Research Letters

Potential contribution of the pearl millet (*Pennisetum glaucum*) variety Okashana-1 to household food security in the northern communal areas of Namibia

Pearl millet is the dominant crop in northern Namibia and Okashana-1 is the only improved variety. A review of available on-farm trials data was conducted in conjunction with assessments of season quality to evaluate the potential contribution of Okashana-1 to household food security. The results showed that adoption of Okashana-1 in the 'Four-Os' has the potential of increasing pearl millet grain yield by 33% using the farmers' current management practices. If management is improved the potential grain yield gain increases to 46%. Under both levels of management the greatest yield gain potential is in the Omusati region. In Caprivi and Kavango the potential yield gain due to Okashana-1 adoption is estimated at 11–12% irrespective of the level of management. The potential benefits of using Okashana-1 are larger when seasons are short and/or have a marked drought towards the end.

Agricultural production in the northern communal areas (NCAs) is based on mixed crop and livestock farming. NCAs include Caprivi, Kavango, Ohangwena, Oshikoto, Oshana and Omusati. The last four are collectively referred to as the Four-Os. Due to the infertile sandy soils having low water holding capacity together with short seasons of low and erratic rainfall, pearl millet is the only cereal that can be productively grown in over 90% of the area constituting NCAs. Generally, pearl millet is considered more efficient in its utilisation of moisture and has higher levels of heat and moisture stress tolerance than does sorghum or maize, giving it ability to grow in harsher environments.[1-4] Pearl millet in northern Namibia is therefore grown on land that is both marginal and fragile. It is the major cereal in the farming system and the staple food crop for all rural households in Kavango and the Four-Os.[5] During the 1992–93 season, it accounted for 96% of the cropped area in the NCAs.[6] Cropping is done largely for subsistence.

The only improved pearl millet variety available to farmers is Okashana-1. Farmers in the Four-Os identified it as a preferred type from an ICRISAT nursery planted at Okashana during the 1986–87 season. This variety was developed by ICRISAT from materials collected in Togo (West Africa) and released by the Namibian Ministry of Agriculture in 1989–90. It is noted for its early maturity, large grain size, fast grain filling ability and high grain yield. Okashana-1 matures in 85–90 days compared to an average of 120 days for the farmers' landrace varieties.[7] The object of this article is to review the potential contribution of Okashana-1 towards household food security in the NCAs. This is done through an assessment of the results of the on-farm variety evaluation trials, the rainfall pattern in the NCAs, the most preferred traits in improved pearl millet varieties, the degree to which Okashana-1 meets these requirements, and the Okashana-1 adoption estimates.

Review of available data

During 1992–93 in the Four-Os, Okashana-1 produced between 38% and 63% more grain than the Farmers' Local

varieties (Table 1). In Kavango there was no significant difference in grain yield performance between the two varieties, although the Farmers' Local variety was marginally superior. The value to cost (V/C) ratio ranged from –32 in the Kavango to 264 in the Four-Os. Results for the 1993–94 season were similar to those for the previous season in both regions (Table 1).

Grain yield performance of Okashana-1 and the Farmers' Local variety during 1994–95 was not significantly different in both Kavango and the Four-Os (Table 1). However, in both regions Okashana-1 had a marginal yield advantage over the Farmers' Local of between 13% and 36%. The V/C ratio ranged from 27 to 49. During 1995–96, Okashana-1 also had a non-significant, marginal yield advantage over the farmers' landrace varieties in Caprivi (13%) and in the Four-Os excluding Omusati (18%). The Okashana-1 yield advantage was, however, substantial and significant in Kavango (38%; *P* < 0.05) and Omusati (105%; *P* < 0.01) (Table 1). The V/C ratio during the 1995–96 season ranged from 19 to 103.

Under farmers' own management there was no significant

Table 1. Mean grain yield (t ha⁻¹) of Okashana-1 and the Farmers' Local varieties in RMFI[†] on-farm evaluation trials during the 1992–93 to 1995–96 seasons.

Season	Variety	Yield and yield gain for indicated locations			
		Four-Os West	Four-Os East	Kavango West	Kavango East
1992–93[8]	Okashana-1	1.71**	1.83*	1.93	1.25
	Farmers' Local	1.05	1.33	2.00	1.33
	Okashana yield gain	63%	38%	–4%	–6%
	V/C ratio #	264	200	–28	–32
1993–94[8]		Four-Os		Kavango	
	Okashana-1	1.00**		0.73	
	Farmers' Local	0.76		0.80	
	Okashana yield gain	32%		–9%	
	V/C ratio	32		–9	
1994–95[9]		Omusati	Oshana	Kavango	
	Okashana-1	2.03	1.40	1.60	
	Farmers' Local	1.80	1.03	1.40	
	Okashana yield gain	13%	36%	14%	
	V/C ratio	31	49	27	
1995–96[10]		Omusati	Other-Os	Kavango	Caprivi
	Okashana-1	1.50**	0.93	0.62*	1.83
	Farmers' Local	0.73	0.79	0.45	1.62
	Okashana yield gain	105%	18%	38%	13%
	V/C ratio	103	19	23	28
All		Four-Os		Caprivi + Kavango	
	Yield gain mean	46%		11%	

*, **Significantly different from the Farmers' Local variety at *P* = 0.05 and *P* = 0.01 level of probability, respectively.

#V/C ratio is calculated from the AGRIBANK pearl millet loan viability assessment price of N$800 and seed prices of N$1 kg⁻¹ in 1992–93 and N$3 kg⁻¹ from 1993–94 to 1995–96, assuming a seeding rate of 2 kg ha⁻¹.

†Researcher-managed, farmer-managed.

Table 2.   Mean grain yield (t ha⁻¹) of Okashana-1 and the Farmers'
Local variety in FMFI† on-farm evaluation trials from 1993–94 to
1995–96.

Season	Variety	Yield and yield gain for indicated locations		
1993–94[8]		Caprivi	Kavango	Four-Os
	Okashana-1		0.32	0.72
	Farmers' Local		0.36	0.67
	Okashana yield gain		–11%	7%
	V/C ratio#		–5	7
1994–95[9]				
	Okashana-1			0.42
	Farmers' Local			0.36
	Okashana yield gain			17%
	V/C ratio			8
1995–96[10]			Omusati	Other-Os
	Okashana-1	1.83	1.01*	1.54**	0.92
	Farmers' Local	1.62	0.78	0.77	0.79
	Okashana yield gain	13%	29%	100%	16%
	V/C ratio	28	31	103	17
All		Caprivi + Kavango		Four-Os
	Yield gain mean	12%		33%

*,**Significantly different from the Farmers' Local variety at $P = 0.05$ and $P = 0.01$ level of probability, respectively. #V/C ratio as in Table 1.
†Farmer-managed, farmer-implemented.

Table 3.   Some season parameters at Okatana (Okat) in the Four-Os and Rundu (Rund) in Kavango during the period when Okashana-1 was tested in the NCAs.

Parameter	1992–93		1993–94		1994–95		1995–96	
	Okat	Rund	Okat	Rund	Okat	Rund	Okat	Rund
Rain (mm)	331	626	552	419	697	254	338	338
SS[1]	L	N	N	N	L	N	L	L
SL[2] (days)	64	120	145	121	90	125	77	62
LSQ[3]	Poor	Poor	Ave.	Good	Poor	Poor	Poor	Poor

[1]Season start; [2]season length; [3]late season quality.

difference in the grain yield performance of Okashana-1 and the Farmers' Local variety except during 1995–96 in Kavango and Omusati (Table 2). During the 1993–94 season the Farmers' Local variety was marginally superior in Kavango. The Okashana-1 yield gain over the Farmers' Local ranged from –11% in Kavango during 1993–94 to a massive 100% in Omusati during the 1995–96 season (Table 2). The V/C ratio ranged from –5 to 103.

Rainfall figures for Rundu and Okatana were used to estimate seasonal characteristics in Kavango and the Four-Os, respectively. Long-term annual average rainfall for Okatana is 400 mm and that for Rundu is 600 mm. Rainfall in the Four-Os was below normal (less than 80% of long-term mean) in two of the four years when the performance of Okashana-1 was evaluated on-farm; while in Kavango it was below normal in three of the four years (Table 3).

Season start (SS) is defined as a rainfall event after October 1, with a three-day cumulative total of 20 mm or more, which is followed by productive falls (i.e. 10 mm or more) at intervals not greater than 10 days, within the next 30 days.[11,12] An early season (E) means SS before November 15, late (L) is after December 15, and normal (N) is in between. Season length (SL) is taken as the period (in days) between the season start date and 10 days after the last productive rain, which should not be separated by more than 20 days from the previous productive rainfall event.[11,12] Season length was very short for one and three years in Kavango and the Four-Os, respectively. Late season quality (LSQ) was estimated as good if no dry periods of more than 10 days occurred and poor if long dry periods were present.

In both regions some terminal (end of season) drought, that is, poor late season quality was experienced in three of the seasons over the test period. In Kavango there was a false season start in 1992–93 and 1993–94. This is a rainfall event after October 1, with a three-day cumulative total of 20 mm or more, which is not followed by a productive fall for intervals greater than 10 days, within 30 days of the initial rainfall event. During 1992–93 a number of trial sites were sown at the time of the 'false' season start and the several non-productive falls received managed to keep some plants alive. While the plant stand was poor, all such plants did not experience terminal drought.

An evaluation of the past 46 seasons' rainfall data for Rundu (Kavango) and Okatana (Four-Os) indicates that there is no difference in the probabilities for season start time, season length, early or late season drought (Table 4). The regions, however, differ significantly in the frequency of both no rain periods greater than 10 days and below-normal seasons. Periods greater than 10 days without productive rain occur more frequently in Kavango than in the Four-Os. The majority of the seasons in Kavango receive normal rainfall while the highest proportion of seasons in the Four-Os receive below-normal rainfall (Table 4).

Further analysis of the rainfall data revealed some interesting observations, listed below: a) Seasonal rainfall amount is independent of the date of season start and early season quality; b) late season quality is independent of early season quality and

Table 4.   Some rainfall season characteristics of Rundu (Kavango) and Okatana (Four-Os) since 1950.

Parameter	% of seasons falling into the parameter category shown		
	Kavango (n = 44)	Four-Os (n = 46)	χ^2
Early:Late:Normal start seasons[1]	27:21:52	22:37:41	>0.1
Average:Good:Poor early season quality[2]	27:52:21	26:57:17	>0.1
Average:Good:Poor late season quality[2]	23:32:46	13:39:48	>0.1
Short:Average:Long seasons[3]	16:9:75	11:22:67	>0.1
Total days of no rain periods >10 days (0:1:2:3:4)[4]	5:16:50:25:5	2:28:44:24:2	>0.1
Number of no rain periods >10 days (0:1:2:3:4:>5)	5:5:25:25:23:18	2:13:24:37:24:0	<0.05
Exp. dry:Dry:Normal:Wet seasons[5]	7:23:57:14	0:44:33:24	<0.01

[1]Early means before November 15, late is after December 15 and normal is in between.
[2]Good means no dry periods of more than 10 days, poor means presence of long dry periods.
[3]Short season is less than 86 days, long season is more than 110 days.
[4]1 = 10 to 40 days; 2 = 41 to 80 days; 3 = 81 to 120 days and 4 = over 120 days.
[5]Exp. (exceptionally) dry means rainfall less than 50% of long-term seasonal average; dry means 51–79%, normal means 80–120% and wet means over 120%.

Table 5. Farmers' preferred traits in improved pearl millet varieties: results of the 1993 MAWRD/ICRISAT on-farm survey.[6,13]

Trait	1-2-3 score[1]	Rank by score	% Respondents ranking trait 1st	Rank by % trait 1st	Okashana-1 adequacy (n_1/n_2)
Early maturity	89	1	21.0	1	123/5
Grain yield	72	2	14.6	2	98/18
Drought tolerance	58	3	9.5	4	84/16
Grain size	55	4	12.5	3	90/6

[1]Score = sum of (number of ranking respondents × rank order value) where: 1st is valued 3; 2nd is valued 2 and 3rd is valued 1.

n_1 = number of respondents indicating that Okashana-1 is adequate.

n_2 = number of respondents indicating that Okashana-1 needs improvement.

rainfall amount during the crop establishment period; c) season length and total number of no rain periods greater than 10 days is dependent on season start date ($P < 0.01$). Early seasons are longer but have longer periods of no productive rain; d) twenty-four per cent of the seasons start early, 47% start at the normal time and 29% are late. Most early seasons (59%) do not have terminal droughts, while most of the late seasons (77%) have terminal drought ($P < 0.01$). The highest proportion (40%) of seasons starting in normal (expected) time have terminal drought; e) seventy-three per cent of the seasons that start late have good early season quality ($P < 0.01$). None of the late seasons had less than 60 mm of total rainfall during the first 4 weeks after effective season start date compared to 18–19% for the early and normal start seasons.

The most preferred varietal trait has been established to be early maturity followed by grain yield (Table 5). For the traits of major concern listed in Table 5, the majority of the concerned farmers found Okashana-1 to be adequate.

The SACCAR impact study estimated that during the 1994–95 season the variety was sown on 17% and 45% of the pearl millet area in the Four-Os and Kavango, respectively.[14] The number of households using Okashana-1 during the same season was estimated to be 72% in both the Four-Os and Kavango.

Discussion

The yield differences between Okashana-1 and the Farmers' Local landrace varieties are largely explained by the season characteristics during the test period. Season length and presence or absence of terminal drought were the primary yield determinants (Table 3). Longer seasons and good late season quality gave the Farmers' Local a yield advantage over Okashana-1 in Kavango during 1992–93 and 1993–94. An additional factor could be the landrace varieties' better adaptation to low fertility and low management production systems. This phenomenon has been reported from the Sahel, which is a similar environment.[15] However, landrace varieties are not necessarily more efficient in moisture utilisation.[16] Many of the Namibian landrace varieties require 120 days to maturity,[7] which is much longer than the effective cropping season that is usually obtained in the NCAs (Tables 3 and 4). This results in drought stress during flowering, grain setting and filling, with consequent yield reductions. To attain yield stability and greater household food security, it is important to grow pearl millet cultivars with water requirement patterns that match the effective growing season of the region. The use of stable cultivars, such as Okashana-1, combined with improved management of the cropping system, imparts stability to productivity in arid environments.[2,3,16] Early flowering tends to give higher yield and greater yield stability than late flowering

if there is a terminal drought. This grain yield performance pattern was demonstrated by Okashana-1 in the Four-Os during the test period and in Kavango during the 1995–96 season.

Early maturing cultivars give maximum benefit where rainfall is reasonably predictable and terminal droughts are common. As reflected by the comparative yields in Kavango, Okashana-1, like all early maturing cultivars, failed physiologically to fully exploit longer seasons whenever they occurred, resulting in lower yield. Although early varieties give lower grain yield during longer seasons, it has been shown by research elsewhere that they improve yield stability.[17,18] This provides good reason for farmers to prefer a mixed portfolio of short and long-cycle varieties. It is known that farmers have always practised pearl millet plant type selection and in the process preserved desired types besides maintaining genetic diversity.[19] The genetic diversity found in the Namibian germplasm collection[20] is adequate testimony of the Namibian farmers' conscious attempts to maintain high genetic heterogeneity as an insurance against total crop failure.

The high adoption rate of Okashana-1 is an indication that it has a definite niche in the production system. Its early maturity compared to local landrace varieties provided a desirable variety combination with the Farmers' Local variety for spreading risk that the farmers immediately grabbed. Okashana-1 offered farmers their most preferred trait in improved pearl millet varieties (i.e. earliness) in combination with good grain yield especially when seasons are short. Farmers in similar environments elsewhere have also been reported to request early maturing varieties.[21] The high Okashana-1 adoption rate is therefore not surprising.

Improved seed is also cheap technology with potentially very high returns on invested capital (Tables 1 and 2). The generally high V/C ratios are way above 2, which is considered the minimum to generate farmer interest in new technologies.[22] Except for the long season and no terminal drought situations experienced in Kavango during the first two seasons of test, the use of Okashana-1 in all other situations led to a very high return, which would and did attract great interest in farmers.

Pearl millet farmers in the NCAs plant the crop over a long period in any one season. A sowing period extending from November to February in Kavango and November to March in the Four-Os has been reported.[23] For all late plantings the use of Okashana-1 improves the chances of a successful harvest. The high Okashana-1 adoption rate is an indication that farmers are exploiting the earliness potential of the improved variety.

It is also recognised that the adoption of improved varieties does not significantly alter the labour input into the production system. Marginal labour input increases may be associated with grain yield gain, resulting in large returns to the labour input.[24] Binswanger and Pingali[25] argue that farmers are always eager to adopt stress-tolerant varieties whether land is scarce or abundant, because they are cheap and do not require extra labour. This is the case with Okashana-1 in the NCAs.

The poor rainfall in the NCAs since 1992 (Table 3) is yet another factor that helps to explain the high adoption rate of Okashana-1. However, farmers had no intention of replacing all their landrace varieties with Okashana-1.[14] This provides a clear signal that farmers are more concerned about stable system productivity as opposed to yield maximisation. Farmers in the NCAs recognise genetic diversity as a viable strategy to improve yield stability and household food security.

Conclusions

Season quality in the NCAs is very unpredictable. Early seasons are not necessarily better seasons. Consequently, the sowing of a mixed variety portfolio (Farmers' Local variety and Okashana-1) from the start of every season is strongly recommended. This adequately spreads the risk as one of the varieties may be better placed to handle the within-season and/or terminal drought in these unpredictable environments. For late seasons, however, landrace varieties have little chance of providing a successful harvest and in this case farmers are best advised to plant Okashana-1 only. Moreover, when the season is late there is a much reduced risk of the crop failing to establish and this should make dry planting a lot more attractive, even with purchased seed.

Okashana-1 adoption is likely to increase both in terms of area sown and number of farmers growing it. Factors in Okashana-1's favour include its ability adequately to meet farmers' expectations for both earliness and grain yield, cheap seed and the farmers' desire to minimise the risk of total crop failure through the use of a variety mix with different maturity ranges. Moreover, in case of a late season start planting Okashana-1 increases the chances of a successful harvest.

The high average yield gains realised when Okashana-1 is used in place of the Farmers' Local varieties indicate its potential contribution to improvements in household food security in the NCAs. Moreover, yield stability would improve with Okashana-1 adoption and therefore give greater assurance for food security from one year to the next.

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Biologically active substances from *Zanthoxylum capense* (thunb.) Harv.

A chemical investigation into the composition of Zanthoxylum capense *yielded several biologically active compounds, including pellitorine. A convenient HPLC method was developed to determine the presence of pellitorine in crude extracts from plants rapidly and qualitatively.*

In our continuing search[1] for biologically active substances of natural origin, the stems, twigs and leaves of *Zanthoxylum capense* (thunb.) Harv. were collected on three occasions in the Potchefstroom and Parys areas of South Africa. Four metabolites of interest, viz. pellitorine, xanthoxylum-γ,γ-dimethylallyl ether, β-sitosterol and sitosterol-β-D-glucoside, were isolated and characterised by physico-chemical techniques. The reported biological activity of *Z. capense* is evidently related to those of pellitorine and sitosterol-β-D-glucoside.

The tree, *Z. capense*, is indigenous to South Africa. Parts of the tree were used by early white pioneers and are still being widely used as a medicine by traditional healers.[2] The latter use the plant for a number of ailments such as colic, flatulent colic, gastric intestinal disorder and as a cure against intestinal parasites. It is also used to cure palsy and as a stomachic. It was reported to have been employed as a snakebite remedy, and is administered by rubbing the powdered root into snakebite wounds after the wounds have been lanced; also, the bark is swallowed repeatedly at fifteen-minute intervals until the snake venom-induced swelling subsides. The bark is also used to cure cattle of gall-sickness.

Zanthoxylum capense was a popular treatment in South Africa during the influenza epidemic of 1918, and was subsequently also used against colds and flu. The root acts against violent chronic coughing and the bark makes a tonic and a cure for sores and blood impurities. The Zulus use the powdered bark to relieve toothache, and against tuberculosis and paralysis. It was employed by whites as an epilepsy remedy and to 'disinfect' anthrax-infected meat, either by boiling the meat with some leaves, or by drinking a leaf infusion after eating the roasted meat.[2] The Mpondo people use the powdered root to cure pimples and 'blood poisoning' in general. The leaves serve as a purgative and parasiticide. The Thonga use the root against bronchitis and as a mouthwash for aphthae in children; a lotion made from the root is applied against acne.[2]

Juritz[3] reported in 1914 the only chemical investigation of *Z. capense* and related that 'A fairly large proportion of a resinous body was extracted, together with tannins and traces of a yellow colouring matter, for which no characteristic tests were ascertained'.

Our collection of plant material took place on three occasions, namely, 1) January 1995 (Parys district, farm Koedoesfontein); 2) July 1995 (Machavie district, Potchefstroom Agricultural College); 3) January 1996 (farm Koedoesfontein). During the exploratory collection in January 1995, only pellitorine was isolated. Large amounts of plant material were collected on the two subsequent occasions and were fractionated as described in the experimental section.

Only β-sitosterol (2) and sitosterol-β-D-glucoside (3) were isolated during the July collection (winter season), and pellitorine and xanthoxylol-γ,γ-dimethylallyl ether were extracted in addition to β-sitosterol in January (summer).

The most salient spectroscopic data, in particular IR, ¹H and

¹³C NMR characteristics, of pellitorine (1) and xanthoxylol-γ,γ-dimethylallyl ether (4) are reported in the experimental section. The NMR assignments are based on the interpretation of DEPT, COSY and HETCOR experiments, which were conducted on all the substances.
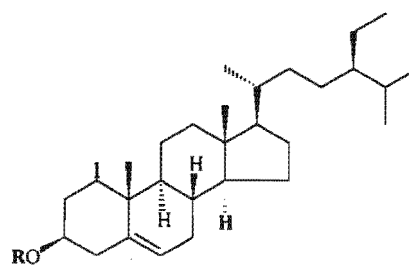
Pellitorine, isolated from *Z. capense*, occurs in several other *Zanthoxylum* species, e.g. *Z. macrophylla*,[4] *Z. zanthoxyloides*,[5] *Z. gillettii*,[6,7] *Z. acutifolium*,[8] *Z. petiolare*[9] and *Z. zanthoxyloides*.[10]
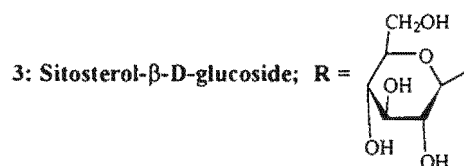

1: Pellitorine

The bioactivity of pellitorine has been established; it was found to exhibit potent ovicidal action against the potato beetle, *Leptinotarsa decemlineata*, even at very low concentrations.[10] Kubo *et al.*[4] isolated several insect growth inhibitors from *Z. macrophylla*, such as pellitorine. Pellitorine has been incorporated into artificial diets, optimised against several economically important agricultural pests, e.g. pink bollworm (*Pectinophora gossypiella*), tobacco budworm (*Heliothis virescens*), corn earworm (*H. zea*) and fall armyworm (*Spodoptera frugiperda*). In these studies, the LD_{90} for pellitorine against *P. gossypiella* was determined as 25 ppm. Pellitorine was used in tests against the house mosquito (*Culex pipiens*) and the freshwater snail (*Biomphalaria glabratus*), both having medical significance. Pellitorine was the most potent compound tested against *C. pipiens*.

Sitosterol-β-D-glucoside (3) is a biologically active compound which exhibits visible antigastro-ulcerative properties against acetic acid-induced ulcers, as well as a visible effect against cold stress-induced ulcers.[11] Sitosterol-β-D-glucoside is the major constituent of a phytomedicine which is sold in Germany for the regeneration of the prostate gland, it has a stimulatory effect on the immune system, and a prophylactic effect on a variety of diseases of civilisation.[12]
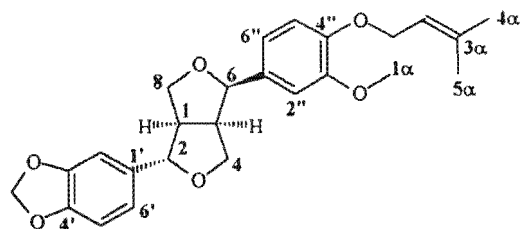

2: Sitosterol; R = H

3: Sitosterol-β-D-glucoside; R =

Several lignans are known to be biologically active, however, the activity of xanthoxylol-γ,γ-dimethylallyl ether, isolated in this study, has not been investigated.

Some of the reported beneficial properties of *Z. capense*[2] may therefore be satisfactorily explained by the secondary metabolites (pellitorine and sitosterol-β-D-glucoside) characterised in this study.

A fast and convenient HPLC method was developed to

4: Xanthoxylol-γ,γ-dimethylallyl ether

determine rapidly and qualitatively the presence of pellitorine in crude extracts from plants. It is important to note that pure pellitorine, upon standing, forms a mixture of at least three amides, containing the fully conjugated *trans-trans*-diene (pellitorine) as the major component.[13] This mixture of isomers will be referred to as the 'pellitory mixture' in subsequent explanations. Maximum absorption of the pellitory mixture occurred at 254 nm. Using MeOH/H₂O (85:15) as eluent at a flow rate of 1 cm³ min⁻¹, a good chromatographic separation of the three isomers, eluting at retention times of 2.4, 3.1 and 3.9 min, was obtained. A diode array detector was used to measure absorption at 189–440 nm.

This HPLC method permits a seasonal study of *Z. capense* to determine if the occurrence of pellitorine in the plant is influenced by seasonal changes, since no pellitorine was isolated from plant material collected during the winter months.

Experimental

Infrared spectra were recorded on a Nicolet 550 series II spectrometer using KBr pellets. UV spectra were obtained on a Shimadzu UV-240 spectrophotometer. Mass spectra were recorded on a VG Micromass 7070-E double focusing mass spectrometer. ¹³C and ¹H nuclear magnetic resonance spectra were recorded on a Varian Gemini-3 spectrometer at 75 MHz and 300 MHz for ¹³C and ¹H NMR nuclei, respectively.

HPLC separations were conducted using a Hewlett Packard series 1050 HPLC system equipped with a quaternary pump, diode array detector and auto sample injector. An HP ODS Hypersil column (100 mm × 4.6 mm) packed with material of 5 µm particle size was used.

Extraction of plant material collected during the winter season

Twigs, stems and leaves of *Z. capense* were collected in the Machavie district on the property of the Potchefstroom Agricultural College during July 1995. This material was dried at 50°C over a period of 24 h and subsequently milled to a coarse powder (7500 g). This powder was extracted by stirring at room temperature for 12 h with CHCl₃/MeOH (50 l, 1:1). The filtrate was concentrated under reduced pressure at 60°C to yield a crude extract (265 g) which was purified according to Fig. 1 to yield β-sitosterol (120 mg) and sitosterol-β-D-glucoside (180 mg).

The crude extract was partitioned between CHCl₃:water (10 l, 1:1) and the CHCl₃ layer was concentrated under reduced pressure at 60°C to yield a sticky mass of material (135 g), which was the subject of further investigation. The CHCl₃ extract (135 g) was chromatographed on a silica gel column (8 × 40 cm, 1000 g silica gel) using CHCl₃ as eluant. Appropriate fractions (20 cm³) were collected, and those showing similar TLC analyses were combined and evaporated under reduced pressure at 60°C yielding six samples.

Fractions 2–4 were combined (55.6 g) and chromatographed on a silica gel column (8 × 50 cm, 1300 g silica gel) using acetone:*n*-hexane (1:10). Appropriate fractions (25 cm³) were collected and those showing similar TLC analyses were combined

Fig. 1.   Extraction of dried plant material (7.5 kg) in July 1995.

and concentrated under reduced pressure at 60°C to yield six samples. The β-sitosterol (0.12 g, 0.0016%, based on dry material), crystallised from acetone to yield pure β-sitosterol mp 143°C.

Fraction 6 (19.2 g) was purified by silica gel column chromatography to yield pure sitosterol-β-D-glucoside (0.18 g, 0.0024%, based on dry material), mp 296°C.

Extraction of plant material collected during the summer season

Fresh twigs and leaves of *Z. capense* were collected in the Parys district on the farm Koedoesfontein during January 1996. The material was dried at 50°C over a period of 24 h and subsequently milled to a coarse powder (7500 g). This powder was extracted at room temperature for 12 h with CHCl₃/MeOH (50 l, 1:1). The filtrate was concentrated under reduced pressure at 60°C to yield a crude extract (255 g), which was partitioned between CHCl₃ and water, and the organic layer between hexane and 90% MeOH. The lipid layer contained some β-sitosterol. The 90% MeOH layer was concentrated and its residue partitioned between water and CHCl₃. The latter layer (86 g) was purified by extensive chromatography on silica gel to yield xanthoxylol-γ,γ-dimethylallyl ether and pellitorine. The xanthoxylol-γ,γ-dimethylallyl ether crystallised from *n*-pentane (0.07 g, 0.0024%, based on dry material), mp 58°C, Rf 0.28 (ethyl acetate/*n*-hexane, 1:4), *m/z* 424, λ_max (MeOH)/233 nm (ε/dm³ mol⁻¹ cm⁻¹ 18100), 280 (8925). IR: ν_max/cm⁻¹ 3000–2800, 1600, 1510, 1450, 1300–1200, 1150, 1050, 1000, 800 and 700. [α]_D – 86.3°. The ¹³C and ¹H NMR spectral data of xanthoxylol-γ,γ-dimethylallyl ether are summarised below.

δ_C 149.40 (S) C-4″, 148.02 (S) C-4′, 147.33 (S) C-3″, 147.26 (S) C-3′, 137.62 (S) C-3α, 135.22 (S) C-1′, 130.98 (D) C-1″, 120.03 (D) C-2α, 119.58 (D) C-6″, 117.62 (D) C-6′, 112.96 (D) C-5″, 109.12 (D) C-5′, 108.15 (D) C-2″, 106.54 (D) C-2′,

101.03 (T) -OCH$_2$O, 87.63 (D) C-2, 82.02 (D) C-6, 70.91 (T) C-4, 69.70 (T) C-8, 65.72 (T) C-1α, 55.84 (Q) -OCH$_3$, 54.52 (D) C-1, 50.03 (D) C-5, 25.70 (Q) C-5α, 18.07 (Q) C-4α.

δ_H 6.90 (m), 6.85 (m), 6.82 (m), 6.76 (m), 6.38 (m), 6.74 (m), 5.92 (s, 2H), 5.50 (t, 1H, J 6.7 Hz), 4.82 (d, 1H, J 5.6 Hz), 4.54 (d, 2H, J 6.7 Hz), 4.38 (d, 1H, J 7.1 Hz), 4.07 (d, 1H, J 9.3 Hz), 3.86 (s, 3H), 3.81 (m, 2H, J 9.0 Hz), 3.29 (m, 2H, J 9.0 Hz), 2.85 (q, 1H, J 7.3 Hz), 1.75 (s, 3H), 1.70 (s, 3H).

Pure pellitorine (2.2 g, 0.029%, based on dry material) was obtained, mp 71°C (ethyl acetate), R_f 0.28 (ethyl acetate/n-hexane, 1:4), m/z 223, λ_{max} (MeOH)/256 nm (ε/dm^3 mol^{-1} cm^{-1} 1390), IR v_{max} (KBr)/cm^{-1} 3300, 3100, 3000–2800, 1650, 1610, 1550, 1450, 1300, 1250, 1150 and 1000. The ^{13}C and ^{1}H NMR spectral data for pellitorine are summarised below.

δ_C 166.60 (S) C-1, 143.25 (D) C-3, 141.33 (D) C-5, 128.27 (D) C-4, 121.82 (D) C-2, 46.85 (T) C-1′, 32.97 (T) C-6, 31.24 (T) C-8, 28.50 (D) C-2′, 28.35 (T) C-7, 22.23 (T) C-9, 19.99 (Q) C-3′ and C-4′, 13.85 (Q) C-10.

δ_H 7.15 (m, J 9.7, 9.8 and 13.8 Hz), 6.01 (m, J 9.8 and 13.9 Hz), 5.74 (d, J 11.1 Hz), 5.35 (m), 3.10 (t, J 6.5 Hz), 2.08 (m), 1.74 (m), 1.34 (m), 1.24 (m), 1.21 (m), 0.85 (d, J 6.7 Hz), 0.81 (t, J 7.0 Hz).

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Nutrient limitation affects growth and attachment of two food spoilage bacteria, *Bacillus subtilis* and *Pseudomonas fluorescens*

The attachment was studied of the food spoilage bacteria Pseudomonas (P.) fluorescens and Bacillus (B.) subtilis to stainless steel test surfaces suspended in Minimal Salts Medium (MSM) or Standard One Nutrient Broth (SONB). Attached cells were enumerated on Standard One Nutrient Agar after being dislodged from test surfaces by being shaken with beads. Counts of planktonic cells grown in SONB and MSM were evaluated in parallel with counts of attached cells. Higher counts of attached P. fluorescens and B. subtilis cells (c. 1 log cfu cm^{-2}) were recovered from surfaces suspended in SONB compared to those in MSM. Counts of planktonic B. subtilis cells grown in SONB exceeded those in MSM by c. 1 log cfu ml^{-1}. By contrast, counts of planktonic P. fluorescens in SONB and MSM were not significantly different (P > 0.05). Scanning electron microscopy showed attached cells of B. subtilis grown in SONB to be rod-shaped, while coccoid shapes were observed for corresponding cells grown in MSM. Attached cells of P. fluorescens were rod-shaped in both SONB and MSM. Evidence of extracellular polymeric substance formation was observed for attached cells of both bacteria in SONB and MSM. These findings have implications for the contamination of foodstuffs by these bacteria.

Biofilms of a wide variety of bacteria can develop *in situ* on food processing equipment.[1-3] The initial stages of adhesion of bacterial cells to surfaces are thought to be, in part, influenced by the nutrient status of the surrounding liquid medium.[4] The types and availability of nutrients on moist food contact surfaces *in situ* are variable.[5] Often, nutrient-rich conditions are encountered in food processing plants during the production cycle, due to residues of proteins and fats being deposited on equipment surfaces.[6] However, low nutrient conditions can also be encountered when cleaning programmes aimed at removal of food residues from food contact surfaces have been completed after production.[5]

Different opinions prevail on bacterial adhesion under nutrient-rich and nutrition-limited conditions. It has been postulated that bacterial cells attach in high numbers to surfaces as a survival strategy when nutrients in the surrounding medium are limited. This is believed to be the result of a higher concentration of nutrients at a surface compared to the corresponding bulk fluid or surrounding liquid medium.[4] Nutrient limitation in the environment adjacent to solid surfaces has also been shown to condition bacteria for adherance,[4,7,8] because they can benefit from an enhanced nutrient status.[7] Although nutrient-limitation tends to favour bacterial attachment to surfaces, certain low-nutrient conditions have been shown to induce detachment.[9] Conversely, other workers have proposed that bacterial adhesion to surfaces also occurs when nutrient concentrations are high in the surrounding fluid medium.[10]

The objective of this *in vitro* study was to simulate conditions for bacterial growth which might occur in food processing environments and hence determine the effect of nutrient limitation on the growth and attachment of *Pseudomonas* (*P.*) *fluorescens* and *Bacillus* (*B.*) *subtilis* as examples of typical food spoilage bacteria.[11,12]

Materials and methods

A rope-inducing *Bacillus* (*B.*) *subtilis* strain[11] and a *Pseudomonas* (*P.*) *fluorescens* strain, isolated from poultry,[12]
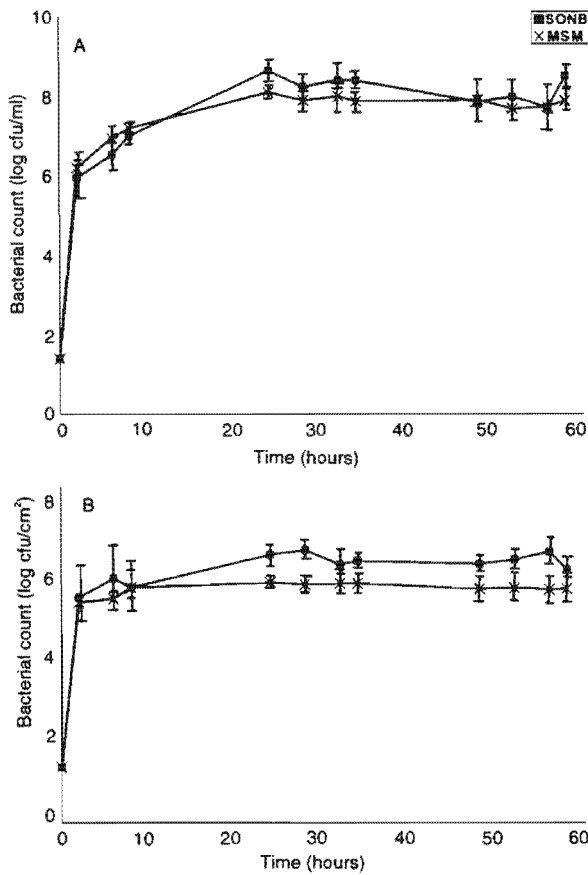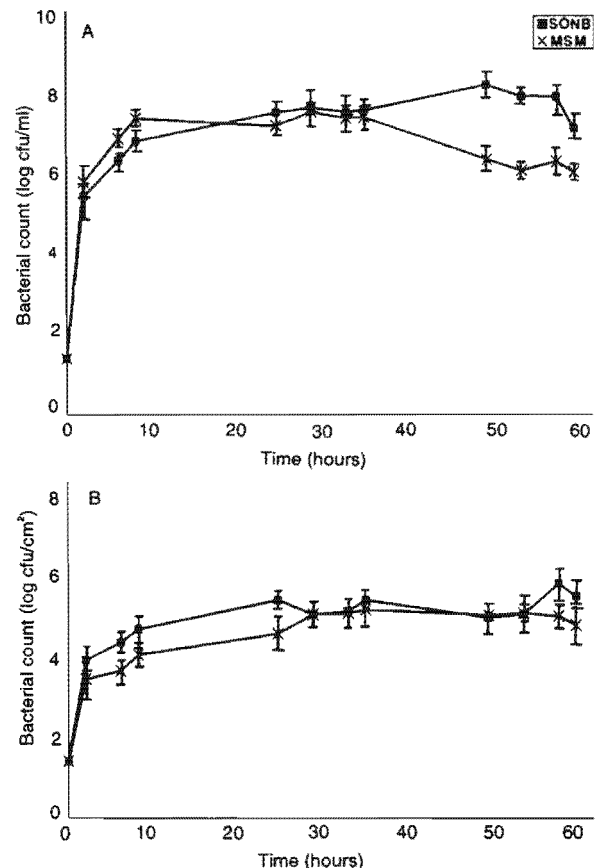
Fig. 1.   Counts of planktonic (*A*) and attached (*B*) *P. fluorescens* cells grown in Standard One Nutrient Broth (SONB) and Minimal Salts Medium (MSM).
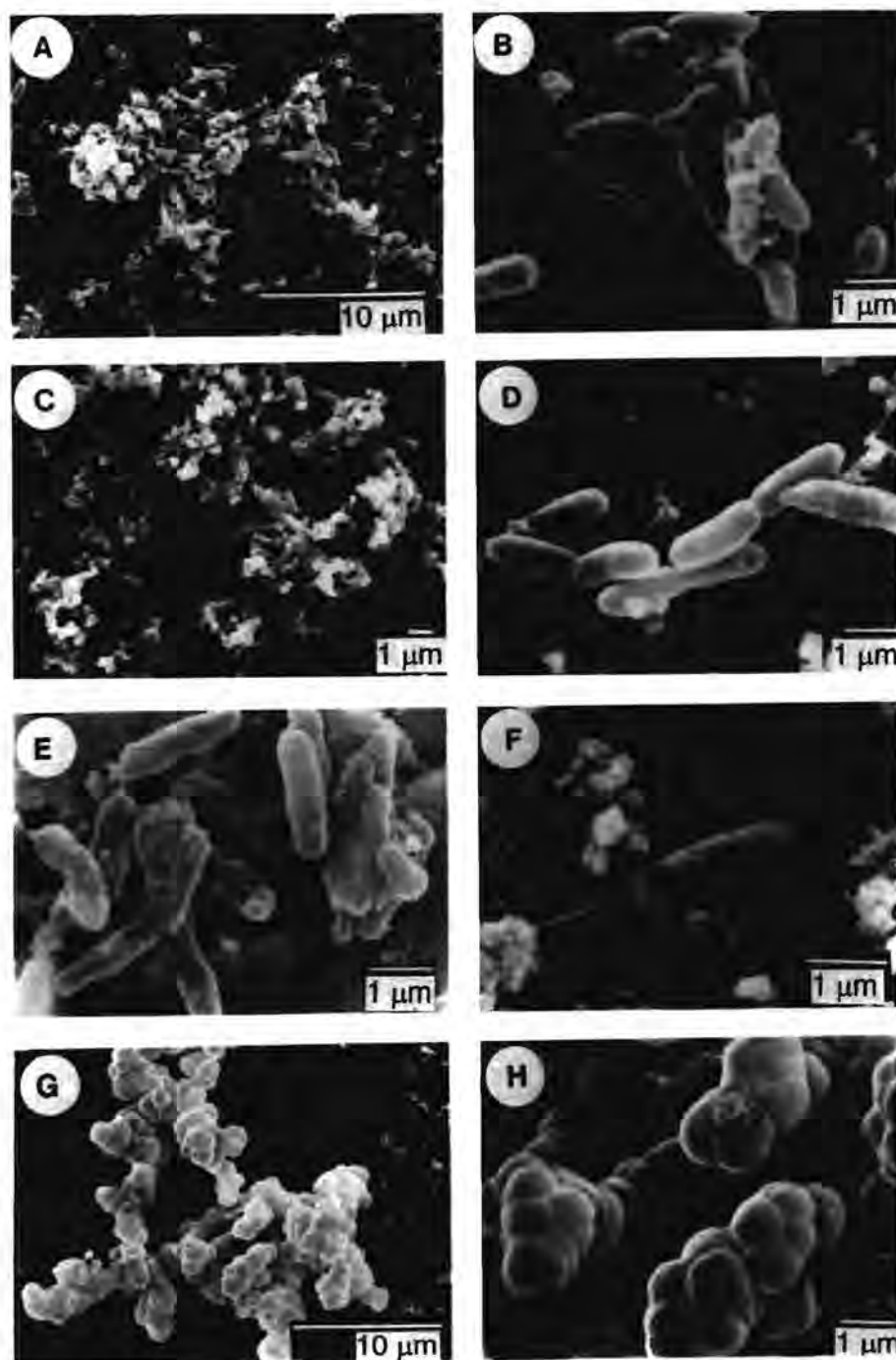
were chosen for this study. Strains were maintained on Standard One Nutrient Agar (SONA) (Biolab, Midrand) plates at 4°C, and sub-cultured every 21 days. Prior to use, each culture was grown in 50 ml Standard One Nutrient Broth (SONB) (Biolab) over-night at 30°C (*Bacillus*) and 25°C (*Pseudomonas*).

Twelve stainless steel test pieces (Grade 304L, polished) of 4-cm^2 surface area each were cut and washed with general purpose detergent, rinsed with distilled water and soaked in 70% ethanol for 5 min.[13] Test surfaces were simultaneously suspended in 600 ml MSM supplemented with 0.04% glucose,[8] or 600 ml SONB for each bacterial isolate. The media were inoculated with 1% (v/v) of an overnight culture of either *P. fluorescens* or *B. subtilis* and incubated at 25°C (*P. fluorescens*) or 30°C (*B. subtilis*). One test piece was sampled every 2–4 h for 12 h, up to 58 h, from both media and for both bacteria. Bacterial cells were dislodged from each test piece by shaking in 20 ml sterile peptone saline with 20 g glass beads (5 mm diameter) for 20 min.[13] Counts of bacterial cells attached to each test piece at each time interval were then determined by duplicate droplet plate counts[14] on SONA and plates were incubated at 25°C (*P. fluorescens*) or 30°C (*B. subtilis*) overnight.

To study planktonic growth, 100 ml of MSM or SONB were each inoculated with 1% (v/v) of an overnight culture of either *P. fluorescens* or *B. subtilis* and incubated as described above. Planktonic cell counts were determined in parallel with counts of attached cells from duplicate droplet plates.[14] The above protocol was repeated on three occasions.

Multifactor ANOVA (Statgraphics 7.0) was carried out on counts of attached and planktonic cells grown in SONB and MSM. The highest counts of attached and planktonic *P. fluorescens* and *B. subtilis*, in SONB and MSM, irrespective of time

intervals, were compared at the 95% confidence level.

Duplicate stainless steel test surfaces exposed to *P. fluorescens* or *B. subtilis* at time intervals corresponding to the highest counts in MSM and SONB were prepared for and analysed by SEM as described by Lindsay *et al.*[3]

Results

Counts of planktonic *P. fluorescens* in SONB and MSM followed a typical growth curve pattern (Fig. 1*A*). Counts of planktonic *P. fluorescens* grown in MSM were generally higher than those in SONB by *c.* 0.2 log cfu ml^{-1} between 2 and 8 h, after which counts in SONB exceeded those in MSM by *c.* 0.5 log cfu ml^{-1}. The highest counts were recorded after 24 h in both media (8.63 log cfu ml^{-1} and 8.09 log cfu ml^{-1} in SONB and MSM, respectively) and were not significantly different ($P > 0.05$).

Counts of attached *P. fluorescens* cells in SONB and MSM increased steeply from 0 to 2 h and remained approximately constant thereafter (Fig. 1*B*). Generally, counts of *P. fluorescens* cells attached to test surfaces suspended in SONB exceeded counts of cells attached to test surfaces suspended in MSM over all time intervals. The highest counts of *P. fluorescens* from test surfaces suspended in MSM (6.10 log cfu cm^{-2} after 24 h) were significantly lower ($P < 0.05$) than those recovered from test surfaces suspended in SONB (6.90 log cfu cm^{-2} after 28 h).

Counts of planktonic *B. subtilis* cells followed a typical growth curve pattern similar to that of *P. fluorescens* in SONB and MSM up to 34 h. Counts in SONB then increased to 8.18 log cfu ml^{-1} after 48 h, followed by a decline to 7.11 log cfu ml^{-1} after 58 h (Fig. 2*A*). In contrast, counts in MSM steadily declined from 7.38 log cfu ml^{-1} after 34 h to 6.03 log cfu ml^{-1} after 58 h (Fig. 2*A*). The highest counts of *B. subtilis* grown in MSM (7.38

Fig. 2.   Counts of planktonic (*A*) and attached (*B*) *B. subtilis* cells grown in Standard One Nutrient Broth (SONB) and Minimal Salts Medium (MSM).

Fig. 3. Scanning electron micrographs of stainless steel test surfaces showing attached cells of *P. fluorescens* (*A–D*) or *B. subtilis* (*E–H*) after growth in Standard One Nutrient Broth (*A, B, E, F*) or Minimal Salts Medium (*C, D, G, H*).

3*A,C*). These were unevenly distributed on test surfaces with extracellular polymeric substances (EPS) connecting cells (Fig. 3*A–D*). Extensive web-like structures of EPS were visible for *P. fluorescens* cells attached to test surfaces suspended in SONB (Fig. 3*A*), whereas only single strands of EPS were visible for corresponding cells attached to test surfaces suspended in MSM (Fig. 3*D*). Qualitatively, SEM suggested that *P. fluorescens* cells attached to test surfaces suspended in SONB produced more EPS than corresponding cells in MSM. Cells of *P. fluorescens* attached to test surfaces suspended in both media consistently displayed rod-shaped morphologies (Fig. 3*A–D*).

Attached *B. subtilis* cells grown in SONB consisted of microcolonies of rod-shaped cells with EPS connecting cells to the surfaces of test pieces (Fig. 3*E,F*). In keeping with results for *P. fluorescens*, SEM suggested that more EPS was produced by attached cells of *B. subtilis* grown in SONB than those grown in MSM (Fig. 3*E–H*). Furthermore, *B. subtilis* cells grown in MSM displayed coccoid morphology (Fig. 3*G,H*) in comparison to the longer rod-shaped cells observed on test surfaces suspended in SONB (Fig. 3*E,F*). In addition, attached cells of *B. subtilis* grown in MSM formed tightly aggregated microcolonies (Fig. 3*G,H*) compared to the more dispersed arrangement of attached cells grown in SONB (Fig. 3*E,F*).

Discussion

Counts of both *P. fluorescens* and *B. subtilis* cells, whether planktonic or attached, were higher when the bacteria were cultured in SONB than in MSM. Therefore, the growth rate of attached and planktonic *B. subtilis* and *P. fluorescens* cells was higher in SONB than in MSM, since metabolic precursors required for growth, such as amino acids, are readily available for uptake by the cells in SONB. By contrast, these precursors must be synthesised by the bacterial cells in MSM, where carbon is the sole nutrient source.

log cfu ml^{-1} after 34 h) were significantly lower (*P* < 0.05) than those in SONB (8.18 log cfu ml^{-1} after 48 h).

Counts of attached *B. subtilis* cells in SONB and MSM increased gradually from 2 to 34 h. Generally, counts of *B. subtilis* cells attached to test surfaces suspended in SONB exceeded or equalled those of cells attached to test surfaces suspended in MSM over all time intervals. The highest counts were recorded after 56 h (5.7 log cfu cm^{-2} — SONB) and 34 h (5.1 log cfu cm^{-2} — MSM) (Fig. 2*B*) and were not significantly different (*P* > 0.05).

SEM confirmed attachment of *P. fluorescens* and *B. subtilis* cells to stainless steel test surfaces in both SONB and MSM.

Pseudomonas fluorescens grown in SONB and MSM on stainless steel consisted of microcolonies of rod-shaped cells (Fig.

Counts of planktonic and attached *P. fluorescens* exceeded the corresponding counts of *B. subtilis* by *c.* 0.5 log cfu ml^{-1} and 1 log cfu cm^{-2}, respectively, in both growth media. Higher counts of attached cells of *P. fluorescens* (*c.* 6 log cfu cm^{-2}) compared to corresponding counts of attached *B. subtilis* cells (*c.* 5 log cfu cm^{-2}) agreed with the findings of Wirtanen and Mattila-Sandholm.[15] The latter found that higher numbers of *P. fluorescens* than of *B. subtilis* cells attached to stainless steel test surfaces after growth in nutrient-rich media for 48 h. These results reinforced the hypothesis that Gram-negative bacteria such as *P. fluorescens* are primary colonisers of surfaces *in vitro*[16] and in

situ.[17] It is thus suggested that the more rapid attachment of *P. fluorescens* to stainless steel test surfaces contributed to higher sessile counts compared to *B. subtilis* in this study. *Bacillus subtilis* cells are larger than *P. fluorescens* cells, which means that carbon availability limits the total biomass of the attached cells of the former, which may account for their lower counts observed in this study.

The highest counts of attached *P. fluorescens* cells grown in MSM were significantly lower ($P < 0.05$) than the highest corresponding counts for SONB. These findings corresponded with reports that adhesion of pseudomonads to surfaces was enhanced under nutrient-rich conditions[10,18] and detachment from surfaces occurred when nutrients were limited.[9] Furthermore, SEM suggested that more EPS was produced by attached cells of *P. fluorescens* grown in SONB than by cells grown in MSM. These results reinforced reports by Wrangsstadh *et al.*,[19] who observed a decrease in EPS production by a starved marine *Pseudomonas* sp., and Ronner and Wong,[20] who noted that different growth media influenced the composition of EPS formed by attached bacteria.

Significantly higher counts of planktonic cells of *B. subtilis* ($P < 0.05$) were recorded in SONB than in MSM after 48 h. Since sporulation of *B. subtilis* is reportedly triggered by nutrient limitation,[21] the significantly lower counts of planktonic cells in MSM than in SONB, after 48 h, suggested that sporulation might have occurred in MSM.[10]

SEM revealed that attached *B. subtilis* cells adopted rod-shaped morphology in SONB but were coccoid-shaped in MSM. This corresponded to reports that attached cells of non-motile bacteria, such as *B. subtilis*, were able to survive limitation of carbon and amino acids by reducing cellular size.[18] Alternatively, the observed structures may have represented *B. subtilis* spores attached to test surfaces.[22] This conclusion was based on qualitative estimations of size (*c.* 1 μm) from scanning electron micrographs, which were within the size range of spores of several *Bacillus* species.[22] More strands of EPS were associated with attached cells of *B. subtilis* on test surfaces suspended in SONB compared to attached cells grown in MSM, which was in keeping with SEM observations of *P. fluorescens*. This result reinforced the hypothesis that nutrient concentration in different growth media influences rate and composition of bacterial EPS formation.[20]

Conclusion

This study demonstrated that cells of the food spoilage bacteria, *P. fluorescens* and *B. subtilis*, attached to stainless steel test surfaces under nutrient-rich and nutrient-limited conditions *in vitro*. Growth and attachment to stainless steel was favoured under nutrient-rich conditions, which contradicted the generally accepted opinion that attachment of bacterial cells to surfaces is favoured when nutrients are limited. Since stainless steel is a common construction material of food processing equipment and both nutrient-rich and nutrient-limited conditions are encountered in food processing environments, this study highlighted the potential of *P. fluorescens* and *B. subtilis* to form films on stainless steel food processing surfaces. Such biofilms may contaminate food products passing through the equipment during processing, which ultimately leads to a shorter product shelf-life and economic losses to manufacturers and consumers.

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The equatorial electrojet and day-to-day variability of Sq

The day-to-day variability of Sq(H) at equatorial stations has been studied using the correlation between sequential variabilities of the parameter at different latitudes. It was found that high correlation exists between Sq(H) values for the same equatorial electrojet (EEJ) stations. On the other hand, there was a low correlation between Sq(H) at non-EEJ stations. The EEJ current is significantly less well correlated with the current over other equatorial stations of non-electrojet fields. This suggests an extraterrestrial cause of the EEJ.

It has long been observed that the form and strength of the Sq current system shows a marked variability from one day to the next. This current, according to Vestine,[1] is believed to arise from fluctuating ionospheric winds, which blow the ionized air across the lines of force of geomagnetic fields, thereby generating electric fields to drive the electric currents. Hence the observed solar daily variations on any particular day reflect the effects of the solar influence operating to produce ionization and the strength of the upper air winds. This variability is even observed when the days are magnetically quiet. Chapman and Stagg[2,3] studied the correlations between the variations in daily range in the three magnetic elements at six different stations and concluded that the correlations between variations in the same elements at two stations fell off as the separation of the station increased.

Further correlation studies have been carried out more recently.[4-15] Osborne[16] found that there was little correlation between the electrojet and the rest of the Sq current system. Mayaud[17] found that the correlation between the daily ranges of Sq(H) at an electrojet station and non-electrojet station was only slightly smaller than that for two latitude stations of similar relative position not subject to the influence of the electrojet. Schlapp[10] found no significant difference between correlation coefficients of pairs of nearby equatorial stations involving and not involving the electrojet. Okeke and Onwumechili,[18] from their preliminary analysis of geomagnetic day-to-day variations in the equatorial zone, concluded that there is strong evidence that the daily variabilities of the EEJ and the worldwide Sq (WSq) are not in phase and consequently combine somewhat destructively at the three EEJ stations.

The present paper reports on a study of the correlation between day-to-day variability of the horizontal component H at different stations between latitude 8.3°N and 30.4°N. We use stations near the dip equator, namely, Trivandrum (T), Kodaikanal (K), and Annamalainagar (M), that experience both worldwide Sq influence and equatorial electrojet influence. The stations outside the dip equator, namely, Hyderabad (H), Alibag (A), Jaipur (J), Ujjain (U), and Sabhawala (S), are also used and they experience only the influence of the WSq current. The equatorial electrojet variability was studied separately using the data obtained by subtracting the results for Alibag from Trivandrum (T–A), Alibag from Kodaikanal (K–A), and Alibag from Annamalainagar (M–A).

Data analysis

The data consisted of published hourly values of the H component of the magnetic field of eight Indian observatories, for three months of the year. The coordinates of the observatories are as indicated in Table 1 and Fig. 1.

The June solstice, equinox and December solstice are repre-

Fig. 1. Location map of the geomagnetic observatories whose data are included in this volume.

sented by the hourly values for the months of June, October and December, respectively. From the hourly values of t hours local time we subtracted the midnight baseline values to obtain the departure from midnight, for any particular day, say the ith day: $H_i - H_0 = H_{ti}$. The variability of H element from one day in the sequence's $(i + 1)$th day is then $h_{ti} - h_{ti+1}$ for a chosen hour t.

The sequential variability (SV) is a measure of the magnitude of day-to-day variability defined as:

$$SV(H) = 1/n \sum | h_{ti+1} - h_{ti} |$$

where the summation goes from $i = 1$ to n, where n = number of values in the batch; $t = 1$ to 24.

For the day-to-day variability of the EEJ alone, the midnight departures at Alibag are subtracted from the corresponding midnight departures at Trivandrum, Kodaikanal and Annamalainagar. This is done because near the dip equator, Sq is jointly caused by both EEJ and worldwide Sq current systems. For the WSq current system, we used the stations outside the dip equator such as H, A, U, J, S, as defined in the introduction. Alibag represents the stations outside the dip equator and when the H, Z, D

Table 1. Magnetic observatories and their coordinates.

Stations	Geographic Lat. °N	Geographic Long. °E	Geomagnetic Lat. °N	Geomagnetic Long. °E
Trivandrum	8.29	76.57	1.25	146.4
Kodaikanal	10.23	77.47	0.60	147.1
Annamalainagar	11.37	79.68	1.40	149.4
Hyderabad	17.42	78.55	7.60	148.9
Alibag	18.63	72.87	9.50	143.6
Ujjain	23.18	75.78	13.50	147.0
Jaipur	26.92	75.80	17.30	147.4
Sabhawala	30.37	77.80	28.80	149.8

Some observations on Holocene changes in periglacial activity at Long Ridge, Marion Island

Extensive evidence of Holocene periglacial activity exists at Long Ridge, Marion Island, in the maritime sub-Antarctic. This includes blockfields, stone-banked lobes, solifluction terraces, Azorella terraces and various forms of patterned ground. This paper examines the spatial distribution and variation of relict, as well as present-day, periglacial forms and activity. Evidence is presented for considerably colder conditions on Marion Island earlier in the Holocene. In addition, evidence is advanced for a steeper periglacial gradient than at present.

Marion Island is one of a few small islands in the Southern Ocean, and hence represents an important location for geomorphological research on climate change in this region. To date, such work has focused mainly on Quaternary glaciations.[1] In addition to his palaeoglaciological work, Hall reported on the widespread occurrence of periglacial landforms,[2,3] and observed that some forms are relict, indicating post-glacial conditions that are cooler than at present.[4] Current geomorphological research aims to use periglacial indicators for climate change on the island. This paper aims to present a preliminary outline of the Holocene periglacial forms present at Long Ridge, examine the climatic changes that are indicated by the differences, and to provide a first interpretation of the trends in the distribution of relict and active periglacial forms.

Study area

Marion Island (46°54′S, 37°45′E) is located in the southern Indian Ocean, and is one of two islands which together constitute the Prince Edwards Island Group (Fig. 1). The island has an area of approximately 290 km² and rises to 1230 m a.s.l. in the central parts. It is characterised by an exceptionally maritime climate, with generally low temperatures, a small diurnal and annual temperature range, high annual precipitation and strong westerly winds.[5] The summer mean maximum and minimum temperatures are 10.5°C and 5.0°C, and the winter means are 6.0°C and 1.0°C, respectively, at the Meteorological Station (24 m a.s.l.). On average, precipitation occurs on 25 days of each month, with a mean annual total of 2576 mm. Winds blow most frequently from the northwest, with an average velocity of 32 km h⁻¹.[5] Present-day frost action at sea level on the island is characterised by diurnal frost cycles frequently associated with needle ice growth.[2,4] At the highest altitudes seasonal freezing, and possibly permafrost, may be present.

Marion Island consists of the peak of a shield volcano.[6] An older sequence of pre-glacial grey basaltic lavas is overlain in places by post-glacial black lavas and scoria material, the most recent having formed in 1980.[10] Hall identified three glacial periods on the island, with the most recent glacial being from 116 000 to 13 000 BP.[11]

Field observations for this study were made on Long Ridge, a 5-km feature composed of the older grey lava, which runs from sea level to approximately 600 m a.s.l. (Fig. 1). The ridge is covered by a till, deposited during the last glaciation, which ended around 13 000 BP. Based on the foregoing, any periglacial features identified on Long Ridge can be ascribed to the Holocene. Three areas were selected for a detailed inventory of periglacial landforms that have developed in the till. These sites are Long Ridge South (500 m a.s.l.), Bill Briggs (350 m a.s.l.) and Long Ridge Bottom (200 m a.s.l.) (Fig. 1). All sites are generally southeast facing and comparable in terms of slope angles and vegetation cover. The vegetation at the study sites consists of fjaeldmark, with sparse to very sparse vegetation cover and a significant amount of rocky material at the surface. *Azorella selago* is the dominant vascular plant within the study area.

Periglacial features

A large number of periglacial forms are found on Long Ridge. Those identified there ranged in size from blockfields to micropatterned ground. Each type of landform is examined in terms of its altitudinal distribution, dimensions and level of current activity. Table 1 summarises the altitudinal distribution and some important parameters of the various periglacial landforms observed. The periglacial features can be divided into relict and active features.

Relict periglacial landforms

Blockfields. Blockfields are 'considerable areas, broad and usually level or of only gentle gradient, covered with moderate-sized or large angular blocks of rock'.[7] Several blockfields are identified at the high-altitude Long Ridge South site. The blockfields are found in an area with maximum slopes of 10–15° and each covers an area of approximately 100 m by 50 m (Fig. 2). They consist of large angular boulders, with *a*-axes of up to 2.5 m. Boulders at the surface are either supported by other similar boulders, or are on a matrix base. No similar features of this magnitude were identified at either the Bill Briggs or Long Ridge Bottom sites.
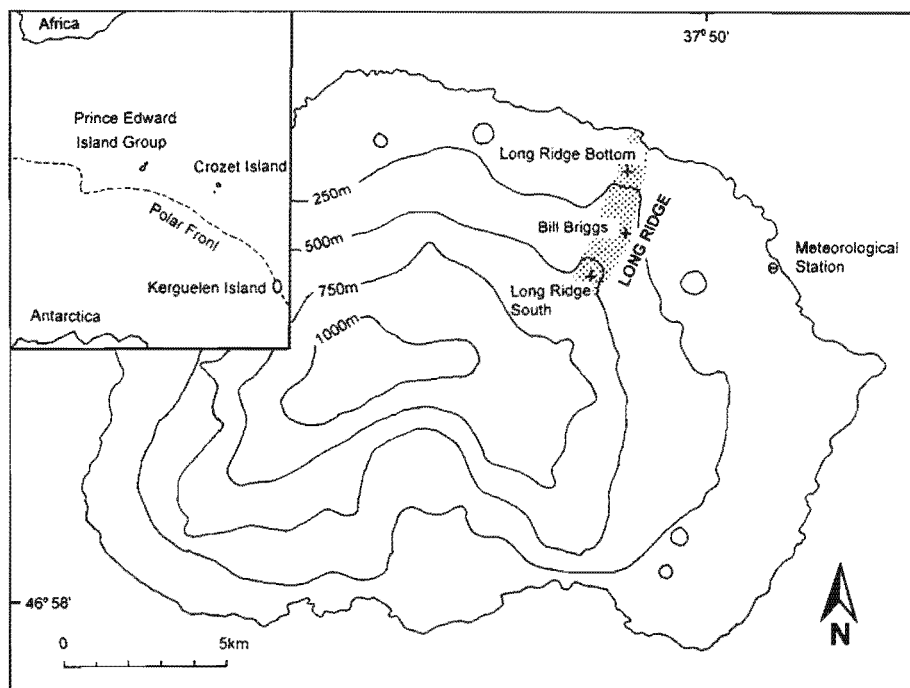

Fig. 1. Location of Marion Island in the southern Indian Ocean and the three study sites at Long Ridge.

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Fig. 2. View across a blockfield on level gradient at Long Ridge South. Note the distinct fabric and imbrication developed in the platy material. Small isolated patches of vegetation indicate pockets of fines near the surface.

Large stone-banked lobes. Small stone-banked lobes have been described on Marion Island by Hall,[3] who also mentions the existence of larger blocky lobes on debris-strewn slopes in steeper areas.[4] The stone-banked lobes are morphologically similar to those described by Benedict in the Colorado Front Range.[8] Large stone-banked lobes are found only at the high-altitude Long Ridge South site (Fig. 3). Forms have downslope lengths of up to 20 m and are several metres wide and high. They occur in an area with slopes of between 20° and 30°, have relatively flat tread surfaces ranging between 0° and 10° and steep fronts composed of openwork material. The tread surface is covered by small clasts supported by a loamy matrix. This surface may support sparse vegetation growth. The boulder front consists of large blocky or platy clasts, which are usually imbricated. The stone-banked lobes can be divided into two groups based on material composition. Lobes with blocky risers are associated with a material supply from bedrock outcrops, while those with platy fronts appear to be the result of transport processes in the till, which is rich in platy clasts.

Stone-banked lobes associated with blocky material from rock outcrops tend to have large to very large blocky fronts up to 5 m high (Fig. 3). These lobes have steep fronts, with angles approaching 80° in places. The blocks show signs of transport in the form of alignment of clasts and imbrication. The riser material consists of blocks up to 1.5 m × 1 m × 1 m.

Fig. 3. Large stone-banked lobe with platy front at Long Ridge South. Height of riser is 2.5 m. Note the lichen cover on blocks and *Azorella* tussocks between clasts as indicators of the relict nature of the deposit.

Stone-banked lobes that are not immediately associated with the disintegration of rocky outcrops have developed in the till material. The lobe fronts are built of platy clasts and tend to be smaller than the blocky front lobes, with risers of up to 3 m. Maximum *a*-axes of clasts are up to 0.9–1 m. The riser fronts tend to be less steep than those of blocky fronts, with angles of 45–65°.

Solifluction terraces. Solifluction terraces are morphologically similar to the large stone-banked lobes, in that they consist of a flat tread of finer material and a steep riser of coarse material on the downslope edge. However, the solifluction terraces' greatest dimension tends to be parallel to the contours, and they have a lower riser than large stone-banked lobes in the same area. Solifluction terraces are typical of areas with low slope angles of between 50 and 100. At the high-altitude Long Ridge South site, a large number of solifluction terraces exist, with a lateral extent of several tens to hundreds of metres and riser heights of up to 2 m (Fig. 4). These terraces tend to be broad and flat, with a downslope extent of up to 15 m. At Bill Briggs the terraces tend to be shorter, possibly due to a landscape control, with riser heights of up to 1 m. There are no terraces of this sort present at the low-altitude site.

Fig. 4. Large solifluction terrace at Long Ridge South. Riser height is about 1 m. Note the smaller *Azorella* terraces in the background. Lichen and *Azorella* growth are indicative of the current stability of the terrace front.

The risers of solifluction terraces within the study area tend to incorporate smaller clasts than those present in large stone-banked lobes within the same area. Most clasts present in the risers have *a*-axes measurements of less than 1 m. All terraces are considered to be relict, as there is significant *Azorella selago* and lichen growth on many of the step risers (Fig. 4).

Sorted nets. Sorted nets are 'patterned ground features occurring in groups whose mesh (interior surfaces) is neither dominantly circular nor polygonal'.[9] Large-scale sorted nets, as are present at the 350-m a.s.l. Bill Briggs site, have not been reported before on Marion Island. They occur in a relatively steep south-facing area, with a gradient between 24° and 28° (Fig. 5). The coarse mesh has a cross-slope dimension of between 3 m and 3.5 m, and a downslope dimension of between 1.5 m and 2 m. The fine patches between the coarse material are linearly aligned in a downslope direction. Material within the coarse section of the nets was platy, with the largest clasts being up to 1.2 m × 0.7 m × 7 cm. Most clasts in the coarse mesh of the nets had *a*-axes of between 15 cm and 70 cm, with larger clasts being found upslope. The relatively fine-grained centres were covered with a mixture of grasses and *Azorella selago*.

Fig. 5.   Sorted nets on a 24° southeast-facing slope near Bill Briggs. Note the wide borders of platy clasts and the distinct imbrication developed in them. Fine centres are occupied by grasses suggesting current stability of the forms.

These sorted nets are relatively large features and are considered to be relict under the present climate. This assumption is based on the growth of a significant amount of vegetation on the finer material, which would not be present under the intense frost action required to form the sorted nets. In addition, larger clasts within the mesh of the net have a lichen and moss cover.

Active periglacial features

Azorella terraces. Azorella terraces are similar to solifluction terraces, but have a distinctive morphology being invariably banked behind a riser of *Azorella selago* (Fig. 6). In addition, *Azorella* terraces are not always orientated directly across the slope. The tread of the step is usually sorted and free of vegetation and has a downslope dimension of between 1 m and 9 m, with most of the *Azorella* terraces being under 6 m. Laterally, *Azorella* terraces extend to a 100 metres or more. The height of the riser is generally between 0.3 m and 0.8 m with occasional terraces attaining risers of up to 1.2 m. Between-site analysis shows a trend for an increase in riser height with altitude (Fig. 7). Riser angles vary between 30° and 80°.

Azorella terraces are considered to be active features at the two higher-altitude sites. Clasts have been pushed through and heaped on top of *Azorella* terraces. Small active stone-banked lobes are located at breaks in the *Azorella* cushions at the higher-

Fig. 6.   View across an 8° east-facing slope with *Azorella* terraces near Bill Briggs. Vegetated fronts are disrupted by sediment movement across the riser.
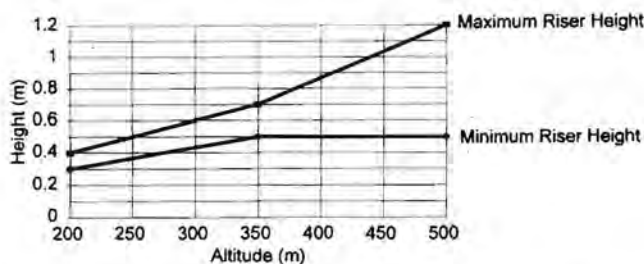

Fig. 7.   Plot of riser height of *Azorella* terraces with altitude, indicating a general increase in size and range in size of the forms with altitude.

altitude sites. It appears that the larger blocky material found in the risers is no longer mobile, as larger blocks are often lichen and moss covered. Further corroboration of current activity comes from experimental sites at Long Ridge South and Long Ridge Bottom. Painted line transects were installed in May 1996 to give an indication of movement rates of surface clasts at both sites. Initial experimental evidence supports the idea that sufficient clast movement occurs to allow *Azorella* terraces to be active at Long Ridge South (unpub. observ.). There is little evidence to suggest that enough movement occurs at Long Ridge Bottom to maintain the steps in their current form.

Small stone-banked lobes. Hall has described small stone-banked lobes on Marion Island with the average riser between 0.29 m and 0.41 m high.[3] In this study, small stone-banked lobes were found on a variety of slope angles from 5° to 30°. Small lobes are very numerous at Long Ridge South, and tend to have a
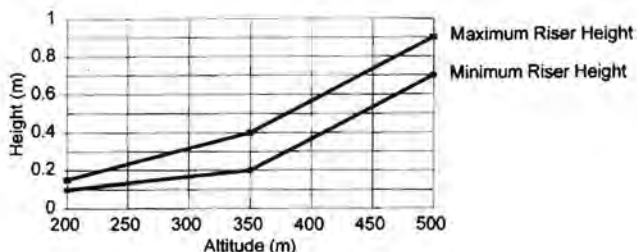

Fig. 8.   Plot of riser height of small stone-banked lobes with altitude, indicating an increase in size with altitude.

riser height of between 70 cm and 90 cm (Fig. 8). These features are also common at the Bill Briggs site, but tend to have a lower riser of between 20 cm and 40 cm (Fig. 9). At the lower altitude Long Ridge Bottom site, small lobes are uncommon, and those present have risers of between 10 cm and 15 cm. Thus, there is a clear altitudinal variation in distribution and magnitude of small lobes (Fig. 8).

The small stone-banked lobes on Long Ridge consist of an unvegetated tread of vertically-sorted gravel and pebble material overlying fine silt and sand, and a lobe riser of far coarser material with *a*-axes of 0.05–1 m. The clasts in the riser are sorted, with the largest clasts at the outward edge. The clasts tend to be platy. Clasts at the outward edges are usually imbricated and are often orientated across the direction of movement.

The small lobes of both types are considered to be active at both Long Ridge South and Bill Briggs. There is a lack of vegetation and lichen on the risers, and preliminary experimental evidence shows (see under *Azorella* terraces) that there is sufficient movement of surface clasts to maintain these features. At the low-altitude site, small lobes appear to be far less active, with vegetation growth on the lobes indicating a relative lack of surface movement.

Sorted stripes. 'Sorted stripes are patterned ground with a

striped pattern and a sorted appearance due to parallel lines of stones and intervening strips of finer material orientated down the steepest available slope'.[9] Hall considers sorted stripes to be the most widespread periglacial form on Marion Island.[2]

Sorted stripes are located on a wide range of slope angles from 0 to 20°. Sorted stripes are found at the two higher-altitude sites. Stripes at Long Ridge South were wider than those at the Bill Briggs site. The coarse stripes at Long Ridge South have an average width of 140 mm, while those at Bill Briggs have an average width of 102 mm. Fine stripes have a width of 84 mm versus 58 mm at the lower site. The coarse stripes consist of material between pebble and gravel size, with the fine stripes made up of sand, silt and clay. According to Washburn, coarse stripes tend to be narrower than fine stripes,[7] however, on Long Ridge the coarse stripes were all wider than the intervening fine stripes. Hall found that coarse stripes were wider than or the same width as fine stripes at 7 out of 12 areas on Marion Island.[2]

The maximum depth of sorting at Long Ridge South was between 10 and 15 cm, while that at the Bill Briggs site was between 4 and 7 cm. This agrees well with results from experimental sites monitoring differential frost heave at 150 m a.s.l., which indicate that frost penetrates to depths of between 5 cm and 10 cm during current diurnal frost cycles.

It is unlikely that there are any fossil sorted stripes on Long Ridge as surface processes are active enough to obliterate any traces of past activity. The sorted stripes at Long Ridge South and Bill Briggs are considered to be currently active and sorted stripe propagation is likely to be occurring. These processes are the subject of ongoing experimentation at the Long Ridge South site. Further, the sorted stripes demonstrate a clear variation with altitude, in terms of their presence, width and depth of sorting.

Discussion

The distribution of periglacial landforms on Long Ridge shows a marked correlation with altitude (Table 1). Most types of periglacial features identified on the ridge are more common and of a greater magnitude at higher altitude. Blockfields, large stone-banked lobes and terraces dominate the Long Ridge South site. The lower-altitude site at Bill Briggs also has a variety of periglacial forms, but on a slightly smaller scale than those present at Long Ridge South. However, the low-altitude Long Ridge Bottom site lacks large-scale relict forms, and is relatively sparse in terms of smaller features. This clearly points to an increase in periglacial activity with altitude, associated with an increase in frequency and/or intensity of frost-induced processes with altitude.

Evidence for an Early Holocene colder period. Long Ridge shows evidence of a colder period conducive to more severe periglacial activity earlier in the Holocene. This is indicated by the presence of a population of large-scale forms including the blockfields, large stone-banked lobes, solifluction terraces and sorted nets. These are distinct from the small-scale active features such as the *Azorella* terraces, small stone-banked lobes and sorted stripes. The larger forms show signs of a lack of movement, including the growth of lichen on exposed clasts, and grass and *Azorella* growth on the riser as well as on the tread surface. The superimposition of smaller active features on top of fossil features provides some of the strongest evidence for an earlier colder period. Active sorted stripes are often found on treads of large relict solifluction features such as terraces. Small lobes with risers of approximately 15 cm are commonly found on top of relict lobes with risers of up to 2 m (Fig. 9). These small lobes show evidence of activity, including a lack of lichen and moss as well as soil disturbance by needle ice. The larger relict lobes show signs of inactivity, such as moss and lichen-covered rocks and the growth of plants (especially *Azorella*) on their risers.

The relict periglacial landforms on Long Ridge are of far greater size than those that result from currently active processes. This implies formation in a considerably more severe frost environment than at present. Currently, frost activity appears restricted to the movement of finer material under diurnal frost cycles. Experimental evidence shows that frost heave is only effective in the top 5–10 cm at low altitudes and to approximately 15 cm at 500 m a.s.l.. By analogy with the findings of Benedict, the relict stone-banked features found at Long Ridge South are suggested to have formed under deep seasonal frost or sporadic permafrost.[8] However, more detailed sedimentological analysis, indicating depth of sorting and thus frost penetration, is required before more specific statements regarding climatic conditions during their formation can be attempted.

The drop in sea level associated with the last glacial maximum must be taken into account in terms of increasing the altitude of any point on Long Ridge. However, the extent of sea-level lowering would be insufficient to explain the decrease of temperature required for the formation of blockfields and stone-banked lobes as found at Long Ridge South. Not even at the highest altitudes are such forms found active under present-day conditions. Evidence for the existence of cooler-than-present post-glacial conditions from Long Ridge agrees well with observations from elsewhere on Marion and Kerguelen Island.[4]

Past and present periglacial gradients. There appears to be a marked difference in periglacial gradients between the current climate and the conditions earlier in the Holocene at Long Ridge. At present, relatively low atmospheric lapse rates result in an increase in maximum depth of sorting in sediment from approximately the top 5 cm at sea level up to 15 cm at 500 m a.s.l. As a result, currently active periglacial landforms do not show marked differences in size at the various altitudes.

The periglacial gradient in the past appears to have been far steeper. Although there is evidence of former

Table 1. Summary of the altitudinal distribution of relict and active periglacial landforms and their main characteristics on Long Ridge.

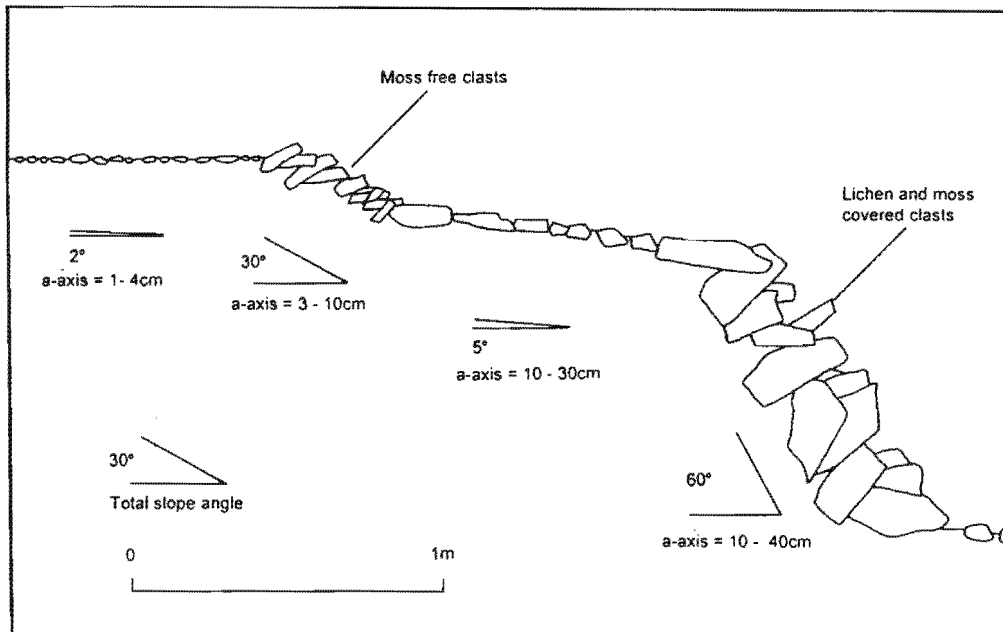|	Long Ridge Bottom (200 m a.s.l.)	Bill Briggs (350 m a.s.l.)	Long Ridge South (500 m a.s.l.)
Relict features			
Blockfields			Common, 100 × 50 m
Large stone-banked lobes			Common, up to 5 m riser height
Solifluction terraces		Abundant, up to 1 m riser height	Abundant, up to 2 m riser height
Azorella terraces	Scarce, 0.3–0.4 m riser height		
Active features			
Azorella terraces		Abundant, 0.5–0.7 m riser height	Abundant, 0.5–1.2 m riser height
Small stone-banked lobes	Scarce, 0.1–0.15 m riser height	Common, 0.2–0.4 m riser height	Common, 0.7–0.9 m riser height
Sorted stripes		Common, depth of sorting 4–7 cm	Common, depth of sorting 10–15 cm

Fig. 9.   Sketch of a small, active stone-banked lobe reactivating the tread of a larger relict stone-banked lobe at Bill Briggs.

colder conditions than the lower slopes. Investigations at other localities on the island may establish whether the form associations at Long Ridge are a localised phenomenon or represent a trend for the entire island. The working hypothesis offered here is that the relict landforms are of early Holocene age and have developed immediately following deglaciation. Geomorphological and other dating techniques should be explored to test this idea.

Conclusion

This preliminary investigation of periglacial activity on Long Ridge has highlighted a number of facets of the periglacial environment of the area. Clear trends exist in terms of altitudinal variation in distribution of active and relict features. Evidence exists for a period of more intensive periglacial activity during the early Holocene on Marion Island under conditions possibly conducive to permafrost at 500 m a.s.l. In addition, there is evidence for a steeper periglacial gradient, which is tentatively linked to the proximity of a retreating ice cap in the early Holocene. Further research needs to be carried out on Marion Island, and on Long Ridge in particular, to allow more quantitative estimation of the palaeoenvironmental conditions and the time during which these landforms developed. This will be addressed during current research into understanding the processes and climatic controls involved in the formation of the landforms, detailed sedimentological analysis and application of geomorphological dating techniques.

periglacial activity at the low-altitude sites, this is limited to small-scale features that indicate a relatively shallow seasonal frost penetration. However, the magnitude of periglacial landforms increases quickly with altitude. Within a few hundred metres of height gain, large-scale (but now relict) periglacial features are present as described above. There are no indications that similar large relict forms may have existed, but were subsequently destroyed at lower altitudes. Considering that factors such as lithology, slope materials, slope gradients and aspect are all comparable at the three sites, variations in landform types and their distribution are considered primarily a function of climatic controls and time. The field evidence thus suggests that over a small increase in altitude periglacial conditions became rapidly more severe, implying a steep periglacial gradient.

Steeper periglacial gradients on the island are interpreted as being associated with mesoclimatic effects associated with the retreat of glaciers at the end of the last glacial. Hall argues for the existence of a large ice mass covering a significant portion of the island during this period.[1] As a result of close proximity to the retreating ice cap and the cold katabatic wind draining from it, slopes at Long Ridge South could have experienced markedly

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Distribution of acetylator genotypes in the coloured population of the Western Cape region of South Africa

Recent advances in molecular biology techniques for polymorphic N-acetyltransferase (NAT2) enzyme characterisation, involving polymerase chain reaction (PCR) multiplication and restriction enzyme cleavage of DNA, were used to determine the distribution of acetylator genotypes and their constituent alleles in the coloured population of the Western Cape region of South Africa. The frequency of slow acetylator individuals in the trial population was $q^2 = 0.286$, indicating a frequency of slow acetylator alleles of $q = 0.535$. The trial population could be shown to be in Hardy-Weinberg equilibrium in accordance with a trimodal pattern of distribution of acetylator genotypes.

N-acetylation is an important detoxification pathway in humans for a wide variety of nitrogen-containing medicinal and non-medicinal agents and compounds with toxic potential.[1,2] Conjugative *N*-acetylation is mediated by one or both of two distinct metabolic systems, depending on the affinity of the substrate for the catalytic enzymes involved, i.e. monomorphic *N*-acetyltransferase (NAT1) and polymorphic *N*-acetyltransferase (NAT2).[2,3] The antituberculosis agent isoniazid (INH) is metabolised by the NAT2 enzyme and the rate of acetylation of INH to acetylisoniazid determines the rate of INH inactivation.[4] Consequently, the NAT2 enzyme characteristics of the individual determine the pharmacokinetic profile of therapeutically active parent compound following a dose of isoniazid.[5]

In common with the rest of South Africa, the Western Cape Province is experiencing a high prevalence and incidence of tuberculosis at the present time. The coloured (mixed race) population is the largest of the ethnically distinct subgroups that inhabit the region and consequently the distribution of acetylator genotypes was determined in this subpopulation in conjunction with other initiatives to combat the disease.

Data from a subgroup of our patients (60/114) have been published elsewhere and it has been shown that: acetylator phenotype and genotype are concordant in the patient with acute pulmonary tuberculosis; fast and slow acetylator alleles are codominant; two fast alleles exist; acetylator phenotypes are trimodally distributed in the coloured population of the Western Cape region.[5] These advances are attributable to the development of accurate molecular biology techniques for NAT2 allele identification,[2] and reliable analytical methods for INH quantitation.[6] Prior to this, it was not possible to distinguish clearly between intermediate and fast INH eliminators and both phenotypes were assigned to a common fast subgroup in accordance with a bimodal distribution model.[7] Consequently, this is the first population study undertaken in humans based on, and utilising, clear concepts of NAT2 genotype and INH eliminator phenotype, and the rules of correspondence between the two.

Methods

Patients. One hundred and fourteen adult patients of both sexes presenting with acute tuberculosis were enrolled in the study for which approval was obtained from our institutional ethics authority. Patients were included in the trial if they perceived themselves to be coloured,[8] were not critically ill and consented to the donation of a blood sample for the purpose of NAT2 gene characterisation. The South African population of mixed ancestry (including Malay, Khoisan, Negroid and Caucasoid stock)

will be referred to as 'coloured' throughout the article.[9]

Since the NAT2 characteristics of the individual are thought not to influence susceptibility to tuberculosis, it was assumed that the NAT2 profile of the patient population would reflect the profile of the coloured population as a whole.

DNA extraction and analysis: Genotypification of NAT2 alleles by PCR amplification. As previously outlined,[5] blood samples were collected into EDTA-treated tubes, and DNA was isolated by proteinase-K digestion and phenol/chloroform extraction as described by Sambrook and co-workers.[10] Mutations in the NAT2 gene were detected by PCR amplification of a 1 000 bp fragment of the gene with the Nat-Hu14/Hu16 primer pair (synthesised by Genosys Biotechnologies Inc., Cambridge, UK) as described by Hickman and co-workers.[11,12] Aliquots of the amplification product were cleaved with either Msp I (191 G→A, 434 A→C), Fok I (282 C→T), Kpn (481 C→T), Taq I (590 G→A), Dde O (803 A→G), or Bam HI (857 G→A) [from Boehringer Mannheim] to identify allelic variations at these positions. Digested fragments were resolved in 3% Metaphor agarose (FMC BioProducts, Rockland, ME) using IX TBE (89 mN TRIS, 89 mM boric acid, 2 mM EDTA) as the running buffer. The 341 T→C mutation, which is not recognised by a restriction enzyme, was detected by allele-specific amplification (ASPCR) with the allele-specific primer pairs described by Hickman and co-workers.[12] Both of the reported ASPCR primer sets were used to control for result accuracy. Results were scored according to the nomenclature of Vatsis and co-workers.[2] A map of the mutations detected by restriction digeston within the 1 000 bp amplified by PCR with the Nat-Hu14/Hu16 primer set, as well as the position of the 341 T→C mutation that is detected by ASPCR, has been shown.[5]

Results

The distribution of polymorphic acetylator genotypes and phenotypes in the population evaluated is shown in Table 1. The

Table 1. Distribution of polymorphic *N*-acetyltransferase genotypes and phenotypes in the trial population ($n = 114$).

Phenotypic group	Genotype	Number of individuals	Phenotypic group totals
Fast group	F F	26	26
Intermediate group	F S1	20	
	F S2	25	
	F S3	3	
	F S4	6	54
Slow group	S1 S1	9	
	S1 S2	10	
	S1 S3	4	
	S1 S4	1	
	S2 S2	3	
	S2 S3	3	
	S2 S4	2	
	S3 S3	0	
	S3 S4	1	
	S4 S4	1	34

S1, S2, S3 and S4 denote the different slow acetylator alleles.

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From Our Men on Mauritius

It is a balmy evening, perfect for several hours of sundowners with charming, erudite company.

US I feel sorry for our old colleagues who are still soldiering on, with ever larger classes of ever weaker students, stuck with ever deteriorating facilities and equipment. I'll bet no one can remember when last a university built a new physics, chemistry or biology building. The letters that I get are rather sad, from disillusioned guys, rather envious of us. I almost feel guilty about being here and enjoying life.

HE I was recently reading an amazing book by Bill Slim, called *Defeat into Victory.* In it he describes what Morale is, and then he goes on to define what is needed to generate Morale.

US Is this one of those things about business management and motivation, like Maslow's five different needs, Herzberg's ideas on job satisfaction, and Senge's disciplines?

HE In a sense, yes, it's the same idea, but Uncle Bill put it down so much more beautifully and simply. Morale is based on three foundations: spiritual, intellectual, and material. All three are necessary for success.

US Please elaborate.

HE Very well.

Spiritual:
• There must be a great and noble objective
• Its achievement must be vital
• The methods of achievement must be active
• Each person must believe that what he does is important.

Intellectual:
• Each person must be convinced that the goal is attainable (and not an out of reach dream)
• He must be convinced that the organisation for which he works is efficient
• He must have confidence in the ability of his leaders, and that they will not squander his abilities.

Material:
• The person must be convinced that he will get a fair deal from his superiors and the organisation
• He must be given the best equipment to do his task
• His working conditions must be as good as possible.

US Just let me run those principles and ideas through my mind again. Mmm. All right. I see. They could apply to almost anything: a factory, an office, a university, even an army! I like them.

HE Good. For fun, let's consider how they might apply to a university, and more specifically, to its science faculty. This of course is dangerous, but what the heck, Plaisance is 10 000 km from Nuu Yuu and the old homeland.

US It's OK, quite safe, classable as Distance Learning for the ones we left behind.

HE Let's ponder: Spiritual. What is our 'great and noble objective'? Well, for me, it was to produce the best-trained BSc graduate, whose abilities made *our* graduates very desirable to industry. Someone who knew stuff, how to use it, and a bit about how the real world works. I knew I had succeeded when a person from industry would phone and say: 'Do you have a recent BSc graduate? We need one of *yours*, not one from daa-de-daah.'

US Now it's my turn: Intellectual. Do you remember those classes of hundreds of engineers and the problems of setting the exams and how the Exams Office always insisted on us submitting the exam papers on time? We could always wander down to the exam hall on the day and be pretty sure that: there would be seats for the students, the papers had been printed, and the whole schumozzle would be about 98% OK. I was always afraid that Admin would bring in some outside consultant expert on efficiency who would decide to delegate that whole exam procedure to the department. The thought still makes me twitch.

HE You are so right: those ladies in the exam section sure sweated for us. Exams were a pleasure — until it came to marking!

HE Now it's: Material. Can you remember how we once applied for some teaching aids that were to be used for helping the weakest of the first-year students, and how some superior Admin committee sent us a letter giving us permission to go out and raise money to buy the stuff? Like the colonel saying; 'Rifleman Snooks, now go out and beg for money to buy yourself a rifle and some rounds, and when you have got them report back here and be ready to fight and bleed and die for the glory of the unit.'

US I remember only too well. It switched us off.

HE And helped me to grab that early retirement package. The result — we can lie here in the sun and happily stagnate and not have to render a report to the research committee.   ❑

Vegetation benchmark

Vegetation of Southern Africa. Edited by R.M. Cowling, D.M. Richardson and S.M. Pierce. 1997. Cambridge University Press, £125, $225. ISBN 0-521-57142-1.

It has been said that southern Africa contains the world's vegetation types in one country and even, as is stated in this book, 'the world in one country'. For the uninitiated this may seem to be a gross exaggeration but as one experiences the variety of biological and social life, the appeal of the diverse landscapes and the vagaries of the climate in different areas, the truth in this statement becomes apparent. The challenge to South Africa's botanists has been how to document and do justice to the outstanding diversity of southern Africa's vegetation in a single volume. To answer this challenge, the collective expertise of many scientists currently concerned with vegetation-related studies on the African subcontinent was drawn together. By involving experts to write on particular aspects of the vegetation of southern Africa and related topics, under the guidance of excellent editorship, it has been possible to compile the most comprehensive compendium of information on the subcontinent's vegetation to date.

Apart from its remarkable floral diversity, South Africa has also been endowed with remarkably dedicated scientists in the fields of plant ecology and vegetation science. The book is dedicated to one of these, John Acocks, whose seminal work, *The Veld Types of South Africa*, formed the basis and inspiration for much of what has followed and has been the benchmark of vegetation classification in southern Africa for many years. Liberal reference is made to Acocks's work in literature pertaining to South Africa's vegetation and it is a fitting tribute that a book on this subject and of this quality should be dedicated to his memory.

The book is well introduced with a complimentary foreword but, more important, a concise and informative general preface. The preface gives the reader a good idea of the aims, scope and setting of the book and encourages one to read on in the realisation that there is still much to learn. It introduces the structure of the book, which is divided into three parts, forming a logical progression from one part to the next. Part 1 comprises four chapters on landscape evolution, climate, biogeography and vegetation palaeohistory, which 'set the scene' and provide the reader with a framework for appreciating present vegetation patterns and processes. The second and principal part of the work consists of 10 chapters which describe the major vegetation units found in southern Africa. The treatment follows the classifica-

tion of the vegetation into seven biomes and three units at the non-biome-scale. Part 3 includes eight chapters on cross-biome topics such as conservation, fire, alien plant invasions and so on. The editors considered these topics to be of global interest and this approach positions the book well to capture the interest of a global audience rather than restricting its appeal to local enthusiasts.

The logical presentation of material in *Vegetation of Southern Africa* makes for a relatively simple evaluation procedure. Each part of the book is separately prefaced, giving a summary and breakdown of the section and the type of information one finds. The chapter material is detailed, well referenced and packed with information.

The palaeohistory of southern Africa is fascinating and the two chapters dealing with the evolution of landscapes and vegetation history transport one back in time to the 'Jurassic Park' that southern Africa once was as the land was moulded and the dynasties of different floras rose and fell. These chapters encourage one to look with new eyes at the complex landscapes that make up the subcontinent and indeed to consider the 'unseen' floras which lie buried from our view. The chapter by R.E. Schulze deals with climate in a more contemporary sense and its link to the present flora of the country. It contains valuable information but it is a great disappointment that the climate maps are published in monochrome! Reproduction of these maps in colour (which I have seen) would have greatly enhanced the chapter since maps such as Figure 2.6 (and others) show little definition between the three darkest units — the colour hues are too close!

The overarching chapter on the phytogeography of southern Africa is an essential prerequisite to the contents of the following chapters. It gives the reader a clear perspective of the floral diversity of the African subcontinent by broadly analysing the phytogeography in terms of ecological, historical and phylogenetic factors, while focusing more specifically on patterns and correlates of species-level endemism. The analysis of the 'age' of different endemic species following Cronk's scheme, however superficial, is to my knowledge the first time this classification has been applied to southern African endemic taxa. This greatly assists in providing an evolutionary time-frame for the extant subcontinental flora.

Part 2 of the book starts with a chapter categorising the biomes of the African subcontinent. It could be argued that this chapter should have been included in the introductory Part 1. Nevertheless, it serves the purpose well of providing a foundation for the descriptive chapters on the various biomes and non-biome-scale units recognised. The period of collaboration among terrestrial ecologists from the mid-1970s to the late

1980s, under the umbrella of the National Programme for Ecosystem Research of the CSIR, was perhaps the most important thrust there has yet been in understanding the patterns and processes in the different biomes. The immense amount of knowledge gained during this period is highlighted in the chapters presented here and the specific intention of achieving some uniformity of treatment of the different biomes is useful for comparative purposes. The approach has, however, also been adequately flexible to allow for the special aspects of each biome to be exposed, for example, the lichen fields of the desert or the intriguing reproductive biology of some plants in the fynbos and succulent karoo. The approach has thus been thorough and comprehensive and a valuable aspect of all the chapters in this section has been the identification of gaps in existing knowledge. There are numerous recommendations for future research to answer pressing questions. One gains a sense of urgency that these questions need answering soon to foster sustainable utilisation of southern Africa's vegetation resources from the grasslands of the interior to the kelp beds on the continental shelf and from the desert to the alpine ecosystems of the high mountains.

The third part of the book presents eight chapters dealing with topical ecological themes. They range from the theory of species diversity to the impacts of abiotic factors such as fire and the influence of human utilisation and alien biota on the natural vegetation. The introductory preamble to the section gives a helpful summary of the following chapters that highlight many intriguing facets which may be seen as being linked in the colourful fabric of vegetation on southern African landscapes. It is appropriate that the book should end with a chapter on conservation; South Africa can be justifiably proud of work accomplished in this arena. However, as we draw close to the end of the millennium, we need to take stock of our natural resources. *Vegetation of Southern Africa* is well timed and provides a good critique of the current state of affairs and will serve as a valuable benchmark publication for future work.

To conclude, some general points require mention. The layout in three sections is laudable and assists the reader in the use of the book. The volume is well indexed and the short glossary is also useful, particularly for readers not familiar with many colloquial terms. There are nevertheless some disappointing aspects. In a work on the vegetation of such a colourful region it is regrettable that there are no colour reproductions of photographs of plant communities and plant species (and maps — see above). It is clear that many of the black-and-white reproductions were produced from colour diapositives. Although this is obviously not a 'coffee-table work', some colour would have greatly

enhanced its appeal and value; for instance, the impact of Figure 22.8 is completely lost due to the lack of colour. There is also a good deal of inconsistency in the layout of captions, resulting in a waste of space. In some instances the captions are crammed into single columns whereas in others they are liberally spread across the width of the page. The small point size but bold font used for the captions is also not appropriate. These editorial matters do detract from an otherwise outstanding publication. Lastly, the price tag makes the book beyond the reach of the average student, biologist and indeed of many libraries, such as those at schools. This is unfortunate, since it will work against the promotion and popularisation of vegetation science in South Africa, where literature on this subject should be much more freely accessible.

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All about pines

Ecology and Biogeography of Pines. Edited by David M. Richardson. 1998. Pp. 527. Cambridge University Press. £95. ISBN 0521 55176 5.

Have you ever wondered where all those pine trees, which seem so much a part of the South African landscape these days, come from? Perhaps you are not even aware that they hail from distant shores, that they are only recent additions to our naturalised flora, and that sometimes they evoke some quite emotional responses as a result of the conflicts that arise between conservationists and foresters. Maybe you never thought about this, even as a serious scientist. As someone who deals with these issues on a daily basis, I am often surprised at the lack of knowledge about the origin of pines and their role in the South African ecology and economy (beyond a handful of foresters, conservationists and dedicated greenies). Well, here is the chance to really inform yourself.

The 111 species that make up the genus *Pinus* are an important and often dominant component of many of the Earth's ecosystems. Pines are essentially restricted to the northern hemisphere, but over the past half century they have been widely planted in Africa, South America, Australia and New Zealand, making them a genus of global importance. This remarkable book sets out to provide a synthesis of what is known about the evolutionary and modern history, distribution, ecology and utilisation of pines.

The book is remarkable for a number of reasons. First, it provides a remarkably comprehensive coverage of the subject, distilled from 3000 references by 40 authors from nine countries, each a leading authority on aspects of the genus. Second, it is remarkable for the fact that this long-overdue synthesis had not appeared earlier. And finally, it is remarkable that this important volume has been conceptualised, pulled together, and edited by an ecologist who hails from the southern tip of Africa, far removed from the natural range of pines and the scientists who have lived among and studied them for decades.

Dave Richardson's interest in pines started when, as a young forestry graduate, he was appointed to investigate the ecology of invasive species in the mountain catchments of the Cape. His studies led him to the realisation that, although a lot was known about pines, there was no single source that addressed the many questions that he sought to answer. Two things struck him at the time — first, that there was an obvious need for a synthesis of the current knowledge on pine ecology and biogeography, and second, that no single-author account (such as Nicholas Mirov's useful, but out-of-date, volume *The Genus* Pinus*) would be able to cover the vast literature on pines. Starting with an initial outline in 1992, and consulting 'hundreds of publications and scores of authorities', the final product, with 22 chapters and 40 authors, appeared earlier this year.

Dave Richardson is deputy director of the Institute for Plant Conservation at the University of Cape Town. His 39 co-contributors hail from nine countries — Australia, Canada, France, New Zealand, Norway, Russia, South Africa, the United Kingdom and the United States. This cosmopolitan group provides perspectives from around the globe, contributing to the comprehensive coverage of the book.

The work is in six parts. The introductory part has a single chapter dealing with an overview of the ecology and biogeography of pines. It covers their origin and evolution, and their morphology and physiology in relation to other conifers. It examines the landscapes that pines occupy in America, Europe and Asia, and looks in some detail at the changes brought about through the interactions between humans and pines.

Part 2, with two chapters, is devoted to phylogeny, systematics and evolution. It gives a comprehensive coverage that explores not only the simple classification, but also its history, and evidence from crossability studies, secondary product chemistry, protein comparisons and contributions from DNA analysis. New evidence on the early origin of pines some 130 million years ago is also reviewed.

Part three (historical biogeography) consists of four chapters that review the late

Quaternary dynamics of pines in northern Asia, Europe, northern North America, and Mexico and Central America, respectively. Here, the dynamics and distribution of a range of pine species in response to changing environmental conditions is reviewed, providing a fascinating picture of the historical ebb and flow of the genus.

Part 4 deals with 'macroecology and recent biogeography' in three chapters. This section is actually a set of case studies, and deals with pines in the Mediterranean Basin, the recent history of pinyon pines in the American Southwest, and with macroecological limits to the distribution and abundance of pines. The distribution, and changes in the distribution, of pines in historic and prehistoric times is reviewed, providing valuable insights into current distribution patterns.

Part 5 (ecological themes) is the largest part of the book, with 9 chapters. These address fire, the evolution of life histories, genetic variation, seed dispersal, ecophysiology, mycorrhizal status, effects on soil properties, insect–pine interactions, and disease ecology. This is a section for the dedicated student, providing in-depth and often fascinating insights into what is known about the ecology of the genus. Given the sheer volume of knowledge that exists, one is again struck by the incongruity that this information had not been adequately synthesised until now.

Part 6 deals with the interaction between pines and humans in three chapters. The first provides a global view of pines in cultivation, from prehistory, through Classical Greek times and the Middle Ages to the 20th century. The second provides an account of how *Pinus radiata* (a narrow endemic from coastal central California) has taken on the world through really extensive planting in the southern hemisphere. And finally, there is a chapter addressing pines as invaders in the southern hemisphere — where the final figure in the book tells it all. It seems as though we can look forward to pines becoming the dominant tree on Earth in the next 400 years, if past trends continue!

The book is very well illustrated by means of maps, black and white photographs, and diagrams. It is something that all serious ecologists, foresters and biogeographers should read, and will no doubt be an important reference for many years to come. My only complaint, echoed in many book reviews published in this country, is the price, which will effectively keep the volume out of reach of average South Africans. But I don't want this to be my last word, which is to encourage readers to avail themselves of the opportunity to read, study and enjoy this remarkable book.

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*Mirov N.T. (1967). The Genus Pinus. Ronald Press, New York.