Hydrobiologia **415:** 223–228, 1999.
J. M. Caffrey, P. R. F. Barrett, M. T. Ferreira, I.S. Moreira, K. J. Murphy & P. M. Wade (eds), Biology, Ecology and Management of Aquatic Plants.
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Phenology and long-term control of *Heracleum mantegazzianum*

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Key words: Giant Hogweed, invasive plants, riparian zones, angling

Abstract

The growth characteristics and reproductive capacity are described for *Heracleum mantegazzianum*, an invasive perennial plant that has significantly increased its geographical range in Ireland in recent years. The effect of cutting on growth and seed production is described. Based on research findings, a detailed Giant Hogweed control programme is presented which could result in the elimination of the plant. A Giant Hogweed eradication programme on the Mulkear River catchment (c. 670 km^2), using this protocol, commenced in 1998 and will continue until 2002.

Introduction

Heracleum mantegazzianum Sommier and Levier is an alien species that was introduced to Ireland in the late 19th Century as an ornamental plant. It has since become naturalised in a number of locations. Up to the late 1960s, the plant formed only localised dominant stands although, since that time, it has noticeably expanded its range and in 1997 was recorded from 30 different 10 × 10 km squares (Wade et al., 1997).

In Ireland, *H. mantegazzianum* most commonly occurs along the banks of rivers and streams, reflecting its dependence on flowing water for long-distance seed dispersal. Following effective colonisation of long stretches of river channel throughout Ireland, a secondary spread onto roadways and adjacent habitats is occurring, mediated by wind and anthropogenous factors.

The uncontrolled spread of *H. mantegazzianum* in Ireland poses a serious threat to human health and to the ecology of infested habitats (Williamson & Forbes, 1982; Tiley et al., 1996; Wade et al., 1997), and threatens to destabilise the delicate equilibrium present in salmonid rivers. Dense stands of this tall, leafy plant can suppress and ultimately exclude indigenous herbaceous plant species, which play an important role in river bank stabilisation. This can result in erosion during winter floods (Tiley & Philp, 1994; Dodd et al., 1994), with large quantities of soil being washed into the river. The relatively fine particulate suspension settles in slow flowing sections of channel, where it will alter substrate characteristics and, as a consequence, make conditions more favourable for abundant aquatic plant growth (Caffrey, 1990). Fine soil and silt particles will clog gravel interstices and render them unsuitable for salmonid spawning. Research in Ireland (Gargan & Caffrey, 1991; Caffrey, 1992) and elsewhere (E.I.F.A.C., 1974; Reiser & White, 1988) has shown that salmon and trout eggs buried in gravel can only develop satisfactorily when a current of water is passing through the gravel. An oxygen deficit to the developing ova results when silt causes a reduction in intragravel percolation. Thus, by altering the substrate and clogging the spawning gravels with silt, *H. mantegazzianum* indirectly has the potential for serious impact on productive salmonid fisheries (Wade et al., 1997).

Why *H. mantegazzianum* has successfully established where other alien plants have failed, or why it has only begun to spread geometrically within the country in the past two decades, is unclear. It could be due to:

(a) the paucity of natural pests and diseases which could limit its spread;

(b) the plant becoming adapted to local conditions through natural selection;

(c) the plant generally growing in areas which are little affected by human activities; or

(d) the plant being highly prolific.

The object of this paper is to describe the phenology of *H. mantegazzianum* in Ireland and to present a control/eradication strategy for this aggressive invasive plant.

Materials and methods

Seven sites where *H. mantegazzianum* has established large dominant stands, often greater than 100 m^2, were studied during 1993. The phenology of seedling, immature and flowering plants was examined. At each site, 10 plants were marked soon after emergence in spring, using different coloured threads to distinguish between seedling, immature and mature plants. Due to vandalism and unseasonal flooding, it was only possible to monitor the growth of marked, immature plants at two sites, on the Mulkear and Shannon Rivers. Sufficient mature, marked plants were available at all but two sites (the Tolka and Dargle Rivers) to provide useful growth data.

At Portmarnock, where spoil had been deposited over tarmac to a depth of $\leqslant$ 15 cm, the effect of substrate depth on growth and seed production was monitored. This represented the 'shallow' site in the study, from which 10 mature plants were selected to compare growth and reproductive capacity with plants from an adjacent site with no soil depth restriction.

At each site, a total count of seed numbers was recorded from 10 mature plants, selected to include a range of plant heights. The relationship between plant height and seed number was tested using a Pearson Correlation coefficient. Seedling density was measured at Portmarnock and Mulkear at 5×1 m^2 permanent quadrats on seven occasions between March and August 1993. Similar quadrats were established in late September at 2 m intervals from the edge of the parent plant stand to determine the extent of seed dispersal.

The effects that cutting had on growth and seed production were examined. In order to determine the effect that the timing of a cut had on seed production, plants in *circa* 100 m^2 plots at Portmarnock and Mulkear were cut to ground level in late March (early cut) and mid-May (late cut). Total seed counts were made from 10 mature plants, to include the range of plant heights in each of the plots, and an ANOVA was used to test statistical differences. The length and width of 50 seeds from the centre of the terminal umbel in each treatment at Portmarnock were measured to examine the possibility that smaller (and possibly less viable) seeds might result after a late cut.

Results and discussion

Seedling density and growth

The fraction of seeds that germinate from the soil bank and establish seedlings in a growing season is small, varying between 0.001 and 10% (Mortimer, 1990). The first seedlings emerged in February, two to three weeks after the first leaves of previous years' plants had emerged. Peak seedling density was recorded at both sites (Portmarnock and Mulkear) in late April, after which numbers declined (Figure 1). By the end of August, only 1.2% of the seedlings recorded in April remained at Portmarnock while at Mulkear, 13.7% of the April population survived. This compares to survival rates of between 11 and 23% recorded on the lower River Shannon by Warde (1985). The difference in survival rates between the two sites probably reflects the smaller peak density of seedlings at Mulkear, although the impact that regular disturbance by walkers at Portmarnock had on survival should also be considered. In Scotland, spring germination produced 400 first leaf stage seedlings m^{-2}, which fell to 33 m^{-2} with full canopy cover of adjacent adult plants in mid-summer (Tiley et al., 1996).

In autumn 1992, large numbers of seedlings that presumably were suppressed from the spring were observed. Seedlings appeared in early September and grew until the end of October. The leaves then died back and the plants overwintered as small taproots. Similar observations were recorded by Warde (1985), Tiley & Philp (1997) and Tiley et al. (1996).

Phenology

Based on studies conducted on the life cycle of *H. mantegazzianum* in Ireland between 1990 and 1993, it appears that most plants flower in their third or fourth year. This agrees with the findings of Stewart & Grace (1984). In the plant's second year, growth from elongated taproots generally begins in early February. Initial growth is relatively slow and maximum stem and leaf enlargement was recorded between mid-May and mid-June. While some of the leaves achieved a width in excess of 1 m, few plants grew taller than 1 m. The majority of plants died back in late August.

Heracleum mantegazzianum plants that were to flower in the current growing season generally

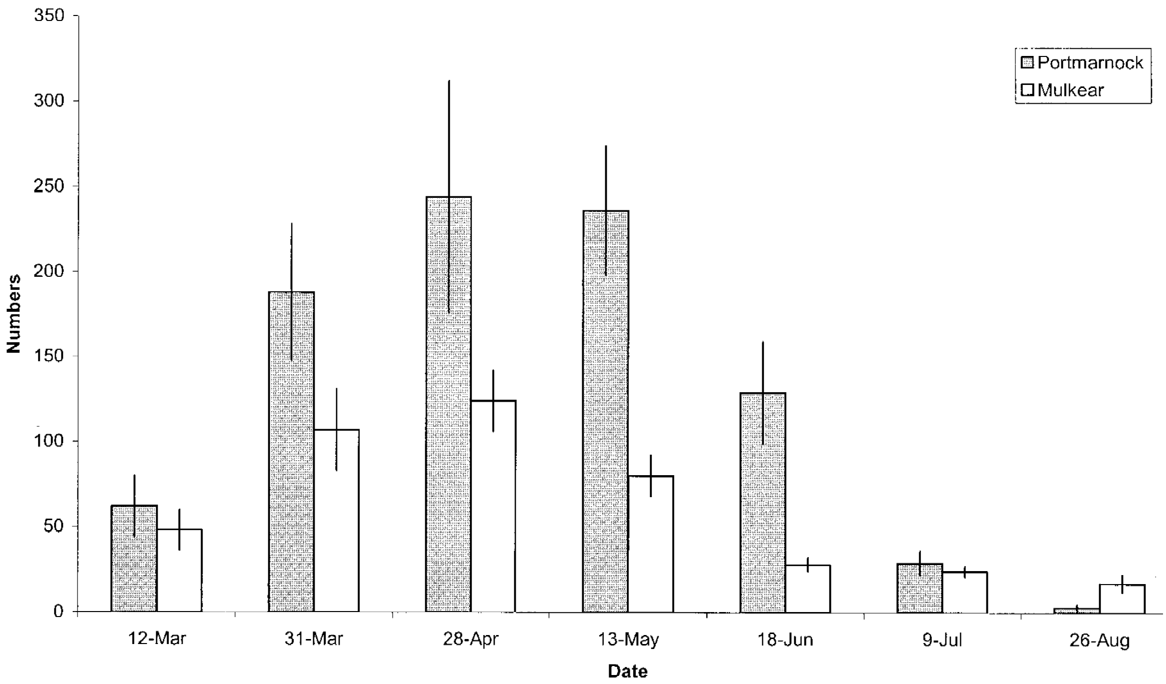

Figure 1. Mean density of *H. mantegazzianum* seedlings m^{-2} recorded in five 1 m^2 quadrats at Portmarnock and Mulkear.

emerged in early February. In the first few weeks of growth, the plant produced large leafy rosettes which shaded light from potential competitor species. Vegetative growth continued until early May, by which time leafy canopies up to *circa* 1 m tall were produced (Table 1).

From May until the end of the growing season (late July), the dramatic increments in stem height resulted from flower stalk elongation. Peak flowering occurred in late June and most seeds had ripened and dispersed by the end of August. The differences in the ultimate plant heights achieved (Table 2) reflect local environmental and substrate conditions.

Effect of substrate depth

The effect of substrate depth on plant height and seed production is shown for plants at Portmarnock in Tables 1 and 2. There was a significant difference ($P < 0.001$) between the maximum height of plants recorded on normal and on shallow substrates. This agrees with Tiley et al. (1996) who observed that plants are shorter and smaller where rooting is restricted, and stressed the need for a sufficient depth of soil to allow the development of the tap-root. Likewise, seed numbers were significantly greater ($P < 0.001$) on normal compared with shallow substrates (Table 2). Plants growing on shallow soil had fewer satellite and axillary umbels. It is noteworthy that the plants growing on shallow soils did not possess true tap-roots but instead adapted to the unfavourable conditions by developing a highly-branched, laterally-spreading root system which provided good anchorage and sufficient food reserves for growth.

Seed production

Williamson & Forbes (1982) state that mature *H. mantegazzianum* plants shed “up to 5000 or more seeds”. Warde (1985) recorded between 14 000 and 29 000 seeds and Brondegaard (1990) reported 27 000 seeds per plant in Ireland and Germany, respectively. Based on estimated counts on single large (2.74 m) flowering plants, Tiley & Philp (1997) recorded 52 800 seeds. Mean seed number per plant for the seven sites examined ranged between 13 884 at Portmarnock and 68 748 on the Dargle. The highest number of seeds recorded from a single plant was 107 984 from a 3.3 m tall specimen on the River Tolka. This plant supported one large apical umbel, nine lateral umbels and 14 tertiary umbels.

Table 1. Mean height (cm) of marked, mature *H. mantegazzianum* plants (n=10) at selected river sites between February and July 1993

Date	8/2		15/3		6/4		3/5		3/6		27/7	
	cm	S.E.	cm	S.E.	cm	S.E.	cm	S.E.	cm	S.E.	cm	S.E.
Portmarnock - normal	3	1.1	43	11	55	21	94	24	146	30	268	55
- shallow	2	0.5	23	4	29	6	43	10	54	12	137	31
Shanganagh	5	2.3	28	9	34	14	65	9	97	26	220	48
Newport	2	0.7	47	13	55	17	64	16	102	19	284	61
Mulkear	4	1.1	48	19	68	18	107	23	147	26	300	54
Shannon	2	0.5	26	8	39	7	62	11	111	30	291	72

Table 2. Plant height and seed numbers in mature *H. mantegazzianum plants* (n=10) from selected river sites. Figures are presented as mean, standard error (S.E.), minimum and maximum values

	Plant height (cm)				Seed number			
	Mean	S.E.	Min.	Max.	Mean	S.E.	Min.	Max.
Portmarnock - normal	278	19	201	369	42 068	5170	17 790	64 254
- shallow	149	13	82	195	13 884	4117	1516	21 857
Tolka	291	7	259	329	44 264	9632	17 688	107 984
Shannon	295	10	226	320	42 820	7144	5154	72 420
Mulkear	306	13	244	366	46 386	6452	13 676	76 992
Newport	299	9	262	366	52 920	4125	42 704	81 410
Dargle	311	6	290	351	68 748	4804	39 084	92 702
Shanganagh	205	10	253	347	18 528	1564	12 478	26 068

A Pearson correlation showed a significant correlation ($P < 0.05$) between plant height and seed number for the 80 plants examined. This finding is supported by Tiley et al. (1996) who report that the number, size and weight of the inflorescence rays correlate with each other, with umbel size of the same order and with overall plant size.

Seed dispersal

Seed dispersal is passive and normally mediated by flowing water or wind. The seeds are large and flat and, even in conditions of strong wind, are unlikely to travel more than a few metres from the parent plant (Clegg & Grace, 1975). Results from quadrat counts conducted in the vicinity of dense plant stands at Portmarnock and Mulkear during the present study showed that in excess of 95% of the seeds fell within 10 m of the colony. Only isolated seeds were observed up to 50 m from the parent stands. Sheppard (1991) observed that few *H. sphondylium* seeds, which are similar to those of *H. mantegazzianum*, travelled more than 50 m from the parent plant.

Long distance seed dispersal, where not mediated by flowing water, commonly results from human activities (Tiley et al., 1996). The presence of isolated, mature stands of *H. mantegazzianum* on major roadways throughout the country, long distances from known areas of infestation, are suggestive of inadvertent human contribution to the dispersal of the species.

Effect of timing of cut on H. mantegazzianum

No mortalities were recorded among plants which were cut to ground level in either early March or late May. Results from these trials are presented in Tables 3 and 4. Significant differences ($P < 0.05$) between all treatments in respect of plant height and seed numbers were recorded.

Seeds from early-cut plants were significantly ($P < 0.05$) longer than those from uncut plants, although no statistical difference (at the 95% level) was recorded for seed width. The seeds produced by late-cut plants were shorter ($P < 0.05$) and narrower (NS) than those recorded from uncut or early-cut plants (Table 4).

Table 3. Effect of cutting in early March and late May on plant height (cm) and seed number

Type of cut	No. plants	Plant height (cm)	S.E.	Significance	Seed no.	S.E.	Significance
No cut	30	244	15	$P<0.05$	34 113	3997	$P<0.05$
Early cut (March)	15	181	13	$P<0.05$	16 880	3596	$P<0.05$
Late cut (May)	30	127	5	$P<0.05$	4281	523	$P<0.05$

Table 4. Effect of cutting in early March and late May on seed size of *H. mantegazzianum* plants at Portmarnock in 1993

Type of cut	No. seeds	Seed length	S.E.	Significance	Seed width	S.E.	Significance
No cut	50	12.8	0.18		8.14	0.14	
Early cut	50	13.7	0.1	$P<0.05$	8.46	0.09	NS
Late cut	50	11.5	0.22	$P<0.05$	7.27	0.15	NS

Tiley & Philp (1997) demonstrated that cutting in late June significantly reduced total inflorescence yields and the seeds produced were viable.

Control strategy for *H. mantegazzianum*

Studies on the distribution of *H. mantegazzianum* in Ireland and the U.K. show that the plant is still in an expansive mode and that further expansion into new ecologically and socially sensitive areas is likely. These studies have further revealed that there are still a number of large catchments in Ireland which are presently free of the plant (Wade et al., 1997). Every effort must be made, therefore, to safeguard these catchments and to eliminate or effectively curtail the spread of the plant in already infested regions.

Prior to 1998, no serious attempt had been made to limit the expansion of *H. mantegazzianum* in Ireland. Long-term control and ultimate eradication can only be achieved through the implementation of a national, co-ordinated and comprehensive management strategy that involves all interested groups (Wade et al., 1997). Failure to embark on such a strategy will lead to even greater problems that will prove more costly to resolve.

H. mantegazzianum populations can only be perpetuated via seeds. Control measures applied before flowering and seed set will limit recruitment to subsequent generations and, if applied systematically over a number of years, will ultimately deplete the seed bank reserve. The longevity of seeds in the soil is unknown, although there are indications that the vast majority of viable seeds germinate within one year (Tiley et al., 1996).

Results from extensive trials have demonstrated the susceptibility of *H. mantegazzianum* to glyphosate (Williamson & Forbes, 1982; Powell, 1988; Caffrey, 1994; Tiley & Philp, 1997). Presented below is a step-by-step protocol for the long-term control of *H. mantegazzianum*, using glyphosate. If strictly adhered to, and the areas are not reinfested from external sources, it could lead to the successful eradication of the plant from any treated catchment.

1. Compile maps which accurately detail the distribution of *H. mantegazzianum* in each affected catchment throughout the country.
2. A catchment approach to treatment with glyphosate must be taken and spraying must commence at the farthest upstream site from which the plant is recorded.
3. Spraying should commence in March or early April, when the plants have expanded their leaves and reached a height of >15 cm. Experience in Ireland has shown that young seedlings and small plants (<15 cm) are less susceptible to glyphosate than their larger counterparts.
4. A dose rate of 5 l ha^{-1} is sufficient to kill treated vegetation.
5. Sections treated in March/April should be re-treated in May or later, if required.
6. The whole catchment must again be surveyed in July and any plants that have flowered, or are likely to flower, should be deheaded or chopped down before seeds are produced. The cut umbels must

be removed from the area and destroyed. Any regrowth should be sprayed with glyphosate as the plant will again attempt to flower and set seed.

7. A further glyphosate treatment in September throughout the catchment will kill late-developing plants or seedlings that survive earlier treatments.

If the above protocol is rigorously applied over a four year period, which is the normal lifespan of *H. mantegazzianum*, the seed reserve will be depleted and the risk of serious reinfestation from within the catchment will be minimal.

Eradication programme on Mulkear Catchment

Large localised populations of *H. mantegazzianum* were reported in the Mulkear catchment by Praeger (1939). The level of infestation has increased dramatically in the past two decades and this has affected practically all beneficial usage of the watercourse (Caffrey, 1994). In 1997, the Office of Public Works compiled maps which detailed the distribution of the plant in the catchment. Planimeter readings indicated that an area of *circa* 35 km^2 was overgrown by *H. mantegazzianum* (A. Casey, pers. comm.). A contractor was commissioned to undertake a four-year control/eradication programme, with follow-up monitoring, on the entire catchment using the above protocol. This detailed programme commenced in March 1998 and will be closely monitored until its completion.

Acknowledgements

The author wishes to thank Ms C. Monahan and Ms M. Fallon for their considerable assistance in the field and laboratory. Thanks are also extended to Mr Gordon Tiley for his constructive comments.

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