CODEX ALIMENTARIUS COMMISSION E

Food and Agriculture Organization of the United Nations

World Health Organization

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Agenda Item 12 **CX/CF 13/7/12**
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JOINT FAO/WHO FOOD STANDARDS PROGRAMME

CODEX COMMITTEE ON CONTAMINANTS IN FOODS

Seventh Session
Moscow, Russian Federation, 8 – 12 April 2013

PROPOSED DRAFT CODE OF PRACTICE FOR WEED CONTROL TO PREVENT AND REDUCE PYRROLIZIDINE ALKALOID CONTAMINATION IN FOOD AND FEED

(AT STEP 3)

Codex Members and Observers wishing to submit comments at Step 3 on the proposed draft Code of practice for weed control to prevent and reduce pyrrolizidine alkaloid contamination in food and feed (see paragraph 8 and Appendix I), including possible implications for their economic interests, should do so in conformity with the *Uniform Procedure for the Elaboration of Codex Standards and Related Texts* (Codex Alimentarius Commission Procedural Manual) before **29 March 2013**. Comments should be directed:

to:	with a copy to:
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Background

1. A first discussion paper on pyrrolizidine alkaloids (PAs) in food and feed and consequences for human health (CX/CF 11/5/14) was prepared by an electronic working group, led by the Netherlands, for discussion at the 5th session of the Committee on Contaminants in Foods.[1]

2. For the 6th session of the CCCF, a discussion paper on Management Practices for the Prevention and Reduction of Contamination of Food and Feed with PAs (CX/CF 12/6/12) was prepared by an electronic working group, led by the Netherlands. This discussion paper updated the first discussion paper with respect to existing management practices and evaluated the possibility to develop a code of practice.

3. At this session, it was reported that there were a number of data gaps and uncertainties regarding the risk of PAs to humans, including:

   - the relative toxicity of different PAs;
   - the major PA contributors in the human diet in different geographical areas;
   - the extent to which animal consumption of PAs contributes to human health effects;
   - the overall risk to humans from PAs;
   - and the efficacy of different management practices.

[1] REP11/CF, paras. 80-83.

However, due to the potential health-threatening effects that can be caused by ingestion of these toxins in feed or food, the Working Group concluded that it is desirable to reduce exposure of both human and animals to PAs as much as possible. The Working Group therefore recommended development of a code of practice (COP) for the prevention and reduction of contamination of food and feed with PA, in particular with regard to weed control as there was useful information available in this regard.

4. The Committee agreed to initiate new work on the development of a Code of Practice for weed control to prevent and reduce pyrrolizidine alkaloid contamination in food and feed. Subject to approval by the Commission, the Committee agreed that the proposed code of practice would be developed by an electronic Working Group led by the Netherlands, working in English only, and open to all Codex members and observers, for comments at Step 3 and consideration at the next session.[2] The 35th Session of the Codex Alimentarius Commission approved this proposal as new work for the Committee.[3]

5. The electronic working group (eWG) was established and members included: Australia, Austria, Brazil, China, Colombia, European Union, FoodDrinkEurope, Germany, International Special Dietary Foods Industries, Japan, Malaysia, New Zealand, Nigeria, United Kingdom, and Vanuatu (see Appendix II). Comments were received from Australia, Austria, Brazil, FoodDrinkEurope, Germany, Japan, New Zealand and United Kingdom.

6. A proposed draft Code of Practice was prepared based on the preceding discussion paper (CX/CF 12/6/12, Appendix I, Management practices). The proposed draft Code of Practice is included in Appendix I to the current document.

Discussion

7. For the Code of practice, different structures are possible. One is based on the management practice, another is based on the type of land. The current structure is based on type of land. Although it still contains repetition of information, it is proposed to use this structure as a basis for further discussion. It should be noted that currently, references are included (in grey). These will be deleted when the document continues in the Step Procedure.

Recommendations to CCCF

8. The Committee is invited to consider the Proposed draft code of practice as included in Appendix I, and to provide their views on the structure of the COP, completeness of current content and/or other matters that possibly should be addressed.

9. As there are still some outstanding discussion points on structure and content of the document, the electronic working group recommends to return the Proposed draft code of practice to Step 2 for redrafting, comments and consideration at the next session of CCCF.

2 REP12/CF, paras. 107-115.
3 REP12/CAC, Appendix VI.

APPENDIX I

Proposed Draft Code of Practice for Weed Control to Prevent and Reduce Pyrrolizidine Alkaloid contamination in Food and Feed

Introduction

1. Pyrrolizidine alkaloids (PAs) are natural toxins occurring in a wide variety of plants. PAs are probably the most widely distributed natural toxins that can affect wildlife, livestock and humans.

2. PAs have a common toxicity profile with the liver being the main target organ of toxicity. Major signs of toxicity in all animal species include various degrees of progressive liver damage (centrolobular hepatocellular necrosis), and veno-occlusive disease. Furthermore, IARC has classified three PAs, lasiocarpine, monocrotaline and riddelliine, as “possibly carcinogenic to humans” (Group 2B). PAs may differ in potency, the relative potencies are currently not known due to lack of oral toxicity data on individual PAs, which hampers risk assessment for PAs.

3. Risks to humans may arise from the intake of PA contaminated food of botanical or animal origin and outbreaks of toxicity in farm animals cause severe economic losses to farmers and rural communities. Direct human cases of poisoning via food are well-documented, such as in the direct and deliberate use of toxic plant species as herbal teas or traditional medicines which in some cases have resulted in deaths. Also, consumption of grain or grain products (flour or bread) contaminated with PA-containing seeds has causedoutbreaks of poisonings. Further, PA-containing parts of PA-containing plants have been identified in agricultural crops, i.e. salad. PAs were also found in products from animal origin, i.e. milk and eggs, indicating transfer of PAs from feed to edible tissues.

4. Although there are gaps in the information available on the toxicity and relative potency of individual PAs, and the contribution of different foods to overall exposure, dietary exposure to PAs should be as low as possible due to the potential health-threatening effects that can be caused by ingestion of these toxins via feed or food. To achieve this, management practices aiming for the prevention and reduction of contamination of food and feed with PAs must be undertaken.

5. Management practices to prevent or reduce PA contamination of food and feed can comprise weed removal/reduction, practices to reduce exposure of food-producing animals, including livestock and bees, to PA-containing plants, and practices to reduce presence of PAs in raw and processed commodities. This Code of Practice focuses on weed control.

6. It should be emphasized that total eradication of PA-containing plants is not feasible or ecologically desirable. Also, grazing animals usually avoid eating most PA-containing plant species under normal circumstances. Generally, livestock graze on PA-containing plants when feed gets scarce in conditions of drought or on over-grazed pastures. Livestock may also consume PA-containing plants when they are present in dried form in feed. Therefore, good feeding practice is important besides management on the level of weed control.

Objective

7. This Code of Practice aims to provide good management practices for weed control of PA-containing plants to prevent and reduce the contamination of food and feed with PAs. In this regard, this code will cover control measures for the management of the PA-containing plant as well as measures for control of plant release and spread.

Scope

8. The scope of this Code of Practice is to provide guidance to prevent contamination of food and feed with PAs on one hand and, where contamination cannot be completely avoided, to reduce the PA contamination in food and feed by weed control. This Code of Practice should be read in conjunction with the Code of Practice for Source Directed Measures to Reduce Contamination of Food and Feed with Chemicals (RCP 49-2001).

Evaluation of compliance with relevant legislation

9. All management practices presented in this Code of Practice shall be followed in compliance with relevant national or international legislation and standards, including general requirement for consumer and worker protection.

Limitations

10. It should be recognized that the implementation of the management measures described in this Code of Practice may be difficult in a number of countries. This may be either due to shortcoming of knowledge or resources or due to geographical, environmental or practical limitations, Due to e.g. the large area of grazing land or inaccessibility of certain regions for agricultural machinery. The measures described in this Code of Practice serve therefore as guidance and each measure described in this Code of Practice should be assessed by national authorities to ensure that it is appropriate and practical for their country-specific conditions.

11. Up to now no detailed information is present concerning the effectiveness of the various management measures. As a result, no full evaluation of the management measures can be conducted. When such information becomes available, an evaluation of the effectiveness of the proposed management measures would be helpful in identifying the most appropriate combination of practices for management of PA-containing plants thereby lowering the chance of PA-contamination of food and feed.

General principles for weed control of PA-containing plants

12. To ensure adequate prevention of spreading of PA-containing plants and to lower the costs of control measures, early detection and identification of these plants is essential followed by action to prevent contamination of food and feed.

13. To achieve an early detection, good education of the farmers and local population is crucial, including contractors and roadside maintenance staff, to raise awareness (FAO, 2010). Education could be done using materials such as leaflets with an overview and description of the most important PA-containing plants and their ecology. Communication with relevant government organizations should also be in place.

14. Once PA-containing plants are detected, the risks for human and animal health must be established in order to verify the need for an integrated weed management plan. In this respect, it must be recognized that the different PA-containing plants may react in a different way to certain management measures. Therefore, it is ever important to keep the ecology of the specific plant in mind. Additionally, influences of weather or climate must be taken into account. When seeking to prevent the spread of the PA-containing plants, all landowners, occupiers and managers must take a collective responsibility to ensure that effective control of the spread is achieved (DEFRA COP, 2004).

Evaluation of the need to proceed to action

15. Before considering any action, the need to proceed to action should be established by identifying the risks posed by the presence of PA-containing plants. This could be done by setting up a tiered risk characterisation approach based on

- toxicity of the particular PAs, if known, present in the plant,
- the relevant contributions of the various PA-containing plants to the specific or total PA intake of the livestock or presence in food/feed, if known,
- proximity of the PA-containing plants to the arable fields and meadows/pastures/grasslands,
- level of infestation,
- local circumstances,
- climate,
- soil type, and
- vegetation cover of receiving land.

The likelihood of PA-containing plants spreading to land used for agricultural practices or grazing and/or feed/forage production should be the determining factor for assessment of the risk (Neumann et al., 2009; DEFRA COP, 2004).

16. One example of assessing the risk posed by PA-containing plants in pastures based on the proximity of the PA-containing plants (bullet 3 above) was found in literature. The following principles were identified for ragwort (*Jacobaea vulgaris*), but these could also serve as guidance for the evaluation of the need to proceed to action for other PA-containing plants:

- high risk: PA-containing plants are present and flowering/seeding within 50 m of land used for grazing by food-producing animals or land used for feed/forage production;
- medium risk: PA-containing plants are present within 50 m to 100 m of land used for grazing by food-producing animals or land used for feed/forage production;
- low risk: the land on which PA-containing plants are present is more than 100 m from land used for grazing by food-producing animals or land used for feed/forage production.

17. In case of a high risk, immediate action may be taken to control the spread of PA-containing plants using appropriate control techniques taking account of the status of the land. In case of a medium risk, a control policy may be established to ensure that when the situation changes from a medium to a high risk of spread, it is identified and dealt with in a time and effective manner using appropriate control techniques taking account of the status of the land. In case of a low risk, no immediate action is required.

18. For risk zoning in relation to food crops, the different ecology of the relevant PA-containing plants should be taken into account. Nevertheless, where infected fields are close together, a similar system may be developed.

Recommended practices

1. Management of the presence of PA-containing plants and control of plant release and spread

19. For managing the presence of PA-containing plants, preferably a combination of non-chemical and chemical methods, i.e. integrated weed management, should be applied to obtain the most effective results.

20. The use of an integrated weed management plan could reduce the use of and reliance on herbicides, thereby lowering the chance on herbicide resistance, and allows weed management in most environments (Naughton et al., 2006). However it should be noted that in those cases where appropriate herbicides are available, their application alone could be sufficiently effective to manage weed presence.

21. Furthermore, an integrated weed management plan should be accompanied with practices to reduce the spread of PA-containing plants thereby preventing infestations to spread.

22. Not all management practices are suitable to be used on every type of land. Therefore, the management practices to control PA-containing plants are discussed hereafter specified by type of land: arable fields, pastures, and areas bordering the crop or pasture.

2. Arable fields

23. It should be kept in mind for the management practices described in this section that their application should not result in harmful consequences for the agriculture.

Management of presence of PA-containing plants

Mechanical methods

24. PA-containing plants in arable fields can be controlled by mechanical methods such as pulling, ploughing, milling and slashing. The timing of applying mechanical methods is important. These practices can best be applied before flowering of the PA-containing plants to prevent seed production and seed spread. When handling the PA-containing plants, suitable precautions should be taken to protect operators' skin and prevent inhalation of pollen.

25. In the case of crops, the best timing of applying mechanical methods is at the start of crop growth. Once the crops are dense, weeds have little chance to grow. In crops such as wheat and millet etc., fields should be weeded prior to planting and periodically during the first six weeks of the growth cycle. A final weeding, about two weeks before harvest, if feasible, could reduce the possibility of contamination of the harvest with toxic seeds significantly. In fact, in legume crops, mechanical or manual weeding may be the only option if infestation is large (FAO, 2010). Attention should be paid to areas bordering the crop, as these may constitute a continuous reservoir for the weed infestation (North West Weeds, 2007, cited by FAO, 2010).

26. Effective manual control requires removal of the root crown and all larger roots. Therefore, manual control may only be effective for seedlings and young rosettes in contrast to bigger plants, which normally develop deep roots. In addition, effective hand pulling is useful for small infestations but is not cost-effective for large ones (Thorne et al., 2005). In case of hand pulling, the plants should be collected in a hermetically sealed bag and destroyed (burned) afterwards. It should be noted that disturbance of the soil may lead to more germination since buried seeds will be exposed to (sun) light.

Chemical methods

27. When applied carefully at the recommended dose of the herbicide, chemical spraying with appropriate herbicides may be an effective way of controlling PA-containing plants. Herbicides used should be registered for application in that specific situation. Also, herbicides should preferably be used in combination with other control methods to increase their effectiveness. The choice of herbicide depends on the specific PA-containing plant species and availability of appropriate herbicides.

28. For most PA-containing plants, in general the most effective time to spray herbicides is when the plants are actively growing and commencing flowering, i.e. in the spring before bloom and in the autumn applied to the new rosettes. Some herbicides require other timing due to their mode of action. PA-containing plants should not be sprayed when the plants are stressed either through lack of water, too much water, disease, insect or mechanical damage, as spray effectiveness will diminish (adapted from Peirce, 2009).

29. The use of non-selective herbicides may damage the crop species and surrounding crops, pastures and environment. Hence, it is better to use selective herbicides or limit the use of non-selective herbicides for spray topping the PA-containing plant (Naughton et al., 2006). Further, some PA-containing plants may develop resistance against a particular herbicide overtime (Thorne et al., 2005).

30. In case of established PA-containing perennial plants, it is better to use systemic herbicides. Systemic herbicides are absorbed either by roots or foliar parts of a plant and are then translocated within the plant system to tissues that may be remote from the point of application.

31. An additional note is to take care that herbicides are applied in the right weather conditions, since the effective concentration of herbicides could be reduced when applied in unfavourable weather conditions, such as rain falls within 5 hours of application (Coles, 1967 cited by Roberts & Pullin, 2007; Forbes et al., 1980 cited by Roberts & Pullin, 2007).

Other methods

32. Soil solarisation, flaming (burning) and use of boiling water are other controlling methods that may be used for small infestations. These methods though may be destructive for other plant species (such as the crop) than the target species. Applying these methods must be directed to the eradication of individual plants and done after good planning taking into account possible risks to the environment.

33. As there is some evidence that changing soil moisture and nutrient availability may influence the PA content of the roots, leaves and flowers of PA-containing plants, cultivation methods may change the PA content of remaining plants. For example, increasing soil moisture will lead to higher PA-concentrations in the roots. PA concentrations are expected to be higher when nutrient availability is low, i.e. higher concentrations were found in plants grown in sand without nutrients than with nutrients. It is however not completely clear whether the same effect may be expected in flowering plants (Kirk et al., 2010; Hol et al., 2003; Brown & Molyneux, 1996).

Control of plant release and spread

Identify alternative plant sources to reduce undesirable growth

34. For crops, sound crop rotations can also minimize weed problems, since it will help to build up soil fertility and structure to produce increasing yields. Increased fertility in its turn will reduce the impact of weeds, and rotating crops can reduce the seeding and germination of weeds (Weed Management Unit, 2009). This should be accompanied by Good Agricultural Practice, such as appropriate sowing time and depth, adequate fertility and moisture at sowing, which is important to ensure good field management (Naughton et al., 2006). Furthermore, agricultural methods such as water and nutrient management or mulching should be conducted.

Control movement of plants/seeds over agricultural zones

35. Assure planting of high quality, weed-free crops (Weed Identification and control Handbook Idaho). When possible by national or regional laws and directives, use seed for planting that is not contaminated (e.g. certified seed) (Naughton et al., 2006).

36. Do not transport PA-containing plants unnecessarily and only when stored in hermetically sealed bags or containers.

Control plant seed movement on vehicles and agricultural machinery

37. Clean vehicles, machinery and equipment that are used in infested areas to prevent introduction of the PA-containing plant to pastures or other agricultural land by spread of seeds. Weed-free buffer zones between infested and un-infested lands will help to contain the infestation (McLaren & Faithfull, 2004).

3. Pastures

38. It should be kept in mind for the management practices described in this section that their application should not result in harmful consequences for the livestock or the pastures.

Management of presence of PA-containing plants

Mechanical methods

39. As for arable lands PA-containing plants can, depending on the extent of the infestation, be controlled by mechanical methods such as pulling, mowing and slashing in pastures. The timing of applying mechanical methods is important. These practices can best be applied before flowering of the plants to prevent seed production and seed spread. When handling the PA-containing plants, suitable precautions should be taken to protect operators' skin and prevent inhalation of pollen.

40. Effective manual control requires removal of the root crown and all larger roots. Therefore, manual control may only be effective for seedlings and young rosettes in contrast to bigger plants, which normally develop deep roots. In addition, effective hand pulling is useful for small infestations but is not cost-effective for large ones (Thorne et al., 2005), nor is it in large areas of pasture. In case of hand pulling, the plants should be collected in a hermetically sealed bag and destroyed (burned) afterwards.

41. For large-scale restorations in pastures, mowing and cutting can be more easily applied. Cutting or slashing tansy ragwort (*Jacobaea vulgaris*) at the start or end of anthesis will reduce the number of flower heads (Siegrist-Maag et al., 2008 cited by Leiss, 2010). Therefore, it is recommended to do the first mowing when half of the plants start anthesis, and the second mowing when half of the re-established plants start anthesis again. On the other hand, fireweed (*Senecio madagascariensis*) should not be slashed in late spring or when more than 25% of the plants are flowering, as the mature plant, that otherwise might have died, may go into re-shooting (adapted from Weed Management Unit, 2009). However, these mechanical methods are not always effective in killing the plants and may even encourage them to re-shoot as is observed with tansy ragwort (*Jacobaea vulgaris*) and Paterson's curse (*Echium plantagineum*) (van der Meijden & van der Waals-Kooi, 1979; Wardle, 1987 cited by Leiss, 2010). As a consequence, slashing or mowing may need to be executed on a very regular basis and be applied in combination with other control measures as part of an integrated weed management plan. For example, high mowing frequencies can be combined with the use of additional nitrogen that will lead to the promotion of fast growing grass species which will impair the germination and establishment of PA-containing plants (Crawley & Nachapong, 1985 cited by Leiss, 2010).

42. Attention should be paid to areas bordering the pasture, as these may constitute a continuous reservoir for the weed infestation (North West Weeds, 2007, cited by FAO, 2010).

Chemical methods

43. When applied carefully at the recommended dose of the herbicide, chemical spraying with appropriate herbicides may be an effective way of controlling PA-containing plants. Herbicides used should be registered for application in that specific situation and used in such a way that unacceptable residues in foods from grazing animals are avoided. Also, herbicides should be preferably used in combination with other control methods to increase their effectiveness. The choice of herbicide depends on the specific PA-containing plant species and availability of appropriate herbicides.

44. For most PA-containing plants, in general the most effective time to spray herbicides is when the plants are actively growing and commencing flowering, i.e. in the spring before bloom and in the autumn applied to the new rosettes. Some herbicides require other timing due to their mode of action. PA-containing plants should not be sprayed when the plants are stressed either through lack of water, too much water, disease, insect or mechanical damage, as spray effectiveness will diminish (adapted from Peirce, 2009).

45. The use of non-selective herbicides may damage the pasture species and surrounding crops, pastures and environment. Hence, it is better to use selective herbicides or limit the use of non-selective herbicides for spray topping the PA-containing plant (Naughton et al., 2006). Some PA-containing plants may however develop resistance against a particular herbicide overtime (Thorne et al., 2005). Examples of active substances that have no or limited influence on grass species are bromoxnil and 2-Methyl-4-ChloorPhenoxyAcetic acid (MCPA). However, it should be ensure that these active substance is allowed for the specific purpose in a specific country. In addition, as these substances are herbicides they may still have an inhibiting effect on crops, so care should be taken in case of possible bordering arable land.

46. In case of established PA-containing perennial plants, it is better to use systemic herbicides. Systemic herbicides are absorbed either by roots or foliar parts of a plant and are then translocated within the plant system to tissues that may be remote from the point of application.

47. An additional note is to take care that herbicides are applied in the right weather conditions, since the effective concentration of herbicides could be reduced when applied in unfavourable weather conditions, such as rain falls within 5 hours of application (Coles, 1967 cited by Roberts & Pullin, 2007; Forbes et al., 1980 cited by Roberts & Pullin, 2007).

Biological methods

Livestock

48. In pastures, PA-resistant livestock can be quite effectively used in grazing management to reduce PA-containing plants since it may weaken the plants and prevent prolific seeding. The best livestock to use are sheep, especially non-pregnant, non-food producing Merino sheep, or goats (Dellow et al., 2008; Anjos, 2010; McLaren & Faithfull, 2004). If lactating animals are used, the milk from these animals must be segregated and not intended for human consumption until it is confirmed that the milk does not contain PAs. Also, if the animals used in biological control of PA-containing plants would be slaughtered for human consumption, it should be ensured that meat and offal have no high levels of PAs, e.g. by application of a withdrawal period prior to the slaughter. When removing these animals from affected areas it should be necessary to avoid transfer of seeds on their hooves, coats and digestive tracts, which can infest a new area. This could be done by placing them into quarantine.

49. Grazing management can be applied on low-level, widespread infestations. Disadvantages include that enough grazing animals must be available; water and fencing or herding to control movement must be set up; and the timing, intensity and duration of grazing must be closely monitored and managed to prevent overgrazing (Thorne et al., 2005).

50. It must be recognized that overgrazing may lead to loss of the competitive nature of the pasture or of native plants, to PA-containing plants to return and spread over the bare soil, and livestock poisoning. Hence, it is recommendable to stop grazing during flowering of (a number of) PA-containing plants as their PA-production is then very high (Naughton et al., 2006; Suter et al., 2007).

51. Antimethanogenic therapy in livestock may increase ruminant resistance to PA toxicity. Animals with no previous exposure to PAs are very susceptible to poisoning while animals with prior exposure to PA-containing plants show enhanced rumen detoxifying activity. The bacterium Peptostreptococcus heliotrinreducans most likely plays an important role in this process (Dick et al., 1963; Lanigan, 1970; Lanigan, 1971; Lanigan, 1976; Lanigan & Smith, 1970; Peterson et al., 1992).

Natural enemies

52. Natural enemies of a plant may be used to control PA-containing plants. It may be an economical and effective method. However, efficacy must have been established and the natural enemy must not present an environmental problem itself (Myers, 2000).

53. Tansy ragwort (*Jacobaea vulgaris*) densities may for example be reduced by the natural enemies Longitarsus jacobaeae (ragwort flea beetle) and a combination of Longitarsus jacobaeae and Tyria jacobaeae (cinnabar moth) (Roberts & Pullin, 2007). Also Cochylis atricapitana, a ragwort stem and crown boring moth from Europe, was found to reduce the plant height of flowering plants and reduced the size and survival of rosettes (McLaren et al., 2000; Gourlay, 2007a). Another bio control agent used is Platyptillia isodactyla (ragwort plume moth) which has as common host marsh ragwort (*Senecio aquaticus*). Deuterocampta quadrijuga (blue heliotrope leaf-beetle) can completely defoliate blue heliotrope (*Heliotropium amplexicaule*), with both the larvae and adults feeding on the leaves (Dellow et al., 2008).

54. However, good bio control is only feasible for a number of species as costs associated with finding, screening and testing potential agents can be very high. As such, successful biological control requires extensive development and establishment phases and costs. For most of the PA-containing plants no effective biological control agent is available.

Other methods

55. Soil solarisation, flaming (burning) and use of boiling water are other eradication methods that may be used for small infestations. These methods though may be destructive for other plant species than the target species. Applying these methods must be directed to the eradication of individual plants and done after good planning taking into account possible risks to the environment.

56. As there is some evidence that changing soil moisture and nutrient availability may influence the PA content of the roots, leaves and flowers of PA-containing plants, cultivation methods may reduce the PA content of remaining plants. For example, increasing soil moisture will lead to higher PA-concentrations in the roots. PA concentrations are expected to be higher when nutrient availability is low, i.e. higher concentrations were found in plants grown in sand without nutrients than with nutrients. It is however not completely clear whether the same effect may be expected in flowering plants (Kirk et al., 2010; Hol et al., 2003; Brown & Molyneux, 1996).

Control of plant release and spread

Identify alternative plant sources to reduce undesirable growth

57. Use alternative plant sources to reduce undesirable growth, i.e. by planting vigorous perennials that will suppress the introduction and growth of PA-containing plants. This can be achieved by 1) sowing winter pasture species; 2) allowing a stand over of summer pasture feed; and 3) growing combinations of winter and summer pastures. Pasture management must also often go along with other forms of weed control, such as herbicides and mechanical means (Ensbey, 2009). This should be accompanied by Good Agricultural Practice, such as appropriate sowing time and depth, adequate fertility and moisture at sowing, which is important to ensure good pasture management (Naughton et al., 2006). Furthermore, conduct agricultural methods such as water and nutrient management or mulching.

Control movement of plants/seeds over pastures

58. Assure planting of high quality, weed-free grass seeds (Weed Identification and control Handbook Idaho). When possible by national or regional laws and directives, use seed for planting that is not contaminated (e.g. certified seed) (Naughton et al., 2006).

59. Do not transport PA-containing plants unnecessarily and only when stored in hermetically sealed bags or containers.

Control plant seed movement on animals

60. In case that livestock has grazed in infested areas, place them into quarantine for several days as seed can be carried on the hooves and coats, and in the digestive tracts of livestock. Inspect these quarantine areas regularly to assure no PA-containing plants will start infesting those areas (McLaren & Faithfull, 2004).

Control plant seed movement on vehicles and agricultural machinery

61. Clean vehicles, machinery and equipment that are used in infested areas to prevent introduction of the PA-containing plant to other pastures or agricultural land by spread of seeds. Weed-free buffer zones between infested and un-infested lands will help to contain the infestation (McLaren & Faithfull, 2004).

4. Areas bordering the crop or pasture

62. It should be kept in mind for the management practices described in this section that their application should not result in harmful consequences for the surrounding crops or pastures. In addition, landowners are most of the time not legally responsible for the areas bordering the crop or pasture, such as road verges, sides of a ditch and ruderal places. Therefore, for this type of land it is extremely important that all landowners, occupiers and managers take a collective responsibility to ensure that effective control of possible spread of PA containing plants is achieved.

Management of presence of PA-containing plants

Mechanical methods

63. PA-containing plants can be controlled by mechanical methods such as (depending on the level of infestation) pulling, mowing, ploughing, milling and slashing. The timing of applying mechanical methods is important. These practices can best be applied before flowering of the plants to prevent seed production and seed spread. When handling the PA-containing plants, suitable precautions should be taken to protect operators' skin and prevent inhalation of pollen.

64. Effective manual control requires removal of the root crown and all larger roots. Therefore, manual control may only be effective for seedlings and young rosettes in contrast to bigger plants, which normally develop deep roots. In addition, effective hand pulling is useful for small infestations but is not cost-effective for large ones (Thorne et al., 2005). In case of hand pulling, the plants should be collected in a hermetically sealed bag and destroyed (burned) afterwards. It should be noted that disturbance of the soil may lead to more germination since buried seeds will be exposed to (sun) light.

Chemical methods

65. When applied carefully at the recommended dose of the herbicide, chemical spraying with appropriate herbicides may be an effective way of controlling PA-containing plants. Of course, herbicides used should be registered for application in that specific situation. Also, herbicides should be used in combination with other control methods to increase their effectiveness. The choice of herbicide depends on the specific PA-containing plant species and availability of appropriate herbicides.

66. For most PA-containing plants, in general the most effective time to spray herbicides is when the plants are actively growing and commencing flowering, i.e. in the spring before bloom and in the autumn applied to the new rosettes. Some herbicides require other timing due to their mode of action. PA-containing plants should not be sprayed when the plants are stressed either through lack of water, too much water, disease, insect or mechanical damage, as spray effectiveness will diminish (adapted from Peirce, 2009).

67. The use of non-selective herbicides may damage surrounding crops, pastures and environment. Hence, it is better to use selective herbicides or limit the use of non-selective herbicides for spray topping the PA-containing plant (Naughton et al., 2006). Further, some PA-containing plants may develop resistance against a particular herbicide overtime (Thorne et al., 2005).

68. In case of established PA-containing perennial plants, it is better to use systemic herbicides. Systemic herbicides are absorbed either by roots or foliar parts of a plant and are then translocated within the plant system to tissues that may be remote from the point of application.

69. An additional note is that the effective concentration of herbicides could be reduced when applied in unfavourable weather conditions, such as rain falls within 5 hours of application (Coles, 1967 cited by Roberts & Pullin, 2007; Forbes et al., 1980 cited by Roberts & Pullin, 2007).

Biological methods

70. Natural enemies of a plant may be used to control PA-containing plants. It may be an economical and effective method. However, efficacy must have been established and the natural enemy must not present an environmental problem itself (Myers, 2000).

71. Tansy ragwort (*Jacobaea vulgaris*) densities may for example be reduced by the natural enemies Longitarsus jacobaeae (ragwort flea beetle) and a combination of Longitarsus jacobaeae and Tyria jacobaeae (cinnabar moth) (Roberts & Pullin, 2007). Also Cochylis atricapitana, a ragwort stem and crown boring moth from Europe, was found to reduce the plant height of flowering plants and reduced the size and survival of rosettes (McLaren et al., 2000; Gourlay, 2007a). Another bio control agent used is Platyptillia isodactyla (ragwort plume moth) which has as common host marsh ragwort (*Senecio aquaticus*). Deuterocampta quadrijuga (blue heliotrope leaf-beetle) can completely defoliate blue heliotrope (*Heliotropium amplexicaule*), with both the larvae and adults feeding on the leaves (Dellow et al., 2008).

72. However, good bio control is only feasible for a number of species as costs associated with finding, screening and testing potential agents can be very high. As such, successful biological control requires extensive development and establishment phases and costs. For most of the PA-containing plants no effective biological control agent is available.

Other methods

73. Soil solarisation, flaming (burning) and use of boiling water are other eradication methods that may be used for small infestations. These methods though may be destructive for other plant species (such as the crop) than the target species. Applying these methods must be directed to the eradication of individual plants and done after good planning taking into account possible risks to the environment.

74. As there is some evidence that changing soil moisture and nutrient availability may influence the PA content of the roots, leaves and flowers of PA-containing plants, cultivation methods may reduce the PA content of remaining plants. For example, increasing soil moisture will lead to higher PA-concentrations in the roots. PA concentrations are expected to be higher when nutrient availability is low, i.e. higher concentrations were found in plants grown in sand without nutrients than with nutrients. It is however not completely clear whether the same effect may be expected in flowering plants (Kirk et al., 2010; Hol et al., 2003; Brown & Molyneux, 1996).

Control of plant release and spread

Control of plant and seed movement from urban to agricultural lands and pastures

75. Provide educational material to horticulturists to correctly identify PA-containing plants to prevent propagation of unwanted plant species. This information may be supported with national or regional regulations on the propagation, sale and distribution of PA-containing plants. Advise the general public on how to prevent the spread of unwanted, PA-containing plants from urban environments into agricultural and other lands.

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