Non-chemical management of docks (*Rumex*) V2 2022

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Table of contents

1. Note 4

2. Introduction: when is a weed not a weed? 4

3. Dock management 5

3.1. Key components of dock biology and ecology 5
3.2. Pasture management 6
3.3. Mixed grazing 8
3.4. Nutrient management 8
3.5. Silage and grazing fields 9
3.6. The role of seedbanks 9
3.7. Dock management at pasture establishment 10
3.8. Biological control 10
3.9. Physical control 11
3.9.1. Direct dock plant removal 11
3.9.2. Electrothermal weeding 12
3.9.3. Other techniques 12
3.9.4. Renewing pasture with high dock populations 12

4. Conclusions 13

5. References 14

List of figures

Figure 1. The green dock beetle (*Gastrophysa viridula*). Larvae skeletonising a leaf (left) adults (right) 5
Figure 2. Dock plant showing regrowing leaves, the crown, the main large tap root and smaller roots sprouting from daughter crowns 5
Figure 3. Section of dock showing the visual similarity between crown and root 6
Figure 4. Beef finishers eating offered broad leaf docks plants while waiting to be moved to new pasture 8
Figure 5. Traditional dock fork (left), modern ergonomic design with interchangeable heads (right) (LazyDogTools.co.uk) 12
Figure 6. Dock plant that has been ploughed under, and then put up a shoot from the buried crown, that has then established a new crown and leaves. Note the elongated bamboo like appearance of the shoot that grew to the surface and that adventitious roots are only produced from the nodes. 13

1. Note

This is an updated version of (Merfield, 2018)

2. Introduction: when is a weed not a weed?

Docks, mainly the broad leaved dock (*Rumex obtusifolius*) and the curly dock (*Rumex crispus*) are common weeds in Europe, especially the cooler and wetter, higher latitudes. They are predominantly a weed of pasture, especially long term pasture, because regular tillage / cultivation kills them so they don't survive in cropping systems. In the past they have been labelled as highly problematic weeds, even being listed in “noxious weed” legislation e.g. in the Republic of Ireland[1] and the United Kingdom[2]. However, this is considered a clear example of overestimating the negative impacts of particular weeds and based on an outdated definition of weeds.

Fundamentally, a weed is a value judgement of the positive and negative attributes of any given individual and/or population of plants at a given point in time. Typically in agriculture, the value judgements are ultimately economic, i.e. does any particular plant or population of plants impact farm profitability. If the answer is no, the plant or population of plants are not weeds they are ‘aliae plantae’ (Merfield, 2022). In many cases, the economic impact of weeds has never been properly calculated, resulting in the view (as evidenced by noxious weed acts) that even one weed is too many and total eradication is required. This is a foolish view, especially where the weeds are in their native range and are impossible to eliminate. For example, according to studies in Ireland, pastures with 15% or less groundcover of docks will produce more total dry matter than the same pasture without docks (Courtney, 1985). Docks are palatable, unlike toxic weeds such as ragwort (*Jacobaea vulgaris*); dock foliage has higher potassium, zinc, magnesium and tannin levels than grass; it has been found to prevent bloating of livestock; and young shoots of *R. crispus* have a good nutritive value for cattle (Courtney, 1972; Humphreys, 1995). So moderate populations of docks do not impact farm economics, and may even benefit livestock and thereby farm profits. Therefore they should not be considered weeds, but rather natural components of farm ecosystems. However, large dock populations have clearly been shown to be detrimental, so they do need to be managed, but not exterminated.

Beyond farm profitability, dock is a host for a wide range of other species in its native ranges, particularly insects. Even where they are exotics, they potentially contribute to biodiversity and ecosystem functions. For example, docks are a dominant food source for the green dock beetle (*Gastrophysa viridula,* Figure 1) and the seed is important to a range of seed-feeders including invertebrates such as beetles. The importance and benefits of weeds is being increasingly recognised (e.g., Gerowitt *et al.*, 2003; Marshall *et al.*, 2003; Blaix *et al.*, 2018; Storkey & Neve, 2018)[3] and so at an ecological level, elimination of docks from farmland is undesirable.

The aim of managing dock and other weeds in modern farming should therefore be to maintain weeds below economically harmful thresholds, rather than aiming for their complete eradication.

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[1] https://www.agriculture.gov.ie/farmingsectors/crops/controlofnoxiousweeds/
[2] http://www.legislation.gov.uk/ukpga/Eliz2/7-8/54
[3] http://www.arc2020.eu/unplanned-vegetation-is-important-aka-weeds-provide-for-needs/

Figure 1. The green dock beetle (*Gastrophysa viridula*). Larvae skeletonising a leaf (left) adults (right)

3. Dock management

Non-chemical control of any weed or plant requires a systems based or integrated approach. The metaphor of 'many little hammers', coined by Liebman & Gallandt (1997), highlights that multiple tools are needed. To work out which tools will be effective and how to use them it is essential to understand the biology and ecology of weeds.

3.1. Key components of dock biology and ecology

Docks are rosette-forming, herbaceous perennials, consisting of a crown (short vertical underground true stem), with large fleshy tap roots (Figure 2).

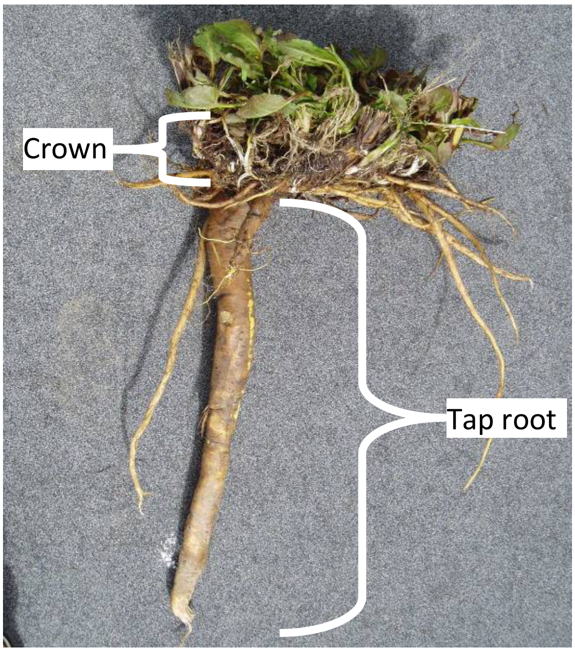

Figure 2. Dock plant showing regrowing leaves, the crown, the main large tap root and smaller roots sprouting from daughter crowns

Leaves and flower stems are produced from the crown. The main means of reproduction are via the large numbers of seeds that are produced, but docks can also produce clones via offshoots from the crown, though the number of new plants produced this way is insignificant, especially as the parent plants also tend to die off.

However, there is significant confusion both among land managers and scientists about the ability of docks to regenerate following disturbance, e.g. tillage / cultivation or digging them up. Only the buds (meristems) in the leaf axils of the true stem are able to dedifferentiate to produce roots. The true root is unable to dedifferentiate, so it cannot produce shoots. It is only the crown that can regenerate, as it is true shoot. However, some people confuse the crown for true roots not realising that the crown is true shoot and not a root. This is probably due to the crown and root appearing quite similar in some plants (Figure 3), especially as the crown produces adventitious roots, so appearing root like.

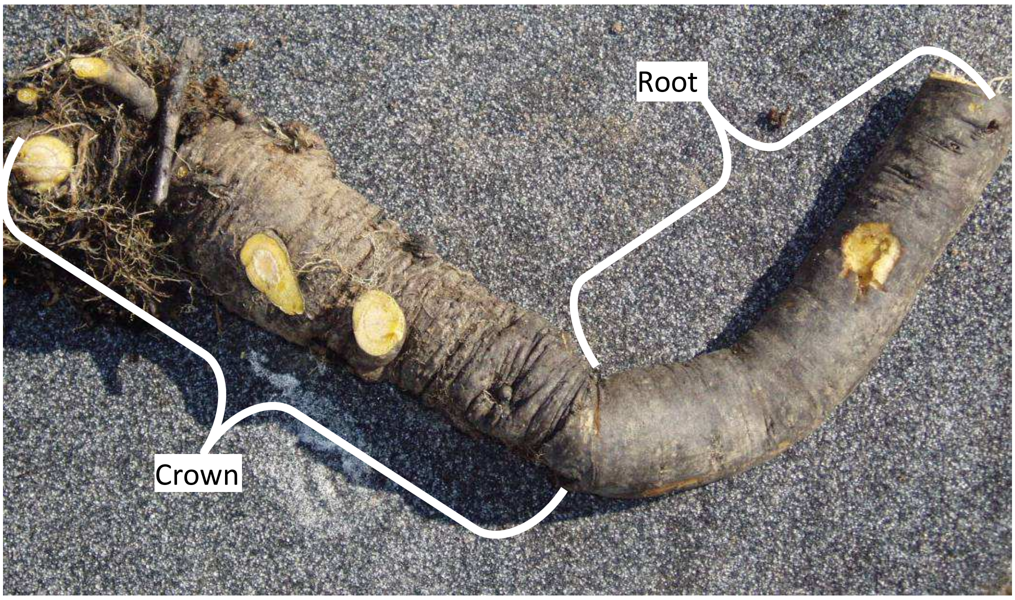

Figure 3. Section of dock showing the visual similarity between crown and root

As a comparison, docks are morphologically identical to rhubarb (*Rheum rhabarbarum*) another member of the Polygonaceae or buckwheat family. Rhubarb also only regenerates from the crown; this is why rhubarb is vegetatively multiplied by splitting the crown, not the root.

Docks tend to maintain a root to shoot ratio around 75% root : 25% shoot, with a higher root percentage over winter and lower one when flowering. Removal of foliage causes the dock to withdraw its root reserves to reestablish its optimal root:shoot ratio, which takes about four weeks. Therefore defoliation at intervals of less than four weeks results in a reduction in plant size, as the root reserves are continually used to replace the foliage. In comparison, defoliation at intervals of greater than four weeks allows docks to accumulate carbohydrates in their roots, with a trend of increased rates of accumulation as the time intervals between defoliation increases. Therefore defoliation intervals greater than four weeks allows docks to become more competitive with pasture.

Dock seeds need light to germinate so they can only establish themselves on open soil, not under the cover of a good pasture sward. It also needs sufficient diurnal temperature fluctuations to germinate, so it is less likely to germinate in winter. Dock seedlings are weak competitors until they are about 40 to 50 days old, at which point the seedling root swells into a tap root. After this point their competitive ability increases rapidly, becoming very high after six months of age.

3.2. Pasture management

Managing any pasture weed is mostly down to pasture management. Good pasture management is based on four key principles:

- Healthy soil, based on optimum pH and nutrient levels, and good structure;
- A highly diverse sward, comprising multiple species of grass, legumes and forbs;
- Short duration, rotational grazing with longer residuals;
- Minimising soil compaction.

A healthy soil is the foundation of all farming. A soil with nutrient deficiencies or sub-optimal pH will not support optimum pasture growth, allowing weeds that can tolerate, or are even adapted to, sub-optimal conditions to out-compete the pasture. Good soil structure is vital for optimum root growth, allowing soils to hold onto moisture; on the other hand, compaction caused by farm vehicles or livestock can destroy soil structure which prevents a soil from draining freely. Observation of docks on-farms shows that they often appear in wet and waterlogged areas of fields, though research on this is lacking. It is not clear if they prefer wet areas or are more tolerant of waterlogging than the pasture species, thus gaining a competitive advantage. Regardless, improving drainage through minimising compaction, using artificial drainage and improving soil aggregation are all important to ensure good structure, optimum pasture growth and minimal weeds.

The common view in farming since the Second World War has been that to maximise yield, the species or cultivar with the highest yield was identified and then grown in monoculture. This view is increasingly being challenged (Weigelt *et al.*, 2009; Sturludóttir *et al.*, 2014). From an ecological perspective, monocultures have many vacant ecological niches that are ripe for weeds to take advantage of. By having multiple species of each of the three key pasture functional groups: grasses, legumes and forbs (e.g. plantain and chicory), the amount of vacant ecological space is significantly reduced, decreasing the space available for weeds. Further, different species grow at different times of year, so ensuring that the ecological niche is full all year round.

Likewise, having multiple species filling different ecological niches can produce higher yields than monocultures (Wendling *et al.*, 2017). From an animals perspective, it is increasingly realised that although simplified pastures with only a few species provide sufficient dry matter for the animal, they fail to provide the diversity of diet the animals need to truly thrive and perform well (Beck & Gregorini, 2020).

The traditional grazing method, set stocking, spreads the animals around the farm so all pastures are being grazed most of the time. This creates the problem that the stock preferentially eat the most palatable species, grazing them out and leaving the unpalatable species, which allows them to prosper due to the reduced pasture competition. In addition, plants keep their root and shoots in balance, so when a plant is continually grazed, it only has a small root system, which coupled with a small amount of leaf, means it can only grow slowly.

The alternative to set stocking is rotational grazing, which has the stock in large herds which only feed on one field or part of a field for a few days, or even just a few hours, before being moved on to new pasture. It is also important not to graze the pasture too low (leave longer residuals), as this means there is only a small amount of leaf area to capture the sunlight the plant needs to regrow, leading to slower regrowth. Also, for pasture species with above-ground buds (meristems) grazing them too low will exhaust them and they will die out. Rotational grazing with long residuals gives the pasture time to grow lots of leaves to capture sunlight and develop a large root system to capture water and nutrients. After it is grazed, it then has the resources in the large root system to quickly regrow new foliage in the absence of further grazing, thereby maximising forage production. This also means that pasture strongly competes with weeds. Further, with rotational grazing, livestock are less able to pick and choose what they eat, so they tend to eat everything, including the weeds, unless they are toxic or highly unpalatable. In such situations, most livestock will eat docks, thereby suppressing them.

After incorrect nutrient levels, soil compaction is the second most important factor impacting pasture (and arable crop) productivity. It is not just large tractors that cause compaction, even small livestock such as sheep will cause compaction when the soil is too wet. It is therefore important to have strategies and systems in place to avoid having livestock on fields when they are too wet and susceptible to compaction. However, docks are most problematic in the colder, wetter, higher latitudes where the soil can be wet for many months over winter. In many cases, livestock are already housed over winter because of this, but a renewed emphasis on compaction management at all times of year is required, e.g. having the resources to move animals to the sheds when there is heavy rain, even in summer.

3.3. Mixed grazing

Livestock species are well known for their varying acceptance of docks. Deer are the most tolerant, even liking docks, followed by goats and sheep which will eat younger foliage; being browsers, goats like the woody flower spikes. These are followed by cattle who will eat docks, especially if hungry (Figure 4), while horses avoid docks as much as possible. Where practical, cross grazing dock tolerating species with intolerant species can assist with keeping docks suppressed.

Figure 4. Beef finishers eating offered broad leaf docks plants while waiting to be moved to new pasture

3.4. Nutrient management

A number of alternative agriculture advocates claim soil nutrient levels are key drivers of weeds. However, there is exceptionally little research data to back up their claims, and the conceptual models of how nutrient levels drive weed populations have not even been formulated (e.g. does the weed have a higher requirement for specific nutrients, or able to tolerate excess or deficient levels; what are the impacts on inter-species competition; is there an effect on seed quality, or germination, etc.?) However, a significant amount of research on the impact of nutrients on docks in pasture was undertaken by Dr James Humphreys in the Republic of Ireland (Humphreys, 1995; Humphreys *et al.*, 1999).

The research clearly showed that potassium (K) is a key driver of dock persistence in pasture because docks have a higher requirement for K than other pasture species, as it is used to drive the partitioning of carbohydrates between roots, leaves and flowers. Where soil K levels are at or below optimum, grass will out-compete docks for K due to its highly competitive fibrous root system, thereby inducing K deficiency in the docks, stunting and making them less competitive. Once soil K levels are above optimum, docks have free access to the excess K, because grass only takes up the amount of K it needs, so docks obtain all the excess K for themselves. Therefore, the higher soil K levels are above optimum, the stronger and more persistent docks will become. Established docks are also highly competitive with pasture through shading from their leaves, thus reinforcing the effect of high K levels.

The simple lesson from this is potassium levels must be kept at or below optimum. The standard cause of excess K levels on livestock farms is due to slurry and farmyard manure application to the fields closest to animal housing. It is essential that soil nutrient tests are regularly undertaken (every three to five years), the nutrient content of each batch of manure is tested, and manure only added in quantities where it will not bring any nutrient level above the optimum, particularly for nitrogen, phosphorous and potassium (NPK).

Humphreys also found a strong interaction between soil nitrogen (N) levels, defoliation frequency and dock populations. At defoliation frequencies of less than four weeks, higher N levels favours grass, at defoliation frequencies more than four weeks, higher N favours docks. So rotational grazing and harvest of conserved feed, e.g. silage, should be focused on a return period of a month or less, especially during the main growing season, and nitrogen must never be over applied, e.g. it is best in multiple small applications than single large applications.

3.5. Silage and grazing fields

Fields that are predominantly used for silage often have high dock levels. The key reasons for this are not due to the return of large numbers of dock seeds in slurry to silage fields, as is commonly believed. This is because the first cut of silage occurs before seeds are set, so few seeds get into the main bulk of silage. Dock seeds are killed by the ensiling process due to low pH. Rumen digestion also kills a significant amount of seed, as does sitting in slurry. So there are multiple reasons why slurry contains zero viable dock seeds.

The key reasons silage fields have high dock populations is because they are typically close to the farmyard, so they are convenient sites for slurry applications; and as silage is being extracted from those fields, they have the highest need for nutrient replacement, so they often receive large amounts of slurry. Slurry is high in K, and (as discussed in section 3.4) high K levels increase dock persistence. In addition, silage fields often have high levels of N which, coupled with infrequent cutting, also favours docks. Furthermore, silage cut close to the ground often results in bare exposed soil, which is what docks require to germinate. Therefore silage fields are almost optimally managed for high dock populations.

The key solutions to this are to ensure N and K levels never exceed optimum through regular soil tests, e.g. every three years, and only applying slurry according to the results of those tests, and where possible to rotate grazing and silage fields, so the shorter term rotational grazing (less than a month return time) starts wearing the docks out.

3.6. The role of seedbanks

Much is made of the longevity of seeds, but many of these studies keep seeds in ideal conditions. In comparison, soil is a highly hostile environment for seeds, being abrasive, chemically caustic and teeming with living things from microbes to vertebrates that view seeds as a highly nutritious food source. Therefore persistence in soil is far less than seeds' potential longevity. It is therefore far more valuable to focus on the half-life of the weed seed bank which, compared to decades for longevity, can be as little as one year (Roberts & Feast, 1972; Gallandt, 2006; Gallandt *et al.*, 2010; Mirsky *et al.*, 2010).

Much is also made of the very large numbers of seeds that weeds such as docks can produce, with 60,000 seeds for broad leaved dock being a commonly-cited figure. However, like seed longevity, this is the maximum seed production under optimum conditions (e.g. in a large undisturbed plant). In a well-managed pasture, with frequent rotational grazing and strategic mowing to remove flower stems post grazing, seed production will be a fraction of this, even zero. However, as few as 600 seeds per plant are required to maintain a seedbank of 12 million seeds; this may sound large but equates to 1,200 seeds per square metre, of which the vast majority (e.g. 90%) will be unable to germinate due to being too deep in the soil, dormant, etc. This leaves just 120 seeds per square metre able to establish themselves if conditions are right. This population is also tiny compared to arable weeds, such as fat hen (*Chenopodium album*) which can have 12,600 seeds per square metre

(Rahman *et al.*, 2006). Humphreys (1995) concluded that because dock seeds need direct sunlight to germinate, in a well managed pasture it would be highly unlikely for many docks to be able to establish themselves. Therefore most docks in a pasture have been there since the establishment of the pasture. It is therefore considered that the dock seedbank is only truly relevant when pasture is newly-established.

However, there is no known research that has studied the size and persistence of the dock seedbank in real pastures, which is a significant knowledge gap that needs addressing.

A core component of any non-chemical weed management strategy for controlling therophyte weeds (weeds that survive as seeds) is minimising weed seed rain, to reduce the size of the weed seedbank. Docks have a mixed strategy of being a perennial, particularly the broad leafed dock, and also producing a large amount of seed, which is their main form of reproduction and dispersal. Therefore a vital long-term strategy is to minimise the weed seed rain from docks by stopping them producing seeds e.g. by cutting or grazing off the flower stems. The best time to do this is when they have just started flowering because this results in the greatest loss to the plant. However, dock seed becomes viable very rapidly after flowering starts, with 15% viability six days after the end of the first flowering, rising to over 90% after 18 days. It is therefore essential not to leave cutting or grazing of flowering stems too long, otherwise viable seed will have set. When the flower stem is cut off, the plants will try to flower again, especially in warmer regions, so these secondary flushes of flower stalks also need controlling.

3.7. Dock management at pasture establishment

As the main route for docks into well-managed pasture is believed to be at establishment, it is clearly a critical point for dock management. There are some well established techniques to minimise docks becoming established in new pasture. The key is to get the pasture species established and to achieve ground cover as quickly as possible to suppress dock seed germination by intercepting light, and then to out-compete the docks while they are still young and uncompetitive.

As with pasture management in general, correct pH and nutrient levels are key to ensure the pasture seedlings can thrive. A good seedbed is also critical. Where time allows, the use of false seedbeds is an exceptionally valuable technique (Merfield, 2015). It is important to only establish pasture at optimum times of year, i.e. when the soil and weather are warm, not cold and wet, to ensure rapid growth. Having a large number of pasture species, especially legumes and forbs with large leaves that quickly cover and shade the soil is particularly valuable. Higher seeding rates can also contribute to faster ground cover. Cattle slurry has also been shown to inhibit dock seed germination without affecting grass seed germination and this can be used to give the new pasture a competitive edge (Humphreys, 1995). However, it is not known what impact slurry has on legumes and forbs so where diverse pastures are sown, slurry should not be applied post sowing, until more information is gained.

3.8. Biological control

Biological control comes in three forms:

- Importation or classical;
- Augmentation;
- Conservation.

Importation involves importing a pest's natural enemies to a new locale where they do not occur naturally. Augmentation involves the supplemental release of natural enemies that already occur in a particular area, boosting the naturally occurring populations. This is further sub-divided into inoculative techniques, where a small starter population is released which reproduces and builds up its population, and inundative techniques, where very large numbers of an organism are released to swamp the pest. Conservation biocontrol aims to boost natural enemies that already exist in the environment, by making the environment more hospitable for them, for example for beneficial insects by providing nectar and pollen through addition of flowering plants.

Importation biological control of docks in Europe is difficult because they are in their native range. Importation biocontrol is best suited to exotic weeds that lacks its predators from its native range. Even then, success (defined as reduction of the weed below economic levels) is only achieved in 10% of cases.

Conservation biocontrol of docks is challenging, because docks already have a large number of species that attack them, so it is particularly hard finding an ecological manipulation that would significantly boost predators of dock to a sufficient number to meaningfully decrease dock populations.

Augmentation techniques, particularly inundative ones using microbes have theoretical potential. There are species of pathogenic fungi that are specific to docks e.g. *Uromyces rumicis.* This type of specificity is very valuable as it means the microbe can be broadcast or sprayed to kill docks without killing pasture species. But, globally the development of mycoherbicides (fungi-based herbicides) has been very difficult and has mostly been focused on weeds in high value cropping systems, due to the cost of the final products. Less than a handful have proved practical and economic, so developing one for docks is considered unlikely.

Inundative augmentation with invertebrate dock pests, e.g. Fiery Clearwing (*Pyropteron chrysidiformis*) or the green dock beetle has potential, but the challenges are considerable, including developing mass rearing systems and then scaling those up to commercial levels. Then distributing the live insects to farmers, getting them to lay sufficient eggs so the larvae kill or suppress enough docks to make an economic difference, all while keeping costs sufficiently low so it is economically viable at the lower per hectare returns of livestock farming, are all considered exceptionally challenging.

3.9. Physical control

Livestock production has among the lowest gross margins of all types of farming (e.g. compared with arable and vegetable crops), and it often occurs on hilly land that is less or unsuited for machinery access, so often it is not financially viable to spend money on direct / physical control techniques of docks. However, there are some situations where it is justified. For example, as most docks are believed to enter pasture during establishment, reducing dock numbers once the pasture is fully established, e.g. six months to a year after seeding, can pay dividends, especially if the pasture is kept for many years, as the benefits of removal accrues year on year.

3.9.1. Direct dock plant removal

The key to effective physical control of docks is that they can only regenerate from the crown (true shoot), not the true roots as discussed in section 3.1. Typically the crown only extends five centimetres below the soil surface, and rarely as deep as 10 cm, therefore as long as the crown is removed the root will eventually die. However, the ability of the crown to regenerate by producing new roots and shoots is prodigious, so the dug up crown must be prevented from reestablishing. In hot dry weather, especially if there is a good thickness of pasture to keep the crowns off the soil, they can just be left on the field to desiccate and die. In less than ideal drying conditions, the crowns may need to be taken off the field and destroyed, e.g. through composting or putting into slurry pits. The main tool for digging the crowns up is the 'dock fork' (Figure 5) which consists of two prongs and a pivot point to ensure a vertical clean lift and ease of use / good ergonomics.

Figure 5. Traditional dock fork (left), modern ergonomic design with interchangeable heads (right) (LazyDogTools.co.uk)

3.9.2. Electrothermal weeding

The other potential means of direct dock control is electrothermal weeding (Merfield, 2016). This technology was widely researched in the 1980s but lost out to herbicides, particularly weed wipers. It is now commercially available again due to the demise of herbicides. Its value lies in its systemic weed kill, due to the electricity flowing through the foliage and into the root system before dispersing into the soil. Where weeds are higher than the crop or pasture, the electricity can be selectively applied to the weeds based on the difference in height. Therefore electrothermal control has considerable potential for pasture weed management as a large majority of pasture weeds overtop the pasture, especially after grazing. Electrothermal weeding is thus both systemic and selective for tall pasture weeds.

The challenge for electrothermal control of docks is that the leaf petiole is very thin compared with the large mass of the crown, which is what needs to be destroyed to kill the dock as a whole. If the electricity is applied to the leaves the petiole will be destroyed before sufficient electricity gets into the crown to kill it. It is thus likely that the electricity would have to be applied to the flower stalk to get sufficient energy into the crown. That may only work on younger plants with smaller crowns rather than old large docks. With hand-held electrothermal machines, it may be possible to directly apply the electricity to the crown itself. However, it is not clear if this would be more effective and efficient in terms of labour and costs than manual removal with a dock fork. More research is required.

3.9.3. Other techniques

A range of other techniques for direct dock control, such as thermal weeding using flame and steam, mechanised dock diggers, etc. have undergone trials. Flame and steam can only defoliate dock plants so are no more effective than grazing and mowing. They also require very large amounts of energy which makes them uneconomic. Mechanical approaches such as the ‘dock twirler’ (Dierauer *et al.*, 2018) with its high capital cost, low agility and thus slow work rate are considered unlikely to match a fit weeding gang using well designed dock forks both for speed and cost.

3.9.4. Renewing pasture with high dock populations

Where dock populations are excessive, it is likely to be cheaper to terminate the pasture and reestablish it rather than try and remove the docks. Typically, shallow (5 to 10 cm), powered cultivation with a rotovator should be used initially to detach the crowns from the roots to minimise their reserves. The rotovator will also break the crowns up, again minimising the reserves of any one fragment that they can draw on to regrow. The crown fragments will vigorously regrow unless the soil and weather is particularly dry, so follow up tillage to stop the fragments re-rooting will be required.

One option is to bury the broken crowns as deep as possible with a plough. Getting good burial with a plough in already cultivated ground can be challenging, however.

An alternative is to use spring tined cultivators and harrows to pull the crowns to the surface to stop them re-rooting. Avoid powered machinery as this will be more damaging to soil structure and is more likely to bury the crowns, effectively transplanting them.

The follow up cultivations are utterly critical because if the crowns are not killed the initial cultivation will create many more dock plants by dividing the crowns, just like for rhubarb.

Ploughing intact docks does not always guarantee success, because if the plants are large, they can send up shoots through a considerable depth of soil and reestablish themselves (Figure 6).

Figure 6. Dock plant that has been ploughed under, and then put up a shoot from the buried crown, that has then established a new crown and leaves. Note the elongated bamboo like appearance of the shoot that grew to the surface and that adventitious roots are only produced from the nodes.

4. Conclusions

The zero tolerance approach of the failed 'war on weeds' must give way to a new focus on the economics of dock management, which tolerates a low population of docks, based on the knowledge that eliminating all dock plants is a waste of money, and they are an important part of the natural biodiversity of Europe. Effective non-chemical dock management is based on a whole-of-system approach. First is understanding dock biology and ecology, particularly the role of the crown. A major part is good pasture management, though having a diverse sward that is grazed rotationally leaving longer residuals. Rotate silage and grazed fields. Ensuring soil nutrients, pH, and structure are all correct. Minimising the weed seed rain and when docks do establish in new pasture, use dock forks to reduce their populations to acceptable levels.

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