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Conyza spp.: From Ugly Duckling to Agriculture's Fittest Swan – Brief Review[1]

Conyza spp.: de Patinho Feio a Cisne Mais Adaptado da Agricultura – Breve Revisão

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ABSTRACT - *Conyza* spp. are widely responsible for yield losses in agriculture due to its worldwide occurrence, resistance to herbicides and other traits which turn these species into first grade weeds. Since the 1980's, these species started to be cited on books both related to the ecology and the weed science, being usually classified as ruderals. Occurrence of *Conyza* in crops shows that these species are highly adaptable due to its recent evolutionary origin and occur in environments prone concomitantly to a moderate set of competition, disturbance and stress. There are also limitations in Grime's theory which may lead us to mistakes about the behavior of *Conyza*. Thus, simple and isolated recommendations certainly will not solve the problem of *Conyza*. Neither soil tillage nor tolerant crops to 2,4-D will free the agriculture from this weed, being necessary an integrated approach to solve this problem which demands qualified human resources in weed science and planning.

Keywords: horseweed, fleabane, ruderal, Grime's theory, demographic theory.

RESUMO - Espécies do gênero ***Conyza*** são responsáveis por perdas de produtividade na agricultura contemporânea devido à ocorrência cosmopolita, à resistência a herbicidas e a uma série de outras características que as tornam plantas daninhas de primeiro escalão. A partir dos anos 1980, essas espécies começaram a ser citadas tanto em livros relacionados à ecologia como à ciência das plantas daninhas, sendo geralmente classificadas como ruderais. A ocorrência atual de ***Conyza*** em áreas cultivadas demonstra que essas espécies são altamente adaptáveis devido à sua recente origem evolucionária e ocorrem em ambientes suscetíveis concomitantemente a competição, distúrbio e estresse moderados. Há ainda limitações na teoria de Grime que podem nos levar a enganos sobre o comportamento de ***Conyza***. Logo, recomendações simples de manejo e isoladas certamente não resolverão o problema causado por plantas desse gênero. Preparo do solo ou culturas tolerantes ao herbicida 2,4-D não livrarão definitivamente a agricultura dessa planta daninha, sendo necessária uma abordagem integrada para esse fim, o que demanda recursos humanos qualificados em ciência das plantas daninhas e planejamento.

Palavras-chave: buva, voadeira, ruderal, teoria de Grime, teoria demográfica.

Conyza spp. (*C. bonariensis*, *C. canadensis*, *C. sumatrensis*) are widely responsible for yield losses in agriculture due to its worldwide occurrence, resistance to herbicides and a series of other traits which turn these species into important weeds (Constantin et al., 2013). The great interest by these troublesome weeds is notorious, and several recommendations about techniques for its suppression from cropping systems appear not only in Brazilian but worldwide agriculture fields. Success in its control, however, has been limited and currently it is one of the most worldwide hard-to-kill weeds.

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Some decades ago this species was rarely cited in books related to ecology and agriculture. For illustrating its evolution in occurrence and importance, 18 books related to field surveys of plant/weed occurrence and its management, published from 1941 to 1993, were randomly sampled. Only six of them cite any species of *Conyza* (syn. *Erigeron*), as summarized in Table 1.

Audus (1976) was one of the first to refer to species of *Conyza* (syn. *Erigeron*) regarding its invasiveness, discussing about the effect of 2,4-D causing fasciation on inflorescences with formation of witches broom. Although this was one of the first references regarding *Conyza* as weed species, nothing was reported about its difficulty of control.

Barbour et al. (1980) cites a study regarding plant succession (secondary succession) as a function of time (years) after field abandonment; *C. canadensis* was reported to be consistent in density and frequency in several fields only one year after abandonment, but after that it started to disappear quickly; this author reported self-allelopathy to the species by means of its decaying roots, thus limiting its occurrence in the environment to the first years of succession. This was lately confirmed by Aldrich (1984). Allelopathy of root extract of *Conyza* was also reported as inhibiting sorghum, wheat, cucumber, turnip and mustard (Constantin et al., 2013). Barbour et al. (1980) also reported the species ability to be part of forbs development in highly stressed, nutrient restrained seashore environments.

Roberts (1982), in his weed control handbook, discusses about time of flowering for weeds regarding day length; *C. canadensis* was reported as one of the few British weeds which flower during the shortening days of autumn, but also no mention is done about its importance as a weed on British cropping fields.

For a plant to become a successful weed in agriculture, it needs to fulfill a series of requirements which will determine its adaptation to climatic, physiographic, biotic and management factors (Monquero, 2014). Radosevich & Holt (1984) summarized the theoretical characteristics that turn a plant species into a weed; from the 12 characteristics for the ideal weed, two are not of concern for being related to perennials; and from the remaining ten characteristics, only one is not fully present in *Conyza* (Table 2).

Data in Table 2 impels one to infer that *Conyza* is prone to be a tough weed; in fact, from the 1980's on, *Conyza* started to be considered an often-seen species from the ecological point-of-view, and a significant weed from the agricultural point-of-view (Table 1). By coincidence (or not), this was when some biotypes of *Conyza* started to evolve resistance to herbicides (Constantin et al., 2013).

Aldrich (1984) reports that the botanical family Asteraceae (Compositae), which includes the Genus *Conyza*, is recognized as being of relatively recent evolutionary origin. There is evidence that the preponderance of weeds from relatively recent evolutionary origin signals for the trend to an increasing of troublesome, highly adaptable weeds in agriculture (Aldrich, 1984), being *Conyza* one of the first Genus to predominate in agriculture-related fields. This species will probably be soon followed by others also from recent evolutionary origin families.

In this sense, plant classification in distinct ways helps to understand and predict species with higher potential to become a weed, since plants with analogous traits are prone to be selected by similar factors. A particular system regarding plant succession after disturbance, proposed by Grime (1979), is of great use for the weed science since it regards secondary plant succession. For an overview about primary and secondary succession, readers are suggested to check Barbour et al. (1980). Carvalho (2013) describes very well the theory of Grime, regarding stress and disturbance to which the area is submitted. Stress are those factors related to resource limitation such as light, water and nutrients, which would limit plant growth; disturbance, on the other hand, describes disruptions in plant existence and coverage such as floodings, mowing, tillage, grazing, fire, earthquakes (Radosevich & Holt, 1984; Carvalho, 2013) and even herbicide applications (Andel et al., 1987) (Table 3).

Table 1 **-** Random references checked for citations about species of *Conyza* or *Erigeron*, listed by year of publication

	Author	Title	Citation	Year
1.	McDOUGALL, W.B.	Plant Ecology	No	1941
2.	KRAMER, P.J.	Plant and Soil Water Relationships	No	1949
3.	OOSTING, H.J.	The Study of Plant Communities	No	1950
4.	ASHBY, M.	Introduction to Plant Ecology	No	1963
5.	GREIG-SMITH, P.	Quantitative Plant Ecology	No	1964
6.	PANDEYA, S.C. et al.	Research Methods in Plant Ecology	No	1968
7.	ASHTON, F.M.; CRAFTS, A.S.	Mode of Action of Herbicides	No	1973
8.	KERSHAW, K.A.	Quantitative and Dynamic Plant Ecology	No	1973
9.	ETHERINGTON, J.R.	Environment and Plant Ecology	No	1975
10.	AUDUS, L.J.	Herbicides: Physiology, Biochemistry, Ecology	Yes	1976
11.	BARBOUR, M.G. et al.	Terrestrial Plant Ecology	Yes	1980
12.	KLINGMAN, G.C. et al.	Weed Science: Principles and Practices	No	1982
13.	ROBERTS, H.A.	Weed Control Handbook: Principles	Yes	1982
14.	ALDRICH, R.J.	Weed-Crop Ecology	Yes	1984
15.	RADOSEVICH, S.R.; HOLT, J.S.	Weed Ecology	Yes	1984
16.	MOORE, P.D.; CHAPMAN, S.B.	Methods in Plant Ecology	No	1986
17.	SILVERTOWN, J	Plant Population Ecology	No	1987
18.	ZIMDAHL, R.L.	Fundamentals of Weed Science	Yes	1993

As a function of intensity of these two factors, Grime (1979) proposes three ecological adaptation strategies for plants: ruderals, competitors and stress tolerators, whose definition and traits escape the scope of this study but can be found in Radosevich & Holt (1984) and Carvalho (2013). In a summarized way, after disturbance, ruderals are those plants which occur in the first stages of the ecological succession, where abundant resources and almost no competition are present, directing most resources to reproduction; competitors are those plants which specialize in obtaining or using scarce resources in intermediary stages of the ecological succession, and stress tolerators prioritize characteristics which guarantee their survival.

For productive sites, as those used for agriculture, it is expected that areas after disturbance will be occupied by ruderals which are lately substituted by competitors; agricultural fields are supposed not to reach the stage where they will be occupied by stress tolerator species since it means the area is undergoing desertification being not suitable for agriculture anymore. In this sense, Aldrich (1984) described plant succession after disturbance reporting four stages for the secondary ecological succession in a given study (Table 4).

The study reported by Aldrich (1984) includes, mostly, ruderals and competitors; from pioneer weeds to true prairie (Table 4). Evidently, weed species are not exclusively from one of the classes present in Table 3 but mix characteristics and abilities as presented by Radosevich & Holt (1984), floating in an equilibrium between stress, disturbance and competition for its occurrence in the community. Aldrich (1984) reported *C. canadensis* as a "pioneer weed", being

Table 2 **-** Ideal characteristics of weeds, and its presence or absence in species of Genus *Conyza*

	Ideal characteristics of weeds [1/]	Present?	*Conyza* characteristics [2/]
1.	Germination requirements fulfilled in many environments	No	Limited by light, temperature, moisture and seed depth in soil
2.	Discontinuous germination (internally controlled) and great longevity of seeds	Yes	Many fluxes along the year, with differences in controls for each flux
3.	Rapid growth through vegetative phase to flowering	Yes	Six weeks from stem elongation to seed production
4.	Continuous seed production for as long as growing conditions permit	Yes	Several fluxes which seed at distinct times, since growing conditions permit
5.	Self-compatibility but not complete autogamy or apomixy	Yes	Autogamy, evolved independently in *Conyza* species
6.	Cross-pollination, when it occurs, by unspecialized visitors or wind	Yes	No need for pollination mediator
7.	Very high seed output in favorable environmental circumstances	Yes	80,000 seeds per plant
8.	Production of some seed in wide range of environmental conditions; tolerance and plasticity	Yes	Several fluxes which seed at distinct times, since growing conditions permit
9.	Adaptations for short-distance and long-distance dispersal	Yes	Water and wind dispersal
10.	Perennials: vigorous vegetative reproduction or regeneration from fragments	*	
11.	Perennials: brittleness, so as not to be drawn from ground easily	*	
12.	Ability to compete interspecifically by special means	Yes	Short time to stem elongation, ability to develop under moderate to high levels of water stress

[1/] Adapted from Radosevich & Holt (1984). [2/] Adapted from Green (2010). * Characteristics 10 and 11 were ignored for being related to perennials.

Table 3 **-** Ecological adaptation strategies of plants as a function of stress and disturbance

Intensity of disturbance	Intensity of stress	
	High	Low
High	Plant mortality	Ruderals
Low	Stress tolerators	Competitors

Source: Adapted from Radosevich & Holt (1984).

this validated by Barbour et al. (1980) which classified the same species as "pioneer dominant" and Green (2010) which stated *C. bonariensis* as being predominantly ruderal.

Currently, most weeds reported in agricultural fields are considered "competitors", and several studies aim to describe the differential competitive ability between weed species and crop plants; several of these studies, however, reach to the conclusion that in equality of conditions (equivalent density and simultaneous emergence), most crops are more competitive than several weed species. Authors often explain this behavior by stating that under field conditions crops occur in a much lower density than weeds, what is usually true, and that this is responsible for weed damage on crops. The general consensus, however, tends to report that most weeds are essentially

Table 4 - Predominant species for each of the four stages of plant succession in old fields in central Oklahoma, USA

Stage 1	Stage 2	Stage 3	Stage 4
Pioneer Weeds (2 – 5 years)	Annual Grasses (3 – 10 years)	Perennial Bunch Grasses (10 – 20 years or more)	True Prairie
Examples: *Helianthus annuus* *Conyza canadensis* *Chenopodium album* *Sorghum halepense* *Digitaria* spp.	Examples: *Aristida oligantha*	Examples: *Andropogon scoparius*	Examples: *Andropogon gerardii* *Panicum virgatum* *Sorghastrum nutans*

Source: Adapted from Aldrich (1984).

competitors, what may or may not be true on a case-by-case basis (Silvertown, 1987).

Furthermore, if we consider the equilibrium between stress, disturbance and competition in a single plant species, according to the theory of Grime (1979), competitive ability would depend greatly upon the environment where species are located. Thus, most competition studies under controlled environments – mainly those by the replacement series (substitutive) methodology, may simply fail in describing the real competitive relations between crops and weeds (Galon et al., 2015).

By analyzing data in Tables 1, 2 and 4 it seems that *Conyza*, in its origin, was not essentially a "competitor" as most important weeds are expected to be, but resembled more to a ruderal; along years it adapted to a wide range of environments and stresses. Regarding the dominant aspect of *Conyza* reported by Barbour et al. (1980), Aldrich (1984) reinforces the importance of phytosociological surveys by reporting that dominant species should be prioritized for management due to its ability to override crop performance and yields.

From the original report of *Conyza* as dominant species in stage 1 of succession (Barbour et al., 1980), Aldrich (1984) also classified other species of *Conyza* (syn. *Erigeron*) as dominants of stage 2 – those that occur from 2 to 10 years after field is abandoned. In this sense, *Conyza* was expected to disappear after ten years of assembly of no-till planting systems, as it is supposed to be essentially a ruderal, which we know to be untrue. Despite the ecological resources cited above, field observations regarding the wide adaptation and great performance of *Conyza* as a weed impels one to consider plants in this Genus to float at least among ruderals and competitors.

Almeida & Vidotti (2014) have not considered all the theoretical knowledge available and classified *Conyza* as "competitor". Reporting back to Table 3, one would be impelled to state that efficient weed control for those species considered as "competitors" would be easily achieved by imposing disturbance to the environment; this would, as expected by theory, eliminate competitor species exchanging them for ruderals which are believed not to cause significant harm to crop plants.

First, one should be aware that disturbance does not include only catastrophic events as earthquakes and vulcanic eruptions; it passes through soil tillage and includes also a simple mowing as well as chemical control with either long residual herbicides or with non-residual herbicides applied several times per cropping cycle (Radosevich & Holt, 1984; Andel et al., 1987). Almeida & Vidotti (2014) applied the theory of Grime in a simple way and concluded that soil tillage (disturbance) would be an almost definitive solution for the problem of *Conyza* in Brazil. So simple? The reality of the Brazilian agriculture shows it is not, otherwise the disturbance caused by herbicides would be enough to eliminate *Conyza* – but they became resistant. This is Nature always one step before us. Research support the evidence that the solution for controlling *Conyza* as proposed by Almeida & Vidotti (2014) does not satisfy farmers expectations in the long term.

Fortunately, most technical bibliography, as that by Constantin et al. (2013) and several others (Vargas et al., 2007; Lamego & Vidal, 2008; Moreira et al., 2010; Silva et al., 2014; Pereira, 2015), do not face the problem of *Conyza* with simplicity and levity. It is a fact that the problem of *Conyza* in Brazil started in the 1980's, as evidenced in Table 1, when the no-till planting system was gaining importance; there is no evidence, however, which links the spread of no-till to the occurrence of *Conyza*.

There is also evidence that the true ecological behavior of weeds lies beyond our current level of knowledge. Grime's theory is prioritized for weed ecology but sometimes we lack in taking a sight into knowledge available elsewhere. Grime's theory is criticized because (i) several factors cause stress on plants, which in turn respond differently to these stresses; (ii) for an species to be plotted into Grime's triangle (competition, stress, disturbance) there is need to relativize all variables, which implies distortions to data; and (iii) only the last life stages of plants are considered, being all behavior of plants in their initial stages ignored (Loehle, 1988; Silvertown et al., 1992; Wilson & Lee, 2000).

Aiming to fix these limitations, the Demographic Theory was proposed (Silvertown et al., 1992) who connected the demographic traits throughout plant's life cycle to life history and proposed a demographic triangle based upon fecundity (F), growth (G) and survival (S). The problem is that classification of a given plant species differs greatly when both theories are compared. In summary, the demographic theory seems to correct some issues on plant classification and may be the way we should follow for the future of weed ecology. It also means that currently we may be discussing about plant classification theories which are about to change.

Despite the new theoretical knowledge to come in plant classification by ecological strategies, tolerance and plasticity, as stressed by Radosevich et al. (1984) (Table 2), are the key for the importance of *Conyza* in Brazilian and by extent to worldwide agricultural cropping systems. It probably started as a ruderal which directed most resources to seed production and dispersal by wind (Dauer et al., 2006) and water (Aldrich, 1984), but due to its flexibility it adapted to highly competitive environments where it currently warriors for water, nutrients, light and physical space (Constantin et al., 2013) and also adapted to stressed environments, e.g. being able to grow and reproduce under high levels of water deficit where most species halt growth or wilt (Neckar et al., 2008).

Although *C. bonariensis* is reported as a temperate climate species (Green, 2010), Zimdahl (1993) reported *C. canadensis* as a hard-to-kill weed by solarization, highlighting its resistance to high temperatures; while pigweed (*Amaranthus* spp.) and some other weeds were eliminated in more than 90% from soil after two weeks of solarization, this control level for *C. canadensis* was only reached after more than eight weeks of solarization. This illustrates how wide is the adaptation range for these weed species, and the necessary research attention which need to be spent to other weeds from recent evolutionary families.

Conyza can be roughly compared to a duck in nature: the duck does not perform as an olympic-level competitor as a walker, a flier or a swimmer, but it does a little of everything. *Conyza* is not a strong ruderal, neither highlighted as strong competitor nor recognized by its high tolerance to stresses, but it performs a little of everything. And it seems it is becoming pretty good in these tasks for survival. Extending the discussion to the theory of Grime, *Conyza* spp. would probably be considered a type-4 (C-S-R) species; it occurs in environments prone concomitantly to moderate set of competition, disturbance and stress (Radosevich & Holt, 1984). As a highly adaptable species, simple and strayed recommendations will certainly not solve the problem of *Conyza*. Neither soil tillage nor tolerant crops to 2,4-D will definitively free the agriculture from this weed. An integrated approach will be needed for this which demands qualified human resources in weed science and planning.

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