

A decimal code for the growth and development stages of wild radish (*Raphanus raphanistrum* L.)

G.P. Madafiglio, R.W. Medd and P.S. Cornish^A

CRC for Weed Management Systems, NSW Agriculture, Orange Agricultural Institute, Forest Road, Orange, New South Wales 2800, Australia.

^AFarming Systems Research Centre, University of Western Sydney Hawkesbury, Locked Bag 1, Richmond, New South Wales 2753, Australia.

Summary

A decimal code describing the growth and development stages of wild radish (*Raphanus raphanistrum* L.) likely to be observed under field conditions is presented. The ten primary growth stages of the code are: emergence; seedling; rosette; stem and bud development; flowering; flower and early pod development; mid flowering and pod development; late flowering and pod development; pod and seed development; and senescence, pod and seed maturation. The primary stages are further divided into secondary stages. The growth stage is assessed on whole plants until early flowering. After the inflorescence branches the assessment is based on individual branches. The code has been designed to be used by farmers, crop advisers and researchers to aid management decisions where timing of herbicide applications is critical.

Introduction

Standard codes describing growth and development stages are available for many crops including cereals (Zadoks *et al.* 1974), canola (Sylvester-Bradley 1985) and peas (Knott 1985). Development of weeds is mostly less well defined and is often classified as being simply seedling or reproductive. The generic description of growth stages of annual broadleaf weeds published by Lutman and Tucker (1987) concentrates on early growth when most herbicides are applied to crops, whilst descriptions of growth stages after flowering are scant.

Wild radish (*Raphanus raphanistrum* L.), an important competitive weed of crops and pastures in Australia, is increasing in significance (Lemerle *et al.* 1996), distribution (Parsons and Cuthbertson 1992) and is difficult to control with existing technology. Recent research has identified the late application of selective herbicides as an effective way to target weed seed production in crops to achieve more effective control of populations. The technique, known as selective spray-topping, was first developed on wild oats (Medd *et al.* 1992, 1995) and has recently been expanded to wild radish (Madafiglio *et al.* 1997). A descriptive scale of wild radish growth and development would provide for more

effective use of the selective spray-topping technique. The flowering of wild radish occurs independently of crop development and can commence from the booting growth stage of cereals (GS 40^A), until dough development stage (GS 80^A) (Reeves *et al.* 1981). Hence it would appear more logical to time herbicide applications in relation to weed development stages rather than crop stage.

The broadleaf weed code proposed by Lutman and Tucker (1987) cannot be interpreted in sufficient detail to identify the appropriate reproductive phase of wild radish for selective spray-topping. The code proposed by Sylvester-Bradley (1985) for canola, a close relative of wild radish, is useful in the vegetative and flower bud development stages, but is not suitable at later stages because of differences in the reproductive growth patterns of the weed compared with the crop. Wild radish has an indeterminate flowering habit, so whilst ever resources are available it will continue to flower, even though some flowers may have developed into pods and appear fully mature on the branch. No existing scale sufficiently describes the pattern of growth and development of wild radish.

Footnote ^AZadoks *et al.* 1974

This paper presents a new decimal scale, which describes the growth and development stages of wild radish, based on observations of field grown plants occurring in crops and pastures.

Growth and development stages

Wild radish is an annual or biennial species, which may grow to greater than one metre high. The young plant develops as a prostrate rosette, from which stems arise (Holm *et al.* 1997). It may produce a single stem, or under favourable conditions several stems may arise from the rosette soon after emergence, and all stems may branch to varying extents to ultimately form the inflorescence (Cheam and Code 1995). First flowers can occur from 4 to 12 weeks after seedling emergence, depending on temperature, and the plant can flower for extended periods (12–42 weeks) depending principally on daylength (Reeves *et al.* 1981) and available soil moisture. Flowers occur in long terminal raceme-like panicle inflorescences, and form cylindrical fruits comprised of a fleshy pod, 2–5 mm wide and 20–70 mm long which terminates in a 10–20 mm long seedless beak (Clapham 1987). Two to 10 seeds typically develop inside each pod (Holm *et al.* 1997). As the pod develops it forms definite constrictions between each seed, and when mature the yellowish brown pod breaks into segments, each containing one seed (Holm *et al.* 1997).

Observations were made of wild radish plants at a number of locations in crops and pastures throughout New South Wales over several seasons. From these observations a development scale for wild radish was designed (Table 1). The scale divides the growth and development of wild radish into ten primary stages: emergence; seedling; rosette; stem and bud development; flowering; flower and early



Figure 1. Wild radish seedling with cotyledons and three true leaves unfolded (GS 1.3).

pod development; mid flowering and pod development; late flowering and pod development; pod and seed development; and senescence, pod and seed maturation. Each primary growth stage is further divided into secondary stages. Photographs of some stages are presented in Figures 1-7.

Considerable plasticity in the growth and development of wild radish occurs depending on the time of year, climate and environment. In some situations plants may progress rapidly through growth stages and seemingly skip some secondary stages. Plants growing without competitive influences are more likely to form large rosettes and the scale has the flexibility to accommodate vegetative plants which have greater than 10 leaves. Alternatively, plants emerging late in a wheat crop may almost bypass the rosette stage and rapidly progress to the reproductive stage. In the transition from the vegetative to reproductive stages some plants may reach the stem elongation stage before attaining 10 leaves.

The exact transition from vegetative growth to reproduction is difficult to observe without dissection of the plant. This is of little practical importance as this transitional period is short, and is visibly recognizable when the first flower buds appear and stem extension generally occurs rapidly, and hence is aptly termed 'bolting'.

Bolting is defined as the elongation of the internodes to form the stem and is associated with the switch from vegetative to reproductive stage of plant development. The term 'branch' refers to an individual raceme, which arises from an axil and is subtended by a leaf. At the start of flowering one branch arises from the main stem; if resources and space are not limiting the plant expands to produce additional stems and branches. The number of branches per stem and stems per plant depends on the duration of the reproductive phase. The initial scale classification (primary stage 5) is based on the main stem and after further development (primary stage 6 and greater) is assessed from the most advanced individual branch, or if appropriate, on an average of several or all branches.

After fertilization of flowers the developing pods grow rapidly and can reach 1 mm diameter in one week, and 2 mm diameter in 2-3 weeks. Viable seed can form within pods as soon as 23 days after flowering (Madafoglio *et al.* in press). The duration of flowering and transition through the development stages is largely dependent on available resources.

Discussion

This growth and development scale has the familiarity of other commonly used cropping codes but presents more detail

Table 1. A decimal code for the primary and secondary growth and development stages of wild radish.

Code	Description
Germination	
0.0	Dry seed
0.1	Start of imbibition
0.5	Radicle emerged (greater than 2 mm)
0.7	Hypocotyl extending
0.9	Cotyledons expanded and folded
Seedling growth (vegetative)	
1.0	Both cotyledons unfolded and green
1.1	First true leaf unfolded
1.2	Second true leaf unfolded
1.3	Third true leaf unfolded
1.4	Fourth true leaf unfolded
1.5	Fifth true leaf unfolded
Rosette (vegetative)	
2.0	Six leaves unfolded
2.1	Seven leaves unfolded
2.2	Eight leaves unfolded
2.3	Nine leaves unfolded
2.4	Ten leaves unfolded
Stem and bud development (reproductive)	
3.0	Flower buds visible in the crown of the rosette
3.1	Stem appearing with flower buds raised above leaves (start of bolting)
3.2	First flower stem extending
3.3	First flower buds yellow ('yellow bud')
Flowering	
4.0	First bud opened
4.5	Half of branches have flowers, no pods present
4.9	90% of branches have flowers, no pods present
Flowering and early pod development	
5.0	Continued flowering; largest pods less than 1 mm diameter (small pods) on the most advanced branch
5.5	Half of branches flowering, with small pods present
5.9	90% branches with flowers and small pods
Mid flowering and pod development	
6.0	Continued flowering; largest pods 1-2 mm diameter (medium pods), slight constrictions between seeds
6.5	Half of branches with flowers and medium pods
Late flowering and pod development	
7.0	Continued flowering; largest pods greater than 2 mm diameter, green and conspicuously constricted between seeds
7.5	Flowering; half of braches with pods greater than 2 mm diameter, yellow-brown
Pod and seed development	
8.0	Flowering completed; leaf senescence
8.5	Half of pods greater than 2 mm diameter, with definite constricted segments
8.9	90% of pods greater than 2 mm diameter with definite constricted segments
Senescence, pod and seed maturation	
9.0	Branches, stems and remaining pods all green
9.5	Half of branches, stem and remaining pods green
10	Branches, stem and remaining pods brown

than the generalized scale reported for broadleaf weeds by Lutman and Tucker (1987). The advantage of this scale is it allows more precise determination of the primary and secondary stages of wild radish plants in the field and has been designed to be independent of the environment in which plants occur.

The scale is intended for use by crop advisers in the management of wild radish to assist in identifying the correct

timing of control measures. Typically a range of growth stages of wild radish occur in the field due to staggered germination (Reeves *et al.* 1981). If appropriate, the most or least advanced plants, or parts of plants, can be described which will accommodate situations where growth is spread over a range of development stages.

One of the intended uses of the code is to specify the optimal growth stage for



Figure 2. Wild radish at the rosette stage, 6 leaves unfolded, cotyledons may not always be present (GS 2.0).



Figure 3. Wild radish at the rosette stage with 9 leaves unfolded (GS 2.3). Note one leaf is obscured.



Figure 4. Wild radish plant with elongating stem and advanced flower buds (GS 3.3).



Figure 5. Flowering wild radish branch with the first flowers visible (GS 4.0)



Figure 6. Flowering wild radish branch with small pods not conspicuously constricted (GS 5.9).



Figure 7. Flowering wild radish branch with more than half of pods greater than 2 mm diameter and conspicuously constricted (GS 7.5).

application of selective spray-topping herbicides in wild radish. The technique involves the late post-emergence application of selective herbicides specifically to reduce seed production. The efficacy of the technique has been found to be highly sensitive to the stage of development. Viable seed of wild radish can be produced within 23 days of flowering, and can generally be found in pods with diameters greater than 2 mm (Madafiglio, unpublished data), maximum size varying with the environmental conditions. Consequently, this scale will enable a more precise specification of stages of development to target in order to time applications to achieve maximum efficacy.

This scale will also assist in standardizing the growth and development description of wild radish. With more observations it may be possible to modify the scale to include other broadleaf weeds that have a similar growth habit.

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