Annex A. Invasiveness and Weediness

A consideration for the environmental risk/safety assessment of a transgenic plant is the evaluation of its potential to have adverse effects on the environment due to increased invasiveness or weediness, relative to the comparator.

Concepts and terms

Whether a particular plant is considered an invasive plant or weed can be context dependent in terms of where and when it emerges and what impact it has on the environment. A cultivated plant may be valued in an urban, agricultural or pastoral setting but may be invasive of natural environments (e.g. olive trees in Australia). A naturally occurring plant may be valued in unmanaged ecosystems but be considered a weed if it emerges in crops and competes for resources[1] (e.g. in North America, milkweed is essential to the Monarch butterfly in unmanaged ecosystems but considered a weed in maize crops). Many documented invasive plants are exotic species that have been introduced to managed and unmanaged ecosystems, accidentally or deliberately, as a result of human cultivation (including ornamentals, pasture species, trees, crops) or human mediated transport (see Pysek et al., 2017, Randall et al., 2017).

It should be noted that there are varied definitions and usages of ‘invasive plant’, ‘invasiveness’ or ‘weed’, ‘weedy’, ‘weediness’ (e.g. see Richardson et al., 2011; Lockwood et al., 2013). While various terminologies may make distinctions between weeds and invasive plants, these terms may be considered broadly synonymous and imply the potential for adverse effects on the environment.

Which terms are used depends on context, including in different jurisdictions and legal frameworks, international organisations (e.g. see IPPC, 2019; IPPC, 2007), scientific disciplines (e.g. weed science vs. invasion biology) and fields of human activity (e.g. agriculture vs environmental protection vs. urban management). The term weed (and weed control) is often used in the context of agriculture or other managed ecosystems but it is also used as a generic descriptor for any plant considered to be a problem, a pest plant, or occurring where it is not wanted. The term invasive plant (or invasive species) is often used in the context of unmanaged ecosystems, though the term weed is also used in this environmental context in some disciplines and jurisdictions. While not all weeds are invasive, this environmental consideration focuses on the impact of the invasiveness of weeds in the environment.

For simplicity, this document uses the terms invasiveness and <u>invasive potential</u> rather than making distinctions between weediness and invasiveness.

<u>Invasion</u> of an ecosystem, whether by plants or other organisms, is considered to be a staged process with a series of conceptual steps (e.g. Blackburn et al., 2011): introduction or entry to the ecosystem; establishment; persistence and survival to maturity; reproduction; dispersal of propagules; increased abundance and geographic spread leading to adverse effects on the environment (e.g. by competition with valued species).

The <u>invasive potential</u> of a plant will depend on the characteristics of the plant and of the receiving environment. A range of characteristics related to invasiveness (derived from known invasive plants) have been proposed (e.g. *Baker’s List*, Baker, 1965) and elaborated (e.g. Richardson et al., 2000), including in weed risk assessment protocols (Pheloung et al., 1999; Downey et al., 2010; FAO, 2011).

Such protocols have also been proposed for assessment of the invasive potential of transgenic plants (Kos et al., 2011; Keese et al., 2014). Whether a given plant will be invasive is dependent on multiple factors related to the characteristics of the plant and the receiving environment. The presence of one or more ‘invasive characteristics’ is not determinative.

Key plant characteristics contributing to invasive potential include those that confer the ability to:

- Establish (e.g. be introduced, germinate, grow) and persist (e.g. survive over time) in a receiving environment;
- Reproduce, generally quickly with large numbers of progeny (e.g. short time to sexual maturity and seed set, large numbers of propagules, including asexual propagules);
- Disperse, generally in large numbers (e.g. small seed size, pod shattering, vegetative propagules or spread over long distances);
- Compete well in the environment (e.g. rapid growth, suppressive growth habit); and
- Overcome abiotic (e.g. climatic conditions), biotic (e.g. competitors, herbivores, diseases) or human (e.g. weed control) constraints.

These characteristics are incorporated in OECD biology documents as described in the *Revised Points to Consider for Consensus Documents on the Biology of Cultivated Plants* (OECD, 2020) and pest risk analysis guidance (e.g. IPPC, 2019). Many domesticated plants have lost invasiveness traits through breeding (Kos et al., 2011). Crop or other plants described as weedy possess or display some traits associated with invasiveness but may not be considered invasive.

Persistence is the ability of plants or their progeny, plant reproductive propagules (seed or vegetative propagules such as rhizomes), to survive (i.e. remain viable), and/or reach maturity and reproduce, and/or remain dormant across growing seasons (e.g. ability of seeds, propagules to enter dormancy and survive in soil over time).

Spread/dispersal is the ability of plants or plant reproductive or vegetative propagules (e.g. ivy stems can establish new plants) to move in the environment by natural (e.g. creeping growth habit or subterranean runners) or human-assisted means (e.g. transport of seed, vegetative propagules after harvest). Many plants and plant propagules have structures or characteristics that facilitate spread directly (e.g. pod shattering), by wind (e.g. seed with fluffy outgrowths, tumbleweeds), by water (e.g. buoyant, water resistant, seeds with shells, air pockets or larger surface area), or by animals or human activity (e.g. hooks or spines that attach seeds to animals or objects (such as machinery), or fleshy fruit attractive to animals such as birds).

Problem formulation

For this consideration, below is a simple example that illustrates the approach for planning an environmental risk/safety assessment. It includes a discussion of assessment endpoints, potential adverse effects, and a linear pathway to harm with corresponding risk hypotheses and information elements to illustrate the approach. As previously indicated in the document (section 1.2.6), the process is often more complex.

(a) Determination of assessment endpoints

As with any cultivated plant, a transgenic plant might have impacts on the environment if it is invasive. An example of an assessment endpoint relevant to evaluating whether the transgenic plant has increased invasive potential relative to the comparator is the abundance of a valued plant species in unmanaged ecosystems.

(b) Identification of potential adverse effects on the assessment endpoints

The identification of potential adverse effects from invasiveness of a transgenic plant should be informed by the characteristics of the comparator (e.g. the unmodified plant), of the transgenic plant (trait, phenotype), and of the potential receiving environment(s). Adverse effects from (non-transgenic) invasive plants often result from competition with and displacement of other plants in managed and/or unmanaged ecosystems.

Knowledge of the invasive potential of the comparator provides important contextual baseline information, for example, whether the plant has any invasive characteristics, whether it survives outside of human cultivation, whether it is considered invasive and where it invades (e.g. in managed or unmanaged ecosystems), and what adverse effects it causes.

Knowledge of the potential receiving environment(s) provides information on where and what adverse effects might occur. For example, if the environment is suitable to support establishment, persistence and growth of the comparator or transgenic plant, whether and how those ecosystems are susceptible or resistant to invasion, whether human management activities are controlling or mitigating invasive impacts, or whether the receiving environment has conditions that might be more conducive to the survival or spread of the transgenic plant than the comparator.

The nature of the trait and phenotype of the transgenic plant informs identification of potential adverse effects, especially whether and how they could increase the invasive potential of the transgenic plant relative to the comparator. Consideration of the transgenic trait will indicate if it may confer or enhance invasiveness traits, or enable the transgenic plant to overcome natural or human constraints that limit the comparator (i.e. confer a competitive fitness advantage). If the trait confers tolerance to water stress, it might enable the transgenic plant to better establish and persist outside of crop fields (i.e. without human irrigation). If the trait confers tolerance to an herbicide, the transgenic plant might escape current controls with that herbicide.

If the transgenic plant has increased invasive potential relative to the comparator, it may establish in ecosystems outside the fields in which it is cultivated. An example of a potential adverse effect on the environment from increased invasive potential according to the assessment endpoints identified above may include reduced abundance of a valued plant species in unmanaged ecosystems.

(c) Identification of plausible pathways to harm, formulation of risk hypotheses, and identification of information elements relevant to evaluating the risk hypotheses

In this section, a plausible pathway to harm is postulated. For each step of the postulated pathway to harm, a corresponding risk hypothesis is formulated that will enable the risk assessor to determine whether the pathway is likely to occur. Once it is shown that any part of the pathway is highly unlikely, one does not need to continue evaluating the subsequent steps in the pathway and can conclude that the specific pathway to harm is unlikely to occur. In addition, examples of information elements that can be used to evaluate the risk hypotheses are given along with their rationales.

Postulated pathway leading to reduced abundance of a valued plant species in unmanaged ecosystems

Propagules (e.g. seeds) from crops can spread from cultivated fields by a variety of means and sometimes establish and persist in unmanaged ecosystems. If a transgenic plant has a relevant changed phenotype (e.g. increased tolerance to an abiotic stressor such as drought), it might have an increased ability, relative to the comparator, to establish, persist, reproduce and spread in unmanaged ecosystems, to compete with other plant species, and thus lead to a reduction in the abundance of a valued plant species in unmanaged ecosystems.

One example of a postulated pathway to harm for this adverse effect is shown in the first column of Table A A.1. Risk hypotheses for each step of the pathway are formulated in the second column and the third column provides examples of information elements for evaluating the hypotheses.

Table A A.1. Postulated pathway leading to reduced abundance of valued plant species in unmanaged ecosystems due to increased invasive potential of the transgenic plant, corresponding risk hypotheses, and relevant information elements

Pathway steps	Risk hypotheses	Examples of information elements
The introduced trait in the transgenic plant confers increased drought-tolerance relative to the comparator	The introduced trait in the transgenic plant does not confer increased drought-tolerance relative to the comparator	Knowledge about the comparator and the nature of the trait and phenotype of the transgenic plant, including the level of drought-tolerance under water stress conditions
Propagules of the transgenic plant are introduced into unmanaged ecosystems	Propagules of the transgenic plant are not introduced into unmanaged ecosystems	Cultivation, harvest and transport practices for the crop, proximity of cropping areas to the unmanaged ecosystem; Biology of the comparator, including propagule dispersal characteristics
Propagules of the transgenic plant germinate, establish and persist in unmanaged ecosystems	Propagules of the transgenic plant do not germinate, establish and persist in unmanaged ecosystems	Reproductive biology of the comparator and transgenic plant, including propagule dormancy; Characteristics and climate of the unmanaged ecosystem e.g. occurrence of drought/rainfall
The transgenic plant reproduces and spreads, resulting in increased abundance in unmanaged ecosystems, relative to the comparator (i.e. the transgenic plant has a fitness advantage and increased invasive potential)	The transgenic plant does not reproduce, spread or increase in abundance in unmanaged ecosystems, relative to the comparator (i.e. the transgenic plant does not have a fitness advantage or increased invasive potential)	Biology of the comparator including any previous history of invasiveness; Data collected on the transgenic plant relative to the comparator (e.g. propagule numbers, numbers or biomass of plants establishing and reproducing under water stress)
The abundance of a valued plant species in unmanaged ecosystems is reduced due to competition from the transgenic plant	The abundance of a valued plant species in unmanaged ecosystems is not reduced due to competition from the transgenic plant	Biology of the valued plant species and ecology of the unmanaged ecosystem; History of invasion of the unmanaged ecosystem
The abundance of valued plant species in unmanaged ecosystems is reduced		

It is important to note that examples of information elements in this table are intended to illustrate the types of information that can be used in evaluating a risk hypothesis, i.e. to determine whether particular pathway steps are likely to occur. However, for any step there might be other information that would be relevant. Rationales for how such information elements may be used to evaluate the risk hypotheses include:

- The level of drought-tolerance of the comparator and the transgenic plant provides information on the potential for increased survival of the transgenic plant in drought conditions, including drought conditions that occur in the unmanaged ecosystem. The level of drought-tolerance is relevant to multiple steps in the pathway;
- Knowledge of the cultivation, harvest and transport practices for the crop, including the proximity of the cropping area to the unmanaged ecosystem, provides information about potential routes for introduction of the transgenic plant to the unmanaged ecosystem;

- The propagule characteristics of the comparator (e.g. structures that facilitate dispersal by wind, water, animals, machinery) provide information on how propagules of the transgenic plant might be introduced to the unmanaged ecosystem;
- Propagule dormancy characteristics provide information on the ability of the comparator or transgenic plant to persist over multiple seasons (e.g. from a seed bank);
- Knowledge of the ecology of the unmanaged ecosystem, including the occurrence of drought (e.g. from rainfall records), provides information on whether the drought-tolerant trait may increase the survival of the transgenic plant in that ecosystem;
- The invasive history of the comparator, either locally or elsewhere in the world, provides information on the invasive potential of the species, including whether drought is a limiting factor. This type of information might include whether the comparator is already present in the unmanaged ecosystem, or whether the species has been identified by the relevant jurisdiction as undesirable (e.g. a 'noxious weed' or a, 'pest'[2]);
- The reproductive and dispersal biology of the comparator (e.g. pollination requirements, numbers of propagules, and dispersal mechanisms, such as wind or pod shattering) provides information on how the transgenic plant may reproduce, spread and increase in abundance in the unmanaged ecosystem;
- The biology and ecology of the valued plant species, e.g. its abundance and distribution in the unmanaged ecosystem, provide information on whether and how it might be affected by the abundance of the transgenic plant (e.g. do they share an ecological niche?). The level of drought-tolerance of the valued plant species provides information on whether the transgenic plant would have a competitive advantage in drought conditions;
- The history of invasion of the unmanaged ecosystem may provide information on whether that ecosystem is susceptible or resistant to plant invasions, and what factors (e.g. drought-tolerance) were important in any previous invasions.

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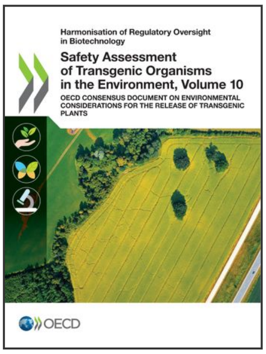
Notes

[1] The impact of weeds on crop production is generally considered to be economic rather than environmental.

[2] Note that the terms used for such declarations will vary between jurisdictions and organisations.



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