A brief word on the ecology of common heliotrope and its relationship with farming systems in the Victorian Mallee

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Introduction

Why common heliotrope is a problem in Australia

Common heliotrope (*Heliotropium europaeum* L.) is an opportunistic annual weed that grows in ‘disturbed’ areas (i.e. areas of bare or sparsely vegetated soil) following summer rain in regions with a Mediterranean climate (hot dry summers, cool wet winters). In its natural habitat, which includes most of the rim of the Mediterranean Sea, farming practices result in there being few disturbed areas during summer, hence common heliotrope is not such a problem. However, in the dry-land cropping belt of southern Australia, the wholesale clearing of native vegetation and the endemic broad acre agricultural practices leave vast areas of fallow, hayed-off pasture and sparse stubble over summer; all of which are ecologically speaking ‘disturbed’, and hence fantastic habitat for common heliotrope.

Carving an ecological niche

As mentioned above, common heliotrope is an opportunistic or ephemeral annual. It will not grow without fail year in year out, rather only when conditions are favourable. Favourable conditions for common heliotrope require sufficient rainfall in the middle of a Mediterranean summer, when little else is growing to compete for that rainfall. Common heliotrope has seemingly evolved germination requirements to ensure that it will only germinate when these conditions exist. Specifically, these requirements are comparatively high temperature and moisture levels. Laboratory experiments have shown that no seeds of common heliotrope will germinate below 18°C, compared to 0 to 5°C for winter and temperate summer annuals. Experiments using polyethylene glycol solutions of different concentrations to give a range of water potentials showed that common heliotrope seeds require less negative water potentials before they will germinate when compared to winter and temperate summer annuals.
The actual amount of water required for germination in the field, as deduced from watering experiments and observation, appears to be between 15 and 20 mm rainfall (Figure 1 and Table 1), a value obviously dependent on climate and soil conditions.

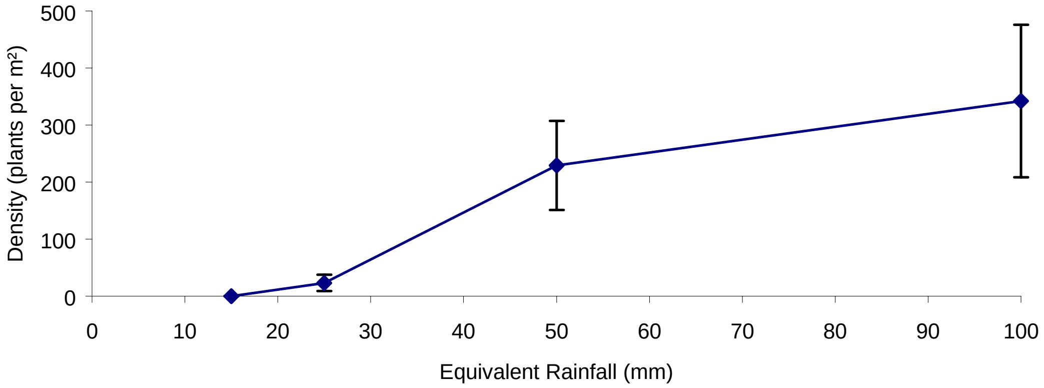

Figure 1. The mean density of the number of emerged common heliotrope plants across a range of different simulated rainfall treatments. The mean values are taken from five replicates of each treatment, error bars are ± the standard error of the mean.

Table 1. Rainfall events at different sites in the Victorian Mallee that did and did not result in the emergence of a cohort of common heliotrope. Only rainfall events between 5 and 30 mm are shown.

Emergence	**Rainfall (mm)**	**No Emergence**	**Rainfall (mm)**
Birchip 22 January 2002	28	Normanville 21 March 2001	9
Normanville 25 October 2000	23	Normanville October 2001	12
Normanville 22 December 2000	17	Normanville 22 January 2002	9

The biological meaning behind the minimum rainfall requirement

It is my hypothesis that the 15-20 mm rainfall required for the germination of common heliotrope is also the minimum amount required for it to survive long enough to reproduce. Common heliotrope flowers when the plants are still very small, about three weeks after germination, and viable seed can be produced in as little as three weeks after flowering. The environment that the young heliotrope plants inhabit is extremely desiccating, and even though evaporation rates are extraordinarily high, because the germinating rain is falling on bare earth, most of it is stored in the subsoil. This works as follows. If 20 mm of rain falls on a summer fallow (bare earth), it will infiltrate to a depth of around 120 mm, assuming a soil bulk density of 1.3 Mg m^{-3}, drained volumetric soil-water content of 20 %, air-dry volumetric soil water content of 5 % and a correction factor for drainage from large pore spaces. With high summer air temperatures, dry winds and many hours of intense sunshine, the water in the top 40 mm of soil evaporates rapidly. Conversely enough, this prevents the water in the subsoil from being lost to the atmosphere by breaking the hydraulic conduction between the subsoil and the atmosphere. So, given that most of the water stored in the top 40mm of soil is lost, which is equivalent to 7 mm of rainfall, the remaining 13 mm is available for transpiration, and hence growth, of common heliotrope plants. Because common heliotrope flowers rapidly after germinating and before it has produced much leaf area, the amount of water it needs to transpire in order to successfully reproduce is comparatively small. Obviously this hypothesis requires a lysimeter experiment to prove it one way or the other, such an experiment is currently being conducted.

More opportunism

Growth and flowering in common heliotrope is indeterminate, so if any water other than that provided by the bare minimum germinating rainfall becomes available (i.e. greater rainfall, subsoil moisture or subsequent rain), then reproductive output can be increased by several orders of magnitude. If there is no further water available other than the germinating rain, then minimum reproduction will occur before the plants die of drought. Thus heliotrope is doubly opportunistic in that it only grows when conditions are favourable, and then reproduces as much or as little as conditions will allow. Once it starts flowering, it will continue to do so until it is either killed by drought, frost or human intervention.

Common heliotrope and farming systems in the Victorian Mallee

Common heliotrope and farmers in the Mallee share a bizarre and antagonistic relationship. Summer fallow is maintained to preserve soil moisture by creating bare earth, on which no plants grow that would transpire any existing, or subsequently arriving soil moisture into the atmosphere. The act of doing this creates the perfect habitat for common heliotrope, which will germinate following exactly the kind of rainfall that farmers hope to trap in their fallow for exclusive use by next season's crop. Obviously, this is a bad thing, as the roots, stems and leaves of common heliotrope create a hydraulic link between the precious subsoil moisture and the greedy, wasteful atmosphere, transpiring the very moisture the fallow is supposed to conserve. Farmers thus cultivate to kill the common heliotrope and create more water-harvesting bare earth, which once again makes for fantastic common heliotrope habitat, and so on and so forth.

Some Observational Biology

Germination and Emergence

This is a brief description of some quantitative observations made of the germination and growth of a cohort of common heliotrope in the Victorian Mallee during January and February of 2002. The field site was a paddock owned by the McClellands, and located some 25 kilometres north east of the township of Birchip. The paddock in question was sown with oaten pasture the previous autumn, and had been well grazed. The site is typical of the dry land farming areas infested by common heliotrope across southern Australia.

A cohort of common heliotrope had grown at the field site the previous summer, ensuring that there was a reasonable amount of seed present in the soil. Table 2 shows the density and distribution of viable common heliotrope seed in the soil seed bank in the top 50 mm in late October 2001.

Table 2. The mean density of viable common heliotrope seeds at different soil depths at the Birchip field site as of 25 October 2002. These values are the mean of 100 randomly taken soil cores of 17 mm diameter.

Soil Depth (mm)	Seed Density (m^{-1})	Standard Error of Mean
0-10	322	70
10-20	251	52

20-30	185	42
30-40	110	28
40-50	128	25
Total	996	136

On The 21 and 22 January 2002, a series of thunderstorms dumped an intense and highly variable amount of rain on the area north of Birchip. At the field site, 28 mm of rainfall was recorded. Soil temperature at 20 mm depth following the rain was more than adequate for germination of common heliotrope, as shown by Figure 2. Figure 3 shows the gravimetric soil water content in the top 50 mm of soil over the emergence period. Emergence occurred around three days after the germinating rainfall, and continued for around twelve days. Figure 4 shows the cumulative emergence at the site, which resulted in a mean density of around 30 plants m^{-1}.

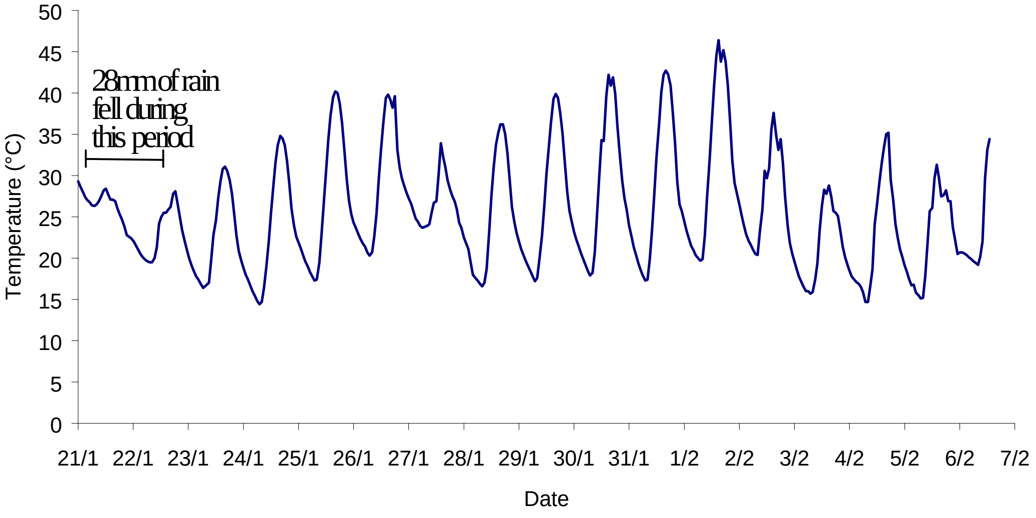

Figure 2. Soil temperature recorded by a thermocouple buried at 20 mm depth following the germinating rainfall event in the summer of 2002. An automatic data logger recorded temperature hourly.

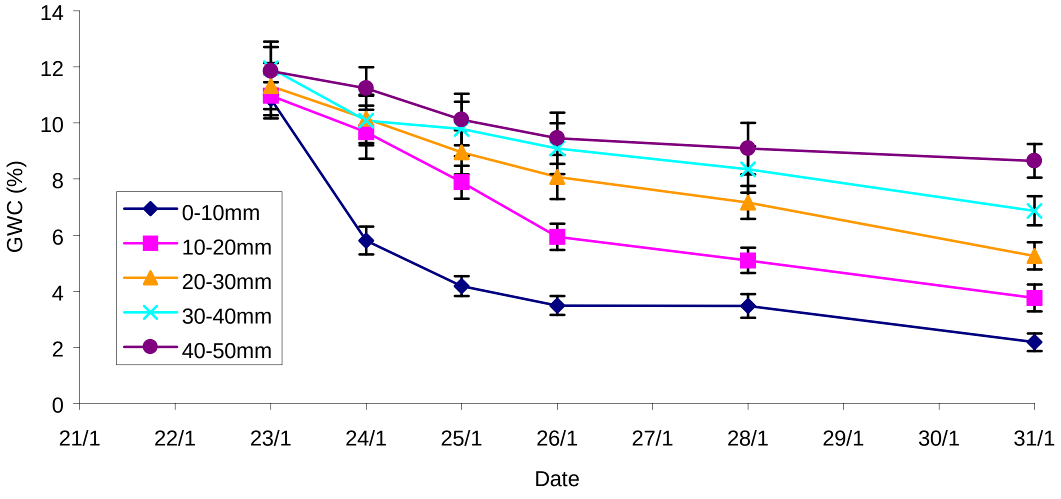

Figure 3. The mean gravimetric soil water content at different depths to 50 mm at the Birchip site following the germinating rainfall. The mean values are taken from 100 soil cores of 17 mm diameter; the error bars are ± the standard error of the mean.

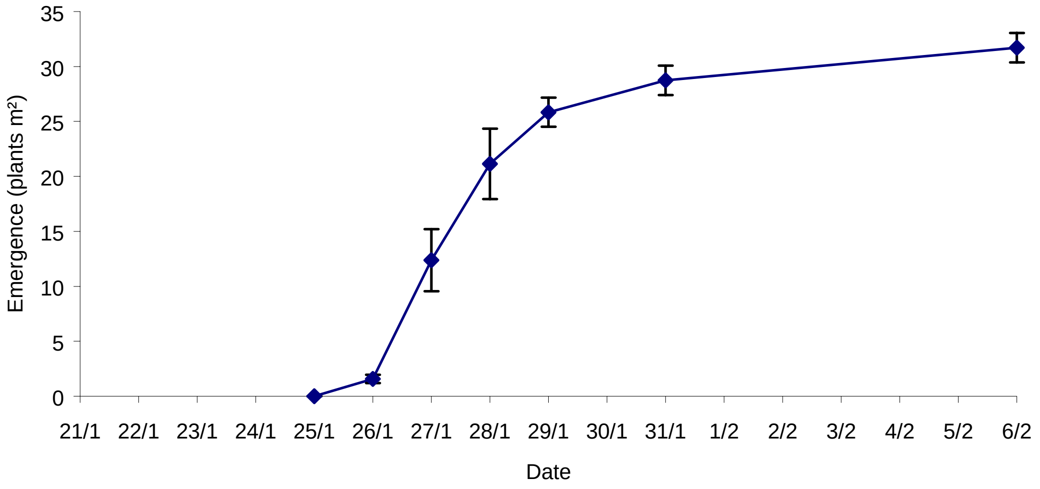

Figure 4. The mean cumulative emergence of common heliotrope seedlings at the Birchip field site during summer 2002. The mean values are taken from ten 1 x 5 m quadrats randomly distributed across the paddock; error bars are ± the standard error of the mean.

In order to determine at what depth the successfully emerging seedlings had germinated, emerged seedlings were removed and the distance from the seed to a couple of millimetres below the cotyledons was measured with digital callipers. These data are shown in Figure 5, and indicate that the seedlings which emerged came from within a very narrow band within the soil profile (8 to 12 mm depth). The pattern of depth of emergence over time can probably be attributed to differences in germination times due to soil moisture content. The initial seedlings come from the deeper, wetter layers of soil where germination was quickest, before seedlings in the shallower, dryer lays of soil germinate and subsequently emerge. As the profile dries out, only seeds positioned deeper continue to germinate and emerge.

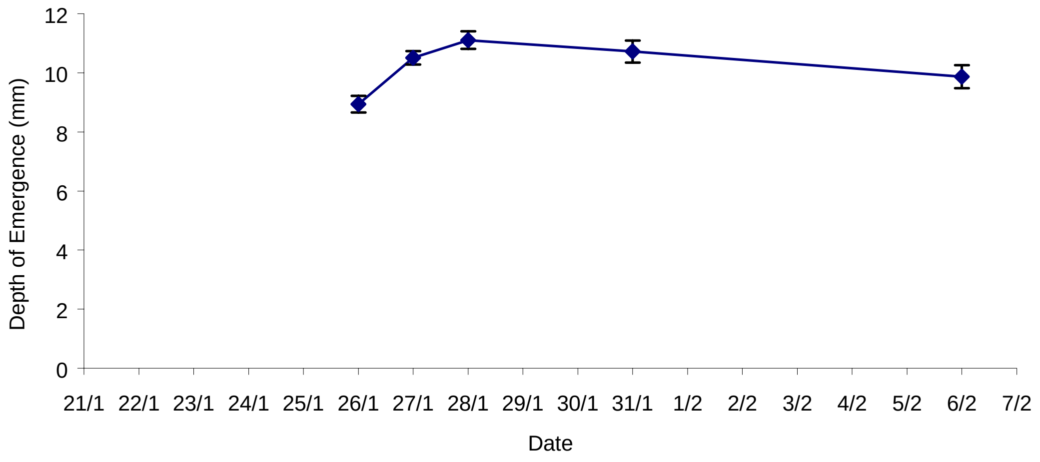

Figure 5. The mean germination depth of successfully emerging seedlings over time at the Birchip field site. The mean values are taken from all plants emerging in ten 1 x 5 m quadrats randomly distributed across the paddock; the error bars are ± the standard error of the mean.

Continued Growth

Figure 6 shows rooting depth over time following emergence. The progress of roots down the soil profile is comparatively slow, and this observation is supported by laboratory experiments on root growth. This result contradicts previous autecological studies of heliotrope, which maintain that heliotrope rapidly develops a deep taproot with which it accesses sub-soil moisture. I believe instead that it develops a root system that methodically exploits the water available from the germinating rainfall, which due to control of germination by the seed is sufficient for reproduction, as discussed above.

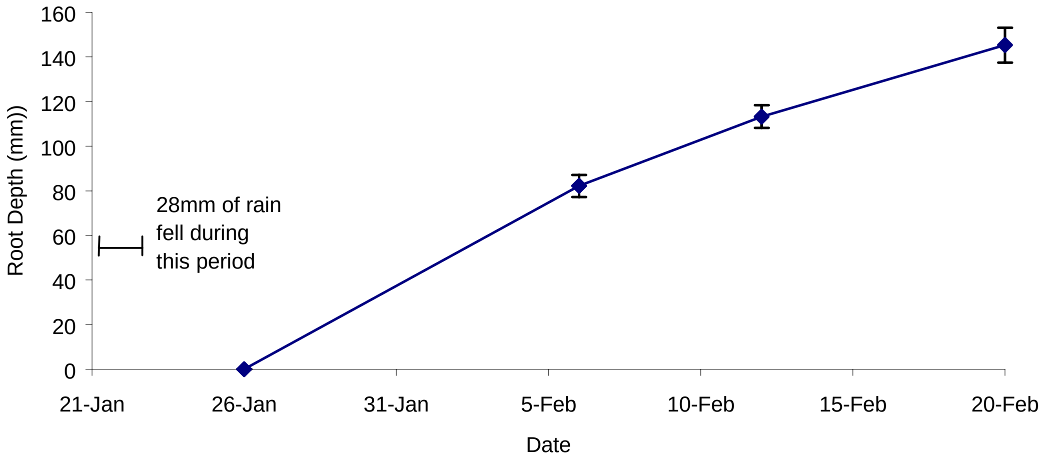

Figure 6. The mean root depth of common heliotrope plants at the Birchip field site over time. The mean values are taken from twenty randomly selected plants; the error bars are ± the standard error of the mean.

Figure 7 shows the gravimetric soil water content around the rooting depth of common heliotrope observed at the field site. It shows that even though the soil water in the top 50 mm is rapidly lost, water stored below the rooting depth of common heliotrope (figure 6) perseveres, as discussed above.

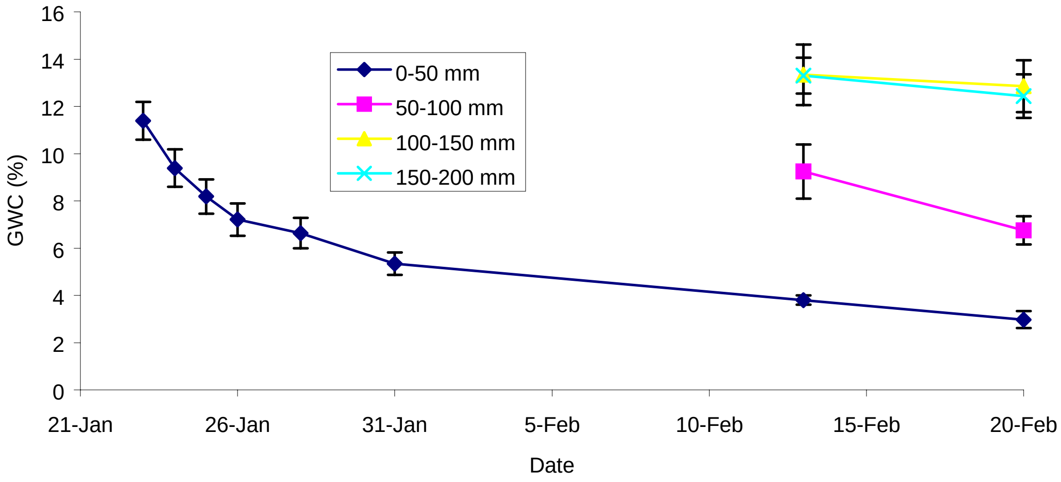

Figure 7. The mean gravimetric soil water content at different soil depths over the period that common heliotrope was growing at the Birchip field site. The mean values were taken from five soil pits randomly distributed across the paddock; the error bars are ± the standard error of the mean.

Acknowledgements

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