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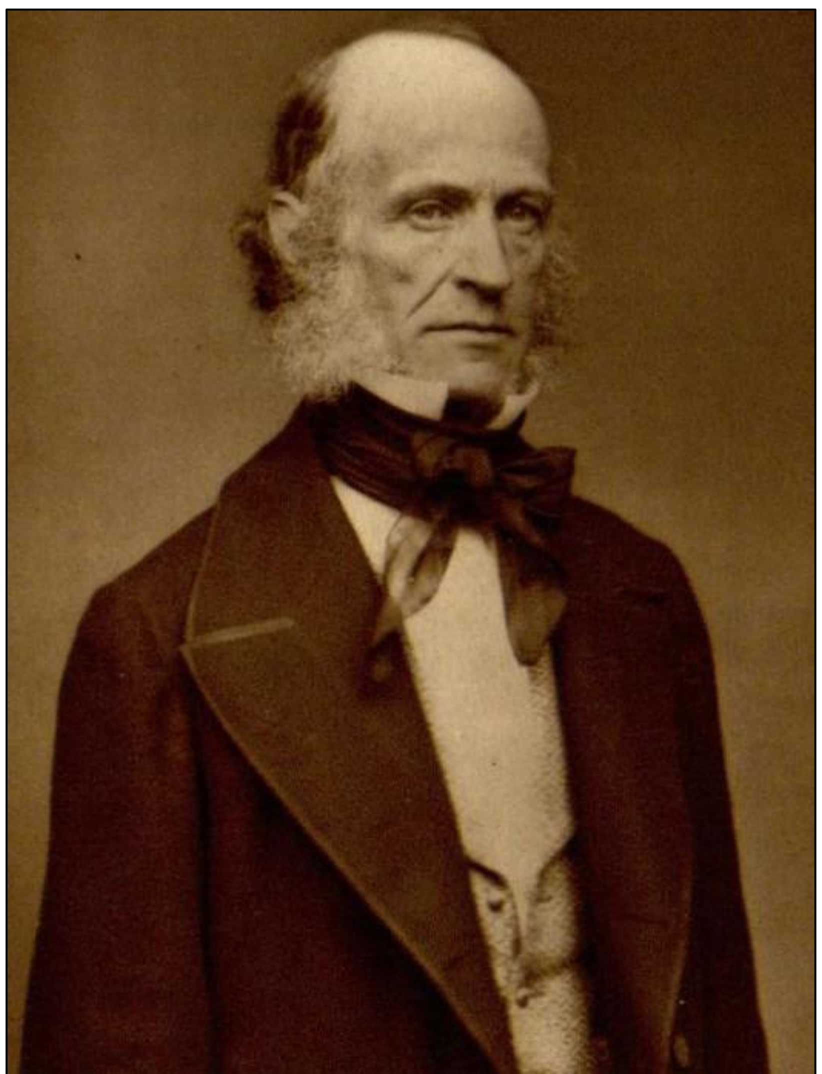

EDITORIAL

'Aliens', 'Natives' and 'Artificial Habitat'- Revisiting the Legacies of H.C. Watson and S.T. Dunn

Nimal R. Chandrasena [1]

[1] Current Address: *Nature Consulting*, 17, Billings Way, Winthrop, WA 6150, Australia

E-mail: **nimal.chandrasena@gmail.com**

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Abstract

Hewett Cottrell Watson, a British botanist and phyto-geographer, might rightfully be the first to apply the term 'alien' to denote 'foreign' species introduced to Britain, which successfully established at various locations in the isles with or without man's help. Botanists recognize Watson for his monumental work *Cybele Britannica*, written in four volumes over 12 years (1847-1859). While applying the term 'alien', along with 'natives' (indigenous species), 'denizens' (long-term residents, introduced species, who might be considered 'naturalized) and 'colonists' (species, colonizing agricultural land and habitat occupied by humans), Watson discussed in detail how difficult it is to assign 'nativeness' to any species.

Stephen Troyte Dunn, who wrote *'Alien Flora of the British Isles'* in 1905, partly adopted H. C. Watson's categorization of species. Both worked without much knowledge of the geological and fossil evidence of plants but agreed that all species, even 'natives', may have been immigrants sometime in the past. All of Watson and Dunn's 'alien' species have several things in common. They are all highly productive (fertile), pioneering or colonizing taxa, which can establish and thrive in disturbed environments ('artificial habitat', *sensu* S. T. Dunn), from which they perpetuate themselves.

Knowledge about the 'foreign' components of a country's flora is ecologically important to understand how species adapt to new environments and influence others. Both Watson and Dunn emphasized the remarkable ability of some introduced to spread, unassisted by man's activities, while others, like '*shadows of men'*, appear to '*follow the plough'*.

The 'colonization process' of these highly successful plants gets them into trouble in the minds of some, who prefer to attribute other meanings, such as 'invasions' to these "foreign" species. A dip into history shows that Watson and Dunn discussed introduced plants without disparaging them. Like humans, colonizing taxa are good at what they are genetically predisposed to do, i.e., adapt and survive even under stressful environments. They are no more 'alien' than we are. They are also no more 'invasive' than we are. As one historian (Alfred Crosby) noted, these species may even help heal the wounds on the earth, torn apart by the real 'invaders' – those '*wretched ingrates*' (humans).

Keywords: 'Aliens'; H. C. Watson; S. T. Dunn; 'invasive species'; invasions; weeds

Opening

"…As the aborigines disappeared with the advance of the whites, so do the native plants generally yield their possessions as cultivation extends, and the majority of the plants to be met along the lanes and streets of villages, and upon farms, are naturalized strangers, who appear to be quite at home, and are with difficulty to be persuaded or driven away…"

William Darlington (1859, p. xiii)

"…Weeds were crucially important to the prosperity of the advancing Europeans and Neo-Europeans. The weeds, like skin transplants placed over broad areas of abraded and burned flesh, aided in healing the raw wounds that the invaders tore in the earth. The exotic plants saved newly bared topsoil from water and wind erosion and from baking in the sun. And the weeds often became essential feed for exotic livestock, as these, in turn, were for their masters. The colonizing Europeans who cursed their colonizing plants were wretched ingrates…"

Alfred Crosby (1986, p. 170)

"…Man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords. The proportions and accommodations which insured the stability of existing arrangements are overthrown..."

"…Indigenous vegetable and animal species are extirpated, and supplanted by others of foreign origin, spontaneous production is forbidden or restricted, and the face of the earth is either laid bare or covered with a new and reluctant growth of vegetable forms, and with alien tribes of animal life..."

George Perkins Marsh, 1864 (1867, p. 36)

"…Whenever man has transported a plant from its native habitat to a new soil, he has introduced a new geographical force to act upon it, and this generally at the expense of some indigenous growth which the foreign vegetable has supplanted..."

"…The new and the old plants are rarely the equivalents of each other, and the substitution of an exotic for a native tree, shrub, or grass increases or diminishes the relative importance of the vegetable element in the geography of the country to which it is removed…."

George Perkins Marsh, 1864 (1867, p. 58)

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In a previous Editorial (Chandrasena, 2020), I analyzed some not well-known ideas of several key 19th Century individuals - William Darlington (1859), Gerald McCarthy (1892) and Asa Gray (1879), which were fore-runners to the development of *Weed Science* in the 20th Century. All three examined and dealt with agricultural weeds in the USA.

As shown in Darlington's quote, many plants introduced by humans across the continents '*take possession'* and settle in the new environments and are then '*hard to be persuaded to leave*'. Darlington was entirely correct. The metaphor he used - that of 'newly-arriving' white Europeans driving the Native Americans away in the American West, was powerful, although perhaps a little overblown. History shows that newly introduced plants, whether in the Americas or elsewhere, did not permanently displace native indigenous plants. Instead of complete displacement, plant species appear to have an uncanny ability to adjust their lifestyles, ecological niches and co-exist. Their interactions are subtle but never '*do-or-die*' battles (pardon my use of the war rhetoric).

George Perkins Marsh's astute observations in his voluminous treatise (1864) remind us of the destabilizing effects of humans on Nature. Marsh spent considerable time explaining how humans transfer species from one place to another, modify the environment, extirpate some plant and animal species while favouring others. These quotes above are a fitting preamble to this essay.

I am thankful for the environmental history books: '*Ecological Imperialism*' by Alfred Crosby (1986), '*War on Weeds In The Prairie West*' by Clinton Evans (2002), '*Weeds: An Environmental History of Metropolitan America'* by Zachary Falck (2010), and Marcus Hall's Editorial (2003) which are essential reading in this regard.

Understanding our cultural relationships with weeds will equip weed scientists worldwide to deal better with weeds. *We must constantly remind ourselves that, ecologically speaking, and for all intents and purposes, the term 'weeds' is a synonym for 'pioneering' or 'colonizing' species* (see Bunting, 1960; Baker, 1965).

Much has already been written about how man was the 'primary agent' in spreading plants and animals across continents. These were either by purposeful introductions, for economic benefits, or by the way of unintentional, incidental, and careless introductions (Watson, 1847-59; 1870; Darlington, 1859; Gray, 1879; Dunn, 1905; Crosby, 1986; Evans, 2002; Falck, 2010). Instead of focusing on the human agent as the culprit, the '*invasive aliens*' narrative tends to blame some plant species as '*guilty, until proven innocent*' – words chosen to unnecessarily create fear and apprehension in the public's mind [1].

In the 17th, 18th, and 19th Centuries, when the focus of the naturalists and plant explorers was on plants of ornamental, horticultural or economic values, no one gave much thought to the colonizing attributes of any species. The capacity of any species to establish itself in a new environment, without much help from man, was regarded as an admirable quality.

No one probably understood these innate capabilities until Darlington (1859) and Gray (1879) made those remarks regarding specific species. Observations from continental Europeans, including Alphonse de Candolle (1855) and Albert Thellung (1912), are noteworthy. Perhaps, Jethro Tull (1762) should also be credited in this regard because he

[1] The often quoted article by Jason Van Driesche & Roy Van Driesche with the provocative title: "*Guilty Until Proven Innocent*" first appeared in the *Conservation in Practice* Magazine, Vol. 2 (1): 8-18. The Magazine is no longer published but has been replaced by the *Anthropocene Magazine*, published at University of Colorado, Boulder, Colorado, USA.

wrote specifically about ‘weeds’ nearly 260 years ago. Promoting his agricultural invention, Tull’s book- *Horse-Hoeing Husbandry or An Essay on the Principles of Vegetation and Tillage*, appreciated weeds. In *Chapter VII – Of Weeds* (p. 73), Tull discussed the strengths of many weedy species, calling them ‘noxious’ (‘*herbae noxiae*’). However, his 18th Century tome was not on introduced species.

As discussed in detail by Crosby (1986), Evans (2002) and Falck (2010), species were introduced to North America for societal benefits, primarily by Europeans. The enthusiastic introducers wished that the plants would establish themselves and may not need looking after. While not all species were successfully established, many did, and those were species with colonizing abilities.

Success in their ‘new environments’ expanded the bio-geographical ranges of many of these remarkable species. Their genetic make-up and innate capacities, related to fecundity, lifecycle strategies, adaptations for stress tolerance and wide ecological amplitudes, are among the reasons why they are so successful. Once introduced, as Crosby (1986) stated (see quote above), ‘*these species help heal the wounds on the earth, torn apart by the real ‘invaders’ – those* ‘*wretched ingrates*’ (humans).

After the initial introductions, humans continue to be helpful by being wholly or partially responsible for creating disturbances, enabling many such colonizing taxa to entrench themselves away from their native ranges successfully. Darlington’s astute observation (1859, p. xiii) on these extraordinarily successful colonizers is also spot-on: ‘*once they are fully established, they will not yield without an argument’*.

‘Alien’ – The Origin of a Term

In this essay, I aim to discuss how the term ‘*alien*’ came to be applied to plants introduced from one country to another. The earliest proponent - Hewett Cottrell Watson (1804-1881), an eminent English botanist and phyto-geographer, was indeed the most significant figure in this regard. ‘*Alien*’ is one category Watson used to assign plants to, alongside other terms - ‘*native*’, ‘*denizen*’, ‘*colonists*’, and ‘*casuals*’. The categorization is discussed in detail in his *Cybele Britannica (*Watson, 1845-1859).

The word ‘*alien*’ (Latin, "*alienus*") means “*foreign*”, “*belonging to another*”, or “*unfamiliar*”. The term used as a noun arose in the 13th or 14th Century. When the verb ‘*alienate’* first appeared, it was a legal term in the mid-15th Century, which was used in transferring the ownership of some property over to someone else, so that it became now “foreign” or “unconnected” to the transferee.

In a legal sense, it was applied to people "*residing in a country not of one's birth*". The on-line etymology dictionary (**https://www.etymonline.com/**) indicates that the sense of "*wholly different in nature*" is from the 1670s. The term ‘*alien*’ then evolved further and was first recorded to mean "*not of this earth*" around 1920. It is now very much a common term used in science fiction.

Marcus Hall [2] pointed out that the term ‘*alien*’ was applied in Britain to ascribe a ‘civil status’ in the past centuries. The Royal Office maintained an “*Aliens Office, Home Office*” to keep track of immigrants and their origins from 1793-1836 [3] In Britain, the ‘*Aliens Act*’ was established in 1793 to “*regulate the growing numbers of refugees fleeing to Britain to escape the French Revolution, and to address the fear that enemy spies might infiltrate Britain during the Napoleonic Wars*” [4]. It seems very likely that H. C. Watson borrowed from some of this terminology.

Steven Troyte Dunn, another English botanist, who worked at London’s Kew Herbarium, and at various overseas stations of the Empire, captured Watson’s ideas about ‘*aliens*’ and ‘*natives*’ when he wrote ‘*Alien Flora of The British Isles’* in 1905. I agree with Marcus Hall’s view (*pers. comm.*, Oct 2020) that Dunn’s use of the term in the book's title may have put an authoritative stamp on the word.

Although Edward Salisbury (1961), a botanist in post-World War II Britain, wrote “*Weeds & Aliens*”, we may discount this book, as it is hardly a botanical treatise. In more recent times, in Australia, Peter Michael (1994) used Watson’s terminology in a helpful chapter he wrote on the *Australian Vegetation* (see Michael, 1994).

In the following sections, I review the above historical uses of the term ‘*alien*’ as applied to ‘*introduced plants’*, briefly contrasting it with another controversial and dubious term, ‘*native*’.

[2] Marcus Hall, Environmental Historian (Institute of Evolutionary Biology & Environmental Studies, University of Zurich).

[3] See: The National Archives, “Aliens Office & Home Office: Aliens' Entry Books” (**http://discovery.nationalarchives.gov.uk/details/r/C8869).**

[4] See: BBC History. Aliens arriving in Britain swore declarations at their port of entry. (**http://www.bbc.co.uk/history/familyhistory/bloodlines/migration.shtml?entry=aliens_act&theme=migration**).

H.C. Watson's *'Aliens'*

When botanists adopted and applied the term '*alien*' to describe a particular plant species in the mid-19th Century, they intended no derision of any introduced species. H. C. Watson (Figure 1) was among the first to use the term in categorizing what he called the '*civil status'* of plants. Watson's monumental treatise, provocatively named – *Cybele Britannica* - was published in four volumes, which spanned 12 years (1847 to 1859).

In Volume I, Watson (1847, p. 1) clarified that phyto-geography traces out the history and distribution of plants in different geographical positions of countries, their conditions of climate, and the physical peculiarities of their surface. However:

> *"…the Cybele was about Geographical Botany, which begins with the plants themselves, whether by individual species, or in generic or ordinal groups, and is concerned about the distribution of plant species or groups over the surface of the earth…"*

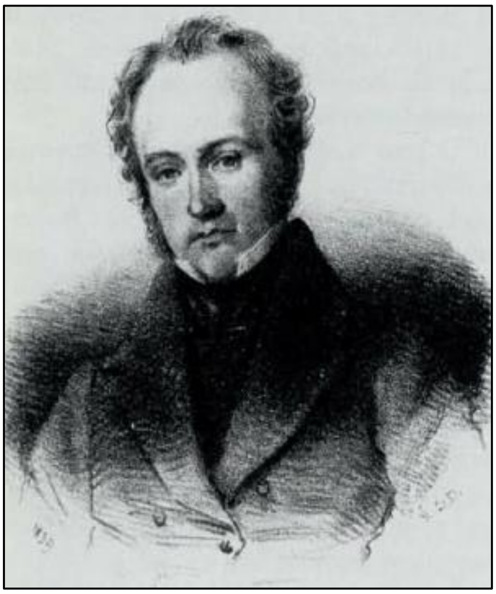

Figure 1*H. C. *Watson- from a sketch by an artist, published in The Naturalist (Feb 1939) [Source: Eggerton, 1979]

Watson deeply regretted the time lapse of 12 years in completing his phyto-geographical works and the '*piecemeal*' nature of the '*successive instalments*'. In the "Postscript" (quote below), he admitted that both phyto-geography and his ideas have changed over that period Watson, 1859, Vol. 4, p. 550):

> *"…During the full dozen years of interval, neither phytography nor phyto-geography have stood still. Nor have the author's own ideas and inspirations been quite unchangeable during the same period…"*

In Volume I, Watson (1847, p. 2) explained that his book was not just a mere catalogue of plants and preferred the term *Cybele* (pronounced: *Sib-el-ee*), invoking a Greek goddess of Nature [5]:

> *"…The author ventures, therefore, to substitute the mythological name of Cybele; that is, the name of a Goddess who was supposed to preside over the productions of the earth…"*

> *"…The name of 'Flora' has long been used for those catalogues of plants, in which are described the species of any definite section of the earth; that of 'Cybele' appeals quite as applicable to one which is intended to show their relations to the earth, as local productions of the ground and climate..."*

In the four volumes of *Cybele* and the subsequent *Compendium* (Watson, 1870), Watson enumerated about 1428 species, a figure much less than 1500-1600 species that previous botanists had documented. Darwin (1859, p. 63) noted in the *Origin of Species* how Watson declined to recognize some varieties as distinct species, which explains the reduced number of species in the *Cybele*:

> *"…Mr. H. C. Watson, to whom I lie under deep obligation for the assistance of all kinds, has marked for me 182 British plants, which are generally considered as varieties, but which have all been ranked by botanists as species; and in making this list, he has omitted many trifling varieties, but which nevertheless have been ranked by some botanists as species, and he has entirely omitted several highly polymorphic genera..."* Darwin (1859, p. 63) [6]

In the *Cybele* (Figure 2), Watson's objective was first to categorize and then assign British plants according to their known geographical distributions in the isles. In so doing, he was somewhat obsessed with determining where the species he encountered originated; whether they should be treated, either as '*indigenous natives'* or those that had been '*introduce*d' by humans, from various countries, such as Europe, Asia and the Americas.

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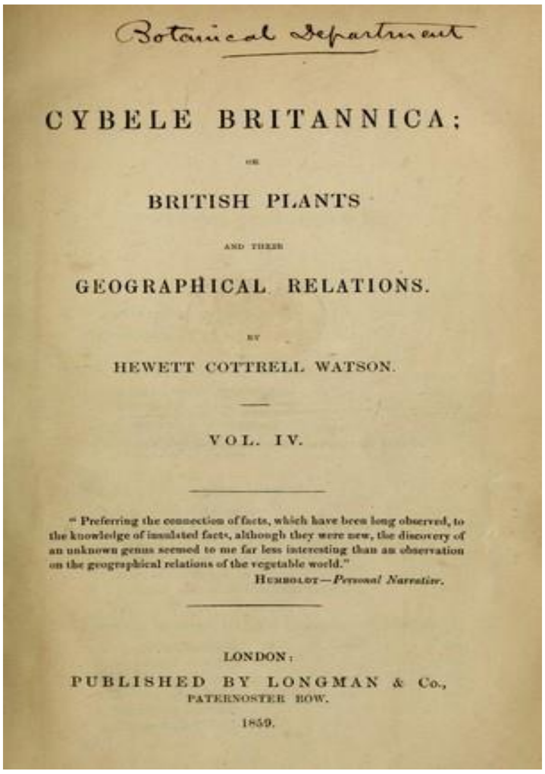
[5] *Cybele* - a nature goddess of ancient peoples of *Phrygia* (an ancient country of Asia Minor) (Source: **https://www.dictionary.com/browse/cybele**).

[6] Darwin's *Origin of Species* first published in 1859; 2nd Edition (1860); 3rd Edition published in 1909, celebrating 100 years of Darwin's birth Available at: (**https://archive.org/details/originofspecies00darwuoft/page/420/mode/2up?q=watson**).


Botanical Department

CYBELE BRITANNICA;

OR

BRITISH PLANTS

AND THEIR

GEOGRAPHICAL RELATIONS.

BY

HEWETT COTTRELL WATSON.

VOL. IV.

"Preferring the connection of facts, which have been long observed, to the knowledge of insulated facts, although they were new, the discovery of an unknown genus seemed to me far less interesting than an observation on the geographical relations of the vegetable world."

HUMBOLDT—*Personal Narrative*.

LONDON:

PUBLISHED BY LONGMAN & Co.,

PATERNOSTER ROW.

1859.

Figure 2 The Cybelle, an image of the front page of the original published Volume I

To describe the species, Watson borrowed several terms from the legal profession. In his words: '*to explain the 'civil status' and local situations'* and the origins of the British flora. The following quote is from the *Compendium to the Cybele*, in 1870:

"…A series of terms, drawn from our own legal and social classifications, has been used to express the various grades of uncertainty or belief with respect to those plants whose aboriginal nativity is more or less unsettled.

"…The terms 'native, denizen, colonist, alien, casual' serve to express a descending series, from the 'truly wild' and pre-historically established species, down to the occasional stragglers from cultivation, or the products of seeds, accidentally imported with merchandise, ship-ballast, or otherwise…"

"…The word "naturalized" has been variously and carelessly applied by botanical writers that it has ceased to carry with it an exact signification. It ought to mean a species originally introduced by man, but now become thoroughly established, by seed or otherwise, among the native plants of the country, and existing without human aid in sowing its seeds or in preparing the ground for them…"

The range of terms Watson used indicated the doubts he had about the possible origins of species. In Volume I, his categories included the term '*incognito'*, which was replaced by '*casuals*' in 1870.

Egerton (2003), Watson's biographer, suggested that treated as controversial in the mid-1850s, the *Cybele* was possibly overshadowed by Charles Darwin's colossal, *Origin of Species* (Darwin, 1859), which was published simultaneously as Watson's Volume 4, i.e. 1859. The *Cybele* also posed many challenges to botanists of the era as Watson spent a great deal of space in the four volumes criticizing others for just creating dubious lists of plant species.

In *Cybele* Volume I, Watson (1847) defined 'alien plants' as those: '*now more or less established but either presumed or certainly known to have been originally introduced by the human agency from other countries'*. Along with the term '*alien*', in the *Cybele* Vol. I, Watson, described several other categories, which are given in Table 1, with some descriptions reduced for brevity.

Watson did not provide the naming authorities of any of the species he described, although botanical names and naming rules were reasonably well established at that time after the Linnaean system of botanical nomenclature [7]. Botanical names with naming authorities did appear in the later Volume- the *Compendium* (Watson, 1870). To understand which species Watson was referring to, I have included the common names of the species. In subsequent works, in the *Compendium* (Watson, 1870), he replaced the term '*incognito*' with '*casuals*' (see below).

In summing up the four Volumes, on the 'native' status of species, Watson reiterated his doubts:

"…It can rarely or never be known whether the species existed in Britain before mankind, or have immigrated into this country more recently; and if the latter, whether their immigration has been effected by natural means of transport only, as distinguished from those afforded to them by the human agency…"

"…It is possible that none of these species was aboriginal natives on the present surface of Britain. It may be that all of them were immigrants into the British islands, at different dates, from other lands; those lands, or some of them, having subsequently ceased to be. Such uncertainties belong at present rather to geological than to geographical botany…"

[7] See: Car Linnaeus and binomial plant names – (**https://en.wikipedia.org/wiki/Carl_Linnaeus**)

Table 1 Watson’s Plant Categories given in the Cybele, Volume 1 1847 (p. 63) and the Compendium (1870) # ##

Term	Description
‘Native’	• Apparently, an aboriginal British species there being little or no reason for supposing it to have been introduced by human agency. (e.g., heather – *Calluna* spp.; English daisy - *Bellis* spp.).
‘*Denizen*’	• a species that can behave as a ‘native’, at present, maintaining its habitats without man's aid, yet, yet liable to some suspicion of having been originally introduced (e.g., orange balsam- *Impatiens fulva;* sweet violet- *Viola odorata*).
‘Colonist’	• A weed of cultivated land or about houses, and seldom found except in places where the ground has been adapted for its production by the operations of man with some tendency. They also appear on shorelines, disturbed grounds, landslips, etc. (e.g., pheasant’s eye- *Adonis* spp.; poppy- *Papaver* spp.; corncockle- *Agrostemma githago*; sweet clover- *Melilotus leucantha*). • *With a tendency also in some of them to appear on the shores landslips, and in what are called "waste places". Ranunculus arvensis, Papaver dubium, Thlaspi arvense, Centaurea cyanus, Alopecurus agrestis are weeds of cultivated land; and would perhaps disappear if plough and spade ceased their work #. Several Chenopodia, Mercurialis annua, Rumex pulcher, Lepidium rudemle, Asperugo procumbens, and others constitute connecting links between the ‘Colonists’ and ‘Denizens’, found chiefly by roadsides, rubbish heaps, dunghills, and near the sea #*
‘Alien’	• Now more or less established, but either presumed or certainly known to have been originally introduced from other countries (e.g., *Sempervivum*; *Mimulus*; *Hesperis*; *Camelina*) ##. • *‘Aliens’ are species certainly or very probably of foreign origin, although several in this category are now well established amid the indigenous flora of this island; others less perfectly so #*.
‘Incognito’	• Reported as British but requiring confirmation as such. Some of these have been reported through mistakes of the species, such as grass-leaved buttercup- *Ranunculus gramineus*. Others may have been temporary stragglers in gardens, such as trumpet gentian- *Gentiana acaulis*. • A few may have existed for a time and become extinct, such as alpine coltsfoot- *Tussilago alpina*. It is not improbable that some of these may yet be found again. A few may have existed for a time and become extinct, such as prickly parsnip- *Echinophora spinosa*.
‘Casual’	• *Casual species are chance’ stragglers’ from cultivation; those occasionally imported and sown with agricultural seeds; those introduced among wool, oil-seeds, or other merchandise; foreign plants found on ballast heaps deposited from ships; and generally, such alien species are most uncertain in place or persistence #*
‘Hibernian’	• Native, or apparently so, in Ireland, or the Channel Isles, though not found in Britain proper

See text for details. In the *Compendium* to the four earlier volumes of *Cybele*, published in 1870, Watson updated and slightly modified his earlier descriptions of the categories. These are given in italics.

From the descriptions in the *Cybele:* [*Sempervivum tectorum* L. (p. 403; succulent, introduced from America); monkeyflower – *Mimulus* sp. (probably, *M. guttatus* Fisch. Ex DC., introduced from America); Dame’s violet - *Hesperis matronalis* L. (p. 157, Eurasian species, introduced to Britain in the 17th Century); false flax [*Camelina sativa* (L.) Crantz] (p. 134, found in ballast heaps; introduced to the UK from Russia and Eastern Europe in the 19th Century).

Watson used the term ‘*alien*’ interchangeably with ‘*introduced species’*, which were relatively recent arrivals in the British Isles, possibly in the past few centuries. He also drew a sharp contrast between the ‘*aliens*’ with species, considered ‘*natives*’ of the isles.

The lengthy discussions in *Cybele*’s four volumes were based on his field collections and observations, complemented by his analysis of other floras, which had previously recorded the long-term residency of different species. In these observations, Watson criticized many other fellow botanists for not being cautious in ascribing ‘native’ status to species[8]. Those

[8] ‘*Juvenile dabblers in botany and very superficial amateurs*’ and *ill-informed writers not only encumber the literature of botany with their own blunders and valueless repetitions but they also disgust and deter more competent persons, whose writings might do real service to science’* (Vol. IV, p. 522).

In one example, Watson ranted no one before him had acknowledged *Sempervivum*, a succulent, from the Americas, as ‘*alien*’ to Britain: ‘*This plant affords a fine instance of the proneness of human beings to follow blindfold any example once set, without taking the trouble to think whether it be right or wrong, wise or foolish*’ (Watson, 1847, p. 403).

species he considered '*natives*' were undoubtedly '*indigenous citizens*' or those '*of aboriginal descent*', which existed in Britain before man's advent and influence.

He described two other categories - '*denizens*' and '*colonists*', contrasting those species with the '*aliens*'. '*Denizens*' do not need man's assistance but were inhabitants of particular places, surviving and perpetuating successfully. In his mind, such species were on well the way to becoming 'naturalized', and some could easily be considered '*natives*' [9]. The term '*denizen*', however, did not survive subsequent botanical writings in the late-19th Century; it just simply disappeared with Watson.

In Volume IV of the *Cybele*, Watson devoted an entire, lengthy chapter of 60 pages, titled: "*On The Introduced Species*", to discuss the species he categorized as '*aliens*' (Watson, 1959, Chapter III, pp. 65-125). As Watson stated: '*The distinction between original 'natives' and 'introduced species' is of primary importance in geographical botany*' (p. 84).

In addition to the terms describing the '*civil status*' of plants, Watson described the '*habitat*' of those plants with another series of terms. Some of these, such as *littoral* (of the shorelines), *lacustral* (of lakes), *agrestal* (of agriculture), are used by ecologists even today, while others died out with age [10].

For this essay, it is helpful to reflect on the examples of Watson's '*aliens*', which appear under '*Ornamental Garden Plants*' (pp. 74-77); '*American Species*' (pp. 77-79) and '*Wayside plants*' (pp. 82-83). All of them, in a strictly botanical sense, are colonizing species, which possess at least some of those attributes of Baker's '*Ideal Weed'* (see Baker, 1965) and thrive in disturbed areas, generally associated with human habitations.

Quoting, Watson:

'…The garden escapees rapidly propagate in a weed-like manner; occasionally passing thence into adjacent wilds, carried there by natural causes or the human agency…"

Among the '*American species'*, Watson named many, which were unknown in Europe before America was discovered: '*they are 'natives' of the Western Continent, introduced into Europe by the human hand'*. Watson argued that a few of these species were well-advanced in '*naturalizing themselves among the natural vegetation*' and may even be accepted as '*true natives'* (Vol. IV, p. 77).

Under '*Wayside plants*', Watson discussed several modes of '*alien*' plant introductions to Britain. These included contaminated grain seeds, wool and other products, and accidental species introductions through: '*ships' ballast (returning coal vessels) thrown ashore from ships or intermingled with merchandise of various kinds*' (Vol. IV, p. 82). He also identified botanic gardens as a source, introducing plants, which may become '*occasional stragglers'* in Britain. In Table 2, I have given some examples of Watson's '*aliens*', drawn from *Cybele* Vol. IV, Chapter 3 with additional comments to exemplify the above points.

Watson doubted the '*native*' claims of many species by other botanists. Following extensive travels and collections, he spent considerable effort teasing out the introduced species from the indigenous British plants. The *Cybele* described many species that he had '*only ever recorded on areas greatly influenced by humans'* (viz. ornamental gardens). Some examples (Vol. IV, p. 76) include several Linnaean species, such as - common violet (*Viola odorata* L.); green hellebore (*Helleborus viridis* L.); periwinkle (*Vinca minor* L.), and stonecrop (*Sedum reflectum* L.; syn. *Petrosedum rupestre* (L.) P.V. Heath). The native ranges of such species are now accepted as Western, Central, Southern, and

[9] The term denizen, from early 15th Century, refers to "a citizen, a dweller, an inhabitant," especially "a legally established inhabitant of a city or borough, a citizen as distinguished from a non-resident native or a foreigner". The origin of the English term is from Anglo-French: *deinzei*n or d*enzein*, meaning "one within" (referring to the privileges of a city franchise; opposed to foreign "one without").

The original Latin word is *deinz* "within, inside"; from Late Latin *deintu*s, from *de*- "from" + *intus* "within". In legal term, a 'denizen' could claim a right to become a permanent resident or citizen of a foreign country because of long-term occupancy of a place (source: **https://www.etymonline.com/word/denizen**)..

[10] Among Watson's habitat categories (pg. 65-66) are terms, such as: (1) *agrestals* (growing in cultivated ground), (2) *viatical* (plants of road-sides and rubbish heaps); (3) *lacustral* (plants immersed in water or floating), (4) *littoral* (plants of the sea-shore), (5) *sylvestral* (plants of wooded or shaded places), etc. These terms persist in modern usage as their meanings are self-evident, quite often, perhaps, without reference to or awareness of Watson's original definitions (Chew, 2006, p. 29).

However, a few habitat terms were too vague and never gained much currency. Examples are terms, such as (1) *ericetal* (plants of moors and heaths); (2) *uliginal* (plants of swamps, or boggy ground); (3) *paludal* (plants of marshy ground, the roots of which are in water or wet ground constantly); (4) *glareal* (plants of dry exposed ground, on gravel or sand); their usage died with Watson (Chew, 2006, p. 29).

Eastern Europe, stretching eastwards to the Baltic States. Watson's determinations about the 'alienness' of such species were indeed justified.

In the chapter '*On the Introduced Species'* (Watson, 1859, pp. 65-125), Watson provided stimulating discussions on '*denizens*' and '*colonists*', referring to many 'weedy species' that colonize and survive, year after year on disturbed habitat. Here, he pointed out that the distinction of '*denizens*' and '*colonists*' with '*aliens*' is a '*fine line*' only and vague as they overlap. The separation of species into categories is based on records of their frequent occurrence within established 'natural vegetation'.

He listed many British species as '*denizen*', which were well on the way to being '*naturalized*' after introductions, requiring no assistance from man to sustain their populations. He called them '*naturalized aliens*' and included many ornamental garden plants, especially fruit trees, such as a variety of *Prunus* L. spp. and medicinal and culinary herbs. After introductions, many such species have spread far and wide in Britain and can sustain themselves without man's aid, far away from human habitations (pp. 79-82), growing '*seemingly wild or spontaneously*'.

Table 2 Some examples of Watson's Aliens #, ##

Species/[Synonyms and Common Name]	**Comments and Revised name#**
Allium ursinum L. [wild garlic]	'*never appears really wild, and in places remote from the abodes of man'*; *most of their localities are near existing houses*'; The native range is West and Central Europe to the Caucasus ##
Anacharis alsinastrum Bab. [Canadian pondweed]	'*The remarkably rapid increase and diffusion recently observed is familiar to all British botanists, though the plant was hardly known to any of them a quarter of a century ago';* A troublesome water weed of unknown origin from the Americas; [*Elodea canadensis* Michx.] ##
Atropa bella-donna L. [belladonna]	' *is supposed to be native in some calcareous tracts, but many of its localities have a very suspicious proximity to old abbeys and monasteries'*. The native range is West and Central Europe to the Caucasus from where it was introduced ##
Barbarea preacox (Sm.) R.Br. [land cress]	'*certainly known to have been brought originally from America'*; The native range is the Azores, South-West Europe to Central Italy and introduced to North America ##; possibly, an error from Watson; [*Barbarea verna* (Mill.) Asch.] ##
Gnaphalium margaritaceum L. [pearly everlasting]	' *a plant of rapid increase by its underground suckers, pronounced native in Britain by several botanists on the faith of its apparent 'wildness' in some places; others assert it was originally introduced from America';* Now established as native to the Indian Subcontinent, Russian Far East and Japan; [*Anaphalis margaritacea* (L.) Benth & Hook.f.] ##
Impatiens fulva Nutt. [orange jewelweed]	'*perfectly established in the county of Surrey, and perhaps through spreading along the course of the Thames river, it is becoming also established in Middlesex';* Native to North America, introduced to Europe and Britain; [*Impatiens capensis* Meerb.] ##
Lysimachia ciliata L. [hairy loosestrife]	'*is stated to be likewise establishing itself in various spots, and with sufficient semblance of wildness to lead to mistakes, were its transatlantic origin not*'; Native range Canada to the USA; introduced to Europe in the late-19th Century ##
Mimulus luteus L. [monkeyflower]	'*has become thus well established in many places, both in England and Scotland';* It grows in wet habitats (marshes and riverbanks). Native in North and South America; naturalized in Britain after first cultivation there ca. 1826; [*Erythranthe lutea* (L.) G.L.Nesom] ##.
Oenothera biennis L. [evening primrose]	'*is less permanent, though become a half-wild weed in many spots'*; A native of Eastern Canada, the USA to Mexico, introduced to Europe as an ornamental at least 350 years ago; widely naturalized in river banks, thickets and sandy places.##
Oxalis stricta L. [yellow woodsorrel]	'*The very imperfectly established'- from America*'; The native range is Central, Eastern China to North and Central Japan, all of North America; now cosmopolitan weed ##
Spartina alterniflora Loisel. [cordgrass]	'*The locally well-established – from America*'; Native to parts of North America; Northern and Southern parts of South America (Argentina); introduced to Europe, Asia, China, Australia, New Zealand; [*Sporobolus alterniflorus* (Loisel.) P.M.Peterson & Saarela] ##
Vinca minor [periwinkle]	'*well adapted to spread over any favourable spot to which they are carried either by natural causes or by human agency*; Native range Europe to Caucuses #

Watson's descriptions are given in Italics, mostly from Volume IV pp. 70-80.

Additional notes from *Kew Science Plants of the World On-Line*: **http://www.plantsoftheworldonline.org/**

The common feature that links the listed '*alien*' species is that they are ***all*** introduced. Some thrive on continually disturbed agricultural habitat ('colonists') or 'stragglers' on shorelines, shipyards, waste dumps and other disturbed habitats. Others, including fruit trees, medicinal and culinary herbs, spread from ornamental gardens into even natural habitats.

Watson recognized that '*native*', '*denizen*', '*alien*' and '*casuals*' are merely terms that help describe the status, occurrence, and condition of a particular species, at a specific time in history. His words were:

> *"…the various grades of uncertainty or belief with respect to those plants whose aboriginal nativity is more or less unsettled. They also express a descending series, from the 'truly wild' and pre-historically established species, down to the occasional stragglers…".*
>
> (Watson, 1859, pp. 65-125)

Nearly 100 years before the discipline of *Weed Science* emerged, Watson referred to widespread agricultural weeds simply as '*colonists*' or '*casuals*'. He recorded the capacity of wild radish (*Raphanus raphanistrum* L.)*;* rapeseed (*Brassica napus* L.; syn. *Brassica campestris* L.); and white mustard (*Sinapis alba* L.) to 'colonize' human-disturbed habitat (i.e., the agricultural field, home gardens and shipyards), and naturally disturbed habitat (i.e., shorelines).

In contrast to '*colonists*', those he called '*aliens*' included many horticultural species, e.g., cinnamon rose (*Rosa cinnamomea* L.); succulent sedums (*Sedum* L. spp.), or economically-useful species, e.g., flax (*Linum usitatissimum* L.); coriander (*Coriandrum sativum* L.); field eryngo (*Eryngium campestre* L.) and many clovers, e.g., Italian clover (*Trifolium incarnatum* L.); Persian clover (*T. resupinatum* L.); horehound (*Marrubium vulgare* L.). All had been accidentally introduced to Britain, and Watson noted that they often grew in disturbed habitats associated with human habitations (i.e., home gardens, ancient castles, abbeys, and monasteries) [11].

As Matthew Chew pointed out (Chew, 2006, p. 30-31), neither he nor Watson's biographer Frank Egerton found reason to suspect that the categories of species were '*essentially chauvinistic*'. I agree with Chew (2006), and may summarise, as follows:

(a) While stating "*the distinction between native and introduced species is absolute and real*", Watson did not suggest the '*natives*' were inherently superior to any '*denizens*' or '*aliens*'.

(b) By describing his formula as one of "*civil claims*", and elsewhere, as "*predial*" (i.e., an archaic adjective relating to landholdings), Watson did seem to ascribe inclusion in the native British flora in combined terms of occupancy rights and a kind of botanical citizenship (Watson, 1859; p. 107).

(c) With time, 'the indications of foreign origin of many '*denizens*' would become *obliterated*, and it would be hard to distinguish them from the '*true natives'* as they will be '*naturalized*' over time.

(d) He saw '*naturalization*' as a natural process that leads to bio-geographical range expansion of many species. However, he made no comments on those 'naturalized' species as causing undue concern to the extant British native vegetation.

(e) Watson also highlighted that 'alien' species occupy corresponding climatic zones across regions in Britain as well as with the European landmass.

The *Compendium* (1870)

As diligent as ever, Watson dedicated the last decade of his life to revising and adding substantially to his earlier works. In 1870, he published a "*Compendium of the Cybele Britannica*", stating that:

> *"…The Compendium was a condensed reprint of the first three volumes of the original work, corrected to the more advanced knowledge of its subject in 1867-1869 (the years in which the three successively printed Parts), must largely supersede the scientific usefulness of the original work*…" (Watson, 1870; p. 630)

Armed with new knowledge of plants and their distributions, Watson saw the necessity to reassess and modify his earlier works. Watson deserves credit for setting in motion what botanists nowadays call 'revisions' of botanical works. Not every botanist, before the 20th Century, has had the time or resources to make such improvements.

Watson strongly believed that it was important for botanists to understand the 'factors' that caused the changes in the biogeographical distribution of species. He was also keen to document the agencies (both human and natural), causes of spread and the

[11] Despite tedious efforts, some of Watson's '*civil status*' determinations were not always correct. One example is common bluebells (*Hyacinthus nonscriptus* L.), which Watson determined as an introduced species (Vol. IV, p. 76). However, its status has been revised as '*native*' to Britain and Western Europe (viz. Belgium, Netherlands, France, Portugal, and Spain). About half of the world's bluebell populations occur in Britain, in woodlands, hedgerows, shady banks, on coastal cliffs and uplands. Bluebells (revised name: *Hyacinthoides non-scripta* (L.) Chouard ex Rothm.) are now 'naturalized' in North America, and New Zealand (**http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:971733-1**).

habitat preferred by individual species, which successfully establish in the new environments.

However, he did not repeat his habitat classification of Volume I in the *Compendium*, possibly because it was more important for him to use the space for other aspects of geographical botany (Egerton, 2003). Nevertheless, with the updated terminology, Watson provided many more examples under the '*native*', '*denizen*', '*colonist*', '*alien*' and '*casuals*' categories. Overall, in the final piece of his major works, Watson described just under 1500 plant species detailing many ambiguities in designating species to different categories.

✳✳✳✳

Watson was undoubtedly a leading figure among the early botanists of the 19th Century who recognized the role of humans in moving plants across biogeographical regions. At the same time, he appreciated that natural agencies also cause long-dispersal of plants. Those days, the industrial revolution had begun to transform societies. The human population had also started to grow exponentially, and interactions across continents had greatly increased through trade, empire-building, conquests, and colonization of other continents (Crosby, 1986). Many plant species, the so-called '*aliens*', spread widely, through human agency, partly by accident and partly by deliberate introductions. In describing these bio-geographical transformations and ecological changes, Watson's voluminous writings ascribe no blame to any species.

H. C. Watson (Figure 3), in later years of his long career, was indeed both a controversial and highly opinionated botanist. Often cantankerous in his writings and dismissive of others, he rarely praised anyone, except, perhaps, Alphonse De Candolle, who is invoked several times, but not always in a positive way (Egerton, 2003). His argumentative disposition did not endear him much to others.

Historical records, reviewed in detail by Egerton (1979; 2003; 2010), indicate that Alphonse De Candolle, Charles Darwin, and Joseph Hooker corresponded well with Watson and had a deep respect for Watson's tireless labours collecting plants and assiduous interpretations of plant distributions. For instance, Darwin praised Watson for not just indicating the number of species, which might be 'true' but also for contributing ideas to the theory of evolution of species and quoted Watson up to 11 times in the *Origin of Species*.

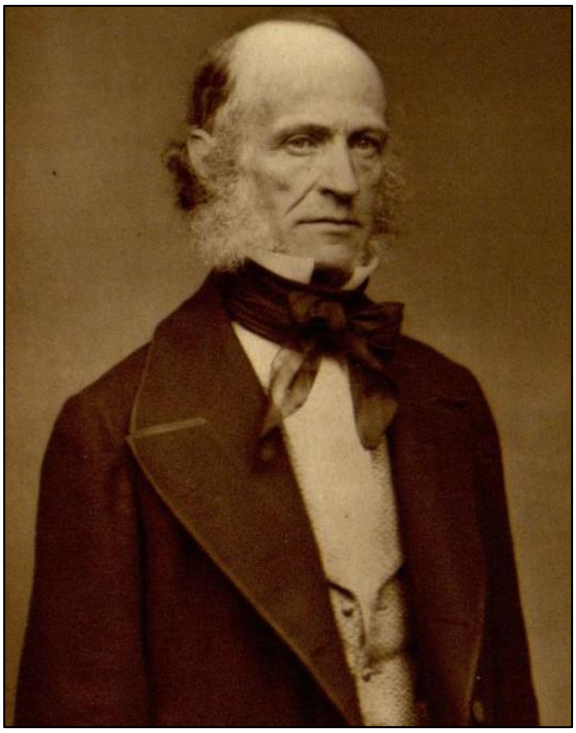


Figure 3 Watson in later years (Source: https://www.wikidata.org/wiki/Q1616636)

As evident in *Cybele* Vol. 4 (1859) and the *Compendium* (1870), even towards the end of his career, he continued to be critical of studies of other botanists. Watson's biographer, Egerton (1979, p. 93), noted: ''*Watson's botanical work was respected by his fellow British* botanists*, but since he often criticized their work, he had few friends among them*'. Watson was not popular among botanists. His hard-nosed attitude and argumentative criticisms of other botanists permeate through all four volumes of the *Cybele* and the *Compendium*.

Although Watson's highly analytical discussions on species distributions set a benchmark for others, he paid scant regard to nor had access to fossil records of plants that existed in the British Isles. This deficiency may have affected his thinking in the well-documented public dispute with Edward Forbes, whom he resented [12]. Watson quarrelled openly with Forbes, accusing him of plagiarism and not having the courtesy to acknowledge the '*rightful work of others*' (Watson's).

[12] A particularly noteworthy dispute Watson had with another scientist, Edward Forbes (1815-1854), is well-recorded in history and has been recently reviewed by Simone Fattorini (2017). Egerton (2003, p. 233) had earlier suggested that the virulence of Watson's personal attacks on Forbes was far beyond a scientific dispute. It showed that Watson was afflicted by ''a lifelong personality disorder'. Recorded history suggested that Watson was resentful of Forbes because the latter (a talented zoologist and palaeontologist, but not an eminent botanist) had, in 1842, beaten Watson in a contest for the chair of botany at the University of London.

A deeper analysis of the Watson-Forbes dispute is beyond this essay. Still, it is evident that, apart from studying the extant British flora, Forbes had indeed used geological data and information in proposing his theory [13]. Based on his analysis, Forbes classified the British vegetation into five zones rather than six, as Watson had suggested (Egerton, 2010, pp. 187–188). Watson had previously divided the British vegetation into three regions, each subdivided into two zones, a total of six zones (Egerton, 1979, p. 91) and felt insulted. Watson also saw Forbes' classification as a challenge to his determinations (see Fattorini, 2017 for a fuller discussion of the dispute).

In subsequent decades, and most certainly, 100 years later, the *Cybele* received appreciation in Britain as a highly significant achievement, which laid the foundation for British Botany (Egerton, 1979; 2003; 2010). Recognized as the first, earnest attempt to put geographical botany on a scientific basis, botanists now acknowledge that the *Cybele* contributed more to British botany than all the outpourings of '*poetic-floristic flummery*' put together in previous decades.

The Botanical Society of Britain & Ireland (BSBI) honoured Watson by naming their Journal – *Watsonia*, published from 1948 until 2010; this Journal is now the *New Journal of Botany.* In the first issue of the Journal, Meikel (1948) wrote:

> *"…the Cybele replaced vague generalizations with concrete facts about the character of the British flora. Previous botanical treatise had been just mere catalogues of plants and localities, with no effort made to discriminate between 'native' or 'alien' species, nor to determine their distribution, vertical or horizontal..."*

Honouring Watson, the BSBI [14] currently maintains a large collection of Watson's specimens as a digital library. The pages dedicated to Watson have extensive notes and a digital map of where he made the collections (Figure 3). The website provides photographs of many of Watson's original herbarium specimens, preserved in various institutions.

Watson's contributions may have also influenced the founders of *Weed Science*, such as George Baker (Baker, 1965). The discipline now understands why colonizing species are widespread (mostly spread by the human agency), and in the habitat types, such taxa dominate. However, an analysis of botanical literature shows that Watson's original terminology, including the term '*alien*', was not widely adopted by other botanists except Stephen Dunn (1905; see below) and, more recently, Salisbury (1961).

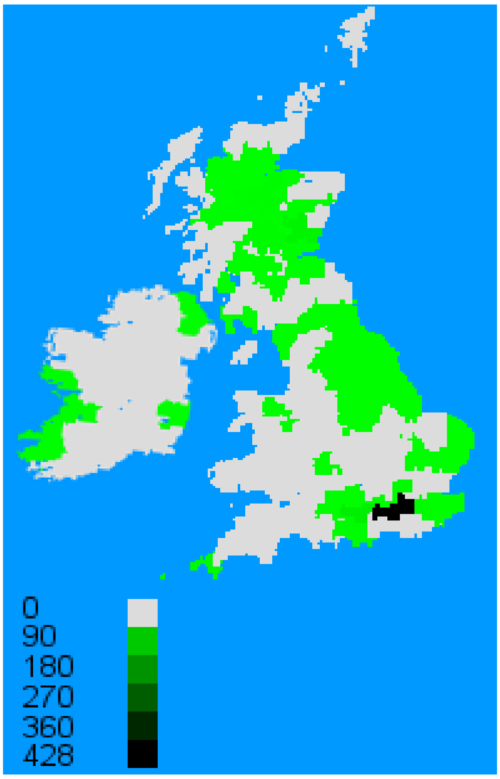


Figure 4 A digital distribution Map of Watson's collections (Total No. of species: 1328)

Stephen Dunn and the British 'Alien' Flora

Following H.C. Watson, one of the earliest British botanists who popularised the term '*alien*' was the British taxonomist Stephen Troyte Dunn (1868-1938). Dunn worked at the Kew Herbarium and served as the superintendent in the Department of Botany and Forestry (1903-1910) in Hong Kong. At Kew, Dunn would have examined large collections of specimens stored at the Herbarium [15].

[13] Egerton (2003) noted that Forbes' botanical production was rather limited (especially if compared with that of Watson). Nevertheless, Forbes became the Professor of Botany at the University of London in 1842 much to Watson's resentment. Because Forbes' professorship salary was not sufficient, he also worked for the Geological Survey of Great Britain as a palaeontologist. Undoubtedly, Forbes used the geological data he had as an advantage.

[14] **Herbaria@home** The digital library is available at: **http://herbariaunited.org/core/specimensearch.php?collector=Mr+Hewett+Cottrell+Watson&colid=2696&search=search&start=160&#searchlist)**

[15] Dunn's association with Kew lasted about 30 years He was an Assistant in the Herbarium for India (1901-1903); before becoming Superintendent of the Botany & Forestry Department, Hong Kong (1903-1910). Dunn had also worked on compiling the 2nd supplement of the *Index Kewensis* (1913-1915) and assisted J. S. Gamble in the preparation of the *Flora*

Just as much as Watson wrestled with designating species as '*native*' or '*alien*', Dunn (Figure 4), too, laboured in categorizing plant species in this way without extensive knowledge of historical plant distributions and current phyto-geography.

In the introduction to his book – "*Alien Flora of Britain"* (Dunn, 1905, p. vii), Dunn clarified that: "*The term alien is used to designate any species which, though now spontaneous, originated in Britain through the human agency*". The definition shows that Watson and Dunn categorized '*alien*' species simply as plants 'introduced' by man. Agreeing further with Watson, Dunn said: "*it is seldom possible to obtain any definite information as to the manner in which they actually arrived in the country*".

Figure 5. A rare photograph of S. T. Dunn from Kew Archives

'Aliens' and 'Unnatural Habitat'

The following passage shows Dunn's thoughts on '*alien*' species went further than those of Watson:

> *"…The term "introduced plant" is not really distinctive, for all plants, native and otherwise, must have been originally introduced to their present habitats. In the great majority of cases, botanists arrive at their conclusions as to the status of a species by a careful observation of its present circumstances in the British Isles, and also of its geographical distribution beyond them…"*
>
> *"…Thus, a species which exists in perfectly wild and natural surroundings, both here and in the neighbouring parts of the world, is deemed 'indigenous', for there is no reason to suppose that its presence is due to any agent but natural dissemination at the time when the flora of North-West Europe originated..."*
>
> *"…**If, on the other hand, a species is always found to be connected with artificial surroundings, it is classed as an 'alien'**..."*

From his viewpoint, '*unnatural habitat'* (i.e. disturbed areas, affected by humans) was '*what botanists must chiefly rely on to distinguish the true alien*' (Dunn, 1905, p. x). Such areas were affected by the human hand and human habitations, e.g., home gardens, agricultural land, waste dumps, roads, railway tracks. Dunn also included pastures and other areas affected by the waste of domesticated animals, pointing out that grazing (viz. disturbances) 'artificially' changes the naturally existing flora.

Regarding species occupying areas of 'natural waste', such as the haunts of wild animals, he reasoned that: '*they offer much the same conditions as those of domesticated cattle, and the natural waste ground flora has been carried on by artificial conditions*' and favoured designating species found on a natural waste site also among the '*aliens*'.

Dunn (1905, p. iix) emphasized how difficult "*the problem presented by some plants, which abundantly accompany human operations but also occasionally appear in wild habitats in their neighbourhoo*d". He then classified the '*better-established aliens*' under the special 'artificial habitats' they inhabit and affect.

> *"…Thus, those which inhabit roadsides are sometimes known as viatical weeds, those of cultivated fields called agrestal, and so on, but the classes are not clearly enough defined to derive much elucidation from these terms…"*

Dunn's writings on '*alien*' species are clear on the role of humans in both species introductions and in creating habitat conditions under which some species thrive and spread widely even into a natural habitat and establish ('*naturalized*'). While some species can grow spontaneously ('wild'), becoming independent of man, others depend on disturbances caused by man's activities for existence.

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of the Presidency of Madras. He then visited America and on his return was re-appointed at Kew as Assistant for India (1919-1925). From 1925-1928 he acted as a Botanist in the herbarium [Sources: (1) **https://en.wikipedia.org/wiki/Stephen_Troyte_Dunn**); (2) Kew Archives: S. T. Dunn at Kew (**https://www.kew.org/read-and-watch/on-the-min**)].

He wrote:

"…In artificial habitat, accompanying human operations, some plants seem especially to take advantage of the (mechanical) disturbance of the ground and the unnatural supply of plant food. Cultivated fields, again, with their abundance of plant-food, harbour all sort of weeds, but only those gain permanence which by quick seeding can withstand the frequent ploughings…" (Dunn, 1905, p. xi).

On 'Natives'

In sharp contrast to the '*alien*' flora, Dunn's '*natives*' were: '*species, which occurred in a natural locality to which it has spread by natural means from a natural source; that is, when it has been disseminated as it would be in a state of absolute nature*'. He stated the spread of plants by water, wind and birds as 'natural means' (Dunn, 1905, p. ix-x).

Dunn, therefore, used the evidence of long-term residency, spread by *natural* means and the abundant occurrence of a species in association with a specific (natural) habitat, as characteristics of identifying it as a '*native*' (Dunn, 1905, p. ix). However, he did not favour calling '*native*' species '*aboriginal*' because:

"…it implies a knowledge of the history of species, which we seldom possess. If the term "aboriginal" were substituted for "native", in many of our local Floras, expressions such as "native on walls, and by roadsides" and "native in hedgebanks" would be inconsistent, for no species could be aboriginal in these situations…" (Dunn, 1905, p. ix)

Introducing agents

Dunn (1905, pp. xiii-xvi) agreed with Watson that economic activities of humans; viz. ships' ballast (including coal ships) and the importation of materials, such as agricultural seeds, flour-making grains, bird-feed seeds, hay, wool, skin, hides and furs, were the primary sources of most 'alien' weeds [16].

Dating back to at least the 14th Century (Dunn, 1905, p. xiv), he cited many species whose 'native' ranges were outside Britain, ranging to Eastern Europe and also as far as Western Asia (the orient). Invoking Watson's '*stragglers*' and '*casuals*', whose presence was always transient in disturbed habitat, Dunn agreed that constant re-introductions were necessary for such species to maintain their presence (Dunn, 1905, p. xiii).

"…By far, the most important agent of plant introduction at the present time is the importation from foreign countries of the kinds of grain, which are most largely used for making flour and for distilleries. In every sack, countless seeds of the corn-field weeds of the country of origin come mixed with the grain.

"…Before the grain is used, these seeds are sifted out and are either thrown away with other rubbish on waste ground or sold for feeding domestic fowls and game. In the former case, astonishing crops of exotic weeds may be produced in a small area, and some of them will possibly survive and become established there for a time..."

"…In the second case, the aliens will spring up here and there around cottages, along roadsides, in coppices, or wherever the birds fed. All the species introduced in this way must be 'corn-field weeds'. It should be remembered that corn has been continuously imported since the 14th Century at least and that some of our oldest recorded weeds may be due to this source…" (Dunn, 1905, p. xiii)

As stated in the *Summary* (p. xv), Dunn enumerated 924 'introduced species' as '*aliens*' in the British Flora. He categorized: (a) 123 as '*old-established weeds of uncertain origin'*; (b) 332 as introduced through horticulture and arboriculture; (c) 206 are *'casual', 'grain-sifting' aliens of recent appearance and little permanence*'.

The *Summary* also refers to 170 other species, '*indicated in square brackets, the greater number are common weeds, recorded from artificial habitats only, but which the author believes to be true natives'* [17].

Dunn pays tribute to the Herbarium and library of Kew, saying: '*The work could hardly have been done in any less completely equipped establishment, for it has been necessary to obtain details of the native area of British plants over the greater part of Europe and Western Asia*…". In the acknowledgement, much like Watson did, Dunn, too, pointed to the absence of relevant bio-geographical information in the floras:

"…And the existing compilations upon the subject afforded little help. In them, no discrimination is attempted between the truly native area and the area over which the plants are wild. Reference has therefore been

[16] Despite the numerous wars and the movements of ships, transporting both soldiers and military equipment, Watson and Dunn do not refer to this contamination pathway as an 'introducing agent' of weedy taxa to Britain.

[17] The *Summary* does not state what the other 93 species are but a presumption that they were considered by Dunn as already 'native' to or well on the way to becoming 'naturalized' in at least some parts of the British Isles appears valid.

necessary to individual foreign local Floras in order to ascertain the exact habitats and status of each species…." Dunn (1905, p. xv)

In the book, Dunn acknowledged Watson's *Cybele* and various other publications, especially articles in the *Journal of Botany*, notes (preserved in the Botany Department of the British Museum) and Watson's herbaria (held at Kew), along with Alphonse De Candolle's *Géographic Botanique*, among the sources he studied. Although Dunn does not state explicitly, it is clear that he followed much of Watson's reasoning regarding how to distinguish between 'true natives' vs 'introduced species'.

However, Dunn jettisoned the term 'denizen' completely, preferring to lump Watson's '*colonists*' and '*casuals*' as '*aliens*', which follow human-caused disturbances (i.e. they were species, which did not generally grow in habitat unaffected or independent of human-caused disturbances). He also applied the term '*wild*' to all plants adapted to grow spontaneously without the aid of the human hand (i.e. *naturalized*).

With his studies on other floras, Dunn differed from Watson's determinations of 'nativeness' of several species (i.e., *Viola, Brassica, Anthemis, Cotula barbata*), favouring to list them as '*naturalized aliens*'. Revisions, such as those, are not uncommon in botany, as additional information on the bio-geographical distributions of species become available based on fossil records and their current abundances elsewhere.

My analysis shows that Watson's '*aliens*' and Dunn's '*aliens*' were merely introduced species with special attributes to spread widely. Interestingly, neither botanist called these '*exotics*' – a term that crept into the botanical jargon in subsequent decades [18]. Their ideas converge on many aspects. For instance, in the absence of much geological evidence, both (erroneously) believed that the '*alien*' species did not arrive in Britain independently of humans, nor could many of them exist without man's help. Watson implied, and Dunn named it by stating: '*Artificial habitat'* conditions were essential for the '*aliens*' to establish. They agreed that, over time, the identities of many 'aliens' would be so 'obliterated', and it would be hard to distinguish them from '*true natives'*.

Subsequent geological research, of peat deposits and organic matter from bogs and lake basins formed during the ice ages (see below) proved that many of the extant 'weedy' species did arrive in the British Isles via natural agencies when the sea levels were much lower in the North Sea, and the English Channel and the islands were connected to the European landmass (Godwin, 1960). After the first establishment, it is unlikely that any pioneering species ever fully 'disappeared' from the flora, except perhaps from very localized areas.

Although species transformations and evolution were not major themes for the two botanists, both drew attention to closely allied species, which may have evolved from common ancestors.

Almost a century after Watson and at least 50 years after Dunn, our founders (Bunting, 1960; Baker, 1965) recognized: the common attributes (adaptations) of colonizing taxa; the critical role of human-caused and natural disturbances in the success of such taxa; and the environmental factors, which are conducive to their establishment. In discussions of the evolution of 'weeds', the possibilities of crossing between closely-allied species are also widely acknowledged.

Apart from commenting on the abundance of species in a specific habitat and spreading wildly, neither botanist wrote about 'ecological explosions' or 'habitat invasions' attributed to the 'aliens'. The current knowledge of the history of ecology enables us to suggest that ecological studies of the potential effects of introduced species came after the eras of both botanists. However, some foundational ideas on weeds – that of human-caused habitat disturbances (including agriculture) and the direct role of humans in the global spread of colonizing taxa - can certainly be attributed, at least in part, to their diligent research.

The Post-Watson-Dunn Era

When they collected and examined common and rare species and studied where they occurred, the focus of those industrious 18th Century botanists was firmly on species, which formed the extant British flora. While attributing nearly all of the 'aliens' to human introductions and human-disturbed habitat, Watson and Dunn were acutely aware that even the so-called 'aboriginal natives' may have also been immigrants into the British Isles, at different dates, from other lands, at some ancient geological times.

Discussing how and why plant species got to where they are currently distributed (i.e. geographical botany), Watson was handicapped by the lack of geological data, such as continental drifts and changes in sea levels during the past ice ages.

[18] '*Exotic*' – a term dating back to the 16th Century, directly from Latin *exoticus*, means "*foreign*" literally "*from the outside*", "*belonging to another country*"; it was used in 1620s in referring to 'exotic' strip-teasers and dancing girls; the term is nowadays used to refer to 'foreign' introduced plants.

Importantly, Watson's *Cybele* and Dunn's '*Alien Flora'* are notably devoid of slander of plant species. Even implicitly, they did not write about 'alien invasions'. Without hyperbole, they wrote on the species' ranges, climatic and other factors that cause plant distributions to expand across continents. A secondary motive, especially with Dunn, might have been to caution other botanists on the risks associated with plant introductions, purposely or accidentally. In the latter part of the 19th Century, as the British Empire grew, Dunn was much aware of the exchanges of live specimens among botanic gardens and enthusiastic plant collectors.

My analysis shows that the absence of geological evidence, such as fossil deposits, pollen analysis, and carbon dating, impeded the determinations of mostly of Watson, and to a lesser extent, Dunn. By mid-20th Century, scientific advances enabled such data and information to establish the origins and history of the 'aliens', specifically, the weedy flora in Britain.

Harry Godwin (1901-1985), a high-profile English botanist, ecologist and 'peatland scientist' who worked at Cambridge, stands prominent in this regard [19]. Later knighted for his work, Godwin was the founder and first Director of the Sub-department of Quaternary Research at Cambridge in 1948 and is acknowledged as the pioneer of the new radio-carbon dating technique of fossils. Godwin's laboratory examined pre-historic deposits from specific sites combining both geological and biological techniques. These included examining fossil impressions in clay and mineral deposits, microscopic pollen identification (palynology), radio-carbon dating, and macroscopic identification of genera and species through carbonized fruits, seeds, and tubers.

Godwin (1960) rejected the view that '*those unwelcome occupants of pasture, wayside and cultivated land*' and '*habitual camp followers*' had entered the country with Neolithic farming in the Bronze Age (3100-1200 BC) [20]. His analyses showed that the entry of many British weeds and ruderals, mainly from the European continent, was long before Neolithic agriculturists entered Britain. Geological evidence suggested that due to the lowering of the ocean level, the southern North Sea was dry throughout the Late-glacial and early Post-glacial periods. As a result, *'the natural migration to and from the Continental mainland was far easier than it afterwards became*' (Godwin, 1960, p. 4).

Expanding weed populations, well before the Bronze Age included many ruderal species, such as mugworts (*Artemisia* L. sp.), nettle (*Urtica* L. sp.), plantain (*Plantago major* L. or *P. media* L.), docks (*Rumex*), clover (*Trifolium*), fairy flax (*Linum catharticum* L.); perennial knawel (*Scleranthus perennis* L.), cornflower (*Centaurea cyanus* L.), lesser knapweed (*Centaurea nigra* L.), *Chenopodium* L. spp., spear thistle [*Cirsium vulgare* (Savi.) Ten.], and musk thistle (*Cardus nutans* L.). Such species survived in the Late-glacial vegetation, dating back to the last Ice Age (ca. 12,000 years ago) [21].

Godwin (1960) highlighted man's role in clearing forests and conversion of the countryside to agriculture and the construction of drainage and road networks, built during the Roman (ca. 55 BC-410 AD) and Anglo-Saxon (ca. 410–1066 AD) periods in Britain [22], as the primary causes of the spread of weedy species in those ancient times. The geological evidence examined has proven that deforestation in Britain began in Neolithic times (about 12,000 years ago) and intensified in the Bronze Age, Iron Age (ca. 1200 BC -100 AD) and subsequent times.

Romans introduced many 'exotic' species from continental Europe for food, flavourings, cosmetics, or other purposes. Examples are - fruit trees [e.g., black mulberry (*Morus nigra* L.); plums (*Prunus domestica* L.); vine (*Vitis vinifera* L.); fig (*Ficus carica* L.)]; vegetables [e.g., parsnips (*Pastinaca sativa* L.), peas (*Pisum sativum* L.); beans (*Vicia* L. spp.); wild radish (*Raphanis raphanistrum* L.)]; spices [e.g., fennel (*Foeniculum vulgare* Mill.); coriander (*Coriandrum sativum* L.); dill (*Peucedamun graveolens* (L.) Hiern.)]; and medicinals [e.g., belladonna (*Atropa belladonna* L.)]. Godwin (1960) also suggested that some of these later established as ruderals, while others may have failed. However, such introductions

[19] Harry Godwin, Professor of Botany, Cambridge University (1960-67); Editor of *New Phytologist* (1931-61);and *Journal of Ecology* (1948-56) (**https://en.wikipedia.org/wiki/Harry_Godwin**).

[20] Godwin's important contribution was made at the 1959 Symposium on: *The Biology of Weeds*. Ideas about the need to better appreciate weed biology and ecology came around in the late-1950s. Leading the effort, John Harper (Oxford University) organized the symposium under the auspices of the *British Ecological Society*, at Oxford, April 2-4, 1959. This seminal event turned the attention of weed researchers to focus more on the origin, evolution, taxonomy, biology and ecology of weeds, including their reproductive systems and habitat preferences.

[21] The most recent glaciation period peaked 18,000 years ago before the interglacial Holocene period began 11,700 years ago (Source: **https://en.wikipedia.org/wiki/Last_Glacial_Period**).

[22] Sources: (1) **https://www.historic-uk.com/HistoryUK/HistoryofBritain/Timeline-of-Roman-Britain/**; (2) **https://www.history.org.uk/primary/resource/3865/anglo-saxons-a-brief-history).**

must have been accompanied adventitiously by many species now part of the British flora.

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Five decades after Dunn, in a period disrupted by two World Wars, Edward Salisbury (1886-1978) [23], a Professor of Botany at the University College, London, re-invented the term ‘*alien*’. Somewhat unfortunately, his book was titled “*Weeds & Aliens*” (1961). During 1943-56, Salisbury was also the Director of Kew Gardens in London, at the height of World War II and what followed. He, too, had access to century-old herbarium specimens at Kew and other Herbaria and considerable interest in weeds.

A book, so provocatively entitled, published while the discipline of *Weed Science* was just about taking shape in the late-1950s and early-1960s, would have had an impact. However, other scientists cautiously avoided the term for many decades until it was again re-invented by the more recent ‘*invasion*’ narrative.

Salisbury likely meant to follow Watson and Dunn and used the term '*alien*' interchangeably with '*introduced*'. Nowadays, some authors use the term to refer to plants becoming weedy when transferred from their native to an *alien* environment, meaning a new environment. Here, while the emphasis is on the new environment, the organism is also regrettably branded with unfavourable undertones, an *alien foreigner* [24].

By combining the terms ‘*weeds*’ and ‘*aliens*’, Salisbury’s book directly spoke to the fear people had of squatters and homeless people, who were plentiful in London during World War II. Floods of refugees entered Britain from Europe due to the massive displacement of people during the war. Salisbury’s words may have reflected such fears of ‘foreign’ immigrants and widely-prevalent attitudes at that time, depicted in many books and films. Still, you could excuse the layperson for being confused!

Inadvertently, Salisbury had given those human adversaries of weeds who want 100% control of colonizing species the perfect weapon! Taking the cue from him, other senior botanists have also used the term. Hiram Wild, a renowned botanist from South Africa, in 1967, published a paper on ‘*Weeds and Aliens’* in Africa and their origin as ‘*American Immigrants*’ (Wild, 1967). Peter Kloot, an Australian botanist, also borrowed the term in discussing plants from overseas, now naturalized in South Australia (Kloot, 1983). The term ‘alien’ was superfluous in both these articles for their key botanical messages.

My view is that the word ‘*alien*’, prone to misinterpretation, was then, and even now, is superfluous to enlightened discourses on colonizing taxa. Alongside the absurd militaristic metaphors (viz. ‘*enemies*’; ‘*invasions*’, ‘*invading armies*’) are relics of the past (see Darlington, 1859; Evans, 2002 [25]) ‘*alien*’ is a term best avoided in dealing with such species.

Alien Plants of Australia

Peter Michael (1994), an Australian botanist, and taxonomist contributed to understanding how the term ‘*alien*’ has been used. He simply followed Watson’s definition and focused on species introduced to Australia from other regions and their possible origins based on available records. Stating how difficult it is to establish whether a particular species is ‘native’ or ‘alien’, he explained:

> *“…In Australia, as in other countries, a high proportion of the ‘alien species’ are weeds of cultivation, pastures, roadsides, and waste places. These weedy aliens may be called* ***pioneer species because of their ability to colonize disturbed or denuded land****. During the history of land development in Australia, relatively few native species have behaved in this way…”.* Michael (1994)

As both Watson and Dunn did, Michael noted that many such ‘alien’ species were strongly associated with man’s activities (viz. settlement, cultivation, home gardens, roadsides, waste places). Some arrived in Australia accidentally along with crop and pasture seeds; others were introduced intentionally.

Quoting Darlington (1963), he pointed out that the ‘*alien*’ species, in general, could be traced back to the regions of origin of crop plants (i.e., South-West, Central and South-East Asia, the Mediterranean, Europe, Central Africa, the USA and Peru, Chile, Brazil and Paraguay in South America). Those that

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[23] E. J. Salisbury (See: **https://en.wikipedia.org/wiki/Edward_James_Salisbury**).

[24] The International Union for Conservation of Nature (IUCN) describes ‘aliens’ as follows:

‘*An Introduced or Alien species means a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e., outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans). It includes any part, gametes or propagule of such species that might survive and subsequently reproduce’*.

‘*An Invasive Alien Species is an alien species, which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity*’.

[25] Clinton Evans’ environmental history book – “*War On Weeds In The Prairie West*” gives a detailed account of the evolution of war-like rhetoric and the hardline attitudes towards weeds in North America.

are sufficiently well established ('naturalized') are widespread and occupy vast areas of the Australian continent. Such species can be considered '*true constituents of the Australian flora'* (Michael, 1994).

He also pointed out that some species, such as creeping woodsorrel (*Oxalis corniculata* L.), in the broad sense, are represented by both '*alien*' and '*native*' forms. Many of the 'alien' species in Australia are also found in a wide range of naturalized floras throughout the world, as Michael (1994) pointed out.

As an example of an 'alien', apparently 'invading' undisturbed native vegetation of Australia, Michael (1994, p. 51) stated the studies of Westman, Panetta and Stanley (1975) on the occurrence of groundsel bush (*Baccharis halimifolia* L.) in uncleared swamps of swamp oak [*Melaleuca quinquenervia* (Cav.) S.T. Blake]. However, such marshes would likely have been continually disturbed by inundation and wetting and drying cycles.

Conclusions

As Watson and Dunn so clearly enunciated, humans, species introductions and disturbed habitat associated with humans were the key aspects of calling a species '*alien'*. There is little doubt that Watson was the primary initiator of the term in botanical literature. However, he applied it only to describe some species in the British Isles that he could not ascribe to other categories.

Watson's 'aliens' were 'immigrants', the greatest majority of which were introduced by accident from Europe, Asia, and the Americas. Despite other contemporary botanists of the era avoiding Watson's terms, the adoption of the word '*alien*' by Dunn in the title of his book gave the term increased credibility.

Watson, unknowingly, set in motion a trend that he could easily have avoided. Some decades after Watson, Dunn, a much-respected botanist of the 'Empire', expanded the meaning of the term 'alien' to include many taxa that Watson had previously categorized as 'colonists' in agricultural landscapes and 'casuals' at disturbed sites. Dunn, too, could have avoided the term without losing the substantive value of what he wrote. Both could have, instead, just referred to such species as 'introduced plants', which might be considered a relatively neutral clear-cut term, without prejudices and bias.

The term '*alien*' is applied nowadays to both animals and plants with little regard for what it means, its implications, or why scientists of the past centuries used the term. In Matthew Chew's opinion (*pers. comm.*, 19 June 2021), there is no chain of credible historical evidence to show that the term 'alien' was appropriated by Salisbury or those who followed.

It is still important for weed researchers to note that as the discipline of *Weed Science* was taking shape, in the crucially important *Weed Biology Symposium* of 1959, eminent scientists, led by John Harper (1960), discussed introduced species and various other weeds without referring to them as 'aliens'. They avoided exaggeration.

While all botanists and ecologists should appreciate H.C. Watson and S.T. Dunn for their colossal botanical contributions, their popularisation of the term '*alien*' may have inadvertently given a perfect weapon to the human adversaries of weeds to treat these highly resourceful organisms with contempt. Negative assumptions on weeds, formed over two centuries in agriculture, have hindered ecologically oriented weed research in areas outside agriculture. Weedy species are not our 'enemies', nor are they 'aliens'. Such negative and definitive terms narrow our vision. Their use, alongside the rampant use of war-like messaging, are unlikely to assist any society in managing colonizing taxa in any situation.

I believe that rallying the public to manage the adverse effects of any colonizing species, introduced to regions away from their native ranges, should be done best with a deeper ecological understanding of individual species rather than confusing terminology. Management should also keep an eye out for economic, environmental, and social implications, without dramatizing issues, and avoid messages that create a visceral dislike for the colonizing plant taxa.

In concluding, I reiterate that ***weedy species are no more alien or villainous than man himself***. With or without humans on the planet, colonizing species will play vital roles in stabilizing the earth's damaged ecosystems, as pointed out by Alfred Crosby (see quote on p. 1). They will also survive any catastrophe on the planet much better than humans would.

To end this essay, I refer to two important quotes, which inspire me every day. Perhaps, other weed scientists may also see weeds and the world in that way? I certainly hope so.

> *"…Justice requires, in the case of plants and persons, everyone shall be innocent until they are proven guilty of wrong..."* Gerald McCarthy (1892)

> *"…Those who cannot remember the past are condemned to repeat it..."* George Santayana (1906, p. 284)

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Literature Cited

Baker, H. G. (1965). Characteristics and Modes of Origin of Weeds. *In*: Baker, H. G. and Stebbins, G. L. (Eds.) *The Genetics of Colonizing Species*. Proceedings 1st International Union of Biological Sciences Symposia (General Biology). Academic Press. New York. 147-169.

Bunting, A.H. (1960). Some reflections on the ecology of weeds. *In*: J. L. Harper (Ed.) *The Biology of Weeds.* Blackwell Scientific, Oxford. pp. 11-25.

Chandrasena, N. (2019). Seeing 'Weeds' with New Eyes. *Weeds*, 1 (2): 1-12.

Chandrasena, N. R. (2020). 'Alien' Species, 'Pertinacious Weeds' and the 'Ideal Weed' – Revisited. *Weeds*, 2 (2): 1-16.

Chew, M. K. (2006). *Ending with Elton: Preludes to Invasion Biology.* Ph.D. Thesis, Arizona State University, Tempe, Arizona (Available at: https://www.academia.edu/4948103/Ending_with_Elton_Preludes_to_Invasion_Biology).

Crosby, A. W. (1986). *Ecological imperialism: The Biological Expansion of Europe, 900-1900*. Cambridge University Press, NY, pp. 368.

Darlington, W. (1859). *American Weeds and Useful Plants: Being a Second and Illustrated Edition of Agricultural Botany*. A.O. Moore Publisher. pp. 460. (Available at: https://play.google.com/books/reader?id=YjBjAAAAIAAJ&hl=en&pg=GBS.PR1).

Darlington, C. D. (1963). *Chromosome Botany and the Origins of Cultivated Plants*, 2nd Edition. George Allen & Unwin, London. p. 231.

Darwin, C. (1859). *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*. London: John Murray. p. 466 *(*http://darwin-online.org.uk/converted/pdf/1861_OriginNY_F382.pdf*).*

De Candolle, A. P. (1855). *Géographie Botanique Raisonnée*, Vol. 2, Paris (Available at: https://www.biodiversitylibrary.org/bibliography/62718)).

Dunn, S.T (1905). *Alien Flora of Britain*. London, West, Newman & Co. pp. 236 (https://archive.org/details/alienfloraofbrit00dunn/page/n5/mode/2up).

Dwyer, J. (2012). Messages and metaphors: is it time to end the 'War on Weeds'? Keynote Address. Proceedings 18th Australasian Weeds Conference, Weed Society of Victoria Inc., pp. 297-305.

Egerton, F. N. (1979). Hewett C. Watson. Great Britain's first phytogeographer. *Huntia*, 3: 87-102.

Egerton, F. N. (2003). *Hewett Cottrell Watson: Victorian Plant Ecologist and Evolutionist*. Taylor & Francis, U.K. pp. 312.

Egerton, F. N. (2010). History of the Ecological Sciences, Part 36: Hewett Watson, Plant Geographer and Evolutionist. *The Bulletin of the Ecological Society of America,* 91 (3): 294-312 (https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/0012-9623-91.3.294).

Evans, C. (2002). *War On Weeds in the Prairies West: An Environmental History*. University of Calgary Press, Calgary, Alberta, p. 309.

Falck, Z. J. S. (2010). *Weeds: An Environmental History of Metropolitan America*. University of Pittsburgh Press. p. 256.

Fattorini, S. (2017). The Watson–Forbes Bio-geographical Controversy Untangled 170 Years Later. *Journal of the History of Biology*, 50: 473–496.

Godwin, H. (1960).The History of Weeds in Britain. pp. 1-10. In: Harper, J. L (Ed.) *The Biology of Weeds*. A Symposium of *The British Ecological Society*, 2-4th April 1959. Blackwell Scientific Publications, Oxford.

Gray. A. (1879). The Predominance and pertinacity of weeds. *American Journal of Science and Arts*, 85 (2): 161-167 (Re-published by Sargent, C.S. (1889). *Scientific Essays of Asa Gray*. Vol II. Essays and Biographical Sketches, 1841-1886.

Houghton Mifflin, NY, pp. 234-243) (Available at: https://www.semanticscholar.org/paper/The-pertinacity-and-predominance-of-weeds-Gray/1d0eee0b8bac1152ba5db00cf1d1ff6a76d92b33).

Guiaşu, R. C. and Tindale, C. W (2018). Logical fallacies and invasion biology. *Biology & Philosophy*, 33: 34 (Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6133178/pdf/10539_2018_Article_9644.pdf).

Hall, M. (2003). Editorial: The native, naturalized and exotic – plants and animals in human history. *Landscape Research*, 28 (1): 5–9.

Harper, J. L (Ed.) (1960). *The Biology of Weeds*. A Symposium of *The British Ecological Society*, 2-4th April 1959. Blackwell Scientific Publications, Oxford. p. 256.

Kloot, P.M. (1983). Early Records of Alien Plants Naturalized in South Australia. *Journal of Adelaide Botanic Gardens*, 6 (2): 93-131.

Marsh, G. P. (1864). *Man and Nature*, *Or Physical Geography Modified by Human Action*. Sampson Low, Son and Marston, London. p. 599 (Available at: https://archive.org/details/bub_gb_4tKNdhQYypgC).

Michael, P. W. (1994). Alien Plants. Chapter 3 (pp 44-64) In: Groves, R. H. (Ed.). *Australian Vegetation*. 2nd Edition. Cambridge University Press, U.K.

McCarthy, G. (1892). Letters to the Editor. *American Weeds*. *Science,* 20 (493): 38. (Available at: http://science.sciencemag.org/content/ns-20/493/38.1).

Meikel, R. D. (1948). H.C. Watson. *Watsonia*, 1: 3-5 (Available at: https://www.biodiversitylibrary.org/item/165153#page/15/mode/1up).

Salisbury, E. (1961). *Weeds & Aliens*. The MacMillan Co., New York. p. 384.

Santayana, G. (1906). The Life of Reason; or The phases of human progress. Chapter XII: Flux and Constancy in Human Nature. (p. 284). Archibald Constable & Co., London (Available at: https://archive.org/details/thelifeofreasono00santuoft/page/n5/mode/2up).

Thellung, A. (1912). La flore adventice de Montpellier. *Mémoires de la Société Nationale des Sciences. Naturelles et Mathematiques de Cherbourgh*, 38, 57-728 (esp. 622-647).

Tull, J. (1762). *Horse-Hoeing Husbandry or An Essay on the Principles of Vegetation and Tillage.* (Available at: http://www.archive.org/details/horsehoeinghusba00tull).

Watson, C. H. (1847). *Cybele Britannica*, or British Plants and their Geographical Relations. Volume I. London: Longman & Co. p. 484. (https://www.biodiversitylibrary.org/item/104172#page/5/mode/1up).

Watson, C. H. (1849). *Cybele Britannica*, or British Plants and their Geographical Relations. Volume II. London: Longman & Co. p. 492 (Available at: https://www.biodiversitylibrary.org/item/104169#page/5/mode/1up).

Watson, C. H. (1852). *Cybele Britannica*, or British Plants and their Geographical Relations. Volume III. London: Longman & Co., p. 574 (Available at: https://www.biodiversitylibrary.org/item/104168#page/7/mode/1up).

Watson, C. H. (1859). *Cybele Britannica*, or British Plants and their Geographical Relations. Volume IV. London: Longman & Co. p. 552 (Available at: https://www.biodiversitylibrary.org/item/104170#page/5/mode/1up).

Watson, H. C. (1870). A Compendium of the Cybele Britannica or British Plants in their Geographical Relations. London: Longmans, Green, Reader & Dyer, p. 671 (Available at: https://archive.org/details/cu31924001689326).

Wild, H. (1967). *Weeds and Aliens in Africa: The American Immigrant*. A Lecture, given at the University College of Rhodesia. 10 Oct 1967 (Available at: https://core.ac.uk/download/pdf/43541105.pdf).

PERSPECTIVE

The Parable of Pines in Australia

John Dwyer [1]

[1] Independent Writer, Melbourne, Australia

E-mail: thedwyers@ozemail.com.au

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Abstract

This article discusses the introduction and present status in Australia of *Pinus radiata* D. Don (known as Monterey Pine, Californian Pine, Radiata Pine, or Remarkable Pine) and speculates why expressions, such as 'environmental weeds' and 'invasive alien species' have been applied to it. It questions whether moves to remove this introduced species in the interests of conservation are based on science or cultural values of particular groups and touches on the implications for how we value and manage our 'natural' environments.

Keywords: Radiata Pine; environmental weeds; invasive alien species; Australian weeds

Introduction

> *'…If that the pine on Pelion's slopes had never felt the axe, and fallen to put oars Into those heroes' hands, who went at Pelias' bidding to fetch the golden fleece !'* Euripides, *Medea* [1]

In 2013 the Yarra Ranges Council in Melbourne's outer east felled two stands of mature Radiata Pine trees (*Pinus radiata* D. Don), comprising 500 trees, in the Richards Reserve in Montrose, replacing them with indigenous species. How was the decision to cut down the pines justified? The Council claimed that *P. radiata* is one of the five most widespread 'environmental weeds' in the Yarra Ranges. The pines were seen as 'Invasive Alien Species' (IAS), threatening nature conservation values. However, the Council's public statements did not refer to any assessment of the particular risks posed by these historical stands (Yarra Ranges Council, 2013).

The Richards Reserve, at its closest, is about 1 km from the Dandenong Ranges National Park and is surrounded by houses. Did the pines pose any threat to that national park? What was the basis for the judgment that the pines were environmental weeds? The felling raises questions about how we should deal with the legacy of the 19th -Century introduction of *P. radiata* to Australia – and other introduced plants, generally.

Although many environmental weed lists compiled in recent years have included *P. radiata*, a list of the most significant weeds published by the Yarra Ranges Council in 2014 did not include *P. radiata* but did include 'blackberry (*Rubus fruiticosus* L. sp. agg.), pittosporum (*Pittosporum* Banks ex Sol. spp.), English ivy (*Hedera helix* L.), spear thistle [*Cirsium vulgare* (Savi) Ten.], montbretia (*Crocosmia* Planch. spp.), creeping buttercup (*Ranunculus repens* L.), wandering trad (*Tradescantia* Ruppius ex L. spp.), Japanese honeysuckle (*Lonicera japonica* Thunb.), nightshade (*Solanum nigrum* L.) and cotoneaster (*Cotoneaster* Medik. spp.)' (Yarra Ranges Council, 2014).

A local field guide, published by the Friends of Sherbrooke Forest and the Department of Conservation, Forests and Lands, listed *P. radiata* among introduced plants present in the Sherbrooke Forest (part of the Dandenong Ranges National Park), but not among the major threats posed to the natural vegetation (Friends of Sherbrooke Forest Victoria and Department of Conservation, 1989).

[1] The quote appears in Euripides' *Medea and Other Plays* (2000), Translated by Phillip Vellacott, Penguin Books, USA.

We know little of the local residents' reaction to this alteration to their cultural landscape, but we may infer that at least some people would miss the trees. The removal was timed to avoid the seasonal feeding on the pines by Yellow-tailed Black Cockatoos (*Zanda furnera*, Shaw, 1794; syn. *Calyptorhynchus funereus*) [2], an indigenous species, which apparently knew and enjoyed the pines but would now need to look elsewhere.

The Radiata or Monterey Pine was widely planted in Australia and other countries following its discovery by Europeans in the mid-19th Century in California. Introduced from California to England by David Douglas in the 1830s under the earlier name *Pinus insignis* Douglas ex Loudon (meaning 'Remarkable pine') (Nisbet, 2009, p. 252), it is a large, handsome, quick-growing tree up to 50 m in height, with thick, dark-brown bark, which on old trees is divided by deep ridges.

The dark-green, thin leaves or needles are in three groups, 8 to 15 cm long, in dense clusters. The female cones may be solitary or in clusters, on short stalks, and are asymmetrically egg-shaped, up to 15 cm long, with scales rounded on their exposed portion. Each scale contains two winged seeds adapted to wind dispersal (Richardson, Richardson, and Shepherd, 2011, p. 9; Spencer, 1995, p. 263; Walsh and Entwisle, 1994, p. 119; The Jepson Herbarium - Jepson eFlora [3]).

Restricted in the wild to a few square miles of hilly terrain near the sea around Monterey in southern California and two small Mexican islands off Baja California, where it is now rare and endangered (Spencer, 1995, p. 264; 2002), Monterey or Californian Pine has been amazingly successful in many countries to which it has been introduced. It has also been planted in various parts of the Californian coast, where it has become naturalised. Given a fresh start in Australia, New Zealand, Italy, and South Africa, this almost extinct pine delighted foresters with its rapid growth and good form (Duffield and Stockwell, 1949).

The species is now one of the most widely cultivated timber plants in the world, in plantations covering some 3.7 million ha in all, including New Zealand (1.2 million ha), Chile (1.3 million), Australia (740,000 to 1 million) (New South Wales Department of Primary Industries, 2008) and Spain (260,000) (Wu et al., 2007). *Pinus radiata* is by far the most important tree in New Zealand (Webb, Sykes, and Garnock-Jones, 1988). Pinus has been popular as a plantation species because it grows rapidly under a range of climatic conditions, producing a most useful softwood timber (Figure 1).

It is suggested that plantation areas in the world are likely to increase. The tree has also been much planted in south-western Britain, near coastal resorts in particular, where mature trees serve as landmarks and give a distinctive character to the landscapes (Mabey, 1997, p. 25).

Figure 1 A pine plantation in* New South Wales, *Australia, grown for commercial timber harvest

It is noted that other species of pines, such as twisted pine (*Pinus contorta* Dougl.), Aleppo pine (*P. halepensis* Mill.), black pine (*P. nigra* Arnold), Mexican weeping pine (*P. patula* Schiede and Deppe), cluster pine (*P. pinaster* Ait.), western yellow pine (*P. ponderosa* Laws), Turkish pine (*P. brutia* Ten.), and Scotch pine (*P. sylvestris* L.), have also been widely introduced in the southern hemisphere and have established populations over considerably

[2] Yellow-tailed black cockatoo (**https://avibase.bsc-eoc.org/species.jsp?avibaseid=E6DFA7077084129A**).

[3] The Jepson eFlora, Vascular Plants of California, University of California, Berkeley (**https://ucjeps.berkeley.edu/eflora/search_eflora.php?name=**).

large areas (Richardson, Williams and Hobbs, 1994; Hill, 1998). However, this essay is confined to *P. radiata* because it has been the species most used in plantations in Australia, Chile, New Zealand, and South Africa.

How have Pinus trees come to fall from grace as trees introduced and cultivated for their beauty and utility for more than 150 years, since around the 1850s and come to be felled in 2013 as an invasive alien species that threatened indigenous vegetation?

Peters (1983) gave a warning referring especially to the Radiata pine that, "*despite the commercial benefits and attractive appearance of the pines grown in Australia, it is a pity that they have been allowed to invade natural vegetation to the extent they have*".

Taxonomy

The taxonomy of *P. radiata* (Figure 2) has been more complicated than the above account suggests. Ian Tyrrell, in his study of the exchange of plants between California and Australia, *True Gardens of the Gods* (1999), prefers the common name '*Remarkable Pine*', a name given by Australian foresters. '*Remarkable'* is simply a translation of *insignis,* the name given to pines originally by David Douglas.

Tyrell suggests that *P. radiata* and *P. insignis* were distinguished as different species, although 'later botanists' identified the different characteristics as 'minor variations of the same species'. Support for the suggestion that *P. radiata* and *P. insignis* were seen as separate but closely related species is provided by John Ednie Brown's *A Practical Treatise on Tree Culture in South Australia* (1883).

Brown, who was somewhat a controversial figure, did make a significant contribution to the cultivation and promotion of pines across Australian States and Territories. It seems that *P. insignis* Douglas ex Loudon, was for a time, the accepted designation but has been replaced by the more accepted name *P. radiata* D. Don [4].

Later fieldwork by Ken Eldridge and his colleagues from the CSIRO Division of Forest Research in 1978 recognised three varieties of *Pinus radiata*: viz. *P. radiata* var. *radiata* from California, *P. radiata* var. *binata* Englem. (Lemmon) from Guadalupe Island, and *P. radiata* var. *cedrosensis* (Howell) Silba from Cedros Island. The varietal name *binata* was first used by Engelmann (1880) and the name *cedrosensis* by Howell (1941), who gave a useful account of its history.

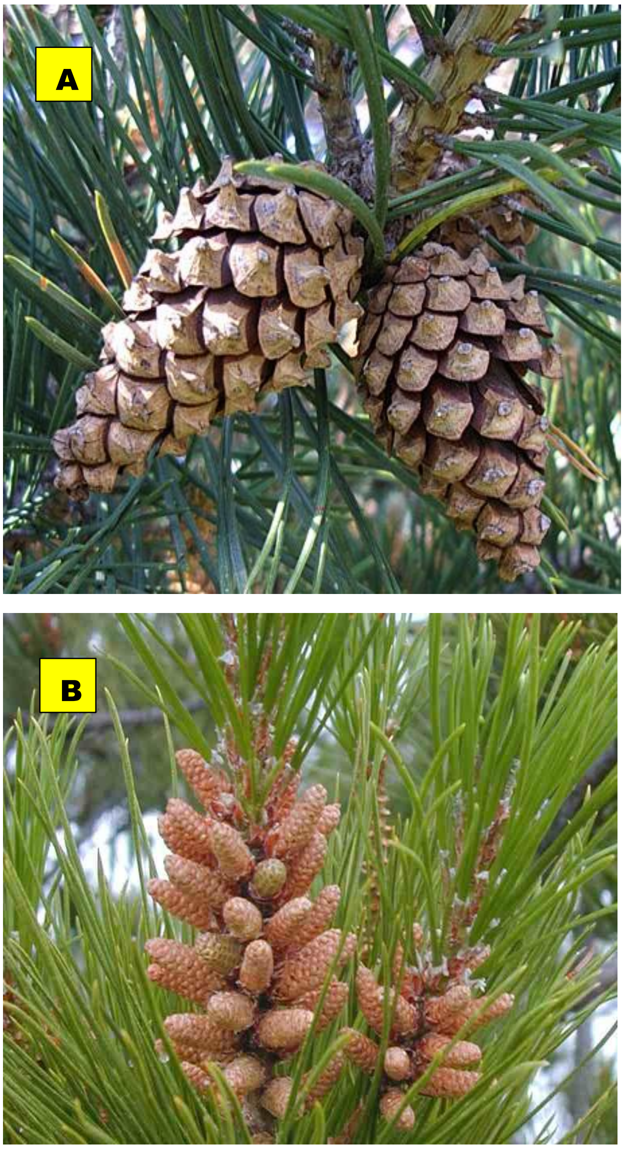

Figure 2 Female (A) and male (B) cones of Pinus radiata

[4] Don, D. (1836). Descriptions of Five new Species of the Genus Pinus, discovered by Dr. Coulter in California. *Transactions of the Linnean Society.* London, 17 (3): 439-444. (Available at: **https://www.biodiversitylibrary.org/page/13787294#page/504/mode/1up**); David Don (1799-1841), who named *Pinus radiata*, was a Scottish botanist who specialized in conifers. He was Professor of Botany at King's College, London (1836-1841), and Librarian at the Linnean Society (1822-1841); also see: Kewscience, *Plants of the World On-line* (**http://powo.science.kew.org/taxon/30020085-2.**

These two island varieties are now considered to be synonymous (Gymnosperm Database [5]). However, they are not recognised in the latest revision of *Pinus* at the Kew Herbarium[6]

Similarly, these varietal names have not been recognised in California (The Jepson Herbarium: Jepson eFlora, 2021); nor in Australia (Hill, 1998). Notwithstanding the falling out of favour, these island varieties are still under cultivation in the Westbourne Arboreta in the Australian Capital Territory (ACT), and they have long been used to widen the genetic base of *P. radiata* in Australia. These two island varieties can, however, be distinguished from the type variety by their leaves being generally in twos rather than threes. Other features align them most closely to *Pinus radiata.*

The full citation of *Pinus radiata* is *Pinus radiata* D. Don, *Trans. Linn. Soc, London 17: 442 (1837).* syn. *Pinus insignis* Douglas ex Loudon, *Arbor. Frutic. Brit.* 4: 2265 (1838).

Pinus radiata has many different common names, some of which are used in this paper. The most popular names are Monterey Pine and Radiata Pine.

Conservation Status – Global

Pinus radiata has been listed as 'Endangered' in the global scene by the International Union for Conservation of Nature (IUCN) Red Lists. The main threats for the extant populations are excessive logging and wood harvesting, pests, diseases and impacts of other weedy species [7].

Introduction to Australia

The species was possibly introduced by gold miners coming from the Californian gold rushes to the Australian goldfields in the early 1850s (New South Wales Department of Primary Industries, 2008), but other accounts say that Victoria's first government botanist, Ferdinand Mueller, introduced the Monterey Pine to Australia (Willis and Cohn, 1993, p. 67).

The earliest introduction record to Australia is of a consignment of seed for the Melbourne and Sydney Botanic Gardens in December 1857 (Spencer, 1995, p. 264). There may have been other introductions, as Adcock's Nursery of Geelong listed *P. insignis* for sale in 1857 (Brookes and Barley, 2009, p. 135). In 1857, it was listed in the catalogue of the Royal Society's *Garden* in Tasmania.

By 1858, the species was under cultivation in the Melbourne botanic gardens. In 1860 it was offered in *Rule's Nursery Catalogue* in Victoria and more widely in nurseries after that (Brookes and Barley, 2009, p. 135).

Mueller (1825–1896), government botanist 1853–96 and Director of the Melbourne Botanic Gardens 1857–73, was a strong advocate of the acclimatisation of useful plants and animals (von Mueller, 1858, 1885). He suggested, as early as 1859, that *P. insignis* would be a good plantation species.

An enthusiast for all conifers, he later described *P. radiata* as 'a splendid dark-green pine, fully to 100 feet high, with a straight stem, occasionally 8 feet in diameter' and 'the quickest growing of all pines' (von Mueller, 1885, p. 283). He propagated a large number among the tens of thousands of plants he distributed each year (Maroske, 1993).

In the 1860s, Monterey Pines were distributed from the Melbourne Botanic Gardens to other botanic gardens, cemeteries, churchyards, landowners and state reserves in Victoria and South Australia and Tasmania (Fox, 2004, p. 193; Spencer, 1995, pp. 264–265). Mueller wrote of Radiata Pine:

> *'…Most extensively distributed through the colony of Victoria and also some other parts of Australia since 1859 by the author of this work, not so much as a timber tree, but to impart quickly and interruptedly a magnificent verdure to towns and landscapes, and to afford early shelter…'* (Friends of ACT Arboret*a, p. 23).*

Rural Victoria was the main beneficiary of the hundreds of thousands of seedlings, many of them conifers including *P. radiata*, distributed by Mueller: '*it was only by determined indifference that any town or*

[5] The Gymnosperm Database. Pinus: (**https://www.conifers.org/pi/Pinus.php**).

[6] (1) Kewscience, *Plants of the World On-line – Pinus radiata* (**http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:30020085-2**; (2) The Plant List (**http://www.theplantlist.org/tpl/search?q=Pinus+radiata&_csv=on**).

[7] (1) Farjon, A. (2013). *Pinus radiata. The IUCN Red List of Threatened Species* 2013: e.T42408A2977955. (**https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T42408A2977955.en**); (2) Farjon, A. (2001). *World Checklist and Bibliography of Conifers.* 2nd edition. The Royal Botanic Gardens, Kew; (3) IUCN. 2013. IUCN Red List of Threatened Species (ver. 2013.1) (Available at: **http://www.iucnredlist.org**).

hamlet did not get plants (especially conifers) free of charge for the ornamentation of their public spaces' (Maroske, 2002, p. 424).

Between 1861 and 1866, some 7,000 Radiata Pine seedlings were distributed by Mueller in Victoria and to South Australia for ornamental plantings and windbreaks (Wu et al., 2007, p. 216). The planting of conifers, in particular *P. radiata* and Monterey cypress (*Cupressus lambertiana* Camiére; syn. *Hesperocyparis macrocarpa* Hatw.), in Tasmania in the late 19th Century was so widespread that today:

> *"…Conifers are integral to the older settled Tasmanian landscapes, especially its rural landscapes … There is a national wealth attached to this living heritage, which can occur as boundaries of internal lines of properties, in arboreta of old homesteads, as single trees, along driveways, isolated in paddocks, along roadways, almost it seems, anywhere…."*
>
> Sheridan (2011, p. 12)

Monterey Pines were also widely used in Victoria and South Australia for windbreaks around agricultural properties and ornamental planting. This use was especially popular in 1850–70 when their dark-green foliage and strong architectural form made a distinctive contribution to the landscape (Spencer, 2002, p. 265). The trees are now important components of many cultural landscapes. For example, there are 13 *P. radiata* in Walhalla cemetery, estimated in 1995 to be about 120 years old (Spencer, 1995, p. 265).

Walhalla, near the Mt Baw Baw National Park, was a gold-mining town in the 1860s and is today a historic township standing as a fascinating reminder of what was once a very rich goldfield (Blake, 1977, p. 270). Another example is at the heritage-registered Smeaton House, built for the overlander and pastoralist Captain John Hepburn in 1849–50, and one of the earliest substantial homesteads in Victoria (Heritage Council Victoria, 1974b). The perimeter of the family cemetery is planted with Monterey Pines and cypresses (Heritage Council Victoria, 1974a).

Pines, planted by German settlers in the 1860s, in what was known as Waldau and has become suburban Doncaster East, can still be found in many parts of this Melbourne suburb, particularly around George (formerly, 'German Lane') and Victoria Street (formerly, Bismarck Street), and to the south-east. They were planted as windbreaks or boundary markers for agricultural properties, orchards in particular, and serve as an indicator of historical property boundaries. There is an outstanding tree at 16 Roderick Street, Doncaster East, on the National Trust's Register of Significant Trees (National Trust of Australia (Victoria), 2001). 'The Pines' still appears as a destination on public transport serving the area.

Monterey Pines were used in 1933 for the Avenue of Honour at Moyston, in central Victoria, the only known example of a commemorative avenue to use the species. Each tree bears an inscribed plaque to commemorate men from the area who served in World War I. The avenue is also on the National Trust's Register of Significant Trees (National Trust of Australia (Victoria), 1989).

Pines planted by early settlers can generate strong emotional ties. The writer Don Watson, who grew up on a small dairy farm in Gippsland, has written about the big *P. radiata* at the front of his family's old house as recurring in his dreams, calling it 'the primary symbol in my subconscious' (Watson, 2014, p. 71).

Establishing Victorian plantations

Years of sustained endeavour were required to establish the *P. radiata* plantations of Victoria. William Ferguson (c. 1827–1887) began work establishing the State Forest Nursery at Mt Macedon in 1872. Ferguson, when employed as the gardener at Flemington House (since demolished), had developed by 1865 one of the most complete collections of *Coniferae* in the colony. His 1868 list of trees growing at Flemington included the Californian *Pinus insignis*, *P. ponderosa*, *P. radiata* and *Cupressus macrocarpa,* among other conifers.

Figure 3 Pines along a fence line in South Australia

A board of inquiry in 1867 had recommended the extensive introduction of coniferous trees into Victoria's state forests. The *Land Act 1869* provided for the reservation of land specifically for timber production. Ferguson was appointed inspector of forests and was instructed to establish the nursery at Mt Macedon. His application to the task of clearing the site and planting thousands of trees, including *P. radiata*, meant that from September 1873, all plants distributed to the many reserves managed by the Lands Department came from this nursery (Wright, 2002). By June 1873, Ferguson had successfully planted more than 10,000 of the choicest and best kinds of Himalayan and Californian timber trees, including 1,500 conifers, *P. insignis* among them (Fox, 2004, p. 207).

By the end of the 1860s, more than 276,000 ha had been set aside as state forests and timber reserves. The Ballarat and Creswick State Forest, proclaimed in 1872, was used for cutting timber until 1882, when it was closed, and John La Gerche (1845–1914) was appointed bailiff and forester to supervise the forest and take proceedings against all persons found cutting or removing timber.

In 1886 La Gerche began an experimental nursery on denuded diggings at Sawpit Gully, enclosing a 2-acre (0.8 ha) plot and transplanting more than 700 seedlings of *P. insignis* (A. Taylor, 1998, pp. 168–171). This old gold-mining site had diggings perforating the slopes and a water race traversing the spurs – a mass of weeds and eroded gullies, some completely denuded by timber splitters. La Gerche considered such disturbed slopes 'the very thing for growing pines' (A. Taylor, 1998, p. 139).

From this small beginning, the plantation was extended to 12 ha in 1888, with more than 8,500 trees planted. The 2,000 trees obtained from Ferguson's Macedon nursery included *Pinus*. The plantation reached its final size of 121 ha with 246,000 trees in 1899 (Heritage Council Victoria, 2015). Angela Taylor characterised La Gerche's achievement:

> *"…The conifers and deciduous trees La Gerche planted were ornamental as well as valuable commercial species. Since the early 1860s, they had been planted by botanists, gardeners and nurserymen in the shaping of 'a common landscape of taste'… across the colony. La Gerche's mixed plantings at Sawpit Gully have created – more than one hundred years later – a picturesque forest…"* (A. Taylor, 1998, p. 139).

The historic plantation, including areas designated as *P. radiata* breeding arboreta, is now on the Victorian Heritage Register and the Register of the National Estate. The *P. radiata* tree in the Creswick Regional Park, known as The Mother Tree, grows on the site originally used by La Gerche to raise seedlings and is seen as a significant living monument to La Gerche and his work (National Trust of Australia (Victoria), 2007).

In 1909 a State Pine Forest was established on a government reserve north of Frankston, in the 6 km^2 set aside for the 'preservation and growth of timber' under the *Land Act 1860*. More than one million trees were planted, the most successful being *P. radiata.* In 1955 wildfire destroyed a large part of the plantation, and in 1956 1.2 km^2 was excised for public housing. The resulting estate became known as 'The Pines', a name that some still prefer to 'Frankston North'.

School plantations

In the 1920s, the Victorian Education Department established a School Forestry Scheme. Schools were to lead the community, arousing interest in forestry by establishing plantations as a teaching resource and a source of revenue. By 1925 there were school plantations in Ballarat, Castlemaine, Creswick, Chiltern, and Porepunkah (Gay, 1925). However, the plantations included eucalyptus species and other conifers such as Western Yellow Pine (*P. ponderosa*), *P. insignis* was regarded as '*the most profitable to grow in school plantations*' and '*the most easily raised in seed beds'* (Gay, 1925).

By 1936, 348 plantations had been established, totalling 1,436 ha. The number of trees supplied annually-averaged 80,000–90,000 – more than a million in all (Gay, 1938, p. 68). The former State School No. 46 at Bulla, its adjacent pine plantation and suspension footbridge are on Victoria's Heritage Register, and 'The survival of mature pine trees from this plantation provides a strong visual coherence to the precinct' (Heritage Council Victoria, 1982).

By 1972, there were 638 plantations involving 702 schools, the net return from the sale of trees totalling $377,784 (Heritage Council Victoria, 1982). Nevertheless, in the 1980s, the project's value began to be questioned. Some plantations were deemed unsuccessful. The Land Conservation Council and government policy called for a reassessment of all school plantations on crown land and decided that new plantations should only be established for educational purposes where the establishment would allow rehabilitation or reforestation of cleared or eroded areas.

Remedial uses of *Pinus radiata*

Lessons learned from Sawpit Gully in using *P. radiata* to rehabilitate land degraded by mining were later applied in the Ovens Valley in north-east Victoria. Professor Alfred Ewart (1872–1937), Victorian government botanist and foundation professor of botany at the University of Melbourne, advised in 1910 that plantations should be established on land around Bright that had been degraded by mining and colonised by St. John's Wort (*Hypericum perforatum* L.). His words were: '*The only profitable use to which the dredged flats could be put would be to use them for forestry purposes, and the Bright district is admirably suited for the growth of coniferous wood'* (Ewart, 1910).

The Forestry Commission planted *P. radiata* on the weed-infested former racecourse at Bright and large areas in the Ovens Valley in 1916, resulting in 'splendid growth' by 1932 (Currie and Garthside, 1932, p. 11). Ewart's *Handbook of Forest Trees for Victorian Foresters* (1925) included *P. radiata*, as did his *Flora of Victoria* (1930).

South Australia

Radiata pines were introduced to the Adelaide Botanic Gardens as early as 1866 when Mueller provided the director with seeds for an avenue (Payne, 2007, pp. 89, 114). A Forest Board was established under the *Forest Board Act (SA) 1875*, chaired by surveyor-general GW Goyder. Australia's first commercial pine plantation was established the next year at Bundaleer (Wu et al., 2007, p. 215), where 8,000 *P. insignis* seedlings were planted (Sheldrick, 2013, p. 302).

One account of the use of *P. radiata* in forestry in Australia centres on South Australia and the work of a young Scot, John Ednie Brown (1848–1899), who had visited North America and written reports for the Scottish Arboricultural Society on the trees he found there (Tyrrell, 1999). Brown was appointed conservator of forests in South Australia at the age of 30 and was responsible for plantings of *P. insignis* in 1878–80. His *Practical Treatise on Tree Culture in South Australia* (1881) went to three editions by 1886.

Brown was Director-General of forests in New South Wales 1890–93 when the position was abolished due to economic depression. He has been called 'the father of economic and scientific forestry in Australia' (Aitken and Looker, 2002), but was a controversial figure, in part due to his belief that forests influenced climate by – among other things – increasing rainfall (Brown, 1883, p. 7). Goyder strongly opposed Brown's attempts to push planting into arid areas.

Sir David Hutchins (1850–1920), who had trained in forestry at the *Ecole Nationale des Eaux et Forêts*, Nancy, came to Australia in 1914 after a long career in forestry in India, South Africa, and other parts of the British Empire. In 1916 he was highly derogatory of Brown, alleging that his plantings were badly organised and injudicious, that he was not a trained forester, and ignorant of current trends in scientific forestry (Hutchins, 1916, p. 253). However, others concluded that Brown made a 'considerable arboricultural contribution' (Carron, 1985, p. 219), and Brown's obituary said that he had long been recognised as 'one of the best experts south of the line' and had retained the position of conservator of forests' with great credit to himself and satisfaction to the department' (West Australian, 1899).

In his *Practical Treatise on Tree Culture*, Brown wrote of the early success of *P. insignis*: 'this is one of the few introductions of pines to the colony which have succeeded to the best of expectations' (Brown, 1883, p. 93). When he left South Australia to take up his New South Wales post in 1890, Walter Gill (1851–1929), described as 'the doyen of Australian forestry', became conservator (Aitken and Looker, 2002, p. 261). Some 10,672,000 trees were planted during his term of office, and he was 'the first in South Australia to utilise successfully the Remarkable pine (*Pinus* insignis) for commercial purposes' (*The Advertiser*, 1929). During Gill's 33-year tenure, *P. radiata* became the dominant species in forest planting in South Australia (Tyrrell, 1999, p. 93).

Western Australia

In 1895, Brown was engaged by the government of Western Australia and produced a *Report on the Forests of Western Australia* (1896). The Department of Woods and Forests was created, with Brown as its first conservator, a post he held 'to the great satisfaction of the government' (Refshauge, 1969). Brown established a state nursery about 75 km south of Perth in 1897. By 1899 some 200,000 plants were under cultivation, with *P. insignis* among 50 kinds of introduced trees (Brown, 1899, pp. 55–56).

This nursery was still functioning in 2007 when it was included in the Register of Heritage Places. In 1897 plantings to that date totalled ‘Poplars of sorts, 10,000; osiers, 5000; planes, 3000; elms, 10,000; tamarisks, 7000; oaks, 500; ash, 500; New Zealand flax, 500’. The addition of 15,000 pine seedlings was planned, some of which would have been *P insignis* (Heritage Council of Western Australia, 2007, p. 7).

Nutrition and site requirements

Early advocates for *P. radiata* frequently claimed that it would do well in difficult conditions, such as degraded agricultural land and even gold diggings (Ewart, 1910, pp. 505–506). Nevertheless, it appears that '*early extensive plantings were made with scant empirical information on growth, little knowledge of diseases, and no understanding of nutritional problems associated with the species*' (Turner and Lambert, 1986, p. 325).

In hindsight, it might have been anticipated that the species would have particular nutritional needs and require favourable soil and climatic conditions to do well. An early indication of nutritional problems occurred in 1939, when extensive dieback in South Australian plantations was due to zinc deficiency (ForestrySA, 2021). The remedy was to spray a zinc sulphate solution onto the foliage early in the trees' development (Carron, 1985, p. 220).

It is now recognised that although '*Radiata Pine has proved to be a very adaptable species in its main adopted countries … its history of successes and failures shows that there are places where it should not be planted and other sites where it is ideal'* (Mead, 2013, p. 15). It prefers:

- Winter rain and relatively dry summers;
- Rainfall greater than 600 mm per year;
- A lack of hot, humid conditions;
- Long-term minimum temperatures above minus 10 degrees Celsius;
- Deep, well-drained soil. Dislikes' wet feet';
- Fertile, acid soils – higher nutrient demand than many other pine species;
- Available ectomycorrhizae, crucial for nutrient uptake;
- Moderate tolerance of salt spray; and
- A latitude zone of about 34–44 degrees (Mead, 2013, pp. 32–33).

Threats to Radiata Pines

Many thousands of *P. radiata* trees have been killed in Australia by the Sirex woodwasp (*Sirex noctilio* Frabicus), native to Europe, Asia, and northern Africa. The insect kills healthy trees by introducing a wood-rotting fungus and toxic mucous when depositing eggs (oviposition) (K. Taylor, 1981, p. 231; University of Maryland, 2008). The seriousness of the threat to *P. radiata* plantations is shown by a 1987 outbreak in South Australia, where 50,000 ha of plantations were infected, and almost five million trees died (CSIRO, 2011).

Although there were probably repeated accidental introductions before the wasp became established in Australian pine plantations, the first mainland infestation occurred near Melbourne in 1961. When a program of expanding the pine plantations began in Victoria, from that time, aiming at an additional 80,000 ha over the next 40 years, there were alarming reports of infestations by *Sirex* wasps in scattered trees and shelterbelts on private property.

An extensive eradication program involved searching out affected trees and destroying the trees and wasps. Nearly 10,000 trees were felled on more than 500 properties. This program was expensive and only moderately successful as the spread of wasps continued.

By 1962 it had been confirmed that the wasp had been in Victoria for at least eleven years (that is, since 1951) and possibly sixteen (since 1946). Encouragement was derived from the fact that, despite no attempt at control until 1962, *Sirex* had occupied relatively little country during such a long period (Forests Commission Victoria, 1963).

Sirex was first detected in New South Wales in 1980 at Albury. It slowly spread north, eventually reaching Queensland in the early 21st Century (Carnegie, Eldridge, and Waterson, 2005). Western Australia has 70,000 ha of pine plantations. As of 1992, Sirex had not established itself in that State, although there have been regular discoveries of its larvae in wood imports (Shea, 1992, p. 2).

Research from the mid-1960s onwards demonstrated the potential of nematode parasites to control Sirex by sterilising the female wasps (CSIRO, 2011). Biological control replaced eradication by destruction in Victoria from 1972 (Carron, 1985, p. 200), since when the Sirex control program has been very successful (Eldridge and Taylor, 1989, p. 5).

Other pests of *P. radiata* include the Western Gall Rust (*Peridermium harknessii*), first noted on Monterey Pines in California in 1880 and thought to have been associated with pines for millions of years as obligate parasites. Control is not easy. Mature fruiting galls can be removed but must be carefully handled to prevent spore dissemination (Adams, 1977, p. 2).

There have been recent warnings that the Giant Pine Scale, an insect that feeds on the sap of conifers, has been found in and around Melbourne. It is regarded as a serious threat to *P. radiata* plantations. Arborists have been trained in identifying and treating it, and a website established to receive reports of suspected sightings (Hyde and Ryles, 2015).

Reports of spreading pines

From the point of view of the pines and the communities that cultivated them, most of this is a success story. However, there was to be a dark side. In New Zealand, a warning was sounded by George Thomson in 1922 that *P. radiata* was spreading naturally and becoming common. Thomson went on to refer to other reports of the plant spreading (Thomson, 1922). In Australia, Ewart in 1930 noted *P. radiata* as '*spreading freely by seed, native to America and recorded as naturalised in SW, S. and E. Victoria. Creswick 1909; Beaconsfield to Emerald, 1913 (*already reported in *Ewart (1915)); Cheltenham and Mentone, 1915'* (Ewart, 1930, p. 65). Ewart had not referred to *P. radiata*'s tendency to spread freely in his *Handbook of Forest Trees for Victorian Foresters* (Ewart, 1925, pp. 476–477), nor listed it in *The Weeds, Poison Plants and Naturalised Aliens* (Ewart and Tovey, 1909), but the 1925 supplement to that work included the following:

> *"…Pinus radiata, Don, 'Remarkable or Monterey Pine' (Coniferae): This American tree was originally extensively cultivated in this State for shelter, shade and ornamental purposes, but of recent years its value for timber has been recognised. In some districts the seeds from cultivated trees have been carried by the wind to the adjoining scrub land, where they have germinated, and the young plants have established themselves among the native flora…"* (Audas and Morris, 1925, p. 13).

I infer that the spreading of pines into bushland was not apparent in 1909, but at some point, between that date and 1925, the situation changed. In any event, despite the observed spreading into adjoining scrubland, the plant was not seen as a troublesome weed.

In 1953, the New South Wales Department of Agriculture published *Weeds*, self-described as 'the most comprehensive book yet published on Australian weeds – native and introduced' (Whittet, 1962). *Pinus. radiata* was not included. Nor was it among the 283 weeds in Lamp and Collet's *Weeds in Australia* (1974), or in Auld and Medd's more comprehensive *Weeds: An Illustrated Botanical Guide to the Weeds of Australia* (1987).

Pines as controllers of other weeds

Despite *P. radiata*'s known propensity to spread, some parties continued to advocate its use to control weeds, such as St. John's Wort (referred to above) and, in New Zealand, blackberry (*Rubus fruticosus* sp agg) and Canadian or Californian Thistle (*Cirsium arvense* Scop), by planting fast-growing trees such as *P. radiata* over the patches (Hilgendorf and Calder, 1952, pp. 105, 205). The plant itself was not listed as a weed.

The environmental turn

From around the 1970s, attitudes began to change. The environment movement gathered strength, and remnant native vegetation ceased to be regarded as 'mere' scrubland, but rather as indigenous species in natural vegetation communities that should be conserved. Exotic plants invading such communities were called 'environmental weeds' (as distinct from agricultural, horticultural and ruderal weeds) in Australia (Amor and Stevens, 1976).

The expression is something of a misnomer, as every weed is in an environment. However, my observations tell me that the environmental movement is not concerned with the 'whole environment'. Instead, it appears to value only the remnant indigenous species. Introduced or exotic species are seen as undesirable or worse. The term 'invasive species' is used more generally in the USA especially, to include introduced species that spread widely without the help of humans. Some regard any naturalised, exotic species as 'invasive'.

An early voice expressing concern was Winty Calder in 1975. In discussing the vegetation of the Mornington Peninsula, south-east of Melbourne, she listed *P. radiata* as a weed, noting that it had been planted there for softwood timber, but its main use had been as windbreaks around orchards and improved pastures: it had 'naturalised, and is spreading into clumps of indigenous trees, many of which it could eventually dominate unless continually removed by hand weeding of the seedlings and young saplings' (Calder, 1986, p. 117).

How serious is the threat?

While it is clear that *P. radiata* has often spread, the question remains how serious a threat it poses for native plant communities in Australia. In 1982 the Victorian Forests Commission published a study that measured its spread into eucalypt forests at 30 sites near Myrtleford, Bright, Beechworth, Tallangatta and

Chiltern. Four Myrtleford sites were groups of mature pines planted as shelter trees, surrounded by intensively grazed farming properties. At the four Chiltern sites, the open eucalypt forest surrounding the pine plantation was mainly Blakely's Red Gum (*Eucalyptus blakelyi* Maiden).

The study found no invasion of the *E. blakelyi* forest and concluded that this forest type appeared to be unfavourable for establishing *P. radiata*. No seedlings were found in any of the shelter tree sites at Chiltern, the authors concluding that seedlings were effectively controlled by intensive grazing and might struggle in open pasture. It was noted that, in undisturbed eucalypt forest, pines could not establish among Tall Bracken (*Pteridium esculentum* Forst f. Nakai) in the riparian zone of streams or among clumps of blackberries (*Rubus fruticosus* agg) (Minko and Aeberli, 1982).

On sites carrying short native grasses, however, pines were commonly found, even when there was 100% ground cover. In eucalypt forests where Narrow-leaf Peppermint (*Eucalyptus radiata* Sieber ex DC) and Broad-leaved Peppermint (*E. dives* Schauer) predominated, the spread of *P. radiata* was found to vary according to the topography of the plantation boundary and its exposure to prevailing winds and to depend on the absence of fire and grazing.

Although the winged seeds of *P. radiata* are adapted for dispersal by wind, other factors, such as receptiveness of the ground, the type and density of ground vegetation, and general climate and seasonal conditions, may affect spread into surrounding native forest. Study results indicated that one pine per hectare could be expected in peppermint-type forests at a distance up to 2.7 km to the South of exposed plantation boundaries and 0.8 km to the east. To the north and west, the distance was 0.4 km (Minko and Aeberli, 1982). A survey published in 2007 found:

> *"…Little is known about the total area invaded by pines, the population biology of* Pinus *species outside of plantations or their impacts on native communities in Australia … Records of pine spread in Australia are scarce. Observations of infestations remain largely anecdotal, and quantification of wildling densities and distributions are mostly restricted to a handful of studies…"* (Williams and Wardle, 2007, p. 722).

Anecdotal observations are provided by publications such as *Environmental Weeds in Victoria* (Carr, Robinson, and Yugovic, 1992), cited as authority for Williams and Wardle's statement that '*Pinus radiata* has been listed as a very serious threat to one or more vegetation formations in Victoria and has been observed spreading into a range of environments including heathland, lowland grasslands and grassy woodland, dry and damp sclerophyll forest and riparian vegetation' (2007, p. 727). However, the 1992 publication cited gives no details such as the exact place and date of the observations, nor any other material by which the anecdotal evidence could be verified. As is so often the case in the weeds literature, it is, in essence, simply a list of 584 plants said to be environmental weeds, defined as 'exotic plants that invade native vegetation, usually adversely affecting the survival of the indigenous flora'. There is no citation of studies of invasions or the effects on indigenous flora.

Similarly, *The Flora of Victoria* (1993) included a chapter by G.W. Carr on '*Exotic flora of Victoria and its impact on indigenous biota'*. This concludes with a list titled 'Environmental weed species in Victoria rated as very seriously invasive in indigenous vegetation', which includes *P. radiata,* but again without any supporting material (Walsh and Entwisle, 1994, p. 293). The bibliography lacks any studies of *P. radiata,* not even Minko and Aelberli's of 1982, described by Williams and Wardle as the only 'quantitative work in Victoria' (Williams and Wardle, 2007, p. 727).

Mechanisms of *P. radiata* spread are little understood, apart from the recognition of wind and possible bird dispersal. Some see *P radiata* as a serious threat, and others classify it as a threat of a lower order. It was not included among the 65 most serious environmental weeds published by the Australian National Parks and Wildlife Service in 1991 (Humphries, 1991). Nor was it included in the comprehensive *Geographical Atlas of World Weeds* (1979), although 21 other Pinus species were listed as present in the USA as weeds (Holm et al., 1979, pp. 280–281). On the other hand, *P. radiata* was included in Randall's comprehensive *Global Compendium of Weeds* (2002).

Measured studies of the spread of *P. radiata* into eucalypt forest adjacent to a large plantation in the Australian Capital Territory began in 1974, reported by Burdon and Chilvers in 1977 when the pine plantation was clear-felled. In 1981 the original 160 × 20 m transect in the eucalypt forest was carefully remapped, as described by Chilvers and Burdon in 1983. It appeared that substantial numbers of young pines were being generated from the wildling pines that had established in the transect, but also that many of the first-year seedlings did not survive.

The tree population was approximately stable, with just a small replacement of eucalypts by pines. However, the pines were growing at a much faster rate than the eucalypts, altering the general appearance of the tree community. Acknowledging that exotic plants rarely establish themselves in stable plant communities without prior disturbance and modification of the environment, the authors considered that the scale of pine establishment seemed out of proportion to the level of disturbance.

They observed that the density of invading pines varied greatly between different sites, with the densest invasions at dry sites with poor, shallow soils. 'Where pine plantations are grown at moister sites with deeper soil levels, and the adjacent eucalypt forest tends to be the "wet sclerophyll" type, invasion is minimal or absent' (Chilvers and Burdon, 1983, p. 244). These observations should be followed up by a detailed investigation of the reasons for the differences.

A later measured study in New South Wales, in 2003, observed similar levels of invasion by *P. radiata* in two different types of dry sclerophyll eucalypt woodlands with differing dominant tree species (Kennedy, et al., 2013, p. 137). There was little evidence that different canopy species influenced susceptibility to invasion. Pine numbers generally diminished with distance from the plantations. Large reproductive pine trees were found up to 4 km from the seed source. Though the wind was an important factor in the spread of *P. radiata*, the presence of isolated trees suggested that dispersal mechanisms in addition to wind may be operating. Yellow-tailed Black Cockatoos observed feeding on plantation trees at both study sites may have been seed-dispersal vectors. Large numbers of young pines were thought to have been sourced from wildlings rather than from the plantation.

Yellow-tailed Black Cockatoos feeding on Monterey Pines may be understood as an example of indigenous fauna adapting to novel ecosystems, of which the pines are part. Kennedy et al. argued in 2013 that 'novel ecosystems are now critical for maintenance of faunal diversity at the genetic, species and ecosystem level, and restoration goals to eliminate novelty might not always benefit faunal conservation' (p. 137). It is hoped that the Yarra Ranges Council considered the alternative food available for the cockatoos when removing the pines on which they were known to feed.

The suggestion that *P. radiata* is not always invasive is confirmed by the experience in Chile. There are more than one million hectares of *P. radiata* plantations there, but the species, although introduced, is not considered invasive (Kruger, Breytenbach, Macdonald, and Richardson, 1989; Williams and Wardle, 2007, p. 722). The interiors of undisturbed native forests are resistant to invasion. Similarly, no invasions by *Pinus* species have been recorded for Colombia or Kenya, despite their large pine plantations. As Williams and Wardle correctly concluded: 'A sound approach to wildling management will not require the removal of all trees, rather an assessment of the risks posed by each stand' (Williams and Wardle, 2007, p. 722).

Pines and landscapes

The spread of *P. radiata* into treeless grasslands and shrublands can alter the character of the Australian landscape. The tall, dark trees contrast strongly with the native vegetation and transform the shape and colour of the countryside. Many local inhabitants have, however, developed an affinity for them (Williams and Wardle, 2007, p. 722). Cultural landscapes with pines as a component may well have heritage significance such that they should be conserved.

Victorian landscapes have been markedly altered by windbreak plantings and amenity plantings in towns (Figure 4). The use of pines and cypresses as windbreaks around orchards and crops, around pastoral homesteads, and along driveways and roads has been widespread in Victoria. Nineteenth-century settlers cleared the land of native vegetation and then realised that they needed to protect their crops, orchards, and gardens from strong winds. Their choice was often to plant pines and cypresses as windrows.

Figure 4 Pines at sunset on the clifftop at Mt Eliza, on the Mornington Peninsula, Victoria.

Today, lines of pines and cypresses planted in the 19th Century are often the only remains of orchards long gone. The association of such plantings with the orchard industry has left many stands of conifers, which now characterise the landscape of regions, such as Templestowe and the Mornington Peninsula. The roadside avenues of pines tell us of the previous land use and have been recognised as landscape elements of cultural heritage significance (for example, Gilfedder, 2001).

In coastal settings, pines were used as windbreaks protecting gardens and as markers of seaside resorts. As specimen trees in parks, gardens, and reserves, they are widely distributed – from coast to mountain – and form components of significant landscapes, where their importance has led to clashes between values of cultural heritage conservation and environmentalism.

A good example is provided by a stand of some 250 pines at the seaside resort Shoreham on the Mornington Peninsula, most dating from the early 20th Century (Figure 5). The place known as The Pines was included in the Victorian Heritage Register in 2002. I was a member of the committee that decided to include *The Pines* in the register.

Figure 5 Heritage-listed pines at Shoreham, Victoria

Registration was supported by members of the local community, who felt a strong attachment to the trees and their place in the landscape, and by Heritage Victoria. Registration was opposed by the committee of management for the Shoreham foreshore and others who contended that *P. radiata* is an environmental weed, and as such, could not be of cultural significance. That argument was rejected.

It was accepted that The Pines was the best surviving example of the planting of pines at a seaside resort in Victoria. It was registered as a place of cultural heritage significance at the State level, as a representative surviving example of pine trees marking a beach resort. The Pines are of aesthetic significance as 'a unique element in a significant landscape' and 'important for their landmark quality on the Western Port littoral of the Mornington Peninsula', giving 'the Shoreham foreshore its distinctive character'. The Pines are also of historical significance (Heritage Council Victoria, 2002).

Competing values

Two Monterey Pines, standing on school grounds on a rocky point by a beach in Taroona, Tasmania, were the subject of lively community debate. The trees (Figure 6), rooted into a midden associated with occupation by the Mouhenneener people dating back 6,000 to 8,000 years, are described as 'living relics of a colonial aesthetic that preferred imported flora and fauna' (Lien and Davison, 2010).

Figure 6 Pines at Taroona, Tasmania. Photograph by Damien Ramon

The Taroona Environment Network (TEN), one of an estimated 60,000 community coast care groups in Australia, has been 'restoring' the foreshore and nearby bushland by removing what they see as invasive species. TEN proposes removing the pines, apparently because they are introduced and do not belong in Australia.

TEN sees its proposal as the straightforward application of environmental science, but its approach is strongly opposed by many local residents, who value the trees and the landscape to which they contribute, both for their beauty and as relics of 20th Century culture in a multi-layered landscape. So there is a clash between these competing values, obscured perhaps by the invocation of science. Properly understood, science is confined to factual explanations of what the case is and not concerned with values, but in environmental science, this distinction has, I believe, often been forgotten.

The conservation of the midden adds to the complexity of the dispute. TEN seeks to conserve Aboriginal heritage, but its removal of introduced Boxthorn (*Lycium ferocissimum* Miers) and Bramble (*Rubus fruticosus* agg.) has exposed the midden to the risk of erosion. To avoid damage to the midden, TEN had fenced off the midden (and the pines). Some argued that to conserve the midden, the pines should be removed. Others said that the pines helped to bind the midden against erosion. Questions arise as to how Aboriginal heritage values relate to European culture and nature conservation.

The environment that Europeans encountered when they arrived in Australia in the late 18th Century onwards had been significantly modified by thousands of years of Aboriginal land management, but there is a tendency for environmentalists to regard as 'natural' the environments that have been created by the Aboriginal people (S. Taylor, 1990, p. 411). There is no clear answer as to which cultural values should prevail, nor any mechanism for resolving the question.

Social anthropologist Marianne Lien, one of the authors of the 2010 paper on the Taroona pines, has described the Australian environmentalists as recreating a 'timeless' Tasmanian landscape, as it was before the arrival of Europeans; establishing their 'sense of place' by literally uprooting the remnants of European plants. However, there was no 'timeless' landscape when the Europeans arrived. The Aboriginal people had deliberately fashioned the landscape. In an insightful essay, Lien compares the environmentalists' sense of landscape to the paintings of John Glover (1767–1849) and suggests that the environmentalists are, like Glover, 'working within the framework of the picturesque'.

Glover depicted the lost landscape of the Tasmanian Aboriginal people that would never be restored. The environmentalists, like Glover, 'work to harmonise the less than perfect present and an imaginary past':

> *"…Glover and contemporary environmentalists both exemplify reflexive interventions in which the making of place involves a transformation that seeks to highlight background potentiality at the expense of foreground actuality. In both cases the imaginary past is a timeless landscape that is seen as capturing an essential dimension of the island's identity, while the presence that is silenced by various interventions (artistic omission or botanical eradication) bears the mark of mobility and historical rupture..."*
>
> *"…Narrating Tasmania within the framework of the picturesque thus implies producing a landscape in which traces of biomigration, human and non-human, are silenced. In this sense, one could argue that both cases concern an active denial of process, yet this denial is in itself the result of conscious human intervention, and in the contemporary case, a consistent and prolonged effort of hard work. To the extent that the landscapes appear in the end as timeless, it is timelessness of a temporary kind, one which serves first and foremost to conceal the transportations and transformations that have, in fact, taken place…."* (Lien, 2007, p. 115).

To regard Australia's landscape as it was at the time of European arrival as the 'timeless work of nature' is to perpetuate the myth that the cultural landscapes made by the Aboriginal people were untamed wilderness.

The error in imagining the pre-1788 landscapes of Australia as wilderness has been exposed often, most recently by Bill Gammage in *The Biggest Estate on Earth: How Aborigines Made Australia* (2011) and Bruce Pascoe's *Dark Emu* (2014).

The European colonisers fundamentally altered the landscapes and continue to shape Australia and its people. Their cultural heritage includes the plants that they introduced. The pines at Tarooma, at Shoreham, and elsewhere in Australia, are in many places, significant markers in landscapes and part of Australia's heritage.

Conclusion

The moral to be drawn from the parable of *Pinus radiata* in Australia is ambiguous. Have the benefits of pines outweighed the risks posed by its potential spread? Was all the work conducted over more than a Century to establish plantations misguided?

Valued as a timber resource and as a distinctive feature of significant cultural landscapes, Monterey Pines, some populations of which are considered as globally 'endangered', have come to be regarded by some people as *Invasive Alien Species* that should be felled and removed in Australia. Nevertheless, I believe that we should not rush to fell the large populations of pines still in Australia without knowing just what is happening in the novel ecosystems of which they are part, and what the consequences might be for the environment as a whole.

As Don Watson concluded, '*we need to love it [the bush] as it is and can be, not the way it was and will never be again'* (Watson, 2014, p. 372). Perhaps the overall lesson is that, while it is often difficult to foresee the consequences of human interventions in the natural world, we should do what we can to conserve the whole environment, including introduced trees in our heritage landscapes, *Pinus radiata* among them.

Since the preparation of this paper, attention has been drawn to a State government report from South Australia by Virtue and Melland (2003) in which the State conducted a Weed Risk Assessment (WRA) of radiata pine, Aleppo pine and Turkish pine.

Both Aleppo pine and Turkish pine were introduced to Australia after the First World War to commemorate the 'Lone Pine of Gallipoli' [8]. The South Australian report includes some additional, helpful information about the introduction and spread of radiata pine in that State (Virtue and Melland, 2003, pp. 59-64). However, the report does not refer to much of the material covered in this paper.

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Literature Cited

Adams, D. (1977). Western Pines and Western Gall Rust. *Tree Notes (California Department of Forestry and Fire Protection), 22*, 1.

Aitken, R., and Looker, M. (Eds.). (2002). *The Oxford Companion to Australian Gardens*. Melbourne: Oxford University Press.

Amor, R. L., and Stevens, P. L. (1976). Spread of weeds from a roadside into sclerophyll forests at Dartmouth, Australia. *Weed Research, 16*(2), 111–118.

Audas, J. W., and Morris, P. F. (1925). *Supplement to Professor Ewart's 'Weeds, Poison Plants and Naturalised Aliens of Victoria'*. Melbourne: Melbourne University Press.

Auld, B. A., and Medd, R. W. (1987). *Weeds: An Illustrated Botanical Guide to the Weeds of Australia*. Melbourne: Inkata Press.

Blake, L. (1977). *Place Names of Victoria*. Melbourne: Rigby.

Brookes, M., and Barley, R. (2009). *Plants Listed in Nursery Catalogues in Victoria 1855–1889*. Melbourne: Garden Plant Conservation Association of Australia.

Brown, J. E. (1883). *A Practical Treatise on Tree Culture in South Australia* (3rd Ed.). Adelaide: E. Spiller, Government Printer.

Brown, J. E. (1899). *The Forests of Western Australia and their Development: With Plan and Illustrations*. Perth: Perth Printing Works.

Burdon, J. J., and Chilvers, G. A. (1977). Preliminary studies on a native Australian eucalypt forest invaded by exotic pines. *Oecologia,* 31(1): 1–12.

Calder, W. (1986). *Peninsula Perspectives: Vegetation on the Mornington Peninsula, Victoria* (2nd Ed.). Melbourne: Jimaringle Publications.

[8] "The Lone Pine" battlefield was named for a solitary Turkish pine that stood at a battleground at the start of the fighting between Australia-New Zealand (ANZAC) troops and the Ottoman Turks, in 1915. The tree was also known by the Anzac soldiers as the "Lonesome Pine". The battlefield was situated near the eastern line of the ANZAC trenches in Anzac Cove in Gallipoli, Turkey (**https://en.wikipedia.org/wiki/Battle_of_Lone_Pine**).

Carnegie, A., Eldridge, R. H. and Waterson, D. G. (2005). History and management of Sirex wood wasp in pine plantations in New South Wales, Australia. *New Zealand Journal of Forestry Science,* 35 (1): 3–24.

Carr, G. W., Robinson, K. E. and Yugovic, J. V. (1992). *Environmental Weed Invasion in Victoria: Conservation and Management Implication*. Melbourne: Department of Conservation and Environment, and Ecological Horticulture Pty Ltd.

Carron, L. T. (1985). *A History of Forestry in Australia*. Canberra: Australian National University Press.

Chilvers, G. A., and Burdon, J. J. (1983). Further studies on a native Australian eucalypt forest invaded by exotic pines. *Oecologia,* 59 (2–3): 239–245.

CSIRO. (2011). CSIROpedia: Innovation Shaping Australia and the world Since 1916 (**http://csiropedia.csiro.au).**

Currie, G. A., and Garthside, S. (1932). *The Possibility of the Entomological Control of St. John's Wort in Australia: Progress Report*. Melbourne: Government Printer.

Duffield, J.W. and Stockwell, P. (1949) Pine Breeding in the United States 147-157 in *Trees – The Yearbook of Agriculture 1949*, USDA Government Printing Office.

Eldridge, R., and Taylor, E. (1989). *Sirex Woodwasp*. Sydney: Forestry Commission of New South Wales.

Engelmann, G. (1880). Geological Survey of California - Botany Vol. 2 – *Coniferae Tribe III – Abietineae* p.128.

Ewart, A. J. (1910). The Ovens River Valley: Report on St. John's Wort, dredging, and the forest flora at the district. *Journal of the Department of Agriculture, Victoria*, 505.

Ewart, A. J. (1915). Proceedings of the Royal Society of Victoria n.s. 27 in *Contributions to the Flora of Australia* No. 22, pp. 297-304.

Ewart, A. J. (1925). *Handbook of Forest Trees for Victorian Foresters*. Melbourne: HJ Green.

Ewart, A. J. (1930). *Flora of Victoria*. Melbourne: Printed by the Government Printer for the University Press.

Ewart, A. J., and Tovey, J. R. (1909). *The Weeds, Poison Plants and Naturalised Aliens of Victoria*. Melbourne: J. Kemp, Government Printer.

ForestrySA. (2021). Forestry, South Australia- Our History (**https://www.forestry.sa.gov.au/About-Us/%20History-of-ForestrySA/).**

Forests Commission Victoria. (1963). *Forty-Fourth Annual Report: Financial Year 1962–63* Melbourne: Government Printer.

Fox, P. (2004). *Clearings: Six Colonial Gardeners and their Landscapes*. Melbourne: Miegunyah Press.

Friends of ACT Arboreta. *Westbourne Woods*. Canberra: Royal Canberra Golf Club.

Friends of Sherbrooke Forest Victoria and Department of Conservation, Forests and Lands. (1989). *Weeds of Forests, Roadsides and Gardens: A Field Guide in Colour for Students, Naturalists and Land Managers*. Belgrave, Melbourne.

Gammage, B. (2011). *The Biggest Estate on Earth: How Aborigines Made Australia*. Sydney: Allen and Unwin.

Gay, W. (1925). School forestry. *Education Gazette and Teachers' Aid*, supplement.

Gay, W. (1938). The School Endowment Plantation Scheme of Victoria, Australia. *Empire Forestry Journal,* 17 (1): 66–69.

Gilfedder, F. (2001). [Various assessments of trees, gardens and landscapes]. In Graeme Butler and Associates (Ed.), *Hastings District Heritage Study, Volume 1: Heritage Place Reports, Project Methods, Recommendations*. Victoria: for the Mornington Peninsula Shire Council.

Heritage Council of Western Australia. (2007). *Hamel Nursery Assessment Documentation*. Perth: Heritage Council of Western Australia.

Heritage Council Victoria. (1974a). Pinus Radiata, Smeaton House: Statement of Significance [VHR T11511]. *Victorian Heritage Database.* (**https://vhd.heritagecouncil.vic.gov.au/places/71013).**

Heritage Council Victoria. (1974b). Smeaton House: Statement of Significance [VHR H0286]. *Victorian Heritage Database* (**https://vhd.heritagecouncil.vic.gov.au/places/1026**).

Heritage Council Victoria. (1982). Former State School No. 46: Statement of Significance [VHR H1643]. *Victorian Heritage Database.* (**https://vhd.heritagecouncil.vic.gov.au/places/178).**

Heritage Council Victoria. (2002). The Pines (Foreshore Reserve): Statement of Significance [VHR H1996] *Victorian Heritage Database* (**https://vhd.heritagecouncil.vic.gov.au/places/12391**

Heritage Council Victoria. (2015). Sawpit Gully Nursery and Plantation: Statement of Significance [VHR 1951]. *Victorian Heritage Database* (**https://vhd.heritagecouncil.vic.gov.au/places/6069).**

Hill, K. D. (1998). *Pinus,* In: *Flora of Australia,* Vol. 48: 589-595, Australian Biological Resources Study, Canberra.

Hilgendorf, F. W., and Calder, J. W. (1952). *Weeds of New Zealand: And How to Eradicate Them* (5 ed.). Christchurch, NZ: Whitcombe and Tombs.

Holm, L., Pancho, J. V., Herberger, J. P., and Plucknett, D. L. (1979). *A Geographical Atlas of World Weeds*. New York: J. Wiley.

Howell, J. T. (1941). Leaflets of Western Botany 3(1) 1-7, *The closed-cone pines of insular California.*

Humphries, S. E. (1991). Appendix 5: Significant environmental weeds of Victoria. In S. E. Humphries, R. H. Groves, and D. S. Mitchell (Eds.), *Plant Invasions of Australian Ecosystems: A Status Review and Management Directions*. Canberra: Australian National Parks and Wildlife Service.

Hutchins, D. E. (1916). *A Discussion of Australian Forestry: With Special References to Forestry in Western Australia, the Necessity of an Australian Forest Policy, and Notices of Organised Forestry in other Parts of the World: Together with Appendices Relating to Forestry in New Zealand, Forestry in South Africa, and Control of the Rabbit Pest*. Perth, WA: Frederick William Simpson, Government Printer.

Hyde, C., and Ryles, J. (2015). *Elm Watch (Friends of the Elms Inc., Burnley), 25*(2), 4.

Kennedy, P., Lach, L., Lugo, A., and Hobbs, R. (2013). Fauna and novel ecosystems. In R. J. Hobbs, E. S. Higgs, and C. M. Hall (Eds.), *Novel Ecosystems: Intervening in the New Ecological World Order* (pp. 127–141). Oxford: Wiley-Blackwell.

Kruger, F., Breytenbach, G., Macdonald, I., and Richardson, D. (1989). The characteristics of invaded Mediterranean-climate regions. In J. A. Drake, H. A. Mooney, and F. DiCastri (Eds.), *Biological Invasions: A Global Perspective* (pp. 181–213). UK: Wiley.

Lamp, C., and Collet, F. (1974). *Field Guide to Weeds in Australia*. Melbourne: Inkata Press.

Lien, M. E. (2007). Weeding Tasmanian bush: Biomigration and landscape imagery. In M. E. Lien and M. Melhuus (Eds.), *Holding Worlds Together: Ethnographies of Knowing and Belonging*. New York: Berghahn.

Lien, M. E., and Davison, A. (2010). Roots, rupture and remembrance: The Tasmanian lives of the Monterey Pine. *Journal of Material Culture, 15*(2), 233–253.

Mabey, R. (1997). *Flora Britannica*. London: Chatto and Windus. pp. 480.

Maroske, S. (1993). Public conferment from the Melbourne Botanic Garden, 1870. *Australian Garden History, 4*(4), 8–14.

Maroske, S. (2002). Mueller, Ferdinand Jakob Heinrich von (1825–1896). In R. Aitken and M. Looker (Eds.), *The Oxford Companion to Australian Gardens*. Melbourne: Oxford University Press.

Mead, D. J. (2013). *Sustainable Management of Pinus Radiata Plantations*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Minko, G., and Aeberli, B. C. (1982). *Spread of Radiata Pine into Indigenous Vegetation in North-Eastern Victoria*. Melbourne: Victorian Forests Commission.

National Trust of Australia (Victoria). (1989). Pinus Radiata (Moyston Avenue of Honour, File Number T12278) (**http://vhd.heritage.vic.gov.au/search/nattrust_result_detail/70782**).

National Trust of Australia (Victoria). (2001). Pinus Radiata (16 Roderick Street, Doncaster East, File Number T12033) (**http://vhd.heritage.vic.gov.au/search/nattrust_result_detail/71534**).

National Trust of Australia (Victoria). (2007). Pinus Radiata (Creswick Regional Park, File Number T12110) (**http://vhd.heritage.vic.gov.au/search/nattrust_result_detail/71848**).

New South Wales Department of Primary Industries. (2008). *Primefacts: Radiata Pine: 'The Remarkable Pine'*: State Forests of NSW.

Nisbet, J. (2009). *The Collector: David Douglas and the Natural History of the Northwest* Seattle: Sasquatch Books. pp. 290.

Pascoe, B. (2014). *Dark Emu*. Broome, WA: Magabala Books.

Payne, P. (2007). *The Diplomatic Gardener: Richard Schomburgk: Explorer and Botanic Garden Director*. Adelaide: Jeffcott Press.

Peters, M. D. (1983). Pinaceae 29-30, *Flowering Plants in Australia.* (Eds. B. D Morley and H. R. Tolkien), Adelaide: Rigby, pp. 416.

Randall, R. P. (2002). *A Global Compendium of Weeds*. Melbourne: RG and F.J. Richardson.

Refshauge, R. (1969). Brown, John Ednie (1848–1899). In Serle et al. (Ed.), *Australian Dictionary of Biography* (Vol. 3). Melbourne: Melbourne University Press.

Richardson, D. M., Williams, P. A., and Hobbs, R. J. (1994). Pine invasions in the Southern Hemisphere: Determinants of spread and invadability. *Journal of Biogeography,* 21(5): 511–527.

Richardson, F., Richardson, R. and Shepherd, R. (2011). *Weeds of the South-East* (2 Ed.). Meredith, Victoria: Richardson.

Shea, S. (1992). *Control of Sirex Woodwasp in Pine Plantations*. Perth, WA: Western Australia Department of Conservation and Land Management.

Sheldrick, J. M. (2013). *Nature's Line: George Goyder: Surveyor, Environmentalist, Visionary*. Kent Town, South Australia: Wakefield Press.

Sheridan, G. (2011). Insights into Tasmania's cultural landscape: The conifer connection. *Australian Garden History, 22* (4): 6–12.

Spencer, R. (1995). *Ferns, Conifers and Their Allies*. Sydney: University of New South Wales Press. pp. 358.

Spencer, R. (2002). Conifer. In R. Aitken and M. Looker (Eds.), *The Oxford Companion to Australian Gardens* (pp. 155–157). Melbourne: Oxford University Press.

Taylor, A. (1998). *A Forester's Log: The Story of John La Gerche and the Ballarat-Creswick State Forest, 1882–1897*. Melbourne: Melbourne University Press.

Taylor, K. (1981). The Sirex woodwasp: Ecology and control of an introduced forest insect. In R. L. Kitching and R. E. Jones (Eds.), *The Ecology of Pests: Some Australian Case Histories* (pp. 231–248). Melbourne: CSIRO Australia.

Taylor, S. (1990). Naturalness: The concept and its application to Australian ecosystems. In: D. A. Saunders, A. J. M. Hopkins, and R. A. How (Eds.), *Australian Ecosystems: 200 Years of Utilisation, Degradation and Reconstruction:* Proceedings of Symposium Held in Geraldton, Western Australia, 28 August – 2 September 1988 (Vol. 16, pp. 411–418). Sydney: The Ecological Society of Australia.

The Advertiser, Adelaide. (1929, 18 July). Death of Mr. Walter Gill: Ex-conservator of forests: Close of a useful career, p. 14.

The Jepson Herbarium: eFlora (2021). Vascular Plants of California, University of California, Berkeley (**https://ucjeps.berkeley.edu/eflora/search_eflora.php?name=**).

Thomson, G. M. (1922). *The Naturalisation of Animals and Plants in New Zealand*. Cambridge University Press, Cambridge, UK.

Turner, J., and Lambert, M. J. (1986). Nutrition and nutritional relationships of *Pinus radiata*. *Annual Review of Ecology and Systematics,* 17: 325–350.

Tyrrell, I. R. (1999). *True Gardens of the Gods: Californian–Australian Environmental Reform, 1860–1930*. University of California Press, Berkeley.

University of Maryland. (2008). *Exotic Pest Threats: Sirex Woodwasp*. College Park: University of Maryland Extension Entomology Bulletin.

Virtue, J.G. and Melland (2003). The Environmental Weed Risk of Revegetation and Forestry Plants. Department of Water, Land and Biodiversity Conservation, Report DWLBC 2003-02. pp. 184.

Revegetation and Forestry Plantsvon Mueller, F. (1858). On a general introduction of useful plants into Victoria. *Transactions of the Philosophical Institute of Victoria,* 2: 93–109.

Von Mueller, F. (1885). *Select Extra-Tropical Plants Readily Eligible for Industrial Culture or Naturalization, with Indications of their Native Countries and Some of Their Uses*. John Ferres, Government Printer, Melbourne.

Walsh, N. and Entwisle, T. (Eds.). (1994). *Flora of Victoria* (Vol. 2). Inkata Press, Melbourne.

Watson, D. (2014). *The Bush: Travels in the Heart of Australia*. Melbourne: Hamish Hamilton.

Webb, C.J., Sykes, W.R, and Garnock-Jones, P.J. (1988). *Flora of New Zealand* Volume IV, *Pinus radiata* (p..58). pp. 1365. Botany Division, DSIR Christchurch, New Zealand.

West Australian (1899, 27 October). Death of Mr. J. Ednie Brown.

Whittet, J. N. (1962). *Weeds* (2 Ed.). Sydney: New South Wales Department of Agriculture.

Williams, M. C., and Wardle, G. M. (2007). *Pinus radiata* invasion in Australia: Identifying key knowledge gaps and research directions. *Austral Ecology,* 32 (7): 721–739.

Willis, J., and Cohn, H. (1993). Botanical exploration of Victoria. In N. Walsh and T. Entwisle (Eds.), *Flora of Victoria* (Vol. 1, pp. 61–78). Inkata Press, Melbourne.

Wright, R. (2002). Ferguson, William (c1827–1887). In R. Aitken and M. Looker (Eds.), *The Oxford Companion to Australian Gardens* (pp. 211–212). Oxford University Press, Melbourne.

Wu, H. X., et al. (2007). Achievements in forest tree improvement in Australia and New Zealand 8. Successful introduction and breeding of Radiata Pine in Australia. *Australian Forestry,* 70 (4): 215–225.

Yarra Ranges Council. (2013). *Shirewide*. Lilydale, Melbourne: Yarra Ranges Council.

Yarra Ranges Council. (2014). *Discussion Paper Four: Weeds and Pests* Lilydale, Melbourne: Yarra Ranges Council.

PERSPECTIVE

The Saga of Genetically-Modified (GM) and Herbicide-Tolerant (HT) Crops in India

Nanjapur Yaduraju [1]

Address: Paramount Prime Apartments, Yadavagiri, Mysore- 570020, India

Email: nyaduraju@gmail.com

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Abstract

This essay is a personal opinion on India's struggles with the regulatory management of technologies involving genetically-modified organisms (GMOs). I intend to provide an analytical viewpoint relevant to India, based on my own experience, both as a weed scientist and a former Research Director.

Approved in 2002, insect-resistant Bt cotton[2](*Gossypium hirsutum* L.) is the only genetically-modified (GM) crop that is currently being grown in India. Bt cotton technology is considered a success story, which catapulted India into the second-largest cotton producer globally with additional benefits of enhanced farmer's income and decreased pesticide use. The opponents of GM technology, however, have a different story to tell. Since then, there have been many attempts to introduce other GM crops, notably with insect-resistant and herbicide-tolerant (HT) traits. Despite years of successful regulatory trials and approval by the highest regulatory body, Bt brinjal (*Solanum melongena* L.) and HT mustard (*Brassica juncea* (L.) Czern.) technologies were put on hold by the Government, owing to the strong opposition by the anti-GM Lobby.

The Government's inability to develop a sound national policy on GMOs and its weakness to deal firmly with activists opposing GM technology are sending the wrong signals. They scuttle innovation, introduce an element of doubting science, prevent access to advanced technologies and private investments. On a more practical note, the indifference and the inordinate delay in Government's action are resulting in large scale illegal cultivation of herbicide-tolerant Bt cotton (HTBt cotton) in several states for the last 4-5 years. There have been widespread protests by farmers and farmer groups demanding access to GM technology. The Government is trying to regulate the use of herbicide glyphosate to stem the illegal cultivation of HTBt cotton. The move will have an adverse impact as it will deprive farmers of a herbicide, which is hugely popular and has the largest market share. It is to be seen what the Government will do with the illegal cultivation of HTBt cotton. Will it go the Bt cotton way? Unable to find a solution to the illicit trade of and unauthorized cultivation of GM cotton, the Government gave official approval for Bt cotton in 2002. Will history repeat itself is a million-dollar question.

Keywords: GM crops, Bt cotton, Bt brinjal, GM mustard, Herbicide tolerant crops, HTBt cotton

[1]Former Director, ICAR-Directorate of Weed Research (DWR), Jabalpur, 482004, India

[2] Strains of the bacterium *Bacillus thuringiensis* produce over 200 different *Bt* toxins, harmful to different insects. Most notably, *Bt* toxins are insecticidal to the larvae of moths, butterflies, beetles, cotton bollworms, but are harmless to other forms of life. The gene coding for Bt toxin has been inserted into cottoncausing it to produce this natural insecticide in its tissues. In many regions, the main pests in commercial cotton are lepidopteran larvae, which are killed by the *Bt* protein in the GM cotton they eat. This eliminates the need to use large amounts of broad-spectrum insecticides to kill lepidopteran pests (some of which have developed resistance to insecticides).

Introduction

It was a dream come true for a budding weed scientist like me to do his Ph.D. research work at Weed Research Organization (WRO), Oxford, UK. Sadly, closed now, it was then considered as the 'Mecca' for weed scientists. It was an exhilarating experience to appreciate and use the sophisticated facilities, interacting with highly competent staff and a rare opportunity for interactions with weed scientists from around the world who visited WRO for short term research work on sabbatical.

Armed with better knowledge and competence in weed science, I returned to the Indian Agricultural Research Institute (IARI) at New Delhi in 1985 to continue my engagement in research and teaching weed science, which went on for over next 15 years until I took up the position of Director, *National Research Centre for Weed Science*, at Jabalpur - now renamed *Directorate of Weed Research* (DWR).

The selective action of herbicides fascinated me from early days, and I hoped that the herbicides would offer a better alternative to manual weeding and would provide relief to millions of farm women and children who spend a good part of their life pulling weeds. Born to a farming family and on a small farm, I have first-hand experience pulling out weeds in rice, apart from familiarity with other agricultural operations. The experience of doing weed control chores in rice, in deep water, with rains showing no mercy on us, was an experience to remember.

As a prelude to the paper's main topic, I provide some insights into the development of weed science as a discipline in India.

Weed Science in India

Systematic research on weed management in India was initiated in 1952 with the inception of *All India Coordinated Research Scheme* on significant crops, such as rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.) and sugarcane (*Saccharum officinarum* L.). In the same year, the weed control section was initiated in the Division of Agronomy at the Indian Agriculture Research Institute (IARI) at New Delhi.

The group was headed by Professor V. S. Mani, with whom I had the privilege of working during my initial years of service at the IARI. The launching of the All India Coordinated Research Project (AICRP) on Weed Control 1978, with centres in many parts of the country, could be termed as a historical development. Weed research in India got further boosted with the establishment of the *National Centre for Weed Science* (NRC-WS) at Jabalpur, Madhya Pradesh, in 1989, which was upgraded as the *Directorate of Weed Science Research* (DWSR) in 2009. The institute was renamed the *Directorate of Weed Research* in 2014 (DWR,2015). Since its inception, the institute has engaged in basic and strategic research on weeds and weed management (DWR, 2014). It also coordinates location-specific weed research under the AICRP-WM, currently operating at 17 centres with six volunteer centres located in different parts of the country [3].

As the Director of the NRC-WS, from 2000 to 2005, I strengthened and streamlined the research and training activities. Besides, all the State Agricultural Universities, currently numbering over 50, offer research and teaching activities in weed science and are responsible for developing weed management recommendations for areas under their jurisdiction. These institutions have done a commendable job in creating awareness among Indian farmers about the importance of weeds and their management in enhancing crop productivity.

The Indian Society of Weed Science (ISWS), established in 1968, with its official publication - *Indian Journal of Weed Science*, and in hosting regular meetings and conferences is also contributing its might in promoting weed science in the country. It was indeed a proud moment for me, as President of ISWS and the Asian-Pacific Weed Science Society (APWSS), when India successfully organised the 25th Silver Jubilee APWSS Conference in 2015 at Hyderabad. I am happy to add that with over 700 participants, it was the largest conference held so far in the history of APWSS.

The beginning of Chemical Weed Control

After decades of efforts by several Indian organisations in the 1960s, farmers began to appreciate weeds as an essential production constraint. Herbicides began to be used to manage weeds effectively, but herbicide use was limited in the initial years due to the high cost of chemicals. Most herbicides used to be imported, and there was inadequate technical know-how of their use.

[3] Source: **https://dwr.icar.gov.in/AICRP-WM-Centers.aspx**.

Policymakers also did not favour herbicides as they believed that India had plenty of cheap labour.

The introduction and large-scale cultivation of short duration and dwarf cultivars of wheat and rice in the 1960s led to the much-talked green revolution in the country. The adoption of these cultivars, which were responsive to high inputs, led to drastic changes in the cropping pattern and the production practices. These changes led to the evolution of several problems, which were not perceived before.

Increased infestations of grass weeds, such as littleseed canary grass (*Phalaris minor* Retz*)* and wild oats (*Avena sterilis* ssp*. Ludoviciana* (Durieu), in wheat, were one such negative impact of the green revolution. Close planting of the crop and morphological similarities of the weeds with the crop proved a big challenge for effective and timely control through mechanical and manual methods. Of the two, *P. minor* was (and still is) the more predominant one.

The use of crop seeds, contaminated with weed seeds, and wheat harvesting using combine harvesters, which are custom-hired and travelled long distances - aided in infesting newer areas. Its severity has been exceptionally high in the rice-wheat system, the most predominant cropping system in an area of >10.0 million hectares (Mha). In less than 5-10 years, *P. minor* became the number one 'pest' of wheat over a large swath of the Indo-Gangetic belt (Figure 1).

***Figure 1 A wheat crop heavily infested with littleseed canary grass (Phalaris minor*)**

Populations ranging from 1000 to 2000 plants/m^2 infested some areas, compelling many farmers to harvest the crop prematurely as animal feed or plough down the crop to make way for planting an alternate summer crop like sunflower (*Helianthus annus* L.). Weed scientists at the IARI, New Delhi and the SAUs in Punjab, Haryana and Uttar Pradesh intensified their research on herbicides against these grass weeds. With the problem reaching its peak and increased complaints by the farmers, experts from overseas were invited to assess the situation and suggest control measures. Professor John Fryer, former Director of WRO, Oxford, was one such expert. I had the privilege of travelling with him to some of the problem areas.

After consultation with Indian counterparts, the experts recommended the use of herbicides to stop the further spread of weeds and to reduce the yield losses. After extensive research, herbicides, such as methabenzthizuron, chlortoluron, metoxuron and isoproturon [4], proved effective in selective control of wild oats and *P. minor* in wheat. Agrochemical companies responded swiftly by making the herbicides available within a short period by importing them, and later, by producing them indigenously.

Among these herbicides, isoproturon, became a clear favourite with the farmers and was adopted widely and quickly. Besides grass weeds, isoproturon gave good control of other major broadleaved weeds found in wheat. It remained a reliable chemical for many years until the development of resistance in *P. minor* in the early 1990s. In retrospect, it is evident that the grass weed problem triggered by the large-scale cultivation of Mexican dwarf wheat marked the beginning of the large-scale use of herbicides in the country. Soon, herbicides became the principal method of weed management in wheat in North-Western parts of India, where labour was expensive, as the migrant labourers carried out most agricultural operations. Looking at the success in wheat, more and more farmers adopted herbicides in other crops and other areas.

Currently, it is estimated that herbicides are being used in India on more than 20 million ha, which constitutes about 12% of the total cropped area in the country (Sharma et al. 2018). The pesticide market in India is relatively small (about USD 1 billion) compared to the global market (USD 33 billion). The share of herbicides is nearly 18% of the total pesticides used and is expected to grow further and faster. Although herbicides have been in use for over three decades, usage has increased only recently. Wheat, rice, soybean [*Glycine max* (L.) Merr.] and sugarcane are the major crops where herbicides are in use with approximate shares of 28, 20, 9 and 7%, respectively [5].

[4] Table 1 at the end of the essay provides the chemical names of the herbicides.

[5] The list of herbicides approved and used in India is available at **http://cibrc.nic.in/mup.htm**.

Brush with Herbicide resistance

Although Indian weed scientists were aware that the continuous use of a single herbicide would lead to the development of resistance in weeds, the first report of resistance, recorded in *P. minor* to isoproturon in wheat, came in the early 1990s (Malik and Singh 1993). The finding caught the scientific community by surprise. It was least expected that the continuous use of the herbicide within a relatively short period of 8-10 years would result in the development of resistance.

R. K. Malik and his team were the first to observe resistant populations of *P. minor* in the Haryana State. Dr. Malik then asked me to check for resistance to make sure that it was indeed a case of herbicide resistance. While it took some time for weed scientists to understand the situation, the problem spread quickly and covered over a million ha in less than five years. Unaware of the resistance development in the weed, farmers resorted to repeated applications of isoproturon, often at higher doses, hoping for reasonable levels of *P. minor* control. I have the first-hand experience of the situation, as I travelled extensively in Punjab and Haryana, collecting *P. minor* seeds from hundreds of fields for research at the IARI.

The situation was reminiscent of what farmers experienced in the pre-herbicide era, during the early 1970s. It presented a threat to the food security of the country, as this region was (and still is) considered as the 'food bowl' of India. Scientists swung into action and began testing new herbicides. The Government of India, too, took cognisance of the situation and enabled priority registration of new herbicides. Among the new molecules, clodinafop, fluazifop-butyl and sulfosulfuron were found effective and were recommended in 1997-98 for controlling the resistant population of *P. minor*.

Despite their higher cost, farmers soon started using the new chemicals, as it was a simple choice between a good crop or total crop failure. The new herbicides brought the resistant *P. minor* infestations under control and restored yields to their previous levels. However, the 'success was short-lived. The alternate herbicides, with their higher propensity for development of resistance, led to increased instances of cross- and multiple-resistance. Currently, *P. minor* is being controlled using a limited number of herbicides, applied either sequentially or as mixtures. Pre-emergence applications of pendimethalin or pyroxasulfone; or post-emergence applications of clodinofop, pinoxadem, sulfosulfuron, or various combinations of clodinofop and metribuzin, sulfosulfuron and metsulfuron or mesosulfuron and iodosulfuron, are currently recommended (Kaur et al., 2020; Punia et al., 2020).

With the choice of herbicides with different modes of action (MoA) being limited, and the farmers' reluctance in doing away with rice-wheat rotation or use of other non-chemical approaches, the problem of *P. minor* is far from over. The experience of herbicide resistance in *P. minor* has made the weed technologists much wiser than before. Except for one more weed, toothed dock (*Rumex dentatus* L.), which has been reported to have developed resistance to some ALS inhibitor herbicides [6] used in wheat (Heap, 2021), no other instance of herbicide resistance has been noticed so far.

GM Crops in India

During this period, I watched closely and with a great deal of interest the development of GM herbicide-tolerant (HT) crops and their popularity in other parts of the world. It was quite natural to appreciate that a non-selective herbicide, such as glyphosate, could be applied to control a broad spectrum of weeds without worrying about the toxicity to the crop. I, too, was impressed with the merits of the technology. Despite the negative campaigning by the anti-GM groups, the technology found large-scale adoption globally within a short time. With the expectation that the technology would help our farmers, Indian weed scientists also started talking about favouring herbicide-tolerant crop technology.

As the then Director of the ICAR-DWR, I organised the first meeting to brainstorm the relevance of the HT crop technology to our farmers back in August 2005. A second meeting followed, under the auspices of ISWS, in 2016. On both occasions, the weed scientists and others who participated overwhelmingly supported the introduction of the HTC technology.

Bt cotton is the only GM crop approved for commercial cultivation in India. The technology has been developed by the Maharashtra Hybrid Seeds Company (Mahyco) - an Indian company, in technical collaboration with Monsanto (Choudhary and Gaur, 2015). Cotton is an important commercial crop in India, and before Bt cotton, the farmers used to incur

[6] Herbicides that inhibit acetolactate synthase (ALS), a key enzyme in the biosynthesis of the branched-chain amino acids isoleucine, leucine, and valine. Examples are herbicides belonging to imidazolinone and sulfonylurea groups.

yield losses to the tune of 30-35% due to infestation of bollworms. The most dominant and destructive being the American bollworm (*Helicoverpa armigera* Hubner). Controlling this pest required a minimum of 6–8 applications of insecticides, mainly pyrethroids, of which some became ineffective due to resistance development in bollworms.

Cotton used to be the major user of pesticides accounting for 46% of total insecticide used in Indian agriculture. The insect-resistant *Bt* cotton varieties expressing novel cry gene(s) were approved for commercial cultivation in 2002. In a short period of 10 years, around 7.2 million small cotton farmers representing more than 90% of total cotton farmers in the country adopted *Bt* cotton (Figure 2). The technology was hailed as a big success story, which propelled India to be a major cotton-producing nation globally. It is reported to have increased the crop yields by 23-43% and farmers profits by 50-130% (Choudharyand Gaur, 2015). Since its introduction, *Bt* cotton has been estimated to have added INR 315 billion (USD 7.2 billion) to national income with 40-60% reduced pesticide use, amounting to INR 11 billion (USD 0.15 billion).

***Figure 2** Luxurious growth of Bt cotton in a farmer's field, the only GM crop commercially approved for cultivation in India*

The introduction and commercialization of *Bt* cotton have not been without objections. Besides the usual concerns, *Bt* cotton has been alleged to cause sheep and cattle deaths following the animals feeding on *Bt* cotton foliage, decrease in soil fertility, adverse human health issues, and to some extent, caused farmers' suicides. Even after nearly 20 years, the controversy has not died down.

Bt Brinjal

Following the success of *Bt* cotton, the Mahyco, in collaboration with Indian public research institutions, developed an insect-resistant brinjal (Aubergine or eggplant) using the *Bt* gene. Brinjal is a high-value vegetable crop that is widely grown and consumed in India. The crop is highly vulnerable to fruit and shoot borer (*Leucinodes orbanalis* Guenee).

In response, farmers spray the crop heavily and repeatedly with highly toxic pesticides but with limited success. After eight years of successful trials and submission of the required data, the Genetic Engineering Approval Committee (GEAC) - the highest statutory body for approval of GMOs in the country, approved *Bt* brinjal for commercial cultivation in 2009 (Figure 3).

***Figure 3** Bt brinjal in an open field trial. Despite the recommendation for commercial cultivation in 2009, the Government, under pressure from the anti-GM lobby, is yet to give final approval*

As expected, the anti-GM Lobby came down heavily, and this time the protests were larger and louder, as this GM technology was with a food crop compared to *Bt* cotton (Figure 4). The Government, unfortunately, succumbed to public pressure, and not only did it stop the technology from being commercialised but also announced a ten-year moratorium on all R&D activities related to GMOs (Choudhary et al., 2014). It dealt a big setback to the research and development of GM crops in the country. It also set a bad precedent in not observing the established norms and could be regarded as political interference in the approval process.

India's loss was Bangladesh's gain. The Mahyco Company promoted this technology in neighbouring Bangladesh, and Bt brinjal was approved there for commercial cultivation in 2013. The technology appears to have found ready acceptance in Bangladesh and is estimated to have been adopted by over 27,000 farmers in 2018 (Shelton et al., 2018). There too, there have been some protests against the technology. The green group, Ubinig, alleged that the Government rushed into introducing GM food crops in Bangladesh, and all the prerequisites were not followed adequately (Meenakshi, 2019).

Figure 4 Public protest against Bt brinjal in Bengaluru in 2010. Photo courtesy: BBC

However, a detailed study carried out by the International Food Policy Research Institute (IFPRI) in collaboration with the Bangladesh Agricultural Research Institute and the Department of Agricultural Extension tells a different story (Ahmed et al., 2019).

The study examined the impact of *Bt* brinjal in Bangladesh on production systems, marketability, and health and found that there was a 51% reduction in the number of pesticide applications, 39% reduction in the quantity of pesticides applied, 41% reduction in the toxicity of pesticides applied, as measured by the Pesticide Use Toxicity Score (PUTS) and 56% reduction in environmental toxicity, as measured by the Field Use Environmental Impact Quotient (EIQ-FUR). It was found that the net yields 42% higher with a 31% reduction in the cost of production (most of this was from reduced use of pesticides), an increase of 27.3% in gross revenues and an increase of Tk 33,827 (approximately 400 USD) per ha in net profits.

Reduced application of insecticides also meant lowering the health risk as most farmers do not use protective measures during pesticide application (Rashid, et al.,2008; Dey, 2010). Many in India still feel that it was a wasted opportunity, and the country could have benefitted a great deal with this technology.

Developments post-Bt brinjal

Further to the moratorium on *Bt* brinjal, the Indian Government set up a Parliamentary Standing Committee to assess the impact of GM crops on agriculture and the environment. The report tabled in the *Lok Sabha* on 9 August 2012 raised concern over the potential and actual effects of GM crops on farming, health, and environment, and it concluded that *GM crops are just not the right solution for the country* (Lok Sabha, 2012). It emphasised that the Government should not promote the views of the biotechnology and seed industry. Further, it added that *Bt*-cotton did not improve the socio-economic conditions of the farmers in the country but had led to further deterioration of farming conditions, especially in the rainfed areas.

Meanwhile, following a lawsuit, the Supreme Court of India appointed a five-member Technical Expert Committee (TEC), which also held that GM crops were not suitable for India and recommended an indefinite moratorium on field trials of GM crops and a ban on their commercial release. Realising that the TEC did not have an agricultural scientist, R. S. Paroda (a former Director-General of ICAR) was later included in the Committee, who did not agree with the TEC recommendations. He made it clear to the Court that the report was submitted without his consent and was 'neither transparent nor objective', and presented a separate report recommending the continuation of field trials (Kumar et al., 2014). Meanwhile, the Government took away the GEAC's 'approval' powers and renamed it *Genetic Engineering Appraisal Committee* (GEAC).

GM Mustard

The popular view for the opposition to GMOs by protesters is that the multinational companies pushed the technologies. However, this was proved wrong when a home-grown technology was also equally opposed. This is related to GM mustard (*Brassica juncea* (L) Czern) resistance to the non-selective herbicide glufosinate by Delhi University.

The team, led by Professor Deepak Pental, developed *Dhara* Mustard Hybrid-11 (DMH-11) through genetic manipulation, inducing sterility in an Indian variety as the female parental line, using the gene *barnase* that was derived from a soil bacterium, and crossed it with the male East European variety (Jayaraman, 2017).

The bacterial gene (*'barstar')* was also introduced in the male line to restore fertility in the offspring (DMH-11) so that the farmer gets fully fertile seeds. Additionally, a herbicide-tolerant third gene ('*bar*'), derived from another soil bacterium, was incorporated to identify plants that have been genetically modified. The '*bar'* gene has been introduced only to facilitate hybrid seed production, and the DMH 11 will not be required to be sprayed with herbicide by farmers, as alleged by critics

India is not self-sufficient with oilseed production, importing over 60% of the total requirement. The vegetable oil import is the third biggest import item after crude oil and gold. In 2014-15 India imported 14.6 million tons of edible oil, costing over INR 700 billion (10 billion USD), and it is estimated the imports could reach 20 million tonnes by 2030. The Government is making serious efforts in boosting oilseed output to reduce the import burden (Economic Times, 2021).

In this background, it is difficult to comprehend why the GM mustard developed domestically with a yield advantage of up to 30% was not approved, despite the strong recommendation by the Indian academia (NAAS, 2016). The anti-GM Lobby, however, feared that the approval for GM mustard would open the gate to several GM food crops. Unfortunately, Government gave credence to the unfounded claims of the activists of the risk of having GM elements in food crops. It is insincere because India is already consuming oil derived from GM crops. Choudhary and Gaur (2015) estimated that about 2.5 million tons of oil derived from GM crops are used in India annually -1.5 million tons from domestically grown *Bt* cotton and the remaining 1.0 million ton through GM soybean oil imported from overseas.

The technology was primarily meant to select male sterile female inbred lines that would be helpful in hybrid seed production. The hybrid obtained was not required to be sprayed with herbicide by farmers, as alleged by the critics. Further, it is known that mustard, being a fast canopy-forming plant, is not much affected by weeds, and farmers seldom use herbicides for weed control in the mustard crop. These vital facts, however, could not impress the GMO opponents. This was once again a major setback for scientists engaged in GM research.

I was personally disappointed, as I was also involved in the initial screening of mustard hybrid lines at ICAR-DWR Jabalpur from 2003-05 (Figure 5). The Delhi University took 14 years and reportedly spent INR 700 million (USD 10 million) of public funds to create the hybrid that was expected to increase mustard production and help India reduce its import bill for edible oil did not make sense to the opponents and the Government.

GM Herbicide Tolerant (HT) Crops

Crops with a genetically-engineered (GE) trait conferring herbicide tolerance were among the first biotechnology-derived crops commercialised in agriculture (Huang et al., 2015). The GE trait conferring tolerance to the 'within-crop' application of the herbicide glyphosate was introduced in soybean and canola in 1996 and, in cotton, in 1997, revolutionising agricultural practices for these crops.

Figure 5 GM-mustard, developed at Delhi University, under trial in a containment facility in ICAR-DWR, Jabalpur during 2002-03. GM-mustard (right) and non-GM control (left) treated with herbicide glufosinate

In 1996, biotech corn was introduced that provided tolerance to the herbicide glufosinate. Herbicide glyphosate affects plant growth by inhibiting 5-enolpyruvyl-shikimate-3-phosphate (EPSP) synthase enzyme that is responsible for the biosynthesis of aromatic amino acids. An EPSPS version resistant to glyphosate inhibition isolated from an *Agrobacterium* strain CP4 (CP4 EPSPS) was used to develop crops resistant to glyphosate (Heck et al., 2005; Huang et al., 2015).

The research and development of HT crops in India started back in 2008 with the first imports made by the trait developer company - Monsanto (now, Bayer) through its Indian subsidiary Mahyco of GM-*Bollgard 2* cotton seeds with HT trait (known as event MON 88913) called Round-up Ready Flex (RRF). Subsequently, they imported *Bt* corn, resistant to the shoot and cob borer, stacked with a glyphosate-resistant gene (Choudhary and Gaur, 2015).

Following the approval from the regulatory authorities, containment and open field trials with these GM crops were carried out in several locations for over 4-5 years by the SAUs and ICAR institutes and encouraging results have been reported in peer-reviewed journals (Chinnusamy et al., 2014; Dixit et al., 2016; Sushilkumar et al., 2017; Yadav et al., 2020). All these successful technologies are still awaiting approval from the Indian Government.

The anti-GMO Lobby

There is continuing opposition to GM crops globally. The main arguments being its purported negative impacts on the environment and ecology, concerns on health and safety of GM food of animals and human beings who consume such crops, and the inaccessibility of the GM technologies to small-holder farmers, due to IP protection and unaffordability. I discuss some of these in the following sections, restricting my comments to HTCs only.

Figure 6 Activists and farmers protest against the clearance of GM mustard outside the Ministry of Environment, Forest, and Climate Change in New Delhi. Photo courtesy: *Outlook*

GM crops replace labour affecting farmer livelihoods

Manual weeding has been the most predominant method of weed management in the country. Despite limitations, manual weeding has been conducted over decades, or centuries, primarily employing family labour. However, socio-economic conditions in India have changed substantially over the past 70 or so years. The country is currently undergoing rapid transformations, including rapid economic growth. The contribution of agriculture to national GDP has come down to around 18% compared to over 50% in the 1950s, with concomitant decreases in people dependent on agriculture.

Urbanisation and intensification of agriculture and allied activities have resulted in labour shortages with sharp increases in wages. Further, many government schemes are in operation, intending to improve the income and livelihood of under-privileged populations. An employment guarantee scheme (**https://www.nrega.nic.in/**) under which employment for one person in the family for a minimum of100 days a year is guaranteed. The*National Food Security Act* (**https://dfpd.gov.in/nfsa-act.htm**) promises 75% of the rural population and 50% of urban households the right to food. Currently, seven kg of food grains (rice, wheat, and coarse grains) per person per month is distributed at highly subsidised rates of INR 1 to 3 (approximately USD 0.14 to 0.42).

In my view, it is therefore unreasonable to assume that herbicides, in general, and GM crops, in particular, will replace labour and affect rural livelihoods. Weed management accounts for 20-30% of the total cost of crop production, and more and more farmers are using herbicides today as it saves 50-60% of the cost compared to manual weeding (Yaduraju and Mishra, 2018). The use of draught animals for mechanical weeding has also been reducing drastically as buying and maintaining them has become expensive lately.

Weeds consumed by humans and used as feed for animals

The activists argue that herbicides would kill weeds, some of which are used by the rural population as leafy vegetables and fodder for farm animals. It is an exaggeration, as only a few weeds qualify as green vegetables, and only a few are palatable to animals. It is well documented that weeds cause significant yield losses by competing with crop plants for costly inputs such as nutrients and water. It is therefore unscientific to suggest 'cultivation' of weeds. Instead, it makes sense to devote a small portion of land for growing such weeds to meet the farmer's needs.

Development of "Superweeds"

Opponents allege that the pollen of HTCs may cross-fertilise with its wild relatives and create what are dubiously called "superweeds". The inter- or intra-species fertilisation is not uncommon in the plant kingdom. At least 44 cultivated crops have demonstrated the capacity for hybridisation with wild and weedy relatives, including rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L), sorghum (*Sorghum bicolor* Moench), soybean, rapeseed, etc. (Ellstrand, et al., 1999). Gene flow, however, depends on the availability of such species near the area of cultivation (Messeguer, 2003). While reviewing the impact of GM crops in the USA, the report prepared by the *National Academy of Sciences* (NAS) observed that "*Although there has been gene flow from GE crops to wild relatives, no examples have demonstrated an adverse environmental effect*" (NAS, 2016).

It may be risky in rice, for instance, where there are many 'weedy' and 'wild' rice races in some areas in the country. Besides the presence of wild relatives close by, many factors, such as adequate fertilisation, ability to produce viable seeds, the fitness of the progeny to survive etc., contribute to the successful establishment of the hybrid. Crop plants, which are not native to the region, and which are introduced, are unlikely to have wild relatives as weeds and are expected to be least risky. In India, corn, soybean, cotton and to a great extent mustard (the leading crops that have been benefitted by GM technology, globally), besides many other crops, are unlikely to result in any adverse effect on biodiversity in the event of cultivation of their GM counterparts (Deepak Pental, 2021, *pers. comm.*, 6 June 2021).

Impacts on biodiversity

The risks of GM crops for the environment, especially for biodiversity, have been extensively assessed before and during their commercial cultivation. Sanvido et al. (2007) reviewed the scientific knowledge available worldwide from 1996-2006, focusing on commercialised herbicide tolerance (HT) and insect resistance (IR) traits and found no scientific evidence to suggest that the cultivation of commercialised GM crops caused any environmental harm. The HTCs involve non-selective herbicides, and there is a genuine concern about their long-term use on flora and fauna. However, unlike in developed countries, where a single crop is cultivated on vast acreages (i.e. monoculture cropping), the situation in India is different.

Over 75% of the farms are under two hectares, with many farmers planting more than one crop in their fields. Hence, the fear of eliminating all vegetation, including the associated flora and fauna, does not hold. The developers of HTCs are required to submit data on such investigations. Commercial cultivation is approved by the regulating agency only after it is satisfied fully with the data on potential biodiversity impacts (MEF&CC, 2015).

GM food is unsafe

It is a misconception that a foreign gene in GM crops will affect food quality and adversely impact human and animal health. Given the controversies, GM food is subject to more stringent analyses than any other food. Before entering the marketplace, GM food is assessed using guidelines issued by several international scientific agencies, such as the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the Organization for Economic Cooperation and Development (OECD) countries (ISAAA, 2016).

The general conclusion from studies conducted over the past two decades is that GM food is no more likely to cause a human or animal health problem via consumption than the same non-GM food. The afore-mentioned *National Academy of Sciences* report in 2016 also concluded that: '*Genetically-engineered crops are as safe to eat as their non-GE counterparts, they have no adverse environmental impacts, and they have reduced the use of pesticides*' (NAS, 2016). It may also be acknowledged that millions have been consuming GM food for years with no single adverse effect. It is reported that about 75% of processed foods in the US have GE ingredients.

However, I favour labelling as the consumers will have the right to know what they are consuming. Despite this science-based evidence, the activists are needlessly targeting GM food. It could significantly contribute to society if these activists could take up far more widespread and dangerous issues in India, such as food adulteration.

The threat of herbicide-resistant weeds

Of all the concerns expressed about HT crops, this one is truly significant. The problem of herbicide-resistant weeds is a global one. There are currently 263 species of weeds that have evolved resistance to 23 of the 26 known herbicide sites of action and 164 different herbicides worldwide (Heap, 2021).

Since the cultivation of HT crops, there has been an exponential increase in the use of glyphosate. Although glyphosate belongs to the low-risk category with respect to the development of resistance, many weeds have developed resistance to glyphosate the world over. According to Heap and Duke (2018), 38 weed species in 34 crops from 37 countries have developed resistance.

It is widely acknowledged that overreliance on a single herbicide and its continuous use are the leading causes for the development of resistance in weeds. Besides herbicides, introducing diversity in weed management involving preventive, mechanical and cultural methods of weed control is an effective strategy in managing herbicide-resistant weeds (Owen, 2001; Norsworthy et al., 2012).

The rational use of herbicides with emphasis on herbicide selection, targeting different sites of action, and their use in rotation, are critical factors in herbicide resistance development. However, many farmers tend to ignore these recommendations and rely on cheaper herbicides. In North America, the HR crop technology provided simple, flexible, effective, and economical weed management options to farmers (Jha and Reddy, 2018). This led to the rapid adoption of glyphosate-resistant (GR) soybean, cotton, and corn, often with the sole application of glyphosate over large areas. Its use was accompanied by a drastic decline in mechanical and cultural methods (Green, 2011; Shaw et al., 2009).

Ultimately, overreliance on glyphosate resulted in the evolution of GR weeds. It is an important lesson for other countries, including India, which may introduce HT technology in the future. Adequate preparedness and following strict guidelines, as suggested above, would mitigate the problem significantly.

The Scientific Community responds

The scientific community in India did not accept the negative campaigning carried out by the anti-GM Lobby and the unscientific decisions the Government took in curbing the research and development of GM crops. Following the moratorium declared by the Government, the *National Academy of Agricultural Sciences* (NAAS) recommended that it is high time to approve the environmental release of the GE varieties, which have been proven to be bio-safe. Highlighting the benefits of these crop varieties, the NAAS report advised their release to farmers and consumers without further delay (NAAS, 2016).

A group of top 17 agricultural scientists in India then produced a paper arguing in favour of GM technology, stressing the need for ensuring food and nutrition security in the country (Datta et al., 2019). They have referred to many reports prepared by the reputed global academia and research papers published in peer-reviewed journals to support positive outcomes of GM crops.

The conservative European Commission in its 2010 report also stated: '*The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se riskier than conventional plant breeding technologies*' (European Commission, 2010).

Datta et al. (2019) chastise anti-GMO campaigns as scientifically baseless and potentially harmful to poor people in the developing world. They argue that the perception carried by anti-GM groups is at variance with the consensus arrived at by significant science academies of the world[7]. Referring to many publications in credible, peer-reviewed journals, Datta et al. (2019) support their pro-GMOs stand. For instance, 147 original studies based on primary data from farm surveys anywhere in the world reporting the impact of GM soybean, maize or cotton on crop yields, pesticide use, and farm profits have shown that, on average, GM technology adoption has reduced pesticide use by 37% increased crop yields by 22% and increased farmer profits by 68%.

An extensive study carried out by the US National Academies of Sciences, Engineering, and Medicine comprising of eminent members from all relevant disciplines and after interacting with domain experts from different countries, reviewing hundreds of peer-reviewed publications have concluded that the GE crops had no adverse environmental impact, had reduced the use of pesticides and the GE food was as safe to eat as their non-GE counterparts (NAS, 2016).

Soon after the moratorium on GMOs was declared, the *National Academy of Agricultural Sciences* (NAAS) organised a Round Table on 14 February 2014 to discuss the future course of action. Held under the Chairmanship of M. S. Swaminathan, it stressed the potential and relevance of research on GM technology in meeting the food and nutritional security of India. It made several recommendations, the important ones being (a) lift the embargo on controlled field trials on GM crops, (b) approve the environmental release of the GE varieties, which have been proven bio-safe, and (c) drop the requirement of obtaining '*No Objection Certificates*' from the States for field trials (NAAS, 2016).

The ICAR-DWR and the ISWS held three discussions over five years involving different stakeholders. They, too, unequivocally supported the new technology and appealed for the withdrawal of the moratorium. Responding to the criticisms aimed at scientists, Datta et al. (2019) rightly observed that:

> *"…While there is always scope for improvement in any institution, indictment of the regulatory bodies is an insult to the integrity of a large body of scientists who have toiled*

[7] The Agencies and Organizations include the US National Academy of Sciences, American Association for the Advancement of Science, The Royal Society (UK), African Academy of Sciences, European Academies of Science Advisory Council, the French Academy of Science, American Medical Association, Union of German Academies of Science and Humanities, Indian National Science Academy, and others.

hard for years to monitor the trials and be part of the approval process…".

Datta et al. (2019) quoted the support of 107 Nobel laureates, who in 2016 appealed to *Greenpeace,* an environmental organisation, to rethink its long-standing opposition to GMOs. The industry also voiced their concern, time and again, about the lack of interest and slowness on the part of the Government in promoting the technology (Jayaraman, 2012). The leading media houses have also been supporting the GM technology by publishing informative and balanced views on issues related to GMOs, to no avail.

While the public and the political leadership recognise the contribution of agricultural scientists in transforming India from a 'food-deficit' to a 'food surplus country, it is disappointing that on GM crops, the voice of science is not well heard. This will surely discourage and dampen the interest and enthusiasm of the scientific community in India and scuttle future innovation.

The dithering Government Response

It was hoped that the new *National Democratic Alliance* (NDA) Government, which came to power in 2014, would take a different approach. The interest to change the course on GM field testing was evident when the regulatory authorities allowed field trials of few GM crops, including HT crops, in 2014 (Kumar, 2015). More than 20 crops underwent various research and field trials for genetic modification. Eight Indian states aligned with NDA have approved field trials of GM crops, between them allowing tests that include transgenic rice, cotton, maize (corn), mustard, brinjal and chickpea (*Cicer arietinum* L)

The new Government was considered more proactive in promoting modern technologies. The Government has an ambitious program of doubling farmers income by 2025 through modernising agriculture and creating an enabling policy environment. However, the Government did not have a road map for taking GMOs forward. Its reluctance to engage in transparent debates about the pros and cons of GM biotechnology aggravated the situation. The details of the meetings of the *Genetic Engineering Appraisal Committee* (GEAC) that used to be publicly posted on its website no longer appear on-line now. The GEAC approved the commercial cultivation of GM mustard, developed by the Delhi University, in May 2017. Still, the Ministry of Environment and Forests did not act while facing powerful opposition from the anti-GM Lobby (Indian Express, 2017).

The NDA government, even after re-election with a better majority in 2019, has not taken GM technology seriously. This is reflected in the establishment of the much-awaited Biotechnology Regulatory Authority of India (BRAI) is yet to take wings. BRAI, as an autonomous statutory agency conceptualised in 2008, was intended to provide a single-window system for transparent and quick clearance of proposals related to biotechnology, including GMOs. Despite several revisions, the BRAI bill is yet to be re-introduced in Parliament.

These developments have not instilled confidence in the industry. Many multinational biotech/seed companies, who at one time were seriously pursuing their efforts in commercialising GM crops, are disappointed with the Government's apathy and are curtailing their products and scaling back investments. The Dow-Dupont deferred the Biosafety Research Level-1 field trials with transgenic insecticide-resistant and herbicide-tolerant GM corn planned during 2018 [8].

Monsanto, now a unit of Bayer AG stung by a series of unfavourable government decisions, withdrew an application in 2016 seeking approval for next-generation GM cotton seeds. The insect resistance and herbicide (glyphosate) tolerance of corn and cotton projects, promoted by Bayer AG, and tolerance of corn, promoted by Corteva, have been put on hold since 2016. The GM seeds have also been subject to litigation for some time in India concerning intellectual property issues. The Delhi High Court barred Monsanto from claiming patents on its GM cotton seeds in 2018. The appeal made in the Supreme Court has also been turned down[9]. The domestic seed companies have welcomed the news as they will no longer be required to pay the hefty licence fee to Monsanto.

On the contrary, the multinational seed companies are disappointed as they feel deprived of protection for their innovation. This will be a massive loss to the country as it will not be able to access modern technologies that are needed for further strengthening of food and nutritional security of the country and for promoting sustainable agriculture.

[8] Source: **http://news.agrompages.com/newsDetail-27162.htm**.

[9] Source: **https://www.ifoam.bio/en/news/2018/05/08/indian-supreme-court-says-seeds-plants-and-animals-are-not-patentable**)

The regulatory system in India

The introduction, testing and release of GMOs in India is governed by a well-drawn out the regulatory procedure through six competent authorities but administered under three different Ministries (MEF&CC, 2015). Rules1989 regulates the regulation of all activities related to GMOs and products derived from GMOs under the provisions of the *Environment Protection Act* (EPA), 1986. The information requirement concerning the safety assessment of GE plants covers GM on protein characterisation, food and feed safety, environmental safety including weediness and aggressive potential, impact on non-target and beneficial organisms, gene flow and crossability studies. The issues are discussed on a case-to-case basis, and the whole idea is to minimise the adverse impact that GMOs and products thereof would have on the environment and human and animal health. GEAC, the highest statutory body in the regulatory system, has powers to revoke approvals in case of new information of harmful effects or non-compliance of stipulated conditions.

While chronicling the history of the regulatory system in India, Choudhary et al. (2014) pointed out three fundamental flaws in the EPA Rules 1989 that need to be rectified. Firstly, GM crops are categorised as 'inherently harmful' under the 'hazardous substance' provision of the *Environmental Protection Act* 1986, which is scientifically incorrect and gives rise to misperceptions about the safety and potential risk of GM crops. Secondly, the EPA Rules 1989 to regulate GM crops were issued not by a 'legislative act' but by an 'administrative order' that remains untenable and liable to change with the discretion of the Environment Ministry, which affects the predictability of the regulations and ignores the need to take into account the views and policies of other concerned ministries.

Finally, the Union Environment Ministry administers the regulation of GM crops in India, whereas agriculture falls under the respective State(s). This often confronts approvals posing a 'Union Vs State' conflict in decision-making on GM crops. Such changes, if made, I am sure will make the regulatory system robust, effective, and sustainable. 'Conflict of Interest' is another commonly quoted criticism, which is not difficult to handle.

The illegal cultivation of HTBt cotton

The absence of a National Policy on GM crops and the Government's indecisiveness has led to a serious and problematic situation. The country is witnessing large-scale illegal cultivation of HTBt cotton. Stared in 2015, the area is increasing with each passing year and has been covered in the media regularly (Times of India, 2020).

Responding in the *Loksabha*, the Lower House of the Indian Parliament, the Agriculture Minister, admitted to the illegal cultivation of HTBt cotton in Maharashtra, Telangana and Gujarat, and the various actions to prevent it (Times of India, 2019). A high-level expert panel, the Field Inspection and Scientific Evaluation Committee (FISEC), set up by the Prime Minister's Office under the Department of Biotechnology to probe illegal HTBt cotton markets in 2018, has estimated the share of the illegal HTBt cotton crop to be 15% of the total cropped area (Hindustan Times, 2020).

Farmers experience a yield reduction of over 20% in cotton due to inadequate weed control (Gharde and Singh, 2018). Weed management, normally achieved through manual and mechanical approaches, constitutes about 30% of the total cost of crop production. Due to scarcity of labour, farmers find planting HTBt cotton and glyphosate for controlling weeds is convenient and economical. This is the primary reason for the growing popularity of HTBt cotton and the farmers’ open defiance for planting illegal cotton seeds.

In four districts of Maharashtra, close to 90% of the cotton grown was under illegal HTBt in 2019, as per *Shetkari Sangathana*- a powerful farmers union in Maharashtra (Financial Express, 2019). *Shetakari Sangathana*, a non-political Union of Farmers, formed to have "*Freedom of access to markets and Technology*" is spearheading the pro-GM crop agitation throughout the country. The Union has accused the Government of denying HTBt technology that has been proved helpful to farmers.

Defying the Government ban, the Union distributed GM seeds of soybean, maize and brinjal to farmers willing to sow the crop (Figure 7). It has also joined hands with farmer's groups in other states to distribute GM crops seeds to farmers. I see this as a contradiction to the argument made by the GM activists that farmers do not want GM technology.

Figure 7 Farmers on protest demanding access to HTBt cotton. To a call given by Shetkari Sangatana– over 2000 farmers broke the law and planted GM cotton at Akoli Jahangir village, Maharashtra, on 10 June 2019. Photo courtesy: Firstpost

For the record, the Government is 'taking action' by booking cases against errant farmers, confiscating seeds etc., but on the ground, I feel nothing much has changed or likely to change soon.

The cotton seed trade accounts for over INR 250 million (USD 3.3 million) per annum and is threatened by the illegal trade of unapproved seeds (The Hindu, 2020). With the huge carry-over of unsold seeds in the 2020 season, the industry is worried over the illegal sale of GM cotton seed, estimated at over 5 million packets (of 450 gm each) in the 2021 season. The seed companies are also urging the Government to act fast.

The anti-GM protesters are mainly silent but for few token comments. The criticisms made by the GM activists of the negative impacts of GM crops on the environment and biodiversity look hollow. It is pertinent to recall a similar large scale illegal cultivation of *Bt* cotton in the country before it was officially approved in 2002 (Jayaraman, 2001). This unlawful and unapproved cultivation, many believe, was the main reason for finally approving the first GM crop in the country. A similar situation could arise with illegally-grown HTBt cotton as well.

Glyphosate targeted

In India, it appears that the situation of illegal cultivation of HT *Bt* cotton is out of control. The anti-GM groups point to a 'regulatory failure', blaming the authorities for their apathy and incompetence in tackling the problem. Unable to confront the two sides - agitating farmers and the protesting activists, the Government issued a draft notification in July 2020, restricting the use of the popular herbicide glyphosate (Economic Times, 2020).

The Government wants to curb the menace of HTBt cotton by restricting the availability of glyphosate. According to the notification, the herbicide application will be allowed only through registered pest control operators, who are almost non-existent in rural areas. The move has been strongly criticised by the farmers, farmer organisations, the industry and academia. Presently, an expert committee is looking at these representations, and its recommendations are eagerly awaited.

It is a desperate attempt, albeit an indirect one, to discourage the cultivation of HT cotton. I feel that this will do more harm than good. The herbicide glyphosate is popular with farmers. It is widely used for weed management in non-crop areas, as a pre-till treatment particularly under conservation agriculture and as a directed spray in broadly spaced crops such as cotton, sugarcane, orchards, and plantation crops. Among the herbicides, glyphosate (with about 14.25 million kg use annually) is the largest selling one, with a 37% share (Brooks, 2019).

Application of glyphosate at low doses is also recommended to control the parasitic weed broomrape (*Orobanche aegyptiaca* Pers.) - a severe problem in mustard in the north-west part of India (Punia, 2014). Brookes (2019) examined the farm-level implications of restrictions on glyphosate use. According to him, besides the non-adoption of GM HT crops, the impacts are likely to be higher weed control costs, low levels of weed control, increased incidence of pests, lower yields and loss of benefits associated with no-tillage.

Meanwhile, the classification of glyphosate as "*probably carcinogenic in humans*" (category 2A) by the *International Agency for Research on Cancer* (IARC) of WHO has added fuel to the fire. At least a few States in India have joined some developed countries in either restricting or banning the use of glyphosate without any detailed scientific discussion on the issue. The IARC's findings have given new ammunition to the anti-GM Lobby, who have intensified their demand not only for the banning of GM crops but also for banning all pesticides, including glyphosate. However, the findings are being contested and warrant detailed scientific scrutiny.

Farmers in India are desperately in need of promising technologies for the management of weeds. The increasing cost of manual weeding and mechanical weeding through draught animals forces farmers to look for alternatives. Mechanical weed control with available hand-drawn tools is not suitable under all soil and climatic conditions. The tractor-drawn machines have limited use, as over 75% of the farmers are either small or marginal with less than two-hectare land. Small power operated weeders are making an entry and will take some time to find popularity. Meanwhile, farmers are experimenting with various local innovations to manage weeds. There are weeders drawn by bicycles or motorbikes.

What is more striking is the innovations made in the use of glyphosate. Glyphosate is applied between crop rows protecting the crop from direct contact with the herbicide (Figure 8). The crops are covered with plastic buckets (in case of broadly spaced crops, such as watermelons, cucurbits), cloth or plastic screens (held manually or drawn mechanically) on either side of the crop row (tomatoes or cotton) (Figure 9).

***Figure 8** Directed application of herbicide glyphosate in cotton using a plastic hood attached to the spray lance. Farmers prefer herbicides as manual weeding is 2-3 times more expensive*

***Figure 9** Inter-row application of glyphosate in cotton crop. The cloth/plastic screens are used to protect the crop from herbicide injury*

More 'advanced' application techniques involve a portable system (drawn by either bullocks or tractors). Here, inverted cut PVC pipes of a certain length with cloth/plastic screens in the sides to cover, say 4-5 crop rows, are drawn by a pair of bullocks and a person walking between the screens applying the herbicide manually. The photos and videos of such innovations have been making rounds on social media. All these point to the fact that farmers are well aware of the efficacy of glyphosate in controlling the weeds, and they are going to extremes to protect the crop from herbicide injury.

These attempts by the farmers underscore the need for technology, such as the use of HTCs to manage weeds without worrying about crop safety. The large-scale adoption of HT *Bt* cotton by farmers in open defiance of the Government's ban is a testimony of their approval of HT technology. Keeping the farmer's interest in view, the Government should lift the ban on GM HT crops and remove proposed restrictions on the use of glyphosate.

Conclusions

Based on the examination of issues related to India and surveys of global literature, I believe that the GE crops can benefit farmers in India. The HT crops, in particular, could substantially reduce the cost of weed management, which accounts for a whopping 20-25% of the total costs of cultivation. It is evident that since their introduction in 1996, GM crops neither had any noticeable negative impacts on the environment nor the health of humans and animals in countries that have been growing these GM crops for many years (see NAS, 2016).

On the negative side, continuous cultivation of HT crops has probably led to the resurgence of herbicide resistance in several weeds. However, learning from the mistakes made by some of these countries, the negative impacts of herbicide-based technologies could be significantly reduced by introducing diversity in weed management involving different methods, with particular emphasis on crop rotation, herbicide rotation and herbicide mixtures.

Currently, in India, genetically engineered cotton and maize have undergone multi-location open field trials and are waiting for over five years for the final approval by the GEAC (Chinnusamy, et al., 2014; Dixit, et al., 2016; Sushilkumar, et al., 2017; Yadav, et al., 2020). After the approval by the GEAC for open cultivation, the GM mustard is awaiting clearance by the Minister of MOEF&CC, and It is time for the Government to act fast and decisively to provide access to these technologies to benefit the farmers.

The large-scale illegal cultivations of HTBt cotton in several Indian States cannot be ignored any longer. The Government's approval for HTBt cotton will formalise illegal planting, benefit more farmers in adopting the technology and legitimise seed trade by eliminating unscrupulous traders.

The GM crops, since their introduction in 1996, are currently being planted on over 190 million hectares in 29 countries, including 24 developing economies (ISAAA, 2019). Further, 43 more countries are importing and consuming GM crops/products as food or animal feed. The accumulated GM crop area from 1996 to 2019 was 2.7 billion hectares, with an earned (1996-2018) economic benefits of USD 229.4 billion to 18 million farmers and their families, 95% of whom were small farmers. It is time for India to take advantage of the challenges and experiences the countries faced in commercialising GM crops to help itself move forward decisively.

As discussed earlier, the review of the vast amount of data indicated no evidence to suspect the safety of food and feed derived from GM crops and the negative impact they may have on the environment, including biodiversity (NAS, 2016; Sanvido, et al.,2007).

The Government should stand firm and not yield to the false propaganda unleashed by the GM activists. Instead, it should believe in science and repose trust in scientists and value their expert advice. It is a dangerous trend to allow a small group of activists to hold the country to ransom.

I hope that the Government will establish the much-anticipated Biotechnology Regulatory Authority of India (BRAI) after incorporating the desired changes that will act as a single-window facility and a clearing house for the proposals in a time-bound manner. Professionalism, transparency, and integrity in its functioning will instil confidence in all the stakeholders, particularly the activists and the public.

All the vital data and facts related to GM technology should be made available publicly and shared appropriately with all stakeholders. It is essential to develop an effective communication strategy with the public in sensitising and creating awareness of the new technologies.

Engaging the public intensely from the beginning will allay misjudged fears and apprehensions. Such activities will help prevent embarrassing and unpleasant situations that may occur at a later time. Further, the Government should also take a stand on intellectual property (IP) rights for genetically modified 'traits', which is not clear. The lack of IP protection scuttles innovation, access to new technologies and harms investments in the country.

The debate for and against GM crops may not end quickly. I am aware that GM crops may not be a panacea, but they have the potential for benefiting farmers and in achieving food and nutritional security targets. Like any technology, GM technology too has some risks. However, I feel that the benefits far outweigh the risks associated with them. While I was concluding this essay, there comes the news that the Government has stalled its decision of allowing scientific field trials of transgenic crops, including indigenously developed *Bt* brinjal (Times of India, 2021a). This was disclosed by the Environment Minister’s written response to a Parliament question in *Rajya Sabha* (Upper House) on 22 March 2021.

This turnaround comes after the central regulator, GEAC, had in 2020 allowed bio-safety research field trials of two new transgenic varieties of *Bt* brinjal in eight States during 2020-23. According to the media reports, this has been done under pressure from *Bhartiya Kisan Sangh* (a fringe body associated with the NDA Government) and heeding to the unwillingness of some States to issue '*No Objection Certificate*s' (NOC) for biosafety field trials. Ironically, the same day, in response to another question, the Minister made the following positive comment on *Bt* cotton: "*Long-term studies conducted by Indian Council of Agricultural Research on the impact of Bt cotton cultivating states has not reported any adverse effect on soil, microflora and animal health*".

This exposes the Government's predicament on this issue. Their action has received widespread criticism in the media, including a piece in the editorial of a leading daily (Times of India, 2021b). The on-going farmer's protest following the introduction of the *Farm Reforms Ac*t in September 2020 has attracted global attention (Wikipedia, 2021). During this standoff, it is unlikely that the Government will antagonise farmers and their supporters yet again by supporting GM technology anytime soon. Copying the famous quote, "*The King is dead, long live the King"*, would it be appropriate to say: "*The GM crops are dead, long live GM crops?"*. Only time will answer this question.

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Literature Cited

Ahmed, A. U., et al. (2019). Impacts of *Bt* brinjal (eggplant) technology in Bangladesh. Project report submitted to the US Agency for International Development. International Food Policy Research Institute, Dhaka. Pp. 117.

Brookes, G. (2019). Glyphosate use in Asia and implications of possible restrictions on its use *AgBioForum,* 22 (1): 1-26.

Chinnusamy, C., Nithya, C. and Ravishankar, D. (2014). Herbicide tolerant GM crops in India: Challenges and strategies. *Indian Journal of Weed Science,* 46(1): 86–90.

Choudhary, B. and Gaur, K. (2015). Biotech cotton in India, 2002 to 2014. ISAAA Series of Biotech Crop Profiles, 22 pp., ISAAA: Ithaca, NY.

Choudhary, B., Gheysen, G., Buysse, J., Meer, P. and Burssens, S. (2014). Regulatory options for genetically modified crops in India. *Plant Biotechnology Journal*, 12 (2): 135-146.

Datta, S., et al. (2019). India needs genetic modification technology in agriculture. *Current Science*, 117 (3): 390-94.

Dey, N.C. (2010). Use of pesticides in vegetable farms and its impact on health of farmers and environment. *Environmental Science and Technology* (II): 134–140.

Dixit, A., Raghuvanshi, M. S,. Singh, V. P. and Sushilkumar. (2016). Efficacy of potassium salt of glyphosate on weed control and yield in transgenic maize. *Indian Journal of Agricultural Sciences,* 86 (10): 1324–1332.

DWR. 2014. DWR - Souvenir, Celebrating Silver Jubilee (1989-2014). 2014. Directorate of Weed Research, Jabalpur India, pp. 140.

DWR (2015). Vision 2050. Directorate of Weed Research. Indian Council of Agricultural Research, Jabalpur 482004, India.

Economic Times (2020). Government plans to restrict use of glyphosate herbicide, *Economic Times*, 9 July 2020 (On-line: **https://economictimes.indiatimes.com/industry/indl-goods/svs/chem-/-fertilisers/government-plans-to-restrict-use-of-glyphosate-herbicide/articleshow/76876869.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst**).

Economic Times (2021). India could unveil a plan to boost oilseeds output, cut veg oil imports in Budget 2021 (On-line: **https://economictimes.indiatimes.com/news/economy/agriculture/india-could-unveil-plan-to-boost-oilseeds-output-cut-veg-oil-imports-in-budget-2021).**

Ellstrand, N. C., Prentice, H. C. and Hancock, J. F. (1999). Gene flow and introgression from domesticated plants into their wild relatives. *Annual Review of Ecology Systematics*, 30: 539-563.

European Commission (2010). A decade of EU-funded GMO research (2001–2010), 268 pp. (On-line: **https://op.europa.eu/en/publication-detail/-/publication/d1be9ff9-f3fa-4f3c-86a5-beb0882e0e65**).

Financial Express (2019). Despite ban HTBT cotton widely cultivated in Maharashtra, 18 June 2019 (On-line: **https://www.financialexpress.com/industry/despite-ban-htbt-cotton-widely cultivated-n-maharashtra/1610553/**).

Gharde, Y. and Singh, P. K. (2018). Yield and economic losses due to weeds in India. Technical Bulletin No. 17, pp. 22. ICAR-Directorate of Weed Research, Jabalpur, India.

Green, J. M. (2011). Outlook on weed management in herbicide-resistant crops: Need for diversification. *Outlooks Pest Management*, 22: 100-104.

Heap, I. (2021). The International Herbicide-Resistant Weed Database. Accessed 21 April 2021 (**www.weedscience.org**).

Heap, I. and Duke, S. (2018). Overview of glyphosate-resistant weeds worldwide. *Pest Management Science,* 74(5): 1040-1049.

Heck, G. R. et al. (2005). Development and characterisation of a CP4 EPSPS-based, glyphosate-tolerant corn event. *Crop Science*, 45 (1): 329-339.

Hindustan Times (2020). Maharashtra and Telangana farmers plant illegal GM cotton in protest (On-line: https://www.hindustantimes.com/india-news/maha-t-gana-farmers-plant-illegal-gm-cotton-in-protest/story-wZZSmJVZiln5KRZsd6jrFI.html).

Huang, J., Ellis, C., Hauge, B., Qi, Y. and Vragona, J. (2015). Herbicide Tolerance. In: Azhakanandam, K. et al. (Eds.), *Recent Advancements in Gene Expression and Enabling Technologies in Crop Plants,* pp. 313-37. Springer Science.

Indian Express (2017). Genetically-modified mustard gets GEAC nod for cultivation. (On-line: http://indianexpress.com/article/india/gm-genetically-modified-mustard-gets-geac-genetic-engineeringappraisal-committee-nod-for-cultivation-4651857/).

ISAAA. (2019). Biotech crops drive socio-economic development and sustainable environment in the few Frontier: Executive summary, ISAAA Brief 55. (On-line: https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp).

Jayaraman, K. (2001). Illegal *Bt* cotton in India haunts regulators. *Nature Biotechnology,*19: 1090. (On-line: https://doi.org/10.1038/nbt1201-1090).

Jayaraman, K. (2012). India's GM clamour mounts. *Nature Biotechnology,* 30: 300 (On-line: https://doi.org/10.1038/nbt0412-300b-).

Jayaraman, K. (2017). Activists bury India's GM mustard hopes. *Nature Biotechnology,* 35: 1124 (https://doi.org/10.1038/nbt1217-1124a).

Jha, P. and Reddy, K. N. (2018). The role of herbicide-resistant crops in integrated weed management. In: R. L. Zimdahl (Ed.), *Integrated Weed Management for Sustainable Agriculture*, pp.1-10. Burleigh Dodds Science Publishing, Cambridge, UK.

Kaur, M. M., Punia, S. S,. Singh, J. and Singh, S. (2020). Evaluation of multiple herbicide resistance in littleseed canary grass (*Phalaris minor*) populations from Haryana, India. *Indian Journal of Weed Science,* 52 (3): 265-269.

Kumar, S. (2015). India eases stance on GM crop trials: States begin to permit field tests of transgenic plants (On-line: https://www.nature.com/news/india-eases-stance-on-gm-crop-trials-1.17529).

Kumar, S., Bhatnagar, R.K., Kranthi, K. R. and Datta, S. K. (2014). The legal battle over field trials of GM crops. *Nature India* (On-line: https://www.natureasia.com/en/nindia/article/10.1038/nindia.2014.14).

Lok Sabha. (2012). Cultivation of genetically modified food crops - prospects and effects. 37th Report, Ministry of Agriculture, Government of India.

Malik, R. K. and Singh, S. (1995). Littleseed canary grass (*P. minor*) resistance to isoproturon in India. *Weed Technology*, 9: 419– 425.

Meenakshi, S. (2019). How *Bt* brinjal hurt the farmers of Bangladesh. Down to Earth (On-line: https://www.downtoearth.org.in/news/agriculture/how-bt-brinjal-hurt-the-farmers-of-bangladesh-63385).

MEF&CC (2015). Regulatory framework for genetically-engineered (GE) plants in India, pp15. Ministry of Environment, Forests and Climate Change, Government of India.

Messeguer, J. (2003). Gene flow assessment in transgenic plants. *Plant Cell, Tissue and Organ Culture,* 73: 201-212.

NAAS (2016). *Policy Brief to Accelerate Utilization of GE Technology for Food & Nutrition Security and Improving Farmers' Income*. Policy Brief No. 1, pp. 15. National Academy of Agricultural Sciences, New Delhi (On-line: http://naas.org.in/documents/pbongecropseng.pdf).

NAS (2016). *Genetically Engineered Crops: Experiences and Prospects.* National Academies of Sciences, Engineering, and Medicine. The National Academies Press, Washington, DC (On-line https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects).

Owen, M. D. K. (2001). World maize/soybean and herbicide resistance. In: *Herbicide resistance and world grains* (Eds. Powels, S. B. and Shaner, D. L., pp. 101-163. CRC Press, Boca Raton, USA.

Punia, S. S. (2014). Biology and control measures of Orobanche. *Indian Journal of Weed Science*, 46 (1): 36–51.

Punia, S. S., Manjeet, J. S., Singh, S. K. and Kamboj, P. (2020). Management of herbicide resistant *Phalaris minor* in wheat. *Indian Journal of Weed Science,* 52 (3): 237-240.

Rashid, M. H., Mohiuddin, M. and Mannan. M. A. (2008). Survey and identification of major insect pest and pest management practices of brinjal during winter at Chittagong district. *International Journal of Sustainable Crop Production*, 3 (2): 27-32.

Sanvido, O., Romeis, J. and Bigler, F. (2007). Ecological impacts of genetically modified cops: Ten years of field research and commercial cultivation. *Advances in Biochemistry, Engineering & Biotechnology,* 107: 235-278.

Sharma, A. R., Yaduraju, N. T. and Das, T. K. (2018). Weed management in Indian agriculture: Current scenario and way forward. *Indian Farming*, 68 (11): 3-8.

Shaw, D. R. et al. (2009). Using a rower survey to assess the benefits and challenges of glyphosate-resistant cropping systems for weed management in US corn, cotton, and soybean. *Weed Technology,* 23: 134-149.

Shelton, A. M. et al., (2018). *Bt* eggplant project in Bangladesh: History, present status, and future direction. *Frontiers in Bioengineering and Biotechnology*, 6: 106.

Sushilkumar, Raghuvanshi, M. S., Dixit, A. and Singh, V. P. (2017). Glyphosate tolerant and insect resistant transgenic *Bt* maize efficacy against shoot borer, cob borer and non-target insect pests. *Indian Journal of Weed Science,* 49 (3): 241–247.

The Hindu. (2020). HTBT issue: we should embrace seed technology, but not through illegal means. (On-line: https://www.thehindubusinessline.comeconomy/agri-business/htbt-issue-we-should-embrace-seed-technology-but-not-through-illegal-means/article32180259.ece).

Times of India. (2020). Pro-GM movement spreads to 11 districts in Maharashtra. (On-line: https://timesofindia.indiatimes.com/india/pro-gm-movement-spreads-to-11-districts-in-maharashtra-bail-of-buldhana-farmer-rejected/articleshow/69932768.cms).

Times of India (2021a). Government junks plan to allow trials of *Bt* brinjal, other transgenic crops. (On-line: https://timesofindia.indiatimes.com/india/govt-junks-plan-to-allow-trials-of-bt-brinjal-other-transgenic-crops/articleshow/81661294.cms?utm_source=email&utm_medium=social&utm_campaign=TOIMobile).

Times of India (2021b). Delay in introducing GM crops will hurt the Indian farmer (On-line: https://timesofindia.indiatimes.com/blogs/toi-editorials/delay-in-introducing-gm-crops-will-hurt-the-indian-farmer/).

Wikipedia. (2021). 2020–2021 Indian farmers' protest. (On-line: https://en.wikipedia.org/wiki/2020%E2%80%932021_Indian_farmers%27_protest).

Yadav, D. B., Singh, S,. Singh, R. and Yadav, A. (2020). Glyphosate use in transgenic maize: Effect on weeds and crop productivity in North-Western Indo-Gangetic Plains of Haryana. *Indian Journal of Weed Science,* 52 (4): 384-390.

Yaduraju, N. T. and Mishra, J. S. (2018). Integrated weed management for doubling farmers' income. *Indian Farming*, 68(11): 9-12.

Common and chemical names of herbicides used in this paper:

Common name	Chemical name
Chlortoluron	*N*'-(3-chloro-4-methylphenyl)-*N*,*N*-dimethylurea
Clodinafop	(R)-2-[4-[(5-chloro-3-fluoro-2-pyridinyl)oxy]phenoxy]propanoic acid
Fluazifop-p-butyl	(R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid
Iodosulfuron	4-iodo-2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino] carbonyl] amino]sulfonyl]benzoic acid
Isoproturon	*N,N*-dimethyl- *N*'-[4-(1-methylethyl)phenyl]urea
Glufosinate	2-amino-4-(hydroxy-methyl-phosphinyl) butanoic acid
Glyphosate	*N*-(phosphonomethyl) glycine
Methbenzthiazuron	1-(1,3-benzothiazol-2-yl)1,3- dimethylurea.
Metoxuron	*N*'-(3-chloro-4-methoxyphenyl)-*N*,*N*-dimethyl urea
Metribuzin	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one
Mesosulfuron	2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-4-[[(methylsulfonyl) amino] methyl] benzoic acid
Metsulfuron-methyl	2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid
Pendimethalin	*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine
Pinoxadem	8-(2,6-diethyl-4-methylphenyl)-1,2,4,5-tetrahydro-7-oxo-7H-pyrazolo[1,2-d][1,4,5] oxadiazepin-9-yl 2,2-dimethylpropanoate
Pyroxasulfone	3-[[5-(difluoromethoxy)-1-methyl-3-(trifluoromethyl)pyrazol-4-yl]methylsulfonyl]-5,5-dimethyl-4H-1,2-oxazole
Sulfosulfuron	*N*-[[(4,6-dimethoxy-2-pyrimidinyl)amino] carbonyl]-2-(ethyl sulfonyl) imidazol [1,2-a]pyridine-3-sulfonamide