Amaranth

Amaranthus spp.

Weed management guide for Australian vegetable production

INTEGRATED WEED MANAGEMENT

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Identification

Amaranthus species are annual (or occasionally perennial) herbaceous plants, native to the Americas, that can grow up to 2 m in height. Here, we discuss *A. viridis* (green amaranth) and *A. retroflexus* (redroot amaranth).

There are approximately 60 *Amaranthus* species worldwide, of which 20 are found in Australia. Specific identification is best achieved based on differences in leaves, branches and flowers.

Green amaranth leaves are alternate, between 3-9 cm in length and 2-6 cm in width, oval to triangular in shape, smooth, and darker green on the top of the leaf. Flowers are brownish-yellow, about 1 mm in length and found at the end of plant stems. Seed is disc-shaped, shiny brown or black, and approximately 1 mm in length. Plants grow up to 2 m in height.

Redroot amaranth can also grow up to 2 m in height, and has a red-pink tap root. Leaves are alternate, oval to egg shaped and up to 10 cm in length, with more prominent veins than green amaranth. Flowers are numerous, greenish, and seed is oval to egg shaped, somewhat flattened, shiny black or dark brown, and approximately 1 mm in length.

Young plants can bear some resemblance to blackberry nightshade (*Solanum nigrum*) and fat hen (*Chenopodium album*), but with experience can be identified by their cotyledons and first true leaves.

Figure 1 includes a series of illustrative photos of green amaranth at different life stages, from a young seedling through to a mature flowering plant. These photos should also help with identification of redroot amaranth and other *Amaranthus* species, which are very similar in appearance at most life stages.

Figure 1 Green amaranth life stages, from emergence to flowering.

There are a number of amaranth species present in Australia, though in this guide we discuss *A. viridis* (green amaranth) and *A. retroflexus* (redroot amaranth) as being broadly representative of these various weeds, in terms of impact and management.

Depending on your location, you may have different amaranth weeds impacting on your vegetable crop. Figure 2 shows redroot amaranth (distinguisable from green amaranth by its green flower head) as well as Powell's amaranth (*A. powellii*, distinguishable by its red branches).

Figure 2 Redroot amaranth (left; Wikipedia) and Powell's amaranth (right; AgPest New Zealand).

Characteristics

Key characteristics

Table 1 Key characteristics of amaranth

Time of germination	Spring and summer.
Time of flowering and seed set	Through summer and autumn (potentially year round in warmer climates).
Reproduction	By seed only.
Seed productivity	Between 230,000 and 500,000 seeds per plant (estimated).
Seed viability	Up to four decades, but most seed not viable after approximately 6-10 years.
Optimum germination depth	10 to 15 mm; no deeper than 65 mm.
Soil type/s	Adapted to a range of soil types, prefers moist soils. Less suited to acidic soils.
Competitive advantages	Early emergence; rapid growth; long-term seed viability; abundant seed production; competes well with crops; able to germinate in low light conditions; year-round growth in warmer climates.

Seasonality

Amaranth is usually a summer annual weed, germinating in spring and flowering from late summer onwards, and surviving over-winter as seed. In tropical or sub-tropical climates it is capable of flowering all year, and producing two generations of plants.

Illustrating the capacity of amaranth to adjust to a variety of climates, seed is capable of germinating at temperatures ranging from 8°C to 45°C, however the optimum range of temperatures for germination (in the case of redroot amaranth) appears to be between 25°C and 40°C. Plants are found up to 1,000 m above sea level, however spread is restricted at higher altitudes given its preference for higher temperatures and a longer growing season.

Seedling emergence is stimulated by a mixture of light, scarification (abrasion), and alternating temperatures. Seed from both green amaranth and redroot amaranth are capable of germinating in darkness, although growing plants are relatively intolerant of shade.

Seed production

Seed production of between 230,000 and 500,000 per individual plant has been reported amongst amaranth species.

Seed viability

Research involving redroot amaranth seed has suggested that more than 90% of seed are viable when freshly harvested from the plant, and most studies suggest that seed can remain viable for 6-10 years. However, after 18 months buried in the soil, approximately 90% of this seed appears to lose its viability. Data on longer-term seed viability are inconsistent, however some research has suggested that approximately 2% of redroot amaranth seed is viable after 40 years of burial in the soil. Longevity increases at greater burial depths in the soil.

The optimum burial depth for amaranth seed to germinate is approximately 10 to 15 mm. Germination declines progressively at burial depths up to approximately 65 mm, and no germination appears to occur for seed buried greater than this depth.

Soil preference

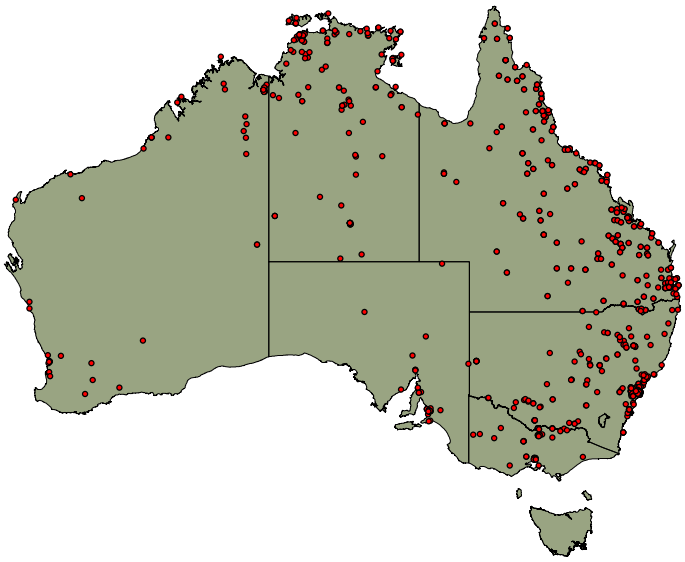
Amaranth shows a preference for moist areas. It is also considered adaptable to a variety of soil types from sandy loam through to clay, though research suggests that redroot amaranth growth is relatively poor in acidic soils. It has a greater tendency to dominate in moist, low-lying conditions with alkaline soils.

Methods of spread

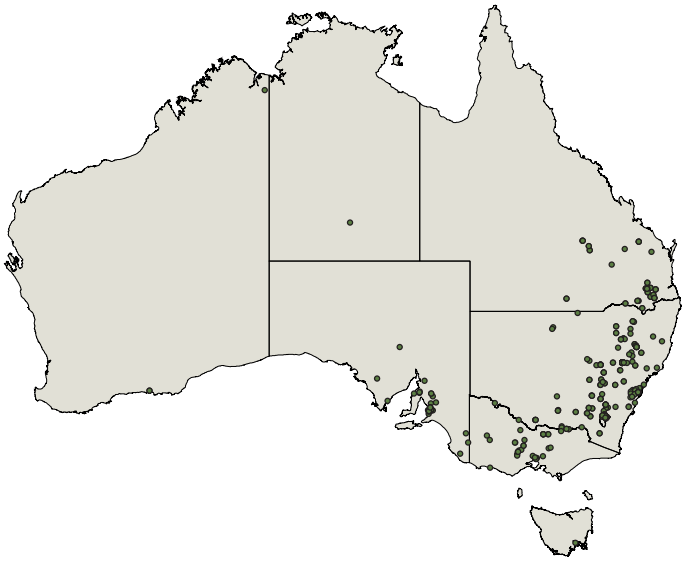
Methods of amaranth spread include water (including surface irrigation water), birds and livestock, fertiliser (manure) application, farm machinery movement, and crop seed contamination. Amaranth seeds are relatively light in weight and are capable of wind transport, but seeds largely fall within 2 m of the parent plant.

Distribution

In Australia, green amaranth is found in all mainland states, while redroot amaranth is most likely to be present in Australia's south-east. Industry surveys have noted amaranth as a weed of vegetable production systems in NSW, NT, Qld, Tas and WA. Although it generally favours warmer climates, Maps 1 and 2 illustrate its capacity to grow in a variety of Australian climates, with green amaranth being the more widespread of the two species.



Map 1 Australian distribution of green amaranth (source: Atlas of Living Australia).



Map 2 Australian distribution of redroot amaranth (source: Atlas of Living Australia).

Impacts

The climatic adaptability of amaranth species, combined with its preference for moist soils and the amount of seed plants are capable of producing, makes amaranth well adapted to the conditions found in vegetable production systems across many parts of Australia. Consequently it is considered one of the most important weeds of Australian vegetable production, particularly of summer crops.

Across the world, amaranth species are considered an important weed in over 70 countries, and a pest in a range of vegetable crops in both the northern and southern hemisphere. In Australia, crops identified as being negatively impacted by amaranth include cucurbits, lettuce, tomato, capsicum and chilli, beans, sweet corn, peas, and brassicas.

Crop competition and contamination

The rapid growth, prolific seeding and long growing season characteristic of amaranth makes these species capable of spreading quickly in vegetable cropping systems, reducing yield and quality by crowding out crop plants and competing for resources.

Research in the United States has found, for example, that severe amaranth infestations can reduce the final yield of potato crops by up to one third, and of beans by up to one half. Significant reductions in the final yield of lettuce crops have also been noted.

On Australian vegetable farms, the size and density of amaranth plants has been noted to interfere with harvesting operations. They are relatively difficult to control in broadleaf vegetable crops due to a lack of registered herbicide options (discussed in more detail below).

It has also been found that amaranth may have a limited allelopathic effect on certain vegetable crops (for example cucumbers), which have been found to be susceptible to higher concentrations of amaranth leachates.

A host of pests and diseases

Amaranth species are noted for their capacity to host a variety of crop pests, diseases and viruses, including caterpillars, cucumber mosaic virus, tomato spotted wilt virus, root-knot nematodes, thrips, and aphids.

Management

Management methods

Table 2 Amaranth management methods

Activity	Suitability	Notes
Tillage	✔✔✔	No later than 2 weeks after emergence. May include stale seed bed. Effectiveness of deep tillage is variable.
Cover crops and crop residues	✔✔	Feasibility of cover crops dependent on cash crop produced and viability of non-crop period in annual rotation. Usefulness of crop residues as weed management option dependent on crop. Good establishment is critical. Plants may survive beneath cover crop canopy.
Maximising crop competitiveness	✔✔	Plant crop at highest practical density without impacting on crop yield, to increase competition.
Farm hygiene	✔✔	Best suited to farms with no current amaranth infestation, or an infestation restricted to one part of the farm.
Hand weeding	✔	As follow-up to early-stage herbicide and tillage. Hand weeding is expensive and not suitable for wide-scale use. Better suited to lighter infestations or targeted (e.g. mature, escapee) plant removal.
Herbicides	✔✔✔	Pre-plant, post-plant and early post-emergence options available. Potential resistance to triazines based on overseas examples.
Biological control	**N/A**	Not currently available in Australia.
Integrated weed management	✔✔✔	Precise combination of techniques will vary from farm to farm.

Tillage ✔✔✔

Because amaranth seedlings are very fragile, delaying crop planting and multiple shallow tillage operations (for example, stirring the soil 2 to 4 times within the first month after initial deep tillage and bed formation tillage to a depth of 2.5 cm to 5 cm), can be effective in stimulating amaranth germination, by exposing previously undisturbed seeds to light. Small seedlings are then easily controlled by follow-up shallow tillage.

This is known as the stale seed bed technique, and is designed to encourage germination of weeds such as amaranth, and to control seedlings before they become too large and/or produce seed. As a consequence, the weed seed bank in the top layer of soil is reduced, so that fewer weeds emerge during the crop growing season. Timing is important: older amaranth plants can often recover from a shallow tillage and produce seed before they are controlled by other means. Such an approach may also not be feasible in vegetable production systems that only include relatively short fallow periods.

Research also suggests that a deep tillage operation (between 40 to 60 cm rather than an approximately 20 cm depth till which is common practice in the industry) can be beneficial in reducing amaranth populations, though results are not consistently successful. This may be partially due to the capacity of amaranth seed to remain viable for longer when buried at greater depths in the soil.

Shallow tillage may also be effective within the crop row in the first 4-6 weeks after crop planting. Feasibility of this option depends on crop type and availability of suitable inter-row tillage equipment. Furthermore, cultivation even within the crop row cannot control all late germinating weeds, and is less likely to be effective against larger or even later germinating amaranth plants.

Figure 3 Shallow inter-row tillage can contribute to reducing the amaranth seed bank, however it is only viable within certain vegetable crops, and only early in the crop life cycle before plants have covered the bed. Shallow tillage before the crop is planted is likely to be of greater benefit.

Cover crops

Cover crops grown in the period between vegetable cash crops offer growers an opportunity to reduce the impact of amaranth on their farm. Selection of cover crop variety will need to take several factors into account, such as cost of and ability to grow the cover crop, its expected soil health benefits, relevance for breaking the disease cycle within the cash crop, and overall contribution to cash crop productivity. Good establishment is critical for achieving effective weed management using the cover crop, including selection of a high yielding variety and using narrow row spacings and higher planting density.

When cover crops are well established and maintained, they can be expected to reduce amaranth emergence, flowering and seed set through competition for resources (particularly light, soil nutrients and water). Because amaranth plants are intolerant of shaded conditions once growing, the success of a cover crop in managing this weed will depend on its ability to quickly form a thick canopy that minimises the amount of light reaching emerging amaranth plants. Cover crops with poorer or slower canopy closure may therefore worsen the amaranth problem.

Cereal rye has been noted in previous research as an effective cover crop option for suppressing redroot amaranth, and certain legumes (e.g. clovers, vetch) have also been found to be effective when planted at high rates. Brassica green manure crops appear to suppress emergence of amaranth plants, and may have an allelopathic effect on these weeds.

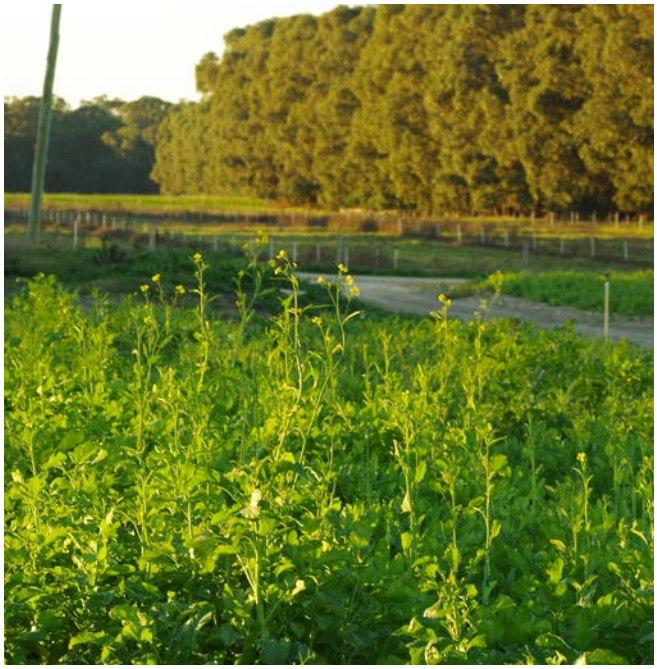


Figure 4 Brassica cover crop varieties such as 'BQ Mulch' being trialled here on a farm near Myalup, WA, may have a biofumigant effect on amaranth.

Maximising crop competitiveness

Agronomic practices, such as increased crop density, that contribute towards the rapid development of a thick canopy cover are likely to lead to less return of amaranth seed to the soil. This is because greater crop density will result in fewer and shorter amaranth plants, fewer flowers, and reduced seed production.

This principle is similar to selecting a competitive cover crop variety as discussed above, and can be expected to be beneficial given that amaranth appears to perform relatively poorly in shaded conditions. Ideally and where possible, wheel tracks would be shaded as well.

However, farmers should remain aware of the possibility that amaranth seedlings and small plants may be present beneath the crop canopy, and may mature, flower and set seed after the crop is harvested and the weeds are exposed to more sunlight.

In addition to increasing planting density, selecting a particularly competitive crop variety may result in more rapid establishment of crop canopy, and greater competition with amaranth and other important weed species.

Higher planting density may have some adverse effects, such as increased competition among crop plants (lowering yield) and greater risk of soil and plant diseases.

Figure 5 Ensuring appropriate planting density to allow good coverage of the crop beds can be useful along with other techniques (such as tillage and pre-plant/pre-emergent herbicide application) to suppress amaranth and other weeds effectively within the crop beds, as this example of a lettuce crop near Gatton, Qld, illustrates.

Farm hygiene

Implementing appropriate farm hygiene practices helps limit the spread of amaranth seeds across and between properties, and onto crop beds from other parts of a property where the weed is present. Common practices include permanent or set vehicle tracks, equipment wash-down, and restricting movement onto the property.

While amaranth may be well managed within the crop beds, it may still be present in wheel tracks, irrigation lines, headlands and nearby non-crop areas such as around sheds and irrigation infrastructure, to the extent that plants are going to seed and replenishing the seed bank in the fields. Effectively managing off-bed amaranth plants may therefore reduce the burden of this weed within crop beds in the longer term.

Farm hygiene may be less relevant for managing amaranth where it has already spread across the whole farm. Other difficulties associated with this approach include the time required to wash equipment down thoroughly, and the potential for uncontrolled spread in flood prone areas.

Figure 6 Establishing a fixed equipment wash-down bay can help restrict the spread of amaranth on the farm, particularly where it is not present at all or only present on part of the farm.

Hand weeding

Hand weeding is effective for removal of amaranth and other important weeds on vegetable farms, particularly those that are flowering or fruiting and setting seed, and/or plants missed when other management approaches have been implemented. Options include digging or hoeing plants out, or potentially pulling larger plants out by hand. Hand weeding may be necessary to remove amaranth plants growing close to crop plants, in crop plant holes in a plastic mulch system, or more generally within the crop bed where selective herbicide options are not available, and where other attempts to manage the weed have been less successful.

Amaranth plants that are flowering and/or fruiting should be removed from the crop rather than left on the ground, to ensure that viable seed are not left near the crop rows to add to the soil weed seed bank for future seasons.

Farmers are generally hesitant to implement wide-scale hand weeding due to its high cost. However, selective hand weeding can be a very effective follow-up to tillage and herbicide control in particular, implemented earlier in the crop life cycle. Removing a few remaining amaranth plants by hand and taking any flowering or fruiting plants away from the paddock may have significant benefits in reducing the weed seed bank in future crop seasons. It may also help prevent herbicide resistance from developing.

Combining tillage with hand weeding and slashing is likely to reduce amaranth populations over time, but will require several years of diligent implementation given the longer-term viability of seed.

Figure 7 Diligent hand weeding over several seasons, utilised in combination with other weed management tactics, can result in almost complete eradication of weeds from the crop. In this paddock in Western Australia, farm staff were encouraged to remove all weeds by hand before seed set. They had succeeded in transforming a previously weedy paddock into one almost entirely free of weeds.

Herbicides

A variety of herbicides are registered in Australia for management of *Amaranthus* spp. across most common vegetable crops (Table 3). Most of these are registered either for pre-emergence application or early post-emergence.

Research suggests that being diligent in application of suitable herbicides to control amaranth is important in reducing the weed seed bank, and keeping it at a low level. This is likely to be even more effective if appropriate herbicide use (suitable to the crop) is employed alongside other weed management techniques.

Residual herbicides are recommended (when available within particular crops) as a follow-up to stale seed beds to minimise reinvasion of amaranth during the crop cycle. Post-emergence herbicides tend to be most successful until approximately the 4-6 leaf stage. Non-selective herbicides such as glyphosate are also effective.

Farmers should consult with their advisor or agronomist for specific product availability in their district, whether herbicide options are registered for the crop/s they grow, and the suitability of these products for their production system.

Table 3 Herbicides registered for management of amaranth in Australian vegetable production

Herbicide active ingredient*	Trading name/s	Group	Vegetable crop/s in which registered	Timing/crop stage
Acifluorfen	Acifluorfen; Reylon Tuxedo; Ardeo	G	Green beans	Apply when crop is at 6 to 7 leaf stage and/or early flowering
Atrazine	Gesaprim	C	Sweet corn, potatoes	Pre-plant, pre-emergence or post-emergence
Chlorthal-Dimethyl	Dacthal 900 WG	D	Brassicas, beans, peas, garlic, onions, carrots, lettuce, potatoes, turnips	At time of seedling or transplanting
Clomazone	Command 480 EC; Director	F	Beans, cucurbits, potatoes	Post-plant pre-emergence
Dimethenamid-P	Frontier-P	K	Green beans, navy beans, sweet corn, corn, green peas, pumpkins and kabocha	At or immediately after sowing; pre-emergence
Diuron	Diurex WG	C	Asparagus, peas	Pre-emergence
EPTC	Eptam	E	Beans, potatoes	Pre-emergence
Ethofumesate	Tramat	K	Beets, onions	Pre- or post-emergence depending on crop
Fluroxypyr	Fluroxypyr	I	Corn	Post-emergence
Ioxynil	Totril	C	Onions	Post-emergence
Linuron	Linuron DF and Flowable	C	Carrots, parsnips, onions, potatoes	Pre- or post-emergence depending on crop
Metham	Metham Sodium; Tamafume (fumigants)	N/A	All crops	Pre-plant
Oxyfluorfen	Baron 400 WG; Goal; Striker	G	Brassicas	Pre-transplant (7 days prior)
Phenmedipham	Betanal Flow 160 SE	C	Beetroot, silver beet	Post-emergence selective
Prometryn	Gesagard; Prometryn 900DF	C	Carrots, celery, potatoes	Pre-emergence, or early post-emergence in carrots
Propachlor	Ramrod	K	Beetroot, onions, transplanted brassicas	Pre-emergence, pre-transplant or at-transplant, depending on crop
Propyzamide	Propyzamide	D	Lettuce	Pre-emergence or immediately after transplanting
S-Metolachlor	Dual Gold	K	Brassicas, beans, sweet potatoes	Immediately after transplanting
Simazine	Gesatop; Simagranz	C	Asparagus	Pre-emergence
Trifluralin	Trifluralin	D	Green beans, navy beans, peas, carrots, brassicas	Pre-sowing or pre-planting

** Details correct at time of writing; please consult the relevant herbicide label/s, contact your reseller for current registration details, or contact the Australian Pesticides and Veterinary Medicines Authority. This table does not include minor use permits, or non-selective options such as glyphosate or diquat. If using crop rotations, the APVMA Public Chemical Registration Information System database may be searched for 'amaranthus' to identify a range of herbicides suited to a range of cropping situations.*

Herbicide resistance

Triazine-resistant amaranth biotypes have been confirmed outside of Australia through comparative field and greenhouse trials. While this does not appear to be an issue at the time of writing in Australia, it is notable given that the triazine herbicide product 'simazine' is registered for use in asparagus crops.

Biological control

Outside Australia, insects have only shown limited potential in studies conducted for their biological control potential of *Amaranthus* spp., though the beetle *Disonycha glabrata* is considered by some to be a potential biological agent. Various pathogens and fungi have also shown some promise as biological control agents for amaranth.

Biological control is no silver bullet for success. Biological control agents may suppress growth and/or flowering of weeds, but will need to be integrated with other management methods.

In Australia biological control has largely only been introduced for some perennial non-grass weeds in aquatic, pasture, and rangeland habitats. The short-term cropping season common in vegetable production makes it difficult for biological control agents to become established at effective levels. Therefore, vegetable farmers are less likely to have the benefit of their use in the near future.

Bringing the control methods together

The three dimensions to success, most likely to provide effective control of major weeds such as amaranth include 'Deliberation', 'Diversity', and 'Dedication'.

In applying this '3D' approach, a variety of options is available as described on the next page. This is commonly known as 'integrated weed management', and is likely to bring you the greatest chance of longer-term success in restricting the impact of amaranth on your farm.

Integrated management of amaranth

Integrating all available and feasible weed control techniques in a timely and diligent way has been shown to be very effective in bringing heavy infestations of broadleaf weed species such as amaranth under control on Australian vegetable farms.

This section has been adapted from the chapter 'Vegetable Weed Management Systems', written by Craig Henderson, and published in the book *Australian Weed Management Systems* (edited by Brian Sindel, University of New England).

Some practices may be implemented for reasons other than weed management, but still have weed management benefits.

Depending on the farmer's circumstances and resources and the extent of the amaranth infestation, whole-of-farm integrated weed management strategies may include the following:

- Shifting most cash crop production to the parts of the farm where the amaranth infestation is lower.
- Including a cash crop or cover crop during the traditional non-cash crop period in the rotation allows use of *selective herbicide options* that have been registered for amaranth control. Fewer weeds may be expected to appear in the paddock when an out of season cover crop is grown. Including a fallow period in the crop rotation may also allow *non-selective herbicide* application to reduce the amaranth seed bank.
- Where a weed infestation is particularly heavy, it may be necessary to produce cash crops only during the warmest months of the year, when crop seeding or transplanting through to harvest is likely to take less time than during the cool season. Through competition and shading, this short crop production period may be beneficial in minimising the renewal of the amaranth soil seedbank, even though the species has a relatively rapid life cycle. Once the crop is harvested, the residue can be quickly ploughed in to prepare the land for the next cropping sequence, also helping to prevent seed set by escapee weed plants.
- Implementing and rigorously adhering to a *farm hygiene* program, for example: undertaking thorough vehicle washdown in between farm sites (especially infested and non-infested areas); laying concrete or gravel tracks along major farm laneways to reduce the amount of soil being spread by vehicles; and planting a competitive grass species (e.g. Kikuyu) along laneways and drainage lines, and mowing these areas to minimise the chance of undesirable weed establishment. Farm hygiene reduces the potential for amaranth seeds outside the vegetable beds to act as sources for recolonisation, and is particularly relevant when parts of the farm are infested while others remain free of the weed.
- *Repeated cultivations* and *herbicides* may be used together to reduce the population of amaranth and other weeds before each crop planting. These approaches may include implementing a stale seed bed, and controlling recently emerged plants either by repeated light tillage or non-selective herbicide application. Cultivating in early summer will kill many seedlings during their peak germination period. Encouraging seeds to germinate and then controlling the plants before seed set can reduce the weed seed bank in the longer term.
- Use of a *drip irrigation system* can mean that the non-irrigated inter-rows remain dry (unless rain falls) throughout most of the growing period, with consequent reductions in amaranth and other weed populations given their preference for higher levels of soil moisture. Such an irrigation system may be integrated with a *plastic mulch* in some high-value vegetable crops such as cucurbits. This will result in little amaranth emergence within the mulched crop beds, though farmers need to remain aware of the potential for weed seeds to germinate in the crop holes, as well as where the mulch has been punctured during laying or during crop management activities.
- *Close plant spacings*, *rapid crop growth* and *canopy closure*, combined with in-crop spraying of *selective herbicides* (where such options are available) can result in reduced seed production of amaranth in the vegetable crop, given that this weed does not perform well in low light conditions beneath the crop canopy. A similar policy may be pursued in cover crop rotations.
- *Hand weeding* also has a role to play in an integrated approach. Farm staff should be encouraged where possible to physically remove and destroy older weeds (particularly those flowering or fruiting) that they come across in the course of their work, especially at harvest time when large numbers of workers are likely to be systematically moving through each field.

Because annual broadleaf weeds such as amaranth rely on rapid turnover of large numbers in the weed seed bank to maintain high populations, an integrated management system of this nature can be expected to result in a relatively sharp decline in weed numbers over time. Nonetheless, farmers need to remain aware of the potential for amaranth seed to remain dormant for several years (particularly at greater depths), and therefore for germination flushes to occur at any stage given suitable conditions.

However, integrated management of amaranth is likely to be effective in reducing its impact at relatively little extra cost to the farmer, given that most of the operations described above would still have been implemented for other reasons and have other farm and crop benefits.

The key to integrated management of amaranth is a planned strategy to link the key management components in a sensible sequence, and the persistence to ensure that each step is diligently carried out. In the longer term, integrated weed management may contribute to improved enterprise flexibility, where cash crops may eventually be grown at any stage of the viable production period without concern that this will result in a vast increase in weed numbers, or that the weed burden will impact too significantly on the cash crop.

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Disclaimer

Descriptions of herbicide use in this guide are not to be taken as recommendations. Herbicides must only be used in accordance with the recommendations provided on herbicide labels. Readers are reminded that off-label use of herbicides may be restricted or not permitted under relevant legislation. Landholders are therefore advised to determine current registrations and legal requirements for herbicides they may be considering, and to consult with their State or Territory government departments regarding the legal requirements they are obligated to adhere to relating to herbicide use and weed control.

Coleman, M., Kristiansen, P., Sindel, B., Fyfe, C. 2021. Amaranth (*Amaranthus* spp.): Weed management guide for Australian vegetable production. School of Environmental and Rural Science, University of New England, Armidale.

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