THE ROLE OF CLIMATE IN OPTIMAL RELEASE STRATEGY DESIGN FOR PAREUCHAETES INSULATA: A NEW CONTROL AGENT FOR TRIFFID WEED (CHROMOLAENA ODORATA)

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Abstract

Poor pre-adaptation to the local climate, has been widely cited as one of the main reasons certain introduced natural enemies fail to establish on target weed species. Locally, the biological control programme on *Chromolaena odorata* has resulted in the unsuccessful releases of both *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae), the most successful agent released globally against the weed, and *P. aurata aurata.* In both cases the reasons for the failure to establish self-sustaining populations were unclear, although climate is likely to have played a role. Concurrent with the release of a new species, *P. insulata*, from climatically similar Florida, USA, into KwaZulu-Natal, a study of physiological tolerances was undertaken to evaluate the potential of this species to survive the local climate. This included degree-day development as well as computer modelling to find optimal release sites, which were ranked in terms of suitability. Results show that, while average local temperatures and humidities at most sites are significantly lower than those of Florida, and generational turnover will be negatively affected, all life stages should be able to survive locally. However, the relative importance of climate in successful establishment cannot be discounted and therefore potential release sites have been prioritised in terms of suitability.

Keywords: Chromolaena odorata, *Pareuchaetes insulata*, climate matching, release strategy design

Introduction

Chromolaena odorata (L.) King and Robinson was introduced to South Africa and KwaZulu-Natal in the 1940s, and has for many years been recognised as a major threat to local biodiversity (MacDonald and Jarman, 1985). Of traditional weed control mechanisms, *viz*. (i) mechanical or physical, (ii) chemical, (iii) cultural and (iv) biological, only the latter, biocontrol, is self-perpetuating and dynamic, and as such a necessary part of any long term solution.

In South Africa, a biocontrol programme against *Chromolaena* has been in place since 1989, and following on its success internationally (Dharmadhikari *et al.*, 1977; Seibert, 1989), *Pareuchaetes pseudoinsulata* Rego Barros, an Arctiid moth species which lays its eggs in batches on the abaxial surface of *Chromolaena* leaves, was imported from Guam, USA, for moth-stage release at several sites (10) around Durban (Kluge, 1991; Zachariades *et al.*, 1999). When the insects failed to establish, ant predation of eggs was implicated as the likely cause (Kluge, 1991; Kluge, 1994). In an attempt to minimise this predation, a second *Pareuchaetes* species, *P. aurata aurata* Butler, which lays its eggs singly, scattered on the ground, was mass-reared (148 000 individuals), and also unsuccessfully released (Kluge and Caldwell, 1996).

Following further successes with *P. pseudoinsulata* internationally a new culture was imported from Indonesia and released, shifting the release strategy to large numbers of larvae (300 000) over a longer period of time, and fewer sites (2). However, this attempt at establishment also failed (Zachariades *et al.*, 1999).

Part of the problem until recently (2002) has been uncertainty regarding the origin of the South African form of *Chromolaena*, which is different from the 'West-African form' that is invasive in West Africa, Asia and Australia. Recent genetic studies show that the South African form may have come from the Caribbean Islands of Cuba or Jamaica ([1]personal communication).

Since 2001 a third species, *Pareuchaetes insulata* Walker, has been the subject of a mass-rearing programme at the South African Sugar Association Experiment Station (SASEX). The original culture was collected from Florida, USA, which exhibits a similar seasonal climate, and new cultures have recently been collected from Cuba and Jamaica.

To maximise the chances of successful establishment, detailed physiological studies were undertaken to determine temperature and humidity tolerances, and potential release sites were modelled for similarity to the collection locality. Preliminary results are reported here.

Methodology

The geographic range which *Pareuchaetes* spp. inhabit has been documented in Cock and Holloway (1982). Most species occur in a tropical climate, which could explain why the two *Pareuchaetes* species introduced to South Africa have not established, as South Africa has seasonal variations in temperature, humidity and rainfall. The relative importance of climate in effecting population establishment, was measured by comparing data on previous releases of *P. pseudoinsulata* in the climate modelling program CLIMEX®, with that of the regions from which they were collected, and those where they have successfully established. CLIMEX was also used to map regions in South Africa where the climate is most similar to the collection locality in Florida; these areas will be prioritised as potential release sites.

The role of temperature in development was also assessed to find optimal growth conditions and critical thermal tolerances. This was accomplished by keeping a cohort of insects at various constant temperatures, *viz*. 15, 20, 23, 25, 30 and 35ºC, and recording the development time. This data is used to further refine release site selection criterion.

Results

Fort Lauderdale in Florida, USA, is warm and has little variation in temperature all year round (long term average temperature variation ranges between 14.4 and 32.4°C). Relative humidity is also high throughout the year (57 to 67%), and rainfall occurs in all seasons. There are few places in South Africa that match Florida very closely in the categories of temperature, rainfall and humidity, but many places that match two of the three categories well (Figure 1). The coastal areas of KwaZulu-Natal specifically, are likely to provide some of the best release sites.

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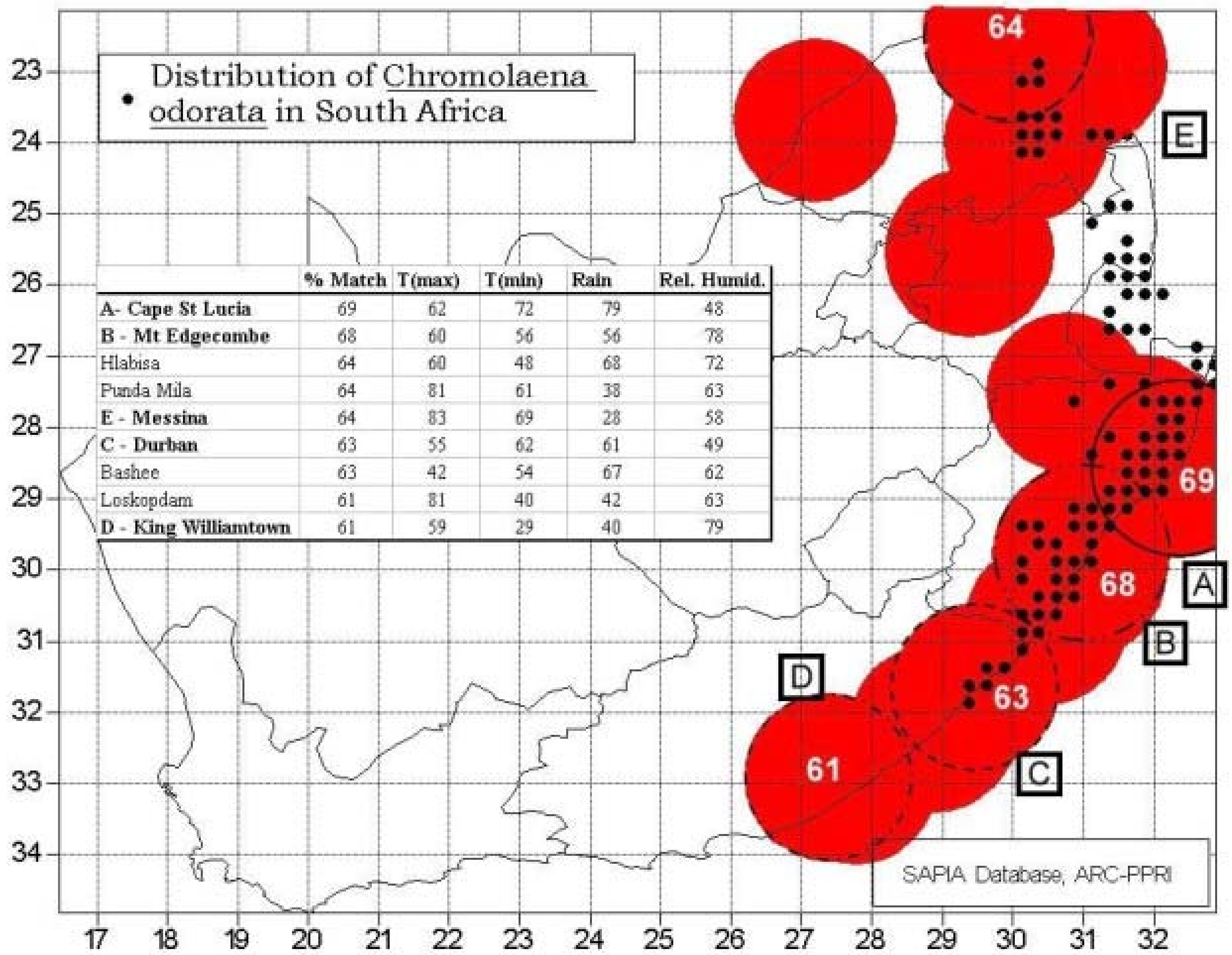

	% Match	T(max)	T(min)	Rain	Rel. Humid.
A- Cape St Lucia	69	62	72	79	48
B - Mt Edgecombe	68	60	56	56	78
Hlabisa	64	60	48	68	72
Punda Mila	64	81	61	38	63
E - Messina	64	83	69	28	58
C - Durban	63	55	62	61	49
Bashee	63	42	54	67	62
Loskopdam	61	81	40	42	63
D - King Williamtown	61	59	29	40	79

Figure 1. Map of predicted optimal release localities (coloured circles) of *Pareuchaetes insulata* from Florida, USA. Black dots represent the current extent of *Chromolaena odorata* in South Africa. Letters represent release sites ranked in order of preference, with detailed climatic data for each included in the table overlay.

In terms of physiological tolerances of the insects, at a constant 25°C, the entire life cycle can be completed in 37.57±1.65 days ([2]unpublished data). Comparing temperatures in South Africa with those of south Florida (the collection locality) using stations added to the CLIMEX database, shows that temperature fluctuations in KwaZulu-Natal and Florida are similar, although 1-2ºC lower in KwaZulu-Natal throughout the year. This relatively small difference will result in fewer generations per year (six to seven), and expose individual life stages to increased mortality risk. By extrapolation of rearing at constant temperatures, a graph of thermal minima was constructed (Figure 2). The graph illustrates the least robust stage; with regard to temperature this is the pupa, which cannot develop below 12°C.

[2] WA Parasram, unpublished MSc. Dissertation.

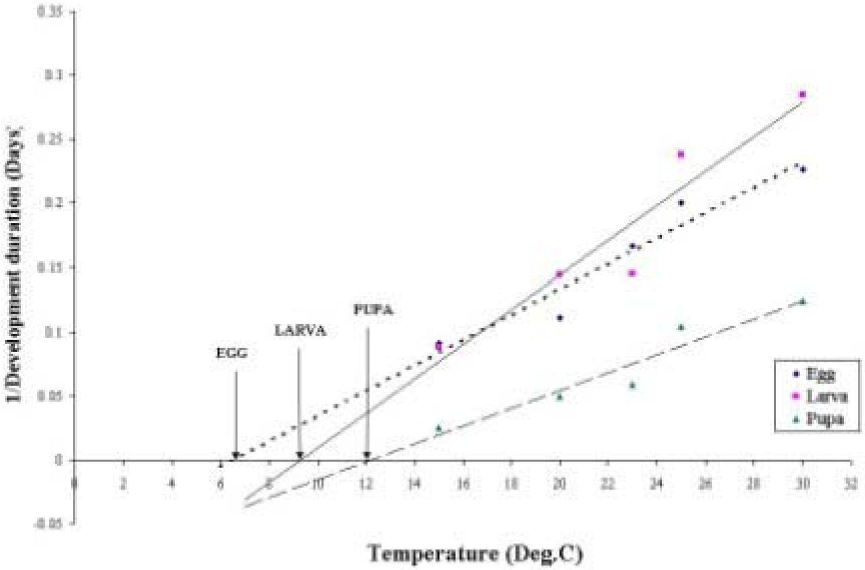

Figure 2. Lower developmental thresholds for *P. insulata* showing susceptibility of different stages to cold temperatures.

Discussion

The three most common reasons cited for failure of new insect biocontrol agents to establish are (i) low release numbers, (ii) climatic compatibility, and (iii) biotype incompatibility (Hopper and Roush, 1993; Beirne, 1985; Memmott *et al.*, 1996; Grevstad, 1999). Both *P. pseudoinsulata* and *P. aurata aurata* were mass reared and released in large numbers, and reasons (ii) and (iii) are therefore possible causes of non-establishment locally (Zachariades *et al.*, 1999). CLIMEX predicts a very poor climatic similarity to Trinidad (the origin of *P. pseudoinsulata*), and *P. aurata aurata* was collected from a different species (*C. jujuiensis*) (Kluge and Caldwell, 1993). Therefore, with the new *P. insulata* culture, insects were collected from South African-type *Chromolaena* in Florida, where the climate is comparatively the most similar to South Africa.

CLIMEX is only able to measure and compare five variables:

- Maximum monthly temperature
- Minimum monthly temperature
- Amount of rainfall
- Pattern of rainfall
- Relative humidity.

CLIMEX nevertheless predicts a 60-70% match for the KwaZulu-Natal coastal datapoints. Certain points inland and in the Northern Province also rank well in the CLIMEX matching system (Figure 1); however, this is usually because most variables, with the exception of one or two, have compared favourably. In the case of Messina, for example, total rainfall is 350-400 mm/year, which impacts negatively on humidity and consequently on the condition of *C. odorata* as a food source. Allowing for these mismatches, the most favourable sites appear along the KwaZulu-Natal coastline and slightly inland. According to the model, *P. insulata* should be well able to survive in KwaZulu-Natal.

Evaluating CLIMEX as a tool for climate matching analysis shows that:

- The program is initially limited by the number of weather stations in the database. This can be easily overcome by adding new stations in a relatively simple procedure.
- The quality of the data is questionable. Broadly, weather stations used are from airports and cities, not natural areas, as would be ideal; however, the general variables used cancel out the locality effect to an extent. Where more detailed data is available, a GIS program such as ArcView would be able to draw more accurate maps, with layers, so that datapoints would be more visible.
- CLIMEX is very easy to set up and use, it is less costly than a GIS program, and it can be a valuable tool in prediction, both of international collection localities onto local maps, and local climatic conditions onto international maps, to define similar zones for agent collection.

Laboratory collected data of cold tolerances also indicates that all life stages of *P. insulata* should be able to survive temperature fluctuations, although all stages are not equally susceptible. The egg and pupal stages are more susceptible to predation and, while the egg stage should develop at temperatures between 6 and 35ºC, the pupal stage needs at least 12ºC for development.

The results indicate that, among the potential reasons for non-establishment, although climate will have an effect, it is unlikely to be the factor that has the greatest effect. The project will continue to establish the role of the other factors, most notably predation and parasitism, as these were reported to have been significant in the establishment of *P. pseudoinsulata*.

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