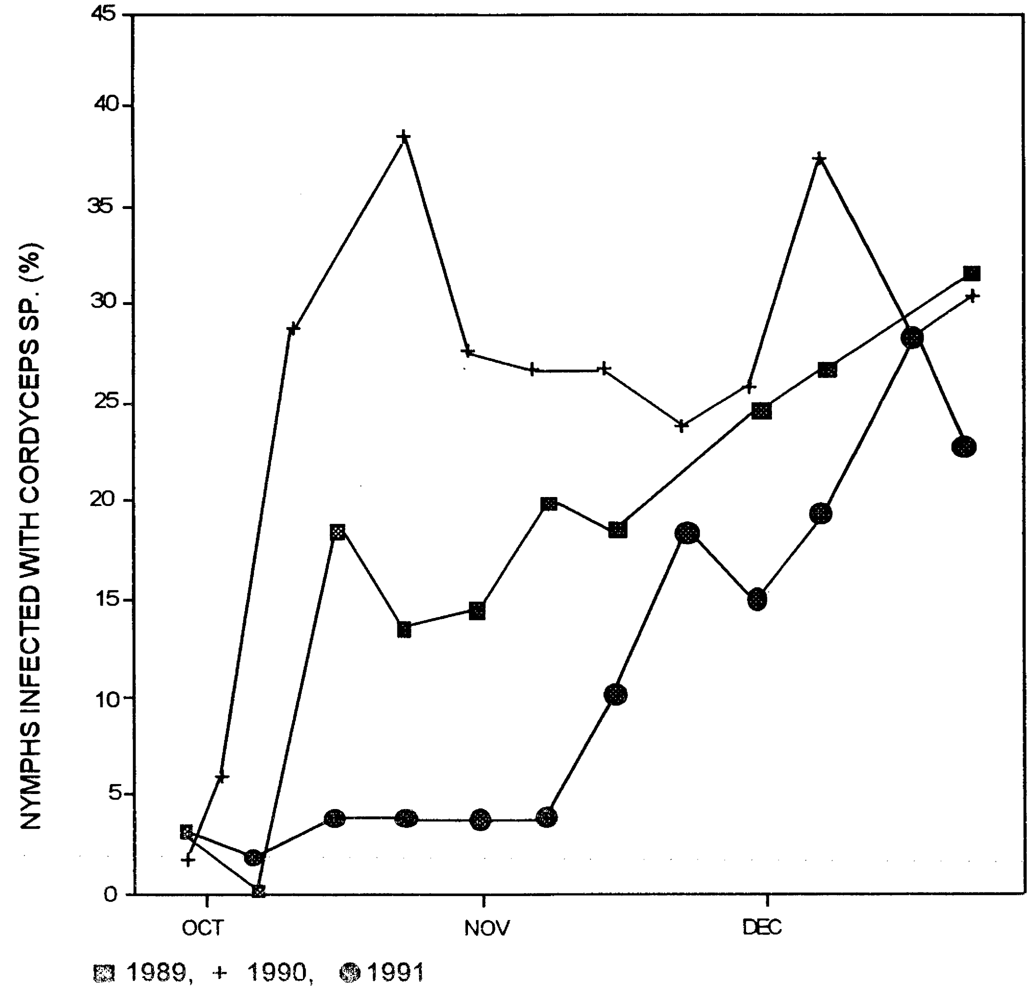
Figure 1. **Summary of *Cordyceps* sp. in cicada nymphs observed in rainfed sugarcane at Ramu. At other times of the year these infections were usually low (< 5%).**



and December, each year with 3, 7 and 11 fields sampled in 1989, 1990 and 1991, respectively. Each of these fields were between 10-25 ha and were sampled at various intervals for the presence of nymphs infected with *Cordyceps* sp. Each sample consisted of a 50 x 50 cm area dug up around a sugarcane plant to a depth of 40 cm. This volume of plant and soil was examined visually in the field and all the cicada nymphs present were recorded. A total of 30 samples were randomly taken from each field at each sampling date. Exuviae found above ground within the area of the sampled plant were also counted in order to estimate total nymph population.

Another 111 fields of 1st, 2nd and 3rd ratoon cane from the estate (8,000 ha) were sampled in November,1991 for the presence of *Cordyceps* sp and cicada nymphs infestations. A further 74 fields were sampled in 1992.

Field Trials

A field trial was planted in mid-November 1990 at RSL in field #DS107. The treatments were ground cadvers infected with *Cordyceps sp* applied in the planting furrow at 30 kg/ha and untreated control.The ground cadavers were first mixed with sandy loam soil (heat treated) before being applied in the furrows. Equal amount of sandy loam soil (without *Cordyceps* sp) was applied in the untreated control plots. The treatments were systematically allocated in the field. Plot sizes were approximately 0.27 ha and treatments replicated 3 times. A similar trial was also planted in

Table 1. **Distribution of cicada nymph densities and *Cordyceps* sp. infection levels in differemt varieties and cane classes. (Number in paranthesis were total number of nymphs collected).**

CLASS/VARIETY	FIELDS SAMPLED	MEAN NYMPHS PER STOOL	*CORDYCEPS* SP. %
1st Ratoon			
Cadmus	22	0.7	8.50 (308)
Q117	7	0.4	13.89 (56)
Others	15	1.5	10.83 (450)
TOTAL/MEAN	44	0.9	11.07
2nd Ratoon			
Cadmus	21	3.1	8.66 (1922)
Q117	2	0.2	0.00 (8)
Others	5	1.9	14.81 (190)
TOTAL/MEAN	28	1.7	7.82
3rd Ratoon			
Cadmus	17	3.2	19.79 (1088)
Q177	7	4.4	1.47 (616)
Others	15	1.3	9.34 (390)
TOTAL/MEAN	39	2.96	10.20

early December 1990 in field #CS109.

Cicada nymph densities and *Cordyceps* sp. infection levels were estimated towards the end of November in 1991 (1R) and 1992 (2R). Thirty sugarcane stools (30 cm x 30 cm x 40 cm) were randomly dug out within a plot and searched for cicada nymphs with *Cordyceps* sp. infections. Egg-mass leaves were sampled in early February of 1991 (Plant), 1992 (1R) and 1993 (2R). Two hundred stalks from each plot were randomly sampled and individual leaves with cicada egg-puntures were counted.

RESULTS

Field Survey

The two species of cicadas found attacking sugarcane at Ramu Sugar Estate were *Baeturia papuensis* and *B. valida*. Prior to 1989, the proportion of nymphs infected with *Cordyceps* sp. were less than 1%.The range of *Cordyceps* sp. infections observed in individual fields from October to December were 2-67% (1990), 0 - 80% (1991) and 0-50% (1992) (Figure 1). During other times of the year infections were usually less than 5%. In general only the 5th instar nymphs were affected by *Cordyceps* sp.

A highly significant correlation was observed between total weekly rainfall (mm) and percentage of nymphs infected with *Cordyceps* sp.

Table 2. **Distribution of *Cordyceps* sp. infection on the estate by different geographical regions. Total number of cicada nymphs is given in parenthesis.**

GEOGRAPHIICAL REGION	NUMBER OF FIELDS	*CORDYCEPS* SP. %
AN + BN	7	0.81 (123)
AS 010-068	9	23.08 (26)
AS100's-600's	11	12.70 (126)
BS	15	2.17 (460)
CN & DN	12	19.58 (189)
CS	11	2.01 (1393)
DS	15	12.99 (462)
EN + FN100's	8	29.23 (804)
ES	7	8.24 (170)
FN 300 -1000's	9	12.49 (961)
FS	4	2.35 (85)
GN	3	5.63 (231)

($r = 0.892^{***}$, df =17, $p < 0.001$). Levels of infections appeared to peak 6-9 weeks after the onset of the monsoon rains. In 1990 the monsoon rains began in early September but in 1991 and 1992 this was delayed until mid-October.

Mean *Cordyceps* sp. infection levels between ratoon classes and 1st ratoon cane fields were not significantly different ($X^2 = 1.63$, df = 2; $X^2 = 1.32$, df = 2, respectively) (Table 1). But those infection levels observed in 2nd and 3rd ratoon cane fields were highly significant ($X^2 = 14.16$, df = 2, $p < 0.001$; $X^2 = 16.56$, df = 2, $p < 0.001$, respectively). Cadmus fields appeared to show higher *Cordyceps* levels than Q117 and the other varieties.

Table 2 shows the distribution of cicada nymphs and *Cordyceps* sp. by different geographical regions on the estate. Highly significant differences were observed in nymph numbers and *Cordyceps* sp. levels to particular geographical regions sampled ($X^2 = 4732.6$, $p<0.001$, df = 11; $X^2 = 77.68$, $p<0.001$, df = 11, respectively).

Baeturia valida has been recorded only in a few localities on the estate. In 1991 about 38 percent of *B. valida* nymphs were affected by *Cordyceps* sp. (N = 803). Regression analysis showed a negative and highly significant correlation between cicada nymphs infected with *Cordyceps* sp. and subsequent nymph populations ($r^2 = -0.971$, $p < 0.001$, df = 4). The relationship was more quardratic than a linear one. Using this relationship, an infection of more than 24% should be sufficient to maintain nymph populations below the critical level of 4 nymphs/stool.

Field Trials

The results from field trials with ground *Cordyceps* sp. in field #DS107 indicated significantly higher levels of cicada nymphs were infected with *Cordyceps* sp. in the innoculated plots than the untreated controls during three seasons (Table 3). In general nymph populations were higher in the untreated ratoon cane than the treated plots, however there were no significant differences observed in average egg-mass leaves.

In field CS109 no significant differences were observed in cicada nymph numbers, egg-mass leaves and *Cordyceps* sp. levels, however the untreated plots had significantly higher *Cordyceps* sp. and egg-mass leaves in the 2 ratoon crop (Table 3). *Cordyceps* sp. infection levels observed in CS109 trial were generally higher than in DS107.

Table 3. **Average number of cicada nymphs, egg-mass leaves and nymphs infected with *Cordyceps* sp. in fields #DS107 and #CS109 following application of ground *Cordyceps cadavers*. Numbers in parenthesis are total nymphs collected.**

	DS107			CS109		
	Innoculated	Untreated control	t-test	Innoculated	Untreated control	t-test
Plant						
Av. nymphs/stool	0.4	0.2	0.648 n.s	0.02	0.01	-
% nymphs with *Cordyceps* sp.	18.80 (36)	0.0 (18)	6.372**	100 (2)	100 (1)	-
Av. egg-mass leaves/100 stalk	-	-	-	-	-	-
1st Ratoon						
Av. nymphs/stool	2.4	4.1	3.406*	1.5	1.6	0.264 n.s
% nymphs with *Cordyceps* sp.	45.77 (216)	0.40 (369)	8.995***	77.0 (135)	81.4 (135)	1.712 n.s
Av. egg-mass leaves/ 100 stalk	124.0	113.0	2.765 n.s	61.7	61.7	-
2nd Ratoon						
Av. nymphs/stool	1.3	1.9	1.858 n.s	0.7	0.7	0.258 n.s
% nymphs with *Cordyceps* sp.	14.20 (117)	4.3 (171)	4.651**	15.0 (51)	27.5 (60)	4.651**
Av. egg-mass leaves/ 100 stalk	230.0	249.3	3.326*	91.0	100.7	3.326*

n.s, not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; (-) not determined.

DISCUSSION

Three species of *Cordyceps* have been recorded attacking cicadids in Papua New Guinea (Kobayasi & Schimizu 1976, Shaw 1984).The species found attacking nymphs of *B. papuensis* and *B. valida* is probably recorded for the first time (H.C. Evans, pers. comm.).

The abundance of *Cordyceps* sp. on cicada nymphs at Ramu Sugar estate increased with the onset of the monsoon rains in October/ November. It is possible that these rains are critical in the movement of the innoculum in the soil. Costilla and Pastor (1986) have shown that irrigating sugarcane fields after ploughing appeared to enhance the pathogenic action of *Cordyceps* causing up to 99.4 percent mortality among cicada nymphs. Under natural and undisturbed soil conditions at Ramu Sugar estate the mean infection levels were about 39% (range = 2-67%) in 1990, 20% (range = 0-80%) in 1991 and 6% (0-50%) in 1992. The lower mean infection levels observed in 1991 and 1992 were probably due to the delay in the monsoon rains.

Older ratoon cane fields appeared to show higher *Cordyceps* sp. levels which were probably due to accumulation of innoculum in the soil from previous seasons. The abundance of cicada nymphs and *Cordyceps* sp. in certain parts of the estate might suggest preference to certain soil types or breeding sites. Kuniata and Nagaraja (1992) showed strong varietal preference for oviposition and therefore certain cane fields might sustain higher levels of cicada infestations. The results from the trials where the planting furrows were innoculated with ground *Cordyceps* (DS107) indicated possibilities of using this technique in the distribution of this pathogen to other parts of the estate having low innoculum in the soil. Pre-treatment levels of *Cordyceps* sp. observed in field DS107 were less than 1% while this was about 28% in CS109. *Cordyceps* sp. levels observed in CS109 were not significantly different probably due to a high initial innoculum already present in the soil at the time of planting. The low *Cordyceps* sp. levels observed in 2nd ratoon cane (1993) was due to estimations made during the dry season in September.

Both cicadid species have a univoltine life cycle with more than 80% of the nymphs in the 5th instar stage by October/November and by end of November about 60% of these would have emerged as adults (Kuniata & Nagaraja 1992). It was observed that this species of *Cordyceps* mainly attacks this nymph stage and therefore it is critical for the pathogenic action of this fungus to be initiated well before nymph emergence. This can be achieved with early monsoon rains or through irrigation.

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