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Bioclimates of Australian *Pinus Radiata* Areas and *Sirex Noctilio* Localities in the Northern Hemisphere

SUMMARY

Pinus radiata plantations in Australia are all in areas that are bioclimatically homologous with areas, mainly mediterranean, of Europe, Turkey and North Africa, where the siricid, *Sirex noctilio*, is indigenous. Thus if climatic compatability is important in the establishment of *S. noctilio*, all exotic pine plantations in southern Australia are vulnerable to this pest.

INTRODUCTION

The accidental introduction of *Sirex noctilio* F. into Tasmania two decades ago and its subsequent dispersal in the radiata pine (*Pinus radiata* D. Don) plantations in Tasmania and Victoria stimulated a survey of Europe, Turkey and North Africa by the Division of Entomology, C.S.I.R.O., for the collection of siricids and their natural enemies. While this work was being carried out a considerable amount of information on the distribution and ecology of siricids, their natural enemies and host trees was accumulated (Spradbery & Kirk unpublished, Hall 1968, Spradbery 1970).

This paper describes the bioclimatic features of areas where *S. noctilio* occurs naturally, and compares them with those areas of Australia where radiata pine is grown.

Many authors (Koppen 1924, Davidson 1937, Blair 1942, Taylor 1932, Taylor 1943, Thornthwaite 1948, and Emberger 1955) have used combinations of climatic parameters to produce formulae to describe a climatic zone, but these were used in specific cases and cannot be applied accurately over wide areas because of the lack of comparable data. Climatic maps have also been prepared (e.g. Knoch and Schulze 1954, Landsberg et al 1965, and Thompson 1965) but they are too general for the present study. Climatological studies of forest areas have been made by Patton (1929), Prescott and Lane Poole (1947), Scott (1960), and Thornthwaite and Hare (1955). These authors used complex formulae which lead to extremely patchy distribution of definable climatic zones with vast areas being left "terra incognita". The usefulness of these formulae is limited to areas for which appropriate climatic data are available.

The UNESCO committees on arid zone research (1958-1963) considered climatic data and local vegetation cover in mediterranean areas in an attempt to overcome the shortcomings of previous work, and to provide a balanced interpretation of data which is biologically meaningful. The bioclimatic classification which was derived permits comparison to be made between widely differing geographical areas, and may be used to define seasons which influence vegetation and the distribution of animals. The bioclimatic maps produced by UNESCO-FAO (1963) are relevant to the *S. noctilio* and *P. radiata* areas under review here.

METHOD

The UNESCO bioclimatic maps (UNESCO-FAO 1963) are based on a study that recognizes temperature, precipitation, and relative humidity. The principal climatic categories are defined by the mean temperature of the coldest month (t) such that when 't' is less than 0°C the area is considered cold temperate or cold, and when 't' is greater than 0°C, the area is temperate, warm temperate or warm. Climatic areas within the range t = –5°C to +15°C, are further sub-divided into warm temperate (+10°C to 15°C), temperate (O°C to +10°C) and cold temperate (–5°C to 0°C), where 15°C indicates regions which are virtually frost-free. Within the warm temperate or temperate category the UNESCO mediterranean climate is defined as one with a definite dry period of 1-8 months coincident with the period of longest daylight. In the absence of a recognisable dry period the climate is termed axeric.

Precipitation is the total monthly precipitation P (in mm), and a "dry month" is defined as one in which P is equal to or less than twice the mean temperature of the month ($P \leqslant 2T$), while a dry season consists of consecutive "dry months". To recognize the influence of atmospheric humidity in the absence of measurable precipitation (e.g. mist or dew), an index of hot weather drought, the xerothermic index x, was evolved (UNESCO-FAO 1963). The index describes the degree of drought as defined by the number of days in a month which are dry from a biological point of view, a physiologically "dry day" being one when the relative humidity is less than 40 per cent.

The xerothermic index is calculated as follows:

$$\text{xerothermic index} = \left[\begin{array}{l}\text{no. days}\\ \text{in month}\end{array} - \left(\begin{array}{l}\text{no. days}\\ \text{with rain}\end{array} + \frac{\text{no. days with mist or dew}}{2} \right) \right] \times \begin{array}{l}\text{humidity}\\ \text{factor (h)}\end{array}$$

where days with mist or dew count as half a dry day.

The humidity factor (h) is an arbitrary value based on the mean monthly relative humidity (R.H.) such that h is 0.9 when R.H. is 40 to 60% (equivalent to 9/10's of a dry day), 0.8 when R.H. is 61-80%, 0.7 when R.H. is 81-90%, and 0.6 when R.H. is 91-100%.

For example, to calculate the xerothermic index for July when there are 4 days of rain, 8 days of mist or dew, and a mean monthly humidity of 65% R.H. (h = 0.8):

$$x_m = \left[31 - (4 + \frac{8}{2})\right] \times 0.8 = 18.4$$

The xerothermic index is obtained by summing the values of x for those months which constitute the dry season.

Bioclimatic data were obtained from the 1 : 5M bioclimatic map of the Mediterranean and the 1: 10M map of southern Australia (UNESCO-FAO 1963). The sources of data used in compiling the UNESCO-FAO bioclimatic map of southern Australia are given on p. 57 of the explanatory notes accompanying the maps. Other data used in compiling Table 1 and Fig. 1 came from records of the Australian Bureau of Meteorology.

The distribution of radiata pine in southern Australia is based on information supplied by the state forestry authorities in New South Wales, South Australia, Victoria, Western Australia and Tasmania. The distribution of *S. noctilio* is based on records of the emergence of insects at the Sirex Biological Control Unit in England from siricid-infested timber collected in the northern hemisphere (Spradbery & Kirk unpublished).

RESULTS

The bioclimatic designations, xerothermic indices, Australian radiata pine localities, and incidence of *S. noctilio* from climatically homologous localities in the northern hemisphere, are given in Table 1. Localities in dynamic bioclimatic zones are marked with arrows indicating the probable shift of their designation. For example, all of the Victorian localities included in the axeric designation experience more or less long dry spells once every 3 or 4 years thus becoming temporarily submediterranean. Each dynamic locality is marked with an arrow pointing towards the designation into which it would fall in an atypical year. The distribution of radiata pine in Australia and *S. noctilio* in Eurasia and north Africa is given in Fig. 1.

Of the eight siricid species occurring in the surveyed area *S. noctilio* was the only one found at localities falling within the mediterranean bioclimatic designations, although it also occurs in colder areas which have no climatic homologues with Australian *P. radiata* areas. Other siricid species occur at axeric localities within the Mediterranean geographic region. (Spradbery & Kirk unpublished).

Of the two common parasitoids *of S. noctilio* encountered in the northern hemisphere, the ichneumonid, *Rhyssa persuasoria* L., was the dominant species (by 2:1) in the temperate areas, and the cynipoid, *Ibalia leucospoides* Hochenw., was the dominant species (by 7:1) in the mediterranean areas. Another four species of parasitoid were from exclusively temperate or cold areas (Spradbery & Kirk unpublished).

All localities in Australia where radiata pine is grown have an equivalent climatic locality in the northern hemisphere where *S. noctilio* is indigenous (Table 1).

TABLE 1

Bioclimatic data and distribution of *P. radiata* in Australia and *S. noctilio* in the northern hemisphere.

P. radiata localities in Australia	xerothermic index (x)	Bioclimatic designation	*S. noctilio* localities
1 Kersbrook, S.A.	125-150	□ Thermomediterranean accentuated	1 Heulva, Spain
2 Crawford, S.A.			
3 Cudlee, S.A.			
4 Nameroo, W.A.			
5 Kuitpo, S.A.			
6 2nd Valley, S.A.			
7 Mundaring, W.A.	100-125	■ Thermomediterranean attenuated	2 Aznalcazar, Spain
8 Metropolitan, W.A.			3 Kazdag, Turkey
9 Kelmscott, W.A.			4 Yenici, Turkey
			5 Remel, Tunisia
			6 Mdiq, Morocco
10 Stawell, V.	75-100	◊ Mesomediterranean accentuated	7 El Saler, Spain
11 Noolook, S.A.			8 Carasquetas, Spain
12 Cave Range, S.A.			9 Guadalmedina, Spain
13 Cornaum, S.A.			10 Panagia, Greece
14 Mt. Burr, S.A. ↓			11 Glyfada, Greece
15 Tantanoola, S.A.			12 O. Nefifik, Morocco
16 Mt. Gambier, S.A. ↓			13 El Harhoura, Morocco
17 Penola, S.A.			
18 Caroline, S.A.			
19 Harvey, W.A.			
20 Collie, W.A.			
21 Kirup, W.A.			
22 Nannup, W.A.			
23 Busselton, W.A.			
24 Glenelg, V.	40-75	◆ Mesomediterranean attenuated	14 Ghisoni, France
25 Heywood, V.			15 L'Ospedale, France
26 Ballarat, V. ↓			16 La Fou, Spain
27 Benalla, V. ↑			17 Mt. Grande, Portugal
28 Manjimup, W.A.			18 S. M. Junto, Portugal
			19 Orhaneli, Turkey
29 Creswick, V. ↑	0-40	△ Submediterranean	20 Covilha, Portugal
30 Beaufort, V. ↑			
31 Daylesford, V. ↑			
32 Trentham, V. ↑			
33 Forrest, V.			
34 Gellibrand, V.			
35 Mansfield, V.			
36 Myrtleford, V.			
37 Beechworth, V.			
38 Pemberton, W.A.			
39 Murraguldrie, N.S.W.			
40 Carabost, N.S.W.			
41 Ouranee, N.S.W.			
42 Green Hills, N.S.W.			
43 Bago, N.S.W.			
44 Buccleuch, N.S.W. ↑	0	▲ Axeric	21 Castanedo, Spain
45 Marysville, V. ↑			22 Cordal Peon, Spain
46 Neerim, V. ↑			23 Rasa Nueva, Spain
47 Strzelecki Hills, V. ↑			24 Las Munecas, Spain
48 Bright, V. ↑			25 St. Jeans, France
49 Tallangatta, V. ↑			26 St. Isidore, France
50 Sale, V.			
51 Pittwater, Tasmania ↑			
52 Scottsdale, Tasmania			
53 Sheffield, Tasmania			

(The numbers preceding localities correspond with Fig. 1)

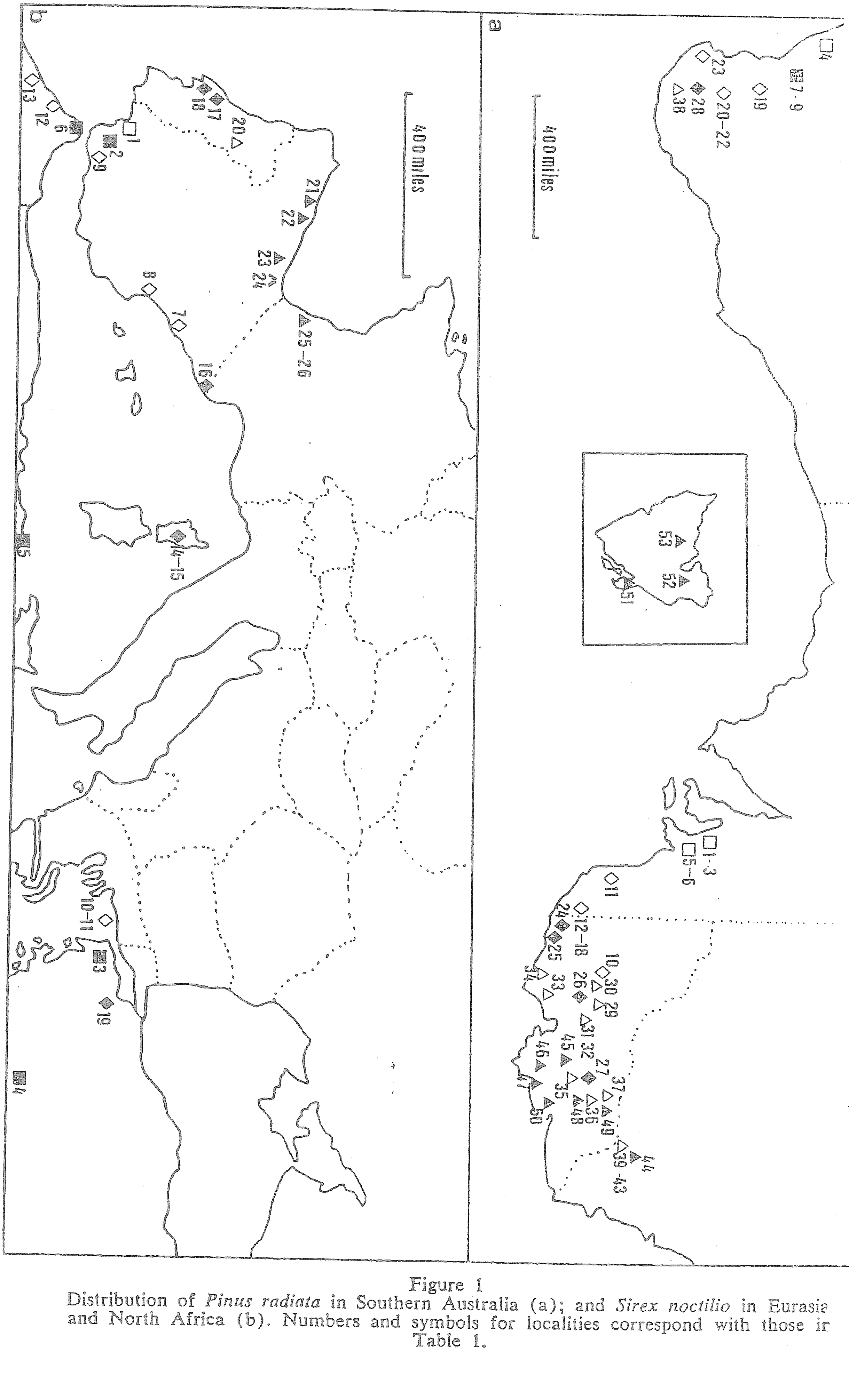

Figure 1
Distribution of *Pinus radiata* in Southern Australia (a); and *Sirex noctilio* in Eurasia and North Africa (b). Numbers and symbols for localities correspond with those in Table 1.

DISCUSSION

Biologically meaningful climatic comparisons of specific localities within different geographical regions are particularly relevant to the study of introduced pests or weeds.

The UNESCO method used here fulfils this need. It is crude but because it uses meteorological data that are readily available it permits useful comparative studies until adequate measurement of other parameters allows greater refinement.

The present study shows that all localities in which *P. radiata* is grown commercially in Australia have bioclimatic counterparts in the northern hemisphere where the siricid, *S. noctilio,* is indigenous. If bioclimatic parameters determine the observed distribution of *S. noctilio,* it is clear that all *P. radiata* stands in Australia are vulnerable to attack by this pest species.

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