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Effects of climate warming on the distribution of C4 grasses in New Zealand

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ABSTRACT Data from pasture and roadside surveys and from an appeal to the public were used to assess whether recent climate warming has increased the spread of C4 grasses. Because of differences in date of introduction, saturation of existing range, ability to spread by seed, frost tolerance, and soil and moisture requirements, each species studied had a different potential increase in response to higher temperatures. Also spread could be exhibited as greater abundance within existing range as well as increase in geographical range. The strongest evidence that could be construed as an effect of climate warming was an increase of about 1.5" latitude in the area of 40% pasture occurrence of paspalum in the last 10-12 years. In the same period both carpet grass and knot-root bristle grass also greatly increased their impact. Most of the species studied (including the annual summer grass) underwent an explosive increase in the last 2-3 years after several particularly mild winters and warm summers. C4 species will probably be an increasing feature of pastures and lawns in future, and this should be accommodated by appropriate management and the introduction of improved pasture and amenity cultivars of this type.

Keywords C4 grasses, climate change, paspalum, pasture survey

INTRODUCTION

A significant and continuing increase in mean annual temperature has occurred in New Zealand this century, particularly in the last 30 years (Salinger 1989).

The distribution of plants with a known temperature threshold may provide a relatively sensitive indicator of climate warming. If the range of a species is limited by minimum growing-season temperatures required for growth or seed production, then rise in temperature should extend the range or increase abundance.

Most panicoid and chloridoid grasses have a carbon assimilation (C4) pathway with a high temperature optimum; they also have varying degrees of frost sensitivity, and are thus well suited to reflect temperature change. This paper examines survey data on the present and past distribution of some C4 grasses in New Zealand, and draws some conclusions about their usefulness as climatic indicators and the implications of climate warming for pastoral agriculture and turf maintenance.

METHODS

Data on the present distribution of C4 grasses were derived from three main sources:

(1) A survey of pasture composition on 583 farms, stratified to represent the distribution of pasture among LUC units by county for the North and South Islands, collected in summer 1987/88 (Field 1989).

(2) 3 sets of roadside samples (totalling 75 sites) of C4 grasses, taken to compare incidences along western (Hamilton, New Plymouth, Palmerston North), central (Pokeno-Tokoroa-Turangi) and eastern (Ruatoria-Napier-Porangahau-Woodville) main highways. At each site abundance (cover) was recorded both along a 50 m section of highway and in adjacent pasture (R/P survey).

(3) An appeal through the press in January 1989 for the public to send in unfamiliar grasses, which provided ***(infer alia)*** several hundred specimens of C4 grasses from gardens, lawns, verges and waste ground from Northland to Otago, together with information on when they were first noticed or seen to increase.

Dates of introduction and spread of C4 grasses around New Zealand were obtained from floras and botanical papers, dated herbarium specimens, and previous pasture surveys by Madden (1940), Levy (1956) and Percival (1977).

RESULTS

The species concerned fall into two groups:

(1) Persistent perennials dispersed by seed and/or stolons or rhizomes, found in pastures, lawns and waste ground, growing mainly in the warm season.

(2) Warm-season annuals which are fast-growing, free-seeding and opportunistic, occurring mostly in gardens, crops and waste ground but also in open places in lawns and pasture.

Only species that enter pasture to a significant extent, chiefly perennials, will be discussed here. Ratstail grass (*Sporobolus africanus* Poir.) and mercer grass (*Paspalum* ***distichum*** L.) have been omitted for lack of space.

PERENNIALS

Paspalum *(Paspalum dilatatum* Poir.)

Historical records First recorded in 1896 in Auckland region. Cheeseman (1906) stated "often grown as a forage plant, increasing in several localities". By 1935 was "abundantly naturalized on roadsides in the North Island" (Allan 1936) and 5 years later (Allan 1940) had reached northern South Island including Westland and Canterbury. Widely collected in Otago in 1970s. Madden (1940) described "paspalumdominant" pastures in Northland, Coromandel and Bay of Plenty. A questionnaire collated by Percival (1977) indicated that the southern limits of areas "where 40% of occupied pasture contains some paspalum" fell then along a line between Kawhia and Tokomaru Bay.

Present **surveys** Found in 182 of 35 1 North Island pasture sites, in every county except two (Taupo and Waiapu) north of Manawatu and Southern Hawkes Bay. Only >10% of cover in 18 sites (including some in Gisborne) and only 3 of these (one in each of Madden's 3 areas) having more than 20%. The equivalent of Percival's 1976 limits of 40% pasture occurrence would be a line between Wanganui and Cape Kidnappers, a shift of about 1.5" latitude. The R/P survey showed 80% presence on both east and west samplings. Presence in adjacent pastures was halved (36% vs 71%) on the east.

Postal specimens came from lawns, verges and waste places throughout the country. Seen as especially aggressive in Waikato, Bay of Plenty, Manawatu, Horowhenua, Wellington and Nelson, but too commonplace in Auckland and Northland to merit much comment. Increased spectacularly in the lower North Island in 1970s, markedly in the last 2-5 years, and has entered pastures in Manawatu, Horowhenua and Marlborough. Substantial "infestations" reported in South Canterbury and the Waitaki Valley, some annually eradicated.

Carpet grass (*Axonopus affinis* Chase)

Historical records First appeared in Northland in 1920s, becoming naturalised in several localities following cultivation (Allan 1936). Collected in Auckland and Coromandel by 1940s and 1950s and in the 70s and 80s in Waikato, Bay of Plenty and Taupo. Only once collected in the South Island, at Farewell Spit (Edgar & Shand 1987). Madden (1940) reported small amounts in low-fertility pastures in Northland and Coromandel.

Present surveys Found in 40 pasture sites, mostly as a minor component, having >10% cover in 7 sites and >20% in 3. Mainly north of Auckland, with isolated occurrences in Coromandel (3), Waikato (1), King Country (4), Eastern Bay of Plenty (1) and East Coast (4). None found in R/P survey. Received by post from lawns and verges in Northland, Auckland, Waikato, Bay of Plenty, North Taranaki (Urenui) and Taupo, and described as an alarmingly invasive lawn weed in the last 2 years.

Kikuyu grass *(Pennisetum clandestinum* Chiov.)

Historical records Recorded by Allan (1940) as "tending to spread from pastures" in Northland. Collected in Wanganui and Granity in the 1950s, Greymouth in the 1960s, and Nelson and Taranaki in the 1970s. Probably deliberately planted in many coastal areas. Now throughout North Island except the southeast, and in Marlborough Sounds, Nelson, Westland (to Greymouth) and Canterbury (Lincoln) (Edgar & Shand 1987). Not mentioned in Madden's pasture survey (1940).

Present surveys Found in 46 pasture sites, usually among the dominant species, with >20% cover in 18 sites, >30% in 10 and <15% in only 15. Most important in Northland (33 sites), but with 26% cover in one Whakatane site. Widespread on road verges in coastal Taranaki from Kotare to Opunake but spreading into pasture in only 2 out of 9 sites. Only seen once on coast north of Gisborne. Received by mail from Northland to Taranaki and Bay of Plenty, and also from Horowhenua, Nelson and Westland, mostly in coastal sites and usually on waste ground. Unusually dominant in Bay of Plenty in 1988189.

Indian doab, Bermuda grass (*Cynodon dactylon* L.)

Historical records Recorded for Auckland in 187 1 (Esler & Astridge 1987) and collected in lower North Island before 1900. In 1906 Cheeseman described it as abundant in fields and waste places in North Island and northern South Island. Allan (1936) commented "a nuisance in arable land" and in 1940 "common to locally abundant in waste places and dry light pasture". Established in Christchurch since 1950s. Madden (1940) reported Indian "doob" in weak, open, danthonia-dominant pastures, mainly in Northland and the East Coast.

Present **surveys** Occurred at <5% cover on 27 pasture sites, mainly in central North Island east of Mt Taranaki and over half in the dry East Coast region. The R/P survey also revealed it as mainly an East Coast species, 3 times more frequent (64% of sites) there on verges and 4 times (24%) in adjoining pastures. Postal returns indicated a thin and scattered distribution in urban and peri-urban situations over all the North Island except for Wellington and Wairarapa, and also in Nelson and

Westland, drawing most attention in Bay of Plenty and Nelson. Mostly a weed of lawns or coastal waste ground.

Knot-root bristle grass (*Setaria geniculata* (Poir.) P.Beauv.)

Historical records Recorded by Allan (1940) in hillside pastures about Auckland city. Collected from Northland, Auckland, Bay of Plenty, Wanganui and Hawkes Bay in 1940s and 1950s and in the South Island in 1970s, when it also began spreading in Manawatu and Horowhenua. Not mentioned by Madden (1940) or Levy (1956). Present distribution (Edgar and Shand 1987) throughout the North Island, Nelson and Westport.

Present surveys Only found 5 times in pasture, averaging little >1% cover in 3 Waikato sites and Tauranga. Not identified along western highways but located 6 times on central and eastern road verges and 3 times also in adjacent pasture. Posted in from almost every district except Taranaki, Rangitikei, Canterbury and Otago, often as lawn weed. The southernmost specimen received was from Greymouth. Particularly abundant in Bay of Plenty and Manawatu. Frequent references to increased abundance in last 2-3 years.

ANNUALS

Summer grass, crab grass (*Digitaria sanguinalis* (L.) Scop.)

Historical records First recorded in 1855 (Edgar & Shand 1987) and for Auckland in 1871 (Esler & Astridge, 1987). By 1906 (Cheeseman) was "abundant as a naturalized weed, waste places and cultivated ground" in both North and South Island. Not mentioned by Madden (1940).

Present surveys In pastures mainly found in area between Whangarei, Waitomo and Opotiki. Three sites in Matamata, Tauranga and Whakatane had >10% cover and the rest <2.5% cover. The R/P survey found the species in >50% of verges north of Matamata and in western North Island, but in only 16% of sites in the east. In the north also frequently found in adjacent pastures, but uncommon to find this south of Te Kuiti except abundant in one New Plymouth site. The commonest species sent in by mail from all districts, accompanied by colourful comments indicating it was growing profusely, taking over gardens and lawns, and showing phenomenal recent increase, especially in last 2-4 years. A farming organisation stated it constituted up to 50% of some Bay of Plenty pastures in 1988/89.

Crowfoot grass (*Eleusine indica* Gaertn.)

Historical records First recorded in Auckland in 1864, but rarely noted there again in next 50 years (Cheeseman 1906). By 1940 (Allan) was infrequent in waste places and cultivated land to latitude 40". Reported early on from Westport, but apparently not currently present in Westland. Not mentioned by Madden (1940).

Present surveys Found in 13 pasture sites, mainly north of Otorohanga and only once (near Kaitaia) > 1% cover (9%). In the R/P survey identified once on the east coast (near Gisborne) but in about 1/3rd of verge sites west and north of Tokoroa. Only in adjacent pasture at 3 sites between Pokeno and Putaruru. Posted in from Northland to Nelson on the west, and once from Hawkes Bay. Particularly prominent in Waikato, Bay of Plenty and Taranaki, with increased abundance in last 2-3 years. Occurs in gardens, lawns and waste ground, particularly where there is heavy treading (e.g. farm gateways).

DISCUSSION

C4 grasses, as a group, are undoubtedly a more abundant and conspicuous element of both our agricultural and urban environment than they were in the past. However, proving this is an effect of climate warming is not easy. There are no clear-cut lines over which indicator species can be expected to move only when temperature rises.

Date of introduction, potential rate of spread, frost tolerance, and site specificity vary in the C4 species discussed, and some may still have been increasing in range when temperatures started to rise appreciably. Others attained a wide distribution long ago, yet have recently increased in abundance within that range. Free-seeding annuals like summer grass colonise suitable sites rapidly and are not limited by winter cold, but fluctuate greatly in abundance in good and bad years. Only where temperature is the main factor limiting increase will climate warming show an obvious effect.

The documented southward spread of paspalum in pastures provides the strongest evidence for a climate change effect. It is unlikely that lack of seed was limiting penetration into pastures, or that a gradual adaptation has occurred (as suggested by Madden 1940), as sexual reproduction is rare. Rising temperatures are very likely also the cause of the relatively recent (10-15 years) expansion of carpet grass south of Auckland, and the rapid increase in impact of knot-root bristle grass in the same period. The explosion in summer grass and its entry into pastures probably reflect enhanced seed production in recent warm summers.

If climate warming continues, an increasing area of North Island pastures will probably have a

significant component of C4 grasses in future, which will alter their seasonal carrying capacity and nutritive value. However, spread should be slow where good management restricts the area of bare soil available for colonisation. In the longer term, importation or development of improved cultivars of desirable C4 forage grasses is warranted to take advantage of the changed conditions.

Fine and coarse turf areas will experience an increasing problem with coarse-growing C4 species. Cultural practices should be designed to limit potential sites for spring invasion of summer annuals, and to restrict the spread of rhizomatous or stoloniferous perennials once invasion occurs. In northern areas line-leaved turf cultivars of perennial C4 species should play an increasingly important role.

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