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# Weed biology — A future*

G. R. Sagar

Department of Agricultural Botany, University College of North Wales, Bangor

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**Summary**

The paper is an attempt to estimate the value of studies of Weed Biology to Weed Control practice. It is argued that much of the biological information available on weeds is not helpful in control and often is not intended to be. A series of proposals is made to provide evidence that a knowledge of some neglected aspects of the biology of weeds might greatly assist in achieving the weed-free environment. The need for a much closer liaison between weed biologists and those concerned with the control of weeds is stressed.

## Introduction

In every programme of study there should be, at not too infrequent intervals, brief pauses to consider the desirability of continuation, the possibility of redirection or of a change of emphasis. In commercial enterprises reviews of projects are frequent and tend to be assessed mainly against an economic background. In research establishments supported on Government funds these reviews are likely to be less frequently undertaken and in academic circles there is a real danger that they will never take place.

If such a review of 'studies in weed biology' were to be undertaken on an international basis what criteria would be used in judgement? In other words what is the value of studies of weed biology?

It is clear that where the economic aspects of weeds are put aside, these plants provide most fascinating material for biological studies. Indeed amongst herbaceous Angiosperms, weed species are probably better known and understood than are the species of 'natural' communities. Those weed biologists whose primary aim has not been the eradication of weeds have made significant contributions to the disciplines of genetics, evolution, plant ecology and taxonomy. It is not my purpose to review these contributions (but see, e.g., Harper, 1960; Baker and Stebbins, 1965; King, 1966). However, where the weed is seen to be a plant which is undesirable and as something to be removed it is much more difficult to see what the study of the biology of weeds has contributed. It is true that there is a general belief that a knowledge of the biology of a weed may be an (essential) preliminary to its control and one must conclude that this explains the kindness with which weed biologists are received

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at Weed Control Conferences. But how many examples are there where there is any truth in the statement? The answer I would suggest is very few, if any. The situations to which I am referring must not be confused either with the pseudo-examples where a knowledge of the biology of the weed has been used *post-factum* to explain success or failure of a control measure or with the very specialised studies of Bakker (1960). There is I am sure an awareness of the sterility of weed biological studies in failing to contribute directly to the problem of the control of weeds but attention is rarely drawn to it.

## The Nature of Studies of the Biology of Weeds

Virtually every aspect of the ecology of weeds has been subject to observation and experimentation. Dormancy, germination, development and reproduction both by seed and by vegetative means have been extensively studied in a wide range of weedy species (see King, 1966) and certain conclusions are possible. Dormancy of seeds is widespread in weed species but is not a prerequisite of a successful weed; the dormancy breaking agents are diverse and presumably so are the mechanisms. Weed species differ in their times of germination and in their general phenology just as they do in virtually every other biological property which is examined at the whole plant level. Baker (1965) has attempted to produce a list of the characteristics of the 'ideal' weed but although most weeds have most of the relevant properties he outlines, there would appear to be exceptions to each rule. It is quite impossible to produce an objective characterisation of weeds as a group based on particular biological properties. This argument is a variant of the age-old problem of defining a weed and that has defied, but at the same time given real amusement to many people (see Harlan and De Wet, 1965). It becomes very clear that the decision as to whether a plant is a weed or not depends on the eye of the beholder and his economic interest. It has, however, come to be assumed that any plant not deliberately sown on land devoted to agriculture or horticulture is (a) a weed (b) therefore undesirable and (c) must be eradicated. The logic of this argument is readily questioned and needs to be, before time, effort and money are spent on assessing the biological parameters of weeds. Increasingly, agriculture is following horticulture as a commercial enterprise. Farming as a way of life, as an art, is being dominated quite properly by economics. A weed then becomes a plant which, if allowed to develop in the system, causes financial loss in any one of a multitude of ways. It is true that the eradication of that weed may not be economically sensible, for the cost of removal may exceed the return — but that is another question. The real point I am trying to make is that every unsown plant in a crop may not be a weed in the economic sense and therefore it is questionable as to how far detailed studies of the biology of such species are likely to be of direct value to agriculture. An extension of this argument leads to the conclusion that it is vitally important to know who the enemy is and how strong he is before beginning the attack. A league table of weeds arranged in order of their economic importance is needed.

The many studies made on the nature of competition between crops and weeds go only part way to providing the data essential for the compilation of such a table. Attempts to define, let alone measure, competitive ability have always ended in failure, perhaps in the main because of the flexibility and variation of the weeds and to a lesser extent the crop. The success and importance of a weed depends more on the chosen crop and the environment and conduct of the test than on any single feature in the biology of the weed. There is, however, an apparently incidental feature of these competition studies which has not received the attention it deserves. Customarily we sow in an arable system a single crop species but to it is automatically added a weed population from self-sown seed or from vegetative propagules. Often, for a time at least, the mixture of crop and weed exploits the environment better than the crop alone. In some cases, the lack of competition between crop and weed may persist for a surprisingly long time and although in these cases weed growth does nothing to contribute to ultimate economic yield, the dry matter which the weed makes, if it is not gained at the expense of the crop, represents a failure on the part of the crop to exploit the environment to the fullest extent. It is possible therefore that studies on the mechanisms involved in the cohabitation of crop and weed may be useful guides in the design of more efficient crop plants or cropping systems.

It is, however, rather a sad fact that many of the studies on crop-weed competition do not go far enough towards demonstrating the precise mechanisms by which interference or cohabitation may occur.

I have digressed a long way from the biology of weeds rather deliberately to show that synecological approaches may have some relevance to crop production although still not apparently making weed control easier.

**How are weeds successful?**

It has already been conceded that there is no single biological characteristic of weedy species that makes them weedy but by a rather circular argument they have one feature in common and this is their ability to survive the agronomic systems in which they occur and it is possible, on the basis of current knowledge, to show how many individual weed species can remain members of the flora of an agricultural system. The understanding and indeed the importance of this aspect of weeds is increasing as continuous monoculture spreads into agriculture. In general terms only, this concept implies that the biology of the weed is such that the operations of the agricultural system do not result in its elimination. To see how this can operate requires only a theoretical treatment.

**Continuous mono-culture spring cereal**

What we have to consider is the minimal requirement for survival plus a small reproductive increment that will allow spread. Both annual and perennial weeds succeed in the spring cereal system. The annual must have dormancy/germination regulation to assure pre- or immediately post crop emergence so that the disadvantages of starting growth later than the crop are avoided. Next, the weed plants must gain sufficient environmental resources from the ecosystem to ensure an adequate return of seed to the soil bank and this will usually be achieved before the crop is harvested. Thus the life-cycle of the weed will normally be shorter than that of the crop. The perennial weed is not bound by such a requirement for specially if the weed's phenology can be shifted by environmental factors it has only to tolerate the crop for there is the guarantee of sole occupation of the environment for a period after the crop is removed. In practice, the perennial is often at an even greater advantage.

Large vegetative propagule resources may confer a starting advantage over the crop in early growth as well as an opportunity to take advantage of crop failures. Even without exploiting these features the perennial weed frequently flowers and sets viable seed before the crop is taken apparently using current photosynthetic production for sexual reproduction if the crop is dense and making vegetative reproduction when the crop is removed.

The growth forms of successful weeds in these situations are several. Amongst the annuals the use of herbicides has reduced the range and at the present time the principal weeds are grasses themselves. It must not be forgotten however that *Sinapis arvensis, Papaver rhoeas, Raphanus raphanistrum, Chrysanthemum segetum* and *Galium aparine,* amongst others, are capable of infesting cereal crops when herbicides are not used. It is clearly *not* a biological requirement of an annual weed of spring cereals that its growth form be like that of the cereal.

For survival in the system under discussion the perennial if it behaves as such must possess some special features. Resistance to cultivations is perhaps the most important and is achieved in more than one way. Where organs of perennation and regeneration are all within plough-depth re-establishment from fragments must be guaranteed while at the same time holding sufficient potential in reserve for re-establishment following subsequent cultivations. This method would seem highly precarious but most of the pernicious weedy perennial grasses have it (see, e.g., Chancellor, 1966). An alternative way of weathering periodic cultivations is the presence of organs of regeneration below plough depth together with an efficient means of bringing a shoot system up to ground level through perhaps 8–10 in. (about 25 cm) of soil.

The features just described are the 'elements for success as a weed of continuous spring-sown cereals'.

## These weeds in a rotation

In fact, of course, the same species tend to be weeds of spring cereals even when that cereal crop occurs with less than annual frequency as a result of the interpolation of other different crops where the weed's adaptations to survival in cereals may not be so valuable. The annual adapted to complete its life cycle within the life of a cereal crop would be unlikely to achieve this in a root crop where mechanical or hand weeding would be too frequent. A new adaptation then becomes essential — an ability for the genotype to survive in the seed phase. Prolonged innate, enforced or induced dormancy of at least a fraction of the population becomes essential together with an extra requirement that when the cereal crop is present there must be a good deal of interest made on the seed capital present in the soil. Thanks to the detailed studies of Roberts (1958–67) we are beginning to get some facts about the dynamics of seed population in the soil bank.

The perennial weeds of the spring cereal crop may again be at a disadvantage in a root crop as long as manual or mechanical weed control is frequent. In fact, in the present economic climate the within-row cultivations are inadequate and substantial vegetative multiplication and often seed reproduction takes place. It must, however, be remembered that some degree of population regulation of the weeds of cereals was achieved by non-chemical weed control practices in certain crops within the rotation.

## Grassland weeds

We now move into the most precarious speculations into an area where the enemy is unknown. Which species of grasses are weeds? Should grassland be sown with one or more species of grass? Others are more qualified than I to answer these questions but it will be generally agreed that the answers will differ according to the particular environments and purposes for which the grassland is required. Despite this it is likely to be agreed that in the Western world grassland is the least well understood ecosystem perhaps of all, but certainly of those ecosystems which are part of agriculture. The significance of 'weeds' in grassland is decidedly unclear but there is a small group of species which are by common consent weeds in any grassland. Most of the species have received the attention of weed biologists and their autecology is well described (e.g., *Pteridium aquilinum, Ranunculus* spp., *Senecio jacobea, Allium* spp. and *Juncus* spp.).

Despite the general qualifications it is possible to consider those attributes of a species which would seem likely to confer success as grassland weeds. In grazed systems any species which is avoided by the grazing animal, for whatever reason, has a most powerful advantage. Even if the species remains ungrazed simply because it has a rosette habit and an apical meristem in a position where it cannot be removed by the animal, it will survive as long as it is sufficiently perennial. It will be at real advantage if in addition it has some form of vegetative reproduction. The perennial habit allied to vegetative reproduction is commonly found in grassland weeds. Annuals do occur, but infrequently, and the most noteworthy are probably the hemiparasites. Seedlings of many species are not uncommonly found in mature grasslands but establishment of new individuals from seed is rarer. Generally, then the perennial habit with vegetative reproduction is commonest. However, the periodicity of growth of the weed may also play a part in its success according to the management system.

Where grass is grown for conservation the system comes closer to that found in arable cultivations and the prerequisite for success as a weed are very different from those in a grazed sward. The rosette habit becomes a disadvantage and there is little to be gained by having any mechanism for avoiding the attention of the grazing animal. Although such systems of grassland management are being developed and are likely to be expanded considerably in the future, the more common practice is still one of grasslands serving dual-purpose for both grazing and conservation. It is perhaps of interest to remember that weed control in grassland is still largely achieved by management rather than by herbicides and a major weapon in weed control in grassland is the ability to change the ecosystem violently from grazing to conservation for very few species of weeds do equally well in both environments. The difficulty in the system however is that the crop species are also violently disturbed by the change and as long as the weed flora can re-establish itself at least as quickly as the crop, weed control practice in grassland based on violently changing management will remain imperfect.

Although I have presented a rather bleak picture here it is in fact not impossible to maintain grasslands comparatively weed free by adopting the techniques of management which graziers developed before weed biology as a discipline was even conceived.

## The future

There is a widespread impression that the weed-free environment is almost with us. This is an exaggeration but the rate of progress towards it is rapid and there is no *a priori* reason why it should not be technically possible within say, the next 10–20 years. I use the word 'technically' here purposely since the economic barriers to its realisation may take longer to be removed. In addition, I am not implying that all weeds will have disappeared within this period, but simply that a sufficient variety of herbicides will exist to allow weed control by chemical means alone. This personal interpretation of the situation means that there are two futures to contemplate.

*The next 10–20 years*

This is the period when three major tasks confront weed control science:

(a) The immediate problem of 'living with weeds'.

(b) The development of herbicides and technologies of use of new and existing herbicides to allow effective control of the hard core of weeds which are serious at present.

(c) The assessment of the consequences of the disappearance of weeds from the agricultural ecosystem.

*Living with weeds*

While we look forward and work towards the weed-free environment certain problems remain and indeed may become increasingly acute. Perhaps the best known of these has already been mentioned — the consequences of continuous monoculture without complete control of all weeds by herbicides. The apparent, though ill documented, increase in the importance of perennial grasses (e.g., *Agropyron repens* and *Agrostis gigantea*) and the annual species like *Alopecurus myosuroides* and the weedy *Avenas* illustrate the need for concern. Until satisfactory herbicide practices appear to resolve this problem (and perhaps put another in its place?) the weed biologist's most worthwhile contribution towards control would seem to be to lead in the development of control measures by the use of non-herbicide techniques. There are both direct and indirect approaches to this problem.

The direct one is to take the example of the chemical manufacturers and on field plot scale in properly designed and constructed field experiments assess the effect on weed populations of e.g., cultivations. It has for a long time troubled me that the technique of rotary cultivation for the control of *Agropyron repens* developed by Fail (1956) was not seized upon as at least a temporary solution of this problem. I fully realise that the technique as originally published is unworkable in some systems but it was so efficient as to suggest that modification of it might be most attractive and the work of Turner (1966) would seem to support this argument. It seems more than a pity that the manufacturers of the appropriate equipment have not been as forceful as those in Chemical Industry.

The indirect approach to the same problem involves preliminary direct work on the biology of the weed in the hope that it will allow *prediction* of the practices which will work in the field. I have from time to time been convinced of the value of this method of attack on the problem but I am now disillusioned and would not advocate it as a primary approach although it remains intellectually most satisfying. As far as the annual weed problem is concerned it is not perhaps as universally serious for economic considerations apart, pre-emergence contact and residual herbicides while not being ideal in all cases will usually allow the crop to gain at least the crucial initial advantage over the weed.

*The difficult weeds*

The importance of this group of weeds needs no emphasis. These are the species for which no herbicides are available or more often where the chemicals available have not been adopted for economic reasons related either to the persistency of the compounds or the low value of the land involved. The solution of this problem depends on either the production of satisfactory herbicides or on the development of methods which allow existing ones to become adequate or on a combination of both. What is required here is a peculiarly evolved weed biologist. The area of understanding and communication must extend from biochemistry through physiology and on to ecology. Biochemists tend to be chemists by training and regard biological variation as something to be avoided as far as possible for it interferes with the reproducibility of their observations. If they rise above the cellular level of organisation it will be into a crop plant and not a wild or weedy one where variability would be greater. Classically physiologists are notorious for their taxonomic ignorance and they too rather dislike intra-specific variation.

On the other hand, weed biologists, it has always seemed, are frequently converts from taxonomy and ecology, disciplines which until recent years have been largely descriptive. I fully realise that newer generations in the disciplines have revitalised them but on the whole they have found so much to do that there has not been the same tendency for them to emigrate into the biology of weeds. The argument that I am really trying to make is that a weed biologist has much to offer in the area of weed control if he will go to sufficient lengths in correlating his studies with those of the chemist who needs to be informed. Perhaps this already happens but if so there is very little evidence of it. More specifically there are some well defined problems:

(a) Selectivity of herbicides frequently depends on biological differences between the weed and the crop. Herbicides have without doubt led to the discovery of these differences rather than the differences leading to the herbicide. There is a desperate need for comparative biochemical studies of crop and weed species.

(b) The penetration of herbicides into the foliar organs is an extremely inefficient process, putting an unknown but large factor into the economics of herbicide usage. Yet how little information there is on the penetration of herbicides in relation to cuticular and cell wall structure.

(c) The uptake of herbicides from the soil is another great unknown. 'Depth-protection' is not much more than a cloak of ignorance. The fascinating distinction in development pattern between wheat and wild oat, although well known long before triallate should have been explored in relation to weed control rather than being recalled after the event. The remarkable studies of Lyndsay and Hartley (1963, 1966) on the regions of the root which herbicides penetrate should be a salutory lessen to our abysmal ignorance of roots and root systems. The ignorance is perhaps greatest for weeds.

(d) The transport of herbicides about plant systems ought again to be a matter of deep concern to the weed biologist. The subject is critical and central to the problem of control of perennial species with underground organs of regeneration. But alas so much of the work done on the systemic properties of herbicides is done on crop plants and it may be quite irrelevant to the weeds for which the results are intended.

I have discussed this subject at greater length elsewhere and some time ago (Sagar, 1961), but repeat now my plea for more work on the transport of herbicides in *weeds*.
(e) The culture of weeds for experimental purposes has been and is still a cause of real concern to those who require them (see e.g., Parker, 1966). I strongly suspect that lying unpublished in the records or minds of weed biologists is almost all the information that is required. It is time it was gathered together — a source book of methods of breaking dormancy for as many species as possible together with an extensive coverage of methods of vegetative propagation for weed species. Perhaps if this were available the reluctance of biochemists and physiologists to work with weed species will disappear.

This list of ideas is not exhaustive but represents an attempt to emphasise two things. First, the lack of communication between weed biology and weed control and second the poor state of our general information about the biology of weeds as a whole despite the vast amount of work which weed biologists have done in the past.

*The consequences of the loss of weeds from the agricultural flora*

There is ample evidence to show that changes in the ecosystem of any given area can have considerable short and long term effects. Without going into details I want to suggest that the ecological consequences of the removal of weeds from agricultural and horticultural systems need to be most carefully assessed. What part do weeds play in the ecosystem? Are there any positive advantages of having a second species (even a weed?) in a monocultural system? Suggestions of a higher incidence of root pathogens following spraying for weed control may be indicative.

A different problem which has received attention is the residue of weed seed in the soil. Assuming no new invasion of seed into an area (a forlorn hope?) how long will it be before the system is free of weed seed? Although the longevity of the Manchurian Lotus now appears to have been exploded there is adequate evidence that although the decline in the size of the seed population is initially rapid, even under conditions of frequent disturbance a small proportion of seeds remain dormant yet viable for considerable periods. Apart from realising the position and having some relevant information, what are we to do? Sit back, and as usual smile knowingly when the weed control workers actually meet the problem? Let this example be different. We are beginning to understand quite a lot about the mechanisms of dormancy in seeds. Is it too much to hope that some group will critically examine this work and extend it with the *deliberate intention* of finding some means of at least stimulating dormant viable seed to germinate if not directly killing such seed *in situ* in the soil. Such a programme would justly be covered by the blanket title 'Studies of the biology of weeds'. Cussans (1966) has outlined other areas of study with special reference to minimum cultivation practices.

*Twenty years on*

You may well feel by now that much of what I have said is sufficiently fictional to prohibit my looking even further ahead. You will be relieved therefore to learn that I believe the applied weed biologists' role will be complete when the environment is weed free and he can then turn to assist if necessary in optimising crop yields or return to his fascination for weeds as material for biological study.

## Conclusions

I have tried as far as possible to draw my conclusions in the appropriate places but some generalities have emerged.

(a) Many of the studies called weed biology have in the past failed to make meaningful contributions towards the control of weeds.

(b) There is a rather desperate need for an extension of work on weeds, not within the framework usually called weed biology but extended specifically into the biochemistry and physiology of weeds.

(c) There is a requirement for more weed biologists to orientate their outlook directly towards weed control.

(d) A need is apparent for more ecological studies based on the weed free environment, but not directly on crop growth so much as on possible deleterious effects resulting from the removal of weeds.

I regret to say that having been asked to speak about growth forms and life cycles in weeds, I have erred and strayed. I have also failed to be fully comprehensive. I hope however I might have stirred some of you a little, if only to question the unwarranted mystery which seems to surround weed biologists.

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