# A study of drought resistance of stinkwort (Dittrichia graveolens)

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## ABSTRACT

Stinkwort (*Dittrichia graveolens)* is a Mediterranean annual composite that flowers in the fall in California at the very end of the dry season after most other annuals have completed flowering and seed set. It can be observed growing on roadsides and in disturbed habitats in hard, compacted soil that appears to be very dry. This seems to indicate that the plant possesses a high degree of drought resistance.

This study sought to investigate two attributes of the plant that might confer drought resistance: plant water use efficiency (WUE) and plant root/shoot ratio. WUE is defined as the ratio of shoot dry weight to weight of water transpired. Root/shoot dry weight ratio is a measure of a plant's ability to maximize use of available soil moisture by developing an extensive root system.

Water use efficiency was determined by growing stinkwort plants in containers, obtaining dry weight values and measuring water lost through transpiration. Corn plants were also grown in this study as a reference crop because the WUE has been well characterized in previous research. It was found that stinkwort plants grown under well-watered conditions did not exhibit high relative water use efficiency. They were found to have a relative WUE value only 51 per cent that of corn. To measure root /shoot ratio, stinkwort plants were collected in the field, and root and shoot dry weights were measured. A relatively low root/shoot ratio of 0.16-0.21 was obtained.

The results of this study did not indicate that stinkwort has the ability to avoid drought stress by means of high water use efficiency or through investment in an extensive root system. Further research is needed to determine whether it employs another mode of drought resistance, such as tolerance of high internal water deficits (low tissue water potential).


## INTRODUCTION

Stinkwort (Dittrichia graveolens) is an invasive plant native to the Mediterranean region that has been spreading rapidly in California in the last few years. It is tolerant of a wide range of soils, including saline and serpentine soils, and of a wide range of moisture regimes. It possesses a life cycle unique among California winter annuals of delaying flowering and seed set until fall, from September to December (Brownsey, Kyser and DiTomaso 2013).

In the Peninsula Watershed of the San Francisco Public Utilities Commission, stinkwort can be observed growing in dry compacted soil along roadsides. It is also found on the disturbed margins of coyote bush (Baccharis pilularis) scrub and of chaparral (Figure 1). In Australia, it grows in mallee shrubland, dry sclerophyll woodland and dry coastal dune vegetation (Queensland Department of Primary Industries and Fisheries 2008).

This suggests that stinkwort has a fairly high degree of drought resistance. According to the most commonly accepted definition of drought resistance (Levitt 1972), drought resistant plants are divided into two groups: drought-avoiding and drought-tolerating plants. Avoidance involves the restriction of water loss or the expansion of the root system to reach a greater supply of water (Kirkham 2003). Tolerance is the ability to perform well, or survive, despite the existence of a stressed condition within the tissues. In this study I sought to evaluate two aspects of drought avoidance by stinkwort: water use efficiency and the ratio of root dry weight to shoot dry weight.

Water use efficiency (WUE) in plants is measured as the ratio of the grams of shoot biomass produced to kilograms of water transpired. Values of WUE differ greatly among plants, with some plants being more efficient in their water use than others (Briggs and Schantz 1914), Schantz and Piemeisel 1927).

Also, absolute values of WUE vary year-to-year with changing environmental conditions, especially with temperature and relative humidity. For this reason, I evaluated the relative WUE of stinkwort, rather than the absolute value, determined as the ratio of the WUE of stinkwort to that of corn, for which WUE has been extensively studied.

In this study, plant root/shoot ratio was used as a measure of the ability of stinkwort to produce an extensive root system capable of exploiting available soil moisture. Samples of roots and shoots of stinkwort were collected in the field in the Peninsula Watershed, and these were used to calculate plant root/shoot ratios.

Figure 1. Stinkwort growing in the Peninsula Watershed of the SFPUC near chaparral with chaparral pea, toyon and manzanita (top) and near baccharis scrub (bottom).

Figure 2. Stinkwort and corn plants growing in 1-gallon pots used in the measurement of water use efficiency.

Figure 3. Stinkwort plants collected in May 2013 for the determination of root/shoot ratio.

## METHODS

*Water Use Efficiency.* A study of the water use efficiency of stinkwort was conducted during the summer of 2011 in Saratoga, California. Stinkwort and corn plants were grown in 1-gal pots, with 15 replicate plants for each species (Figure 2). Water consumption was measured by weighing plants after they had been watered to bring them up to field capacity and then re-weighing them after water had been lost to evaporation and transpiration (evapotranspiration). Pots were re-watered before plants experienced significant water stress.

To measure the transpiration component of evapotranspiration, 5 replicate empty pots were used to measure evaporation of water from the soil surface. These pots were watered at the same time as the pots with stinkwort and corn and were re-weighed when the pots with stinkwort and corn were re-weighed. Transpirational water loss was then determined by subtracting the average amount of surface evaporative water loss from these pots from the total amount of evapotranspirational water loss for the pots with stinkwort and corn.

Shoot dry weight values were obtained by harvesting shoots and allowing them to air-dry. WUE values were calculated for each plant by dividing shoot dry weight by the total weight of water transpired by the plant during the experiment.

Mean values of WUE for corn and stinkwort were compared using the Student's t-test to determine whether they were statistically different.

*Root/shoot Ratio.* In August 2011 large stinkwort plants were collected in the Peninsula Watershed. Roots were carefully excavated to prevent root loss, and the plants were allowed to air-dry. Dry weight values of roots and shoots and root/shoot ratio were then obtained for each plant.

To determine whether the root/shoot ratio might changes during the course of plant development for stinkwort plants, a second sample of younger stinkwort plants was collected in May 2013 (Figure 3). Root/shoot ratios were obtained using the same procedure as in 2011.

Mean values of root/shoot ratio for 2011 and 2013 were compared using the Student's t-test to determine whether they were statistically different.

## RESULTS

*Water use efficiency.* The absolute values of WUE were 1.75 gm/kg and 0.90 gm/kg for corn and stinkwort, respectively. The average value of relative WUE for stinkwort was only 51 per cent of that of corn, and the difference in mean values of WUE for stinkwort and corn was statistically significant (Figure 4, p<0.02).

*Root to shoot ratio.* The ratio was 0.21 for the mature plants collected in 2011 (Figure 5). The ratio was 0.16 for the younger plants collected in 2013, and the difference in mean values of the older and younger plants was statistically significant, (p<0.02), apparently indicating that the root/shoot ratio increases with plant age.

| t-Test: Root/Shoot Two-Sample Assuming Equal Variances | | |
|---|---|---|
| | | |
| | Corn | Stink wort |
| Mean | 1.826489066 | 1.286363636 |
| Variance | 0.530762436 | 0.158543224 |
| Observations | 15 | 15 |
| Pooled Variance | 0.34465283 | |
| Hypothesized Mean Difference | 0 | |
| df | 28 | |
| t Stat | 2.519615854 | |
| P(T<=t) one-tail | 0.008866339 | |
| t Critical one-tail | 1.701130934 | |
| P(T<=t) two-tail | 0.017732678 | |
| t Critical two-tail | 2.048407142 | |

Figure 4. Student's t-test comparison of mean values of water use efficiency for corn and stinkwort.

| t-Test: Two-Sample Assuming Equal Variances | | |
|---|---|---|
| | | |
| | Younger (2013) | Older (2011) |
| Mean | 0.156666667 | 0.215 |
| Variance | 0.002007692 | 0.002685185 |
| Observations | 27 | 28 |
| Pooled Variance | 0.00235283 | |
| Hypothesized Mean Difference | 0 | |
| df | 53 | |
| t Stat | -4.458626111 | |
| P(T<=t) one-tail | 2.15819E-05 | |
| t Critical one-tail | 1.674116237 | |
| P(T<=t) two-tail | 4.31639E-05 | |
| t Critical two-tail | 2.005745995 | |

Figure 5. Student's t-test comparison of mean values of stinkwort root/shoot ratio for younger plants collected in 2013 and for older plants collected in 2011.

## DISCUSSION

It was found in this study that stinkwort has a relatively low relative WUE, only 51 percent that of corn. This low relative value is similar to that found for some weeds, such as lamb's-quarters and polygonum, but is much lower than for other plants such as pigweed (*Amaranthus*) (Schantz and Piemeisel 1927. Thomas 1973). (See Figure 6.)

In large part, this difference in WUE is due to the fact that stinkwort, like almost all other composites, possesses the C3 photosynthetic pathway. Other plants, such as pigweed and corn, possess the C4 photosynthetic pathway. The C4 pathway is inherently more efficient in water use. It apparently evolved in the tropics as an adaptation to the higher temperatures and greater evapotranspirative stress there (Sage 2004). Though high WUE may have adaptive value in hot dry environments, it is not always correlated with drought resistance (Blum 2005).

It also was found in this study that stinkwort has a relatively low root/shoot ratio, 0.16-0.21. This is similar to the value found by Brownsey in her work on stinkwort (Brownsey 2011). Practitioners who work on stinkwort in the field have noticed the conspicuously small, compact size of the root system. In general, opportunistic early-successional annual plants have a lower root/shoot ratio than later-successional woody plants (Monk 1966).

Other late-season annuals, such as yellow starthistle and tarweeds, have deep root systems that are able to utilize deep residual soil moisture. Though stinkwort is also able to develop deep roots, it does so more slowly than these other annuals (Brownsey, Kyser and DiTomaso 2013).

Does this indicate that stinkwort lacks drought resistance? The current study failed to show that stinkwort possesses high water use efficiency or a high root/shoot ratio as adaptations for avoiding drought. However, given that it grows in dry habitats, some other mode of drought avoidance may be used by stinkwort, such as low stomatal conductance or low hydraulic conductivity. The resin and glandular trichomes covering the plant may act as a barrier to transpiration, as is the case for the closely related species *Dittrichia viscosa* (Stephanou and Manetas 1995).

Alternatively, it may have the ability to resist drought through drought tolerance. The ability of stinkwort to grow on saline soils (Garve and Garve 2000), for example, suggests that it may be able to maintain a low osmotic potential. In a preliminary study of drought tolerance, I sought to measure the water potential of stinkwort plants in the field using the Chardakov dye method (Knipling 1967), but results have been inconsistent. I have also begun a drought tolerance test of stinkwort plants growing in a hydroponic system (Figure 7), using polyethylene glycol (PEG-6000) as an osmoticum (Michel and Kaufmann 1973).

| Common Name | Scientific Name | Absolute WUE (gm shoot dry wt/kg H2O) | Relative WUE (relative to corn) | Photosynthetic pathway |
|---|---|---|---|---|
| tumble weed | Amaranthus graecizans | 3.85 | 1.34 | C4 |
| purslane | Portucaca oleracea | 3.56 | 1.24 | C4 |
| pigweed | Amaranthus retroflexus | 3.28 | 1.14 | C4 |
| Russian thistle | Salsola tragus | 3.18 | 1.10 | C4 |
| corn | Zeaz mays | 2.88 | 1.00 | C4 |
| cocklebur | Xanthium strumarium | 2.41 | 0.84 | C3 |
| nightshade | Solanum triflorum | 2.05 | 0.71 | C3 |
| lamb's-quarters | Chenopodium album | 1.52 | 0.53 | C3 |
| polygonum | Polygonum aviculare | 1.47 | 0.51 | C3 |

Figure 6. Weeds studied by Schantz and Piemeisel (1927) showing absolute WUE, relative WUE and photosynthetic pathway.

Figure 7. Hydroponic system used for drought tolerance test of stinkwort.

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