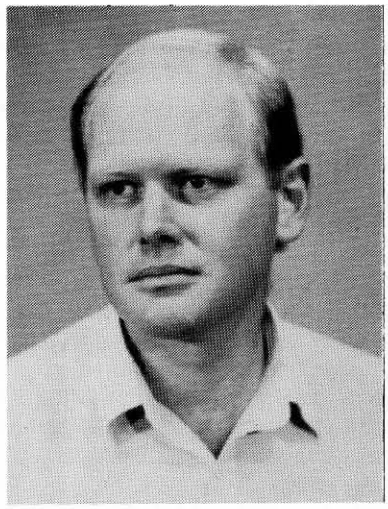
REVIEWS



Navua sedge in pastures in Fiji

I. D. Black*
Ministry of Agriculture and Fisheries, Koronivia Research Station, P.O. Box 77, Nausori, Fiji

Summary

Navua sedge (*Cyperus aromaticus* [Ridl.] Mattf. & Kuk. = *Kyllinga polyphylla* Willd. ex Kunth) is the worst weed in the Fiji Islands, both in terms of area covered and loss of productivity in the dairy industry. The sedge is ignored by grazing animals, leading to overgrazing of the grass and further ingression by the sedge. Cattle will graze the sedge when no preferred forage is available, but its feed value is very low. Chemical and mechanical control methods are available but neither is long term or readily accepted by farmers. No biological control methods have been found and none of the common preferred grass species in the wet zone competes effectively with Navua sedge. Two introduced setaria grasses currently appear to offer the best chance of long-term control.

Introduction

Navua sedge (*Cyperus aromaticus* [Ridl.] Mattf. & Kuk. = *Kyllinga polyphylla* Willd. ex Kunth) Figures 1 and 2) was first noted in Fiji in 1933 (Parham, 1959) but the exact date of introduction is unknown. As its common name suggests, it first became a major weed problem around Navua on Viti Levu, the largest island of the Fiji group. From there it spread to other wet parts of Viti Levu and to Vanua Levu and Taveuni, the second and third largest islands of the Fiji group. It is also present on some of the smaller islands.

Viti Levu may be divided conveniently into three rainfall zones (Figure 3). The wet zone has an average annual rainfall greater than 2800 mm without a distinct dry season and the dry zone an average rainfall of 1500 to 2200 mm with a distinct dry season from May to October, while the intermediate zone falls between them both geographically and in rainfall. The pastures of the wet zone are heavily infested with Navua sedge (especially those used for dairy farming, Figure 3), and it continues to spread in pastures including those grazed by beef cattle and goats. Infestation of the dry and intermediate zones is confined to damp, low lying pasture and waste areas, and it has not estab-

Figure 1 Navua sedge (drawing by T. L. Mune).

* Present address: Department of Agriculture, Mount Pleasant Laboratories, Launceston, Tasmania 7250.

lished in areas where the soil is subject to a prolonged dry period. In addition to being a weed in grazing areas, it is also a weed under coconuts, in ditches and on roadsides, lawns and turf, root crops and rice fields (Karan, 1975).

The most important pasture species in the wet zone are para grass (*Brachiaria mutica* [Forsk] Stapf.) on the flats and Batiki blue grass (*Ischaemum aristatum* L.) and Koronivia grass (*Brachiaria humidicola* [Rendle] Sweickt) on the hills. The legumes desmodium (*Desmodium heterophyllum* [Willd.] D.C.) and, to a lesser extent, sensitive plant (*Mimosa pudica* L.) are also present. Where overgrazing has occurred carpet grass (*Axonopus compressus* [Swartz] Beauv.) and lacuntu grass (*Ischaemum timorense* Kunth) may also be present and produce some forage. The grasses splendida setaria (*Setaria sphacelata* [Schum.] Stapf. and Hubbard var. *splendida*) and kazungula setaria (*Setaria sphacelata* var. *sericea* cv. Kazungula) are currently being used to renovate some dairy pastures and are increasing in importance.

Dairying occurs in the wet zone of Viti Levu in a region around Suva, and Navua sedge is the most important constraint on productivity. A survey of dairy farms carried out in 1979 showed that 55% of the dairy pasture area was covered with the sedge (Singh *et al.*, 1981 and pers. comm., 1982). The flats tend to have greater infestation than the hill pastures (Karan, 1975), probably because dairy farmers have tended in the past to use hill pastures less (Parker *et al.*, 1979). In many paddocks there is an almost pure stand of Navua sedge. Dairy productivity in Fiji is very low compared to temperate areas, with milk production per cow averaging five litres per day and calving 60% per year (V. Kumar, pers. comm., 1982). Navua sedge infestation reduces the carrying capacity of dairy pastures and, because cattle graze the sedge when there is no preferred forage available, contributes to the low productivity per cow through its poor feed value. It is not known whether the low feed value of the sedge is due to nutrient imbalance, low digestability or reduced intake because of low palatability.

The increased ingression of Navua sedge into wet zone pastures grazed by beef cattle and goats is probably due to higher grazing pressure and is a cause for concern. The lower returns from these pastures compared to dairying means that farmers are even less likely to implement effective control measures.

Figure 2 Mature stand of Navua sedge.

Identification and worldwide distribution

The identification of Navua sedge has been the subject of some controversy. J. W. Parham sent specimens abroad and was given the names *Kyllinga monocephala* Rottb. in 1956, *Cyperus melanospermus* (Nees) Valch-Suring in 1957, and finally *Cyperus aromaticus* (Ridley) Mattf. and Kuk. in 1959. According to Rao (1972) it was later re-identified as *Kyllinga elata* Steud. Karan (1975) has given details and reference about these name changes. It was classified again in 1976, this time as *Kyllinga polyphylla* Willd. ex Kunth (Karan, 1976), but the Queensland Herbarium has not accepted the transfer of this species from *Cyperus* to *Kyllinga* (R. W. Johnson, pers. comm., 1982). The reason for the dispute is that some taxonomists regard the genus *Cyperus* as all embracing while others divide it up into smaller genera, of which *Kyllinga* is one (S. S. Hooper, pers. comm., 1982).

Navua sedge is indigenous throughout tropical Africa (excluding the Congo Basin), Madagascar, Mauritius and the Seychelles. From there it has been introduced into Sri Lanka, the Malay Peninsula, Fiji, Samoa, the Solomon Islands, the New Hebrides and Tahiti (Karan, 1975; Koyama, 1979; S. S. Hooper, pers. comm., 1982). It has recently been found in the Cairns district of North Queensland (Anon., 1980).

Morphology and anatomy

Navua sedge is 'a grass-like perennial plant usually between 0.3 and 0.7 m high but occasionally noted between 1.2 and 2 m high. The leaves are linear-lanceolate and mostly clustered at the base of the plant, and the cone or button-like clusters of flowers are borne at the apex of a three-angled flower stalk subtended by six leaf like bracts, of which three are long and three are short' (Mune and Parham, 1967; Figure 1).

Koyama (1979) and Mune and Parham (1967) both give more detailed botanical descriptions of the plant whilst Karan (1971, 1975) has provided a detailed account of its morphology, anatomy and development.

Reproduction and persistence

Navua sedge spreads by both vegetative reproduction and seed. Karan (1975) found that the main shoot has a basal swelling usually consisting of one to five closely situated nodes. Buds from the second node give rise to secondary, tertiary and succeeding tillers, whilst those of the third node occasionally give rise to branches of the scape. The plant persists by means of a superficial sympodial rhizome system which is formed by many such conical swellings joined together at their bases.

Karan (1975) determined that shoots produced a mean of 251 S.E. ± 2.5 seeds, from a sample of 500 taken from pastures at Koronivia Research Station in Fiji. On heavily infested pasture at Koronivia he estimated a seed production of 456×10^6 ha^{-1} from 1.82×10^6 shoots on flat paddocks and 208×10^6 seeds ha^{-1} from 0.83×10^6 shoots on hillside paddocks. Germination tests showed that a succession of light and dark conditions provide the best stimulation to germination. Continuous light alone is sufficient for 75% germination at 15°C but none at

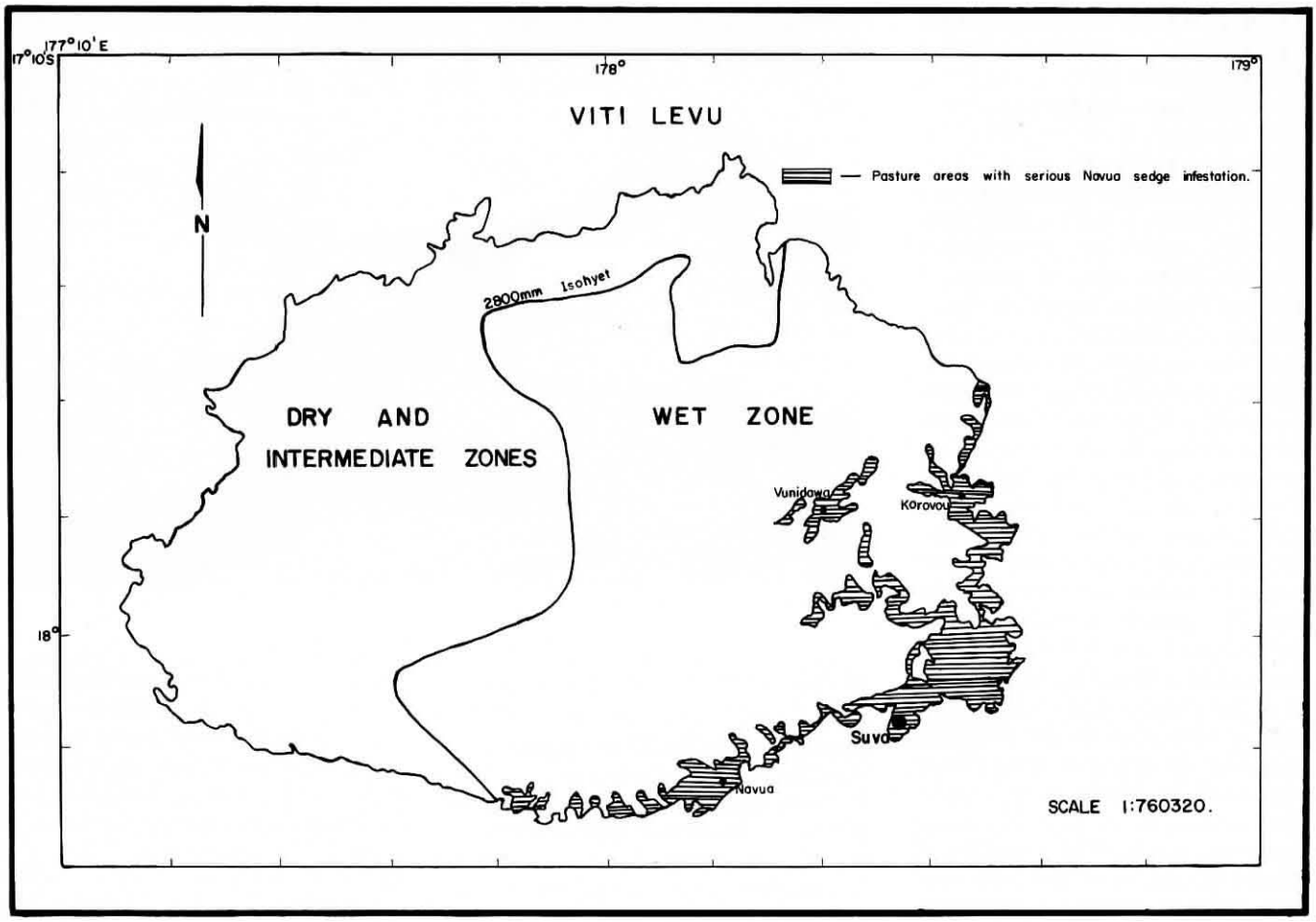


Figure 3 Map of Viti Levu, Fiji islands, showing pasture areas with serious Navua sedge infestation (Land Use Section, Ministry of Agriculture, Fiji, and P. Saville, pers. comm., 1983).

25°C. Karan concluded from this and other studies that a germination of 75% to 80% was likely at normal Fiji ambient conditions of daylength and temperature. The dormancy and longevity of seed remain to be studied.

Mode of spread

The mechanisms of spread have been documented by Mune (1959) and by Karan (1975). Navua sedge is not readily grazed where grasses and legumes are available, and the sedge spreads into the space left after overgrazing either vegetatively or by germination of seeds. The hoof prints of grazing animals and the wheel ruts of vehicles may provide areas for colonization. There is no apparatus attached to the seed to allow it to drift any distance in the wind but the seed and its dispersal unit are quite light and some undoubtedly spreads for short distances when released in strong winds. The important modes of spread between areas are through the movement of stock and vehicles and to a lesser extent in contaminated rice seed and road fill. Seeds are spread via the digestive tract, coats and hooves of animals (Mune, 1959). There may also be some vegetative reproduction when earth with viable pieces of sedge is dislodged from animal hooves and vehicles.

Control methods

Cutting

Ordinary grazing or mowing will not destroy the plants, since Karan (1976) found that when Navua sedge was cut at 10 cm from the soil surface at weekly intervals during the first 8 weeks after germination virtually 100% recovered. The elongated inflorescences are however prevented from developing.

The largest dairying property in Fiji operates a zero grazing method of feeding their milkers. The cows are permanently accommodated in feeding stalls and forage cut from para grass pasture is brought to them. The para grass pastures are harvested at a height of 30 to 35 cm and fertilized after each cut. The method slows down but does not stop the rate of Navua sedge ingression into the pasture compared to normal grazing, because the grass cannot be selectively grazed and grows taller than the sedge. The lack of bare ground left after grazing and lack of dung may also contribute to the slower rate of ingression. The cows eat all the cut herbage including sedge (G. Blakeney, pers. comm., 1982). This technique has generated considerable interest within the farming community, and other farmers are considering adopting the practice because it prolongs the life of para grass pastures and utilizes all the cut herbage.

Competition from grasses

A cutting trial to evaluate the grasses splendida setaria, para grass and *Paspalum plicatulum* Michx. was established in 1980 on an alluvial soil at Koronivia Research Station in an area previously heavily infested with Navua sedge (Krishna *et al.*, 1982). Two years after planting a visual estimate of the species composition of the plots showed that most of the suppression of sedge came from the grass species *per se*, but increased cutting height and cutting interval contributed while nitrogen application also helped with setaria and *P. plicatulum* (Table 1). Splendida setaria showed good resistance to sedge ingression while para grass was by far the least competitive.

Splendida setaria, para grass, *P. plicatulum* and Koronivia grass were

assessed under grazing conditions for their competitive ability against Navua sedge in established pasture (Krishna *et al.*, 1982); infestation of the sedge was 38%, 68%, 91% and 95% respectively. Setaria therefore proved to be the most resistant to sedge ingression even though a large quantity had been removed from the trial area and used as planting material elsewhere. *P. plicatulum* was much less competitive under grazing than under cutting.

A grazing trial was carried out on Batiki blue grass pastures at Koronivia Research Station to compare milk production from dairy cows under two rotations of different length, but after two years the project had to be terminated because Navua sedge had overrun the trial area. At the beginning of the experiment there was an estimated 20% infestation of the weed, whereas at termination it was 77% (Parker *et al.*, 1979).

Table 1 Percentage Navua sedge infestation in grass plots subject to cutting[1]

	Setaria[2]	Sedge	Para	Sedge	Paspalum[3]	Sedge	S.E. ± Grasses	S.E. ± Sedge
Nitrogen rate (kg ha^{-1})								
0	69.7	3.3	4.2	27.8	56.1	7.5		
200	85.9	1.1	6.7	28.6	77.5	7.2	1.0	1.1
400	89.4	1.4	10.8	29.7	81.7	5.0		
Cutting height (cm)								
8	78.9	3.3	5.3	30.5	69.7	10.3		
13	81.1	1.9	5.8	31.1	71.1	4.7	1.0	1.1
18	85.0	0.6	10.6	24.4	74.4	4.7		
Cutting interval (weeks)								
2	74.2	3.3	2.8	31.1	58.9	8.3		
4	84.2	1.4	7.5	32.2	76.1	7.2	1.0	1.1
6	86.7	1.1	11.4	22.8	80.3	4.2		
Overall	81.7	1.9	7.2	28.9	71.8	6.6	0.6	0.7

[1] After Black *et al.* (1983). Percentages are visual estimates
[2] *Setaria sphacelata* var. *splendida*
[3] *Paspalum plicatulum*

Manual and mechanical control

Mune and Parham (1967) outlined measures for the control of Navua sedge which included carefully cutting around each clump with a spade and turning the whole plant and root system over, ensuring that practically all of the root system is treated in this way. This works well for isolated clumps. Large infestations on arable land are best controlled by ploughing (ensuring a complete turnover of the soil to destroy the sedge and bring the rhizome system to the surface), followed by discing and planting a vigorous pasture grass.

Rolling pasture at regular intervals of 8 to 12 weeks in combination with controlled grazing is also an effective method of controlling the sedge (Mune and Parham, 1967). When the sedge is knocked down with heavy rollers the stems are bent and broken at ground level and die slowly, forcing the rootstock to send up new shoots, which gives the grass a chance to get above the sedge and smother it. They state that the treatment rapidly reduces the sedge to a minor place in the pasture, and this is endorsed by Karan (1976 and pers. comm., 1982).

Patel (1969) reported that Navua sedge can be effectively controlled when the pasture land is cultivated and rotated with rice and other crops.

Chemical control

A large number of herbicides have been screened for control of Navua sedge over 25 years, and Karan (1976) reviewed the literature on chemical control of the sedge to that date. Mune and Parham (1967) recommended a mixture of 4-CPA and sodium chlorate but N. Patel (unpublished data, 1969) and Cates (1969) found that the mixture was too damaging to pasture grasses and that the sedge was first to recover. It is therefore no longer in use. Patel (1970) found that MSMA at 4.5 kg ha^{-1} showed excellent activity against Navua sedge while the pasture grasses recovered completely in 4 to 5 weeks; his success with MSMA was later confirmed by others (Karan, 1976). Karan (1976) studied the effect of a number of herbicides on Navua sedge in the glasshouse. MSMA at rates at and above 2.24 kg ha^{-1} and MSMA + 2,4-D at rates at and above 1.12 kg ha^{-1} of each gave complete kill. The effectiveness of the MSMA + 2,4-D mixture was confirmed in the field by Hartland (1975) and by Karan (1976). However, it was not nearly as active as in the glasshouse, and both the mixture and MSMA alone require repeat sprayings to effect 100% control. The difference between the glasshouse and the field may be due to the degree of spray coverage that is practicable when spraying a dense sward of the sedge. Field trials by Karan (1976) showed cyperquat to be an excellent selective herbicide and glyphosate to be an effective herbicide for total vegetation control, although with the latter the area has to be replanted with suitable pasture species. Unfortunately cyperquat was never registered in Fiji. Navua sedge seedlings at the 5 to 7 leaf stage can easily be killed by spraying a low dose of paraquat, MSMA, 2,4-D or 2,4,5-T (Karan, 1976).

Since Karan's paper in 1976 there has been no new breakthrough in chemical control. Black *et al.* (1983) found the addition of dicamba to the MSMA + 2,4-D mixture gave a slightly enhanced effect, but not enough to warrant the extra cost. MSMA + phenothiol was somewhat more effective than MSMA + 2,4-D at comparable rates. Excellent selective control of Navua sedge has been demonstrated with glyphosate used through a wiping applicator in pastures that retain an understorey of grass (I. Black, unpublished data).

Biological control

Work by the Commonwealth Institute of Biological Control in East Africa and India has produced no biological control agent of any promise (Karan, 1976). Simmonds (1975) reported that a number of insects attack it, but these are either polyphagous species which may become pests or if oligophagous do little damage to the plant. Vigorous strains of *Bactra venosana*, *B. minima minima* and *Athesapeuta cyperi* were introduced from Pakistan in 1971 and liberated in the fields around Koronivia (Rao, 1972). Four species of *Bactra* were already present in Fiji (Diakinoff, 1964; Rao, 1972). Neither the recent introduction nor those already present have had any impact on the weed (Kamath, 1979 and pers. comm., 1982).

Discussion

Navua sedge in pasture is typical of weed problems which remain until the ecosystem is permanently altered in favour of preferred species or until a new species is introduced that is more competitive than the weed.

Both chemical and mechanical methods are available for controlling Navua sedge, but both suffer from the problem that they are not a long-term solution and require repeated applica-

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tions, and neither method of control has been readily accepted by the farming community. Chemical control is a continuing cost which is ill afforded by many poor farmers with cash flow problems. Heavy rollers have only been used by one large company because of a lack of machinery on small dairy farms and the wet nature of much of the flat dairy land. They are impractical on the hills.

From the information available and from general observation none of the preferred grass species in the wet zone – para grass on the flats and Batiki and Koronivia grass on the hills – competes effectively with Navua sedge under normal grazing pressure. The data and observations indicate that splendida setaria is relatively resistant to Navua sedge ingression and that it grows well on both the alluvial soils of the flats and on the latosols of the hills. Kazungula setaria has also been established in the wet zone, and it appears to be more resistant to Navua sedge ingression than para grass but less than splendida setaria. Both setarias have been shown to be superior to para grass in terms of milk yield in Fiji (Singh *et al.*, 1982). Splendida setaria has a low seed viability and has to be established vegetatively, but kazungula setaria can be established from seed. The setarias currently appear to offer the best chance of long-term control of Navua sedge.

In the past there has probably been too much emphasis on research into chemical control of Navua sedge, possible because herbicide evaluation is relatively quick and inexpensive compared to some other avenues of research. The current and planned research programmes aim for a more balanced set of studies. Two grazing trials (one on the flats and one on the hills) are designed to evaluate integrated control strategies under grazing. They will study the effect of para grass, splendida setaria and kazungula setaria on the flats and of Batiki blue grass, Koronivia grass and splendida setaria on the hills on sedge ingression when subject to high or low grazing pressures with or without fertilizer and spot treatment with herbicides. The objective of two cutting trials on the same soils as the grazing trials is to evaluate the response of mixed swards of Navua sedge and grasses to different cutting heights. Glasshouse and controlled environment studies are planned to evaluate the longevity of Navua sedge seed in the soil, the nutrient requirements of Navua sedge, and the principal grasses of the wet zone and the response of Navua sedge and these grasses to shading. Finally, research continues into the refinement of chemical control techniques. A prototype hand held wiping applicator suitable for applying glyphosate to Navua sedge infested pastures that retain an understorey of grass is being evaluated and the effectiveness of low-volume controlled droplet applicators is being assessed.

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