

The dynamics of *Helicoverpa* populations : can we predict ?

Gary P. Fitt ¹, Martin L. Dillon ¹, Peter C. Gregg ², Myron P. Zalucki ³ and David A.H. Murray ⁴

1- CSIRO Cotton Research Unit, Narrabri

2- Dept. of Agronomy, University of New England, Armidale

3- Dept. of Entomology, University of Queensland, Brisbane

4- Division of Plant Protection, Qld Dept. of Primary Industries, Toowoomba

INTRODUCTION

Helicoverpa punctigera (Wallengren) and *H. armigera* (Hubner) have a number of characteristics which make them highly successful pests of numerous crops in Australia, including cotton (Fitt 1989). They are highly mobile, have a broad host range and can increase in numbers rapidly when conditions are favourable. Current pest management relies on regular sampling and application of pesticides when thresholds are exceeded. It seems unlikely that the need for regular crop checking can ever be abandoned, but here we discuss prospects for predicting changes in *Helicoverpa* abundance which may assist pest managers in the future.

Helicoverpa populations have been the subject of intensive ecological study for some time and we are now beginning to understand, in a quantitative way, some of the factors which influence their seasonal patterns of abundance. In addressing the question: "can we predict *Helicoverpa* abundance?", it is necessary to consider the various spatial scales over which the populations of these pests are distributed. For cotton growers, predictions of likely changes in numbers, particularly of eggs on cotton, within the cotton growing regions will be of prime interest. But as our ecological studies have expanded it has become clear that to understand dynamics in cropping regions it is necessary to look much further afield, to populations outside cropping areas. Thus the two spatial scales; 'within cropping areas' and 'inland non-cropping areas' are linked and must be understood together if we are to ever provide useful predictions.

In this paper we discuss how our studies of the ecology of *Helicoverpa* populations, and the development of computer models, is leading to an integrated capacity to provide the industry with predictions of changes in *Helicoverpa* abundance before, and during, the cotton season.

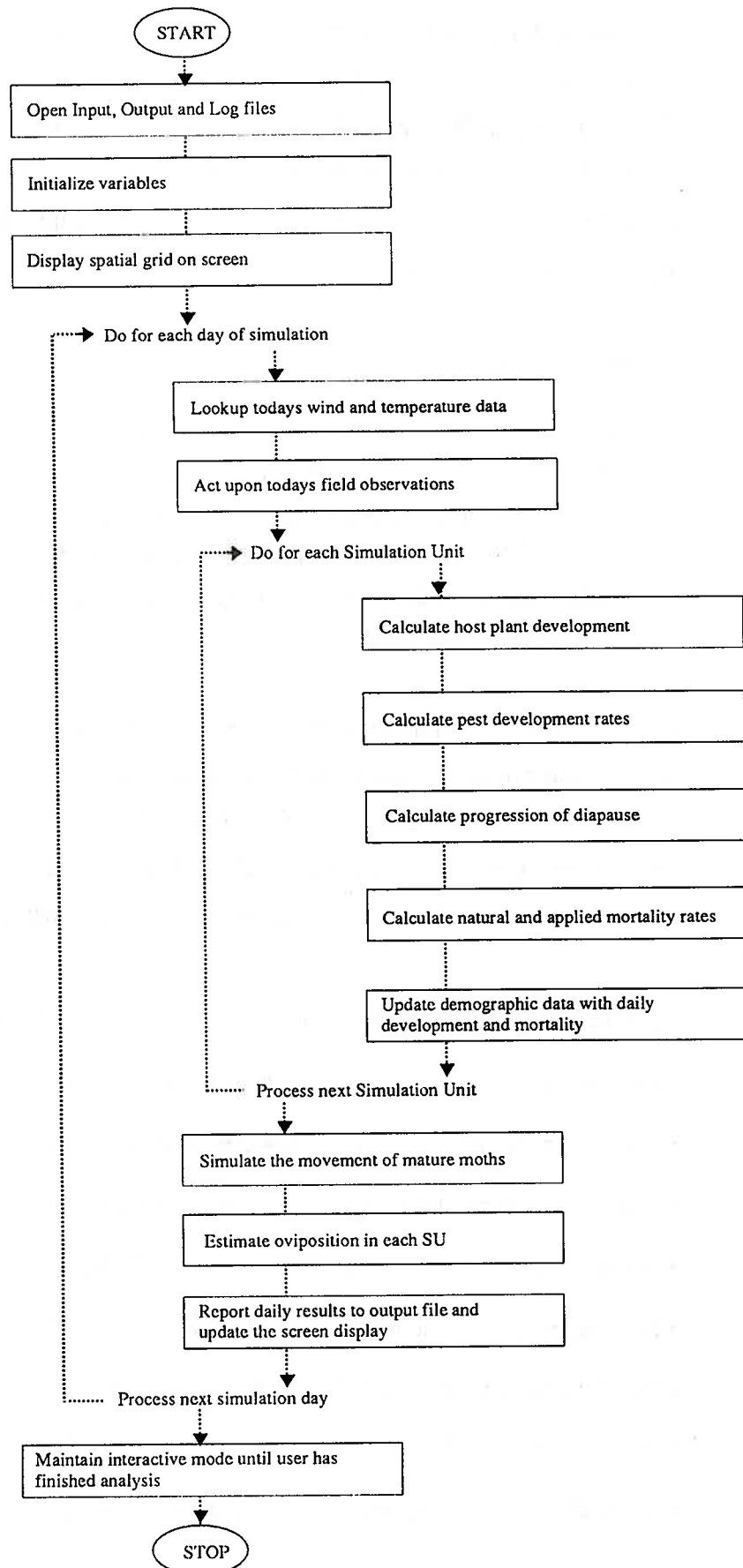
REGIONAL PREDICTIONS: DEVELOPMENT AND VALIDATION OF THE HEAPS MODEL

To address the need for regional predictions of *Helicoverpa* abundance in cotton areas, CSIRO has for some time now, been developing the HEAPS model (*HElicoverpa Armigera* and *Punctigera* Simulation). The model has reached a high level of development and is virtually complete, except for a module to simulate insecticide resistance. The original rationale for constructing this model was to have a means of predicting likely changes in numbers of *Helicoverpa* eggs on cotton crops during the growing season. The model is now at a stage where such predictions can be made and this feature will be available on a limited scale from 1992/93.

Details of the structure and applications of HEAPS have been published elsewhere (Dillon and Fitt 1990, Dillon 1991, Fitt and Dillon 1992). Seven modules have been completed with respect to our current understanding of *Helicoverpa* biology: (i) Spatial representation of cropping areas, (ii) Moth movement, (iii) Oviposition, (iv) Development, (v) Pupal diapause, (vi) Mortality and (vii) Host phenology. A suite of subroutines also exist that handle input, output and the screen interface. Figure 1 shows a flow chart of the model components.

HEAPS differs significantly from previous models of *Helicoverpa* populations (Hartstack *et al.* 1978, Stinner *et al.* 1974) in that the simulation includes a spatial dimension requiring explicit modelling of local adult movement. HEAPS divides a region into a series of simulation units which can be of any size and develops populations independently in each unit. To initiate the model, information is required on the identity and spatial arrangement of host plants in the region together with information on initial numbers of *Helicoverpa*. Parameters for larval development and survival are dependant on temperatures and on the type and stage of development of the host plants in each unit. The emergence of moths, and their subsequent movement between simulation units is predicted on the basis of a series of behavioural rules in response to forecast temperatures and wind conditions. The spatial configuration of HEAPS make it readily adaptable to different cropping systems provided information on the identity and distributions of major host plants is available. (And that the plants are covered by the suite of plant phenology models currently available).

Figure 1. HEAPS FLOW CHART



Several of the HEAPS subroutines have been validated successfully, and we are reasonably happy with our ability to predict the development and emergence of populations (Figure 2), lifetime fecundity and oviposition behaviour of adults, the development and flowering of crops and some aspects of survival and movement of adults. This latter point, adult movement, has been the subject of much research (Fitt and Dillon 1992) and remains a significant difficulty in simulating population dynamics over a region.

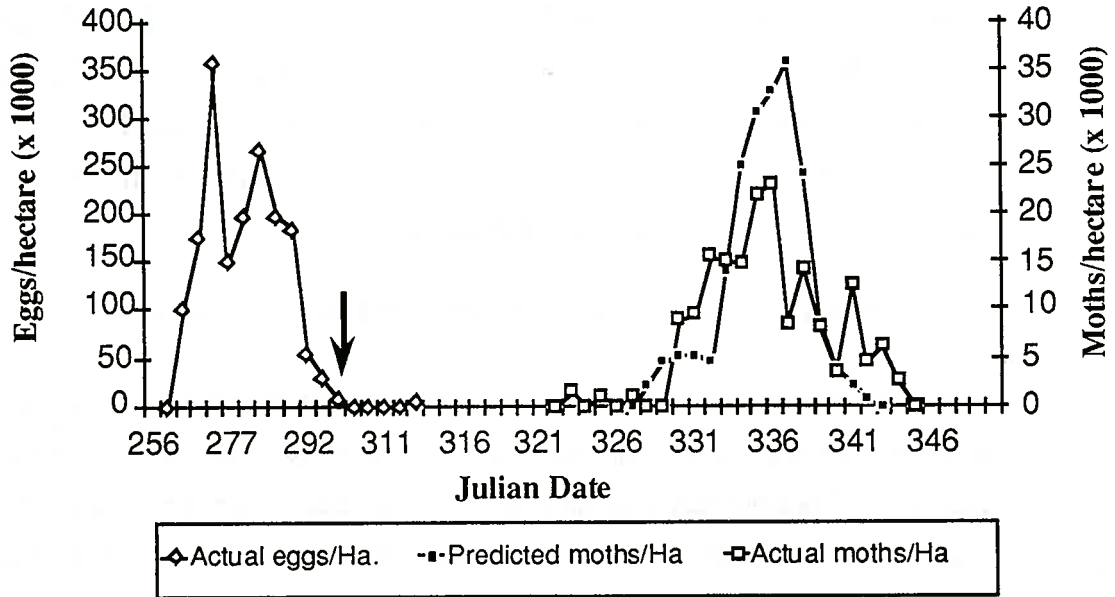
USES OF HEAPS

The HEAPS model has been designed as a research tool with a variety of potential uses in mind. The immediate practical application of HEAPS will be to provide short term predictions of likely *Helicoverpa* densities in discrete parts of a cotton growing region. Full-scale validation of the model has commenced in the Namoi/Gwydir and will be expanded to the Darling Downs and central Queensland cotton growing regions in the near future.

An equally important application will be to utilise the model to explore alternative strategies for management of *Helicoverpa* on a regional basis. For example it will be possible to simulate the effect of area-wide pesticide applications on overall *Helicoverpa* numbers and resistance status. Other strategies which could be simulated and/or environmental influences which could be evaluated using HEAPS include:

- the introduction of pest resistant cottons or other host plants
- the consequences of cultivating stubble to kill overwintering *H. armigera* pupae
- changes in the mix, or spatial arrangement, of crops grown in a region
- changes in the planting sequence, or area sown, of various crops within a region
- the effectiveness of trap cropping and push-pull strategies
- the effects of implementing various decision support systems (eg, entomoLOGIC)
- the impact of seasonal climatic conditions on *Helicoverpa* distribution and density
- the importance of the spring arrival of migratory moths in diluting local resistance
- alternative strategies for managing the introduction of transgenic cottons.

Figure 2. Numbers of eggs laid and moths emerged from a chickpea crop. For moths the figure shows actual emergence and the predicted emergence from the HEAPS model (simulating from Oct. 26, Jday 299 indicated by arrow).
(note different axes for eggs and moths)



PREDICTING SPRING IMMIGRATIONS

One aspect of *Helicoverpa* dynamics which HEAPS cannot deal with is long distance immigration. In particular we have been unable to explain the regular appearance of large numbers of *H. punctigera* which frequently arrive in September in regions where local overwintering is rare or emergence does not occur until some weeks later (Fitt and Daly 1990). This influx of spring immigrants establishes the first generation of the season on spring crops and weeds. It is the survival of this generation that then sets the scene for the cotton season.

To understand the origins of these spring outbreaks we commenced studies of *Helicoverpa* populations in inland regions and for the last four years we have operated a network of pheromone and light traps, and conducted surveys for winter breeding, over much of inland Australia. The trapping network is now extensive (Figure 3) and includes 26 sites established in inland regions by 1989, and a further 51 sites added in 1990, mostly in the south-east (Fitt *et al.* 1991) in collaboration with the CSIRO's Double Helix Club, a school based science club. A network of

10 light traps were added in 1990 and 1991 (Figure 3) to provide additional information on the breeding potential of inland populations.

In addition to trapping we conduct regular surveys over extensive areas mainly from May to September each year and utilise satellite images of ground vegetation to show the extent of breeding habitats. Details of much of this work have been given in other publications (Fitt *et al.* 1990, 1991, Gregg *et al.* 1990). Here we focus on winter breeding and our ability to predict subsequent migrations of *Helicoverpa* into cotton areas over the last few seasons.

WINTER BREEDING AND SPRING PREDICTIONS (1989-1991)

In the late autumn and early winter of 1989, rainfall was above average in much of eastern Australia. There was heavy rain in south-west Queensland, and a small area around Quilpie received the highest rain on record for April-June. The rain and subsequent flooding of the Cooper Creek and Diamantina River systems produced abundant growth of native *Helicoverpa* hosts in the families Asteraceae, Goodeniaceae and Fabaceae, both in the floodplains and in the surrounding open *Acacia* woodlands. Very large populations of *Helicoverpa* spp. developed on these hosts (Figure 4). In July 1989, we estimated that there were about 2×10^{11} larvae in an area of 90,000 km², roughly coinciding with the region of record rainfall in SW Queensland (Fitt *et al.* 1990). In September the host plants dried off quickly with the onset of hot dry weather. In this season we made no predictions, but demonstrated conclusively that *Helicoverpa* from the Channel country arrived in the cotton areas of northern NSW and southern Qld in September (Gregg *et al.* 1990).

In 1990 heavy rainfall occurred over a wide area of eastern Australia, with extensive areas of areas of south-western Queensland receiving record April-June falls. *Helicoverpa* hosts were abundant, and large numbers of larvae were found during the winter. Drawing on our accumulated understanding from previous years' work we accurately predicted, in July of 1990, that a significant migration would occur (Figure 4) and that if climatic conditions during October were average, allowing good survival of the first generation, then *H.punctigera* could be expected to be abundant. This was precisely what happened and exceptionally heavy pressure on cotton during November, December and part of January led to shortages of endosulfan.

Figure 3. Trapping Sites of the *Helicoverpa* Inland Research Group

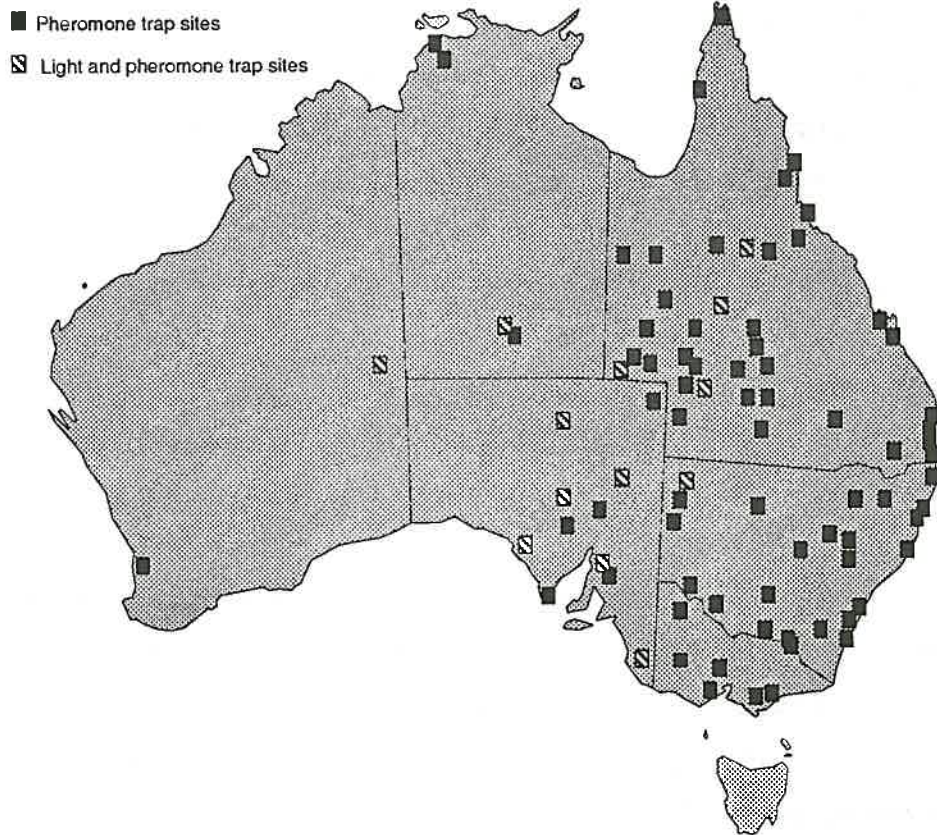
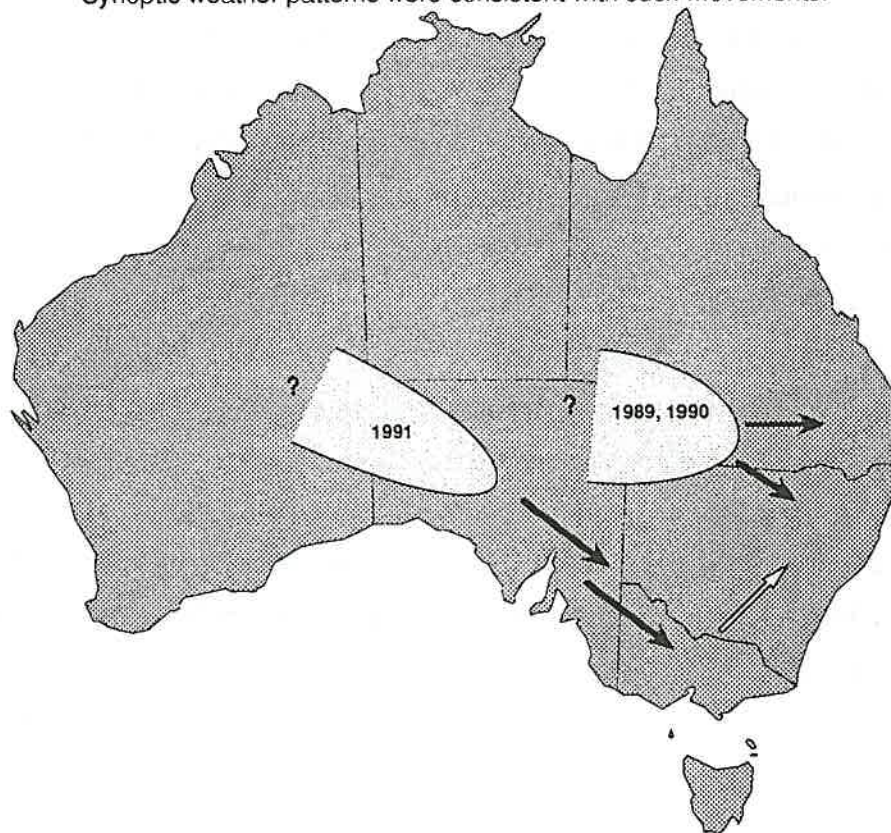


Figure 4. Source areas and likely spring migration patterns for *Helicoverpa* spp. A possible migration route for 1991 is indicated by the white arrow. Synoptic weather patterns were consistent with such movements.



In 1991 there was an extremely dry autumn and winter in the regions of south-west Queensland which, the previous two winters, had supported large populations of *Helicoverpa*. Almost no host plants for *Helicoverpa* were present. Larvae were found only in the lower regions of the flood plains, where limited flooding from late summer rain in central Queensland had produced some growth of verbines (*Psoralea* spp.). These hosts persist when conditions become dry and may play an important role in maintenance of remnant *Helicoverpa* populations in the inland, but in 1991 they supported only localised and relatively small populations. Accordingly we made a prediction (Fitt *et al.* 1991) that *Helicoverpa* should not be as abundant as in the previous year.

However there was a qualification, since a large portion of the Great Victoria Desert in western South Australia, and adjacent areas of Western Australia, had received above average rainfall in the autumn and winter of 1991. A survey of this region in September revealed extensive areas of host plants and evidence of substantial winter breeding of *Helicoverpa* over a wide area.

We speculated that this previously unknown source area may produce moths which could also migrate into northern NSW. As it happened the story was a little more complex (Figure 4). The population in the Great Victoria Desert was extensive, covering about 500,000 square kilometres. Newly emerged moths began to leave that area during late July/August but the major migrations commenced about September 10. Our now extensive network of traps across eastern Australia (Figure 3) effectively monitored these movements which carried moths on westerly and north westerly winds right through southern Australia. These moths produced extremely high densities of larvae on spring legume crops (field peas, lupins, chickpeas) in South Australia, Victoria and southern NSW. Some of the moths from the Great Victoria Desert also appeared to reach northern NSW producing the major trap peak in September. The first of these immigrants arrived about September 17. Synoptic weather patterns at the time were consistent with moths being transported over such distances.

In addition there was evidence from the Macquarie valley and Bourke later in the season that each time there was a southerly change during November/ December there was an influx of *Helicoverpa* and major egg-laying peak. Anecdotal evidence from southern Australia shows that successive generations of *Helicoverpa* were produced during late spring/ early summer after which those populations petered out. The observations in the Macquarie region suggest there were several migrations on southerly wind systems of moths generated in southern Australia as a result of breeding by that first influx of migrants in spring. Thus the explanation of the spring migrations of *H. punctigera* this year was somewhat more complex than we had previously seen. The lesson seems to be that we need to look even further afield if we are to forecast *Helicoverpa* dynamics each season.

IMPLICATIONS FOR FORECASTING

Vast areas of inland Australia are clearly potential sources for spring outbreaks of *H. punctigera* if rainfall is sufficient to enable host plant growth. Our experience with reasonably successful predictions over the last 2 seasons suggests that a forecasting system based on rainfall and satellite imagery, combined with pheromone trapping and surveys for larval breeding appears feasible. For summer crops such as cotton, the system also has to take into account local weather and host growth in mid to late spring.

THE FUTURE

Although the HEAPS model is now virtually complete, several components require extensive testing. In a new CRDC funded project the entire model will be validated in three growing areas (Namoi, Darling Downs and Central Qld) over three years. We will then be in a position to provide regular predictions of short term changes in *Helicoverpa* numbers in specific growing areas. In addition the model will be progressively used to evaluate a range of potential area wide management strategies and their impact on *Helicoverpa* abundance and pesticide resistance.

With regard to the broader perspective of providing forecasts of major immigrations into cotton areas from inland breeding areas, we propose to develop a forecasting system. This would integrate information on *Helicoverpa* numbers over broad areas of Australia, climatic factors, particularly rainfall and associated vegetation responses, and synoptic weather to provide predictions of the size and timing of immigrating populations. These forecasts could also then be used to initialize the HEAPS model and hence provide higher resolution predictions of *Helicoverpa* dynamics within specific cotton growing regions.

The basis for the forecasting system would be a spatial insect model to be developed in the Centre for Tropical Pest Management in Brisbane which will provide predictions of insect migration and will focus initially on *Helicoverpa*, drawing extensively on work of the *Helicoverpa* Inland Research Group (Fitt, Gregg, Zalucki and Murray). Such a system would formalise the predictions we have successfully made over the last few seasons. Whether the forecasting system eventuates depends on the perceived need by agricultural and chemical industries and by funding bodies. We hope the issue may be resolved later this year.

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