Broom corn millet (*Panicum miliaceum*): a new menace for maize and sweetcorn growers in New Zealand

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Summary Broom corn millet (*Panicum miliaceum*) is an aggressive annual grass weed that is rapidly establishing in many maize and sweet corn crops in New Zealand. It has a C4 photosynthetic pathway and can reach up to 2 m high in crops. It is readily identified by its quick germination, rapid and vigorous growth, wide leaves (up to 2 cm wide), hairy stem and distinctive large black seed that can persist in the soil for a number of years. The seed can germinate within days of ripening and its large size gives it a growth advantage over all other grasses and many broadleaf weeds. From our research we have preliminary results on: (1) time and depth of emergence in New Zealand soils; (2) survival of the seed in maize and grass silage stack, pasture balage, and sweetcorn wilter; and (3) the efficacy of several pre-emergence herbicides used in maize crops. In pot experiments all herbicides were less effective against this weed than other annual grass weeds, such as summer grass (*Digitaria sanguinalis*) and rough bristle grass (*Setaria verticillata*).

Keywords Broom corn millet, *Panicum miliaceum*, grass weeds, sweetcorn, maize.

INTRODUCTION

Broom corn millet (*Panicum miliaceum* L.) is a recent grass weed currently undergoing rapid range expansion and causing problems for many arable farmers. This weed possibly had multiple entry points to New Zealand according to herbaria records (Anon. 2010). It was first recorded in Auckland and Palmerston North in 1961 and in a railway yard in a Northland granary in 1967. The first two infestations were probably from birdseed and the second from imported grain where it was a contaminant. More recently it was found in Ararimu, in a choumollier (*Brassica oleracea*) crop (most likely contaminated seed), and Taihape, where bird seed was thrown out, in 1975. Another infestation from birdseed occurred in Wellington in 1999, where it was found outside an aviary. There are also records from Hastings (1976) and Otago (1988) but unfortunately these records do not give details of the environment in which it was found or how the seed got there.

Also there are four voucher specimens, three from Gisborne (1995, 2001 and 2004) and one from Hawke's Bay (1998) – all found in sweetcorn or maize crops. These latter records are important to farmers as they indicate the move from point of introduction into the production sector. There is no official record but anecdotal evidence suggests that it established in Marlborough about the same time. Gisborne and Hawke's Bay are sufficiently close to each other and these records could have come from the same introduction. However, neither is close to most of the earlier records and Marlborough is even more distant from them. Therefore it can be concluded that within two decades there have been multiple introductions of broom corn millet into New Zealand by a variety of pathways.

What we do know, however, is that once in the production sector this weed was rapidly spread from one field to the next via agricultural equipment (Westra *et al.* 1990). Although it is likely to be spread by cultivation and other equipment, the main culprit was sweetcorn harvesters. So much so that in one district the weed was colloquially named after the largest processing company of the region.

BIOLOGY

Broom corn millet is a fast-growing summer annual grass that can grow more than 2 m tall in crops. It is readily identified by its quick germination, rapid and vigorous growth, wide leaves (up to 2 cm wide), hairy stem and distinctive large black seed. It has a C4 photosynthetic pathway, which means its growth rate is determined mainly by temperature rather than light or moisture. It is grown as a crop (proso millet) for animal and bird feed in many northern hemisphere countries. The New Zealand infestation matches the description for the black seeded wild type (wild proso millet), which is also a serious weed in many countries (Wilson and Westra 1991).

Broom corn millet germinates during the warmer months of October to March and its germination appears to not be constrained by day length. Wiese and Binning (1987) found the threshold temperature for germination of broom corn millet to be 6.9°C cf. 9.7°C for barnyard grass (*Echinochloa crus-galli*), 6.0°C for fathen (*Chenopodium album*) and 10.0°C for redroot (*Amaranthus retroflexus*), which are other major weeds of maize and sweet corn. However, this

threshold temperature for broom corn millet appears to be in disagreement with local evidence. Results from a germination plate experiment carried out at Massey University showed the lowest germination temperature to be 13°C (one seed) while 15–20% of seed germinated at 15°C. Germination still occurred at the maximum temperature of 35°C (C. McGill unpublished data). These temperatures better match casual observations from the field.

Broom corn millet seed has no dormancy and is able to germinate within days of shattering under the right conditions. It has been noted to emerge within a few days of soil disturbance in the field. In a depth of emergence study where we placed broom corn millet seed at depths of 30–170 mm in 16 different soils collected from the major sweetcorn growing regions, Poverty Bay, Hawke's Bay, Manawatu and Marlborough, broom corn millet emerged from the shallowest depths after 5 days in light soil while it took 10–14 days to emerge from the deeper depths. It was able to emerge from 170 mm in seven of the soils but emerged from 120 mm in all soils.

The ability of broom corn millet to emerge quickly as well as from deep within the soil is due to its large seed size. Thousand seed weight for this species is 4.35 g, cf. yellow bristle grass (*Setaria pumila*) 2.41 g, barnyard grass (*Echinochloa crus-galli*) 2.27 g, rough bristle grass (*Setaria verticillata*) 1.35 g, smooth witchgrass (*P. dichotomiflorum*) 0.75 g and summer grass (*Digitaria sanguinalis*) 0.61 g (T. James unpublished data). James *et al.* (2002) have previously shown the relationship between seed size and depths from which they can emerge.

Broom corn millet also has the ability to set seed in a very short time if under stress. Normally it would grow into a multi-tillered plant producing thousands of seeds, but we found in both pot and field trials that when under stress from severe competition, lack of water or nutrient resources or of late germination (autumn), broom corn millet plants were able to set seed within 5 weeks of emergence, much quicker than the other C4 grass weeds in the experiments.

MANAGEMENT

From observations of trials and discussions with growers and industry representatives it appears that broom corn millet is not a difficult weed to kill but it is a difficult weed to manage. Due to its spread via sweetcorn harvesting equipment, broom corn millet is mainly a weed of this crop. Sweetcorn is slower to establish than maize, requiring a longer critical weed-free period. Planting time also influences the critical weed-free period, with early planted sweetcorn (early November) requiring twice as long a weed-free period than that planted in late December (Williams II 2006).

Broom corn millet populations as low as five plants m^{-2} have resulted in 5% yield loss, while 20–40 plants m^{-2} have given up to 50% yield loss (Williams II *et al.* 2008a,b). However, this crop competition is highly influenced by the relative time of emergence of the weed to the crop, and regularly irrigated sweet corn crops are generally more resistant to competition than those reliant on natural rainfall (Williams II *et al.* 2008a,b).

In pot experiments we found that pre-emergence herbicides were less effective against the large seeded broom corn millet than other annual grasses (James *et al.* 2009). The herbicides evaluated included alachlor, metolachlor, dimethanamid, two formulations of acetochlor, and proprietary mixes of acetochlor with atrazine or metribuzin, and each was tested in representative soils from Waikato, Bay of Plenty and Poverty Bay as well as in a high organic matter, peat-based soil. The problem in controlling broom corn millet with pre-emergence herbicides was not only the lack of long term control (Shenk *et al*. 1990) but also their low initial efficacy soon after application. There are two likely reasons for this. Firstly, the quick emergence of broom corn millet may enable the plant to emerge before the herbicide has been fully activated with rain, irrigation or incorporation into the soil. Secondly, if the seed is near the surface it is possible that the emerging coleoptile simply does not absorb sufficient chemical to kill the plant before it emerges. Thus with either mechanism, some of the seeds that are near the surface and emerge quickly are not adequately controlled.

With pre-emergence herbicides often failing to adequately control this weed, growers are looking for post-emergence herbicide options. Broom corn millet is able to germinate over a long period of time and as a C4 weed it is more likely to germinate as temperatures rise rather than due to a soil disturbance. Thus the timing of post-emergence applications is critical and frequently a single application is insufficient. Our recent trials have shown that nicosulfuron gives excellent control of this weed as long as it is applied before or soon after tillering commences and the plants do not get too large; this is in keeping with overseas results (Williams *et al.* 2000). However, this can often require a second application if there is a further germination flush. To avoid two applications of nicosulfuron, many growers are using mesotrione for early post-emergence weed control. This herbicide gives excellent control of the broadleaf weeds but often only partial control of broom corn millet. It does, however, slow the development of plants, which assists with subsequent control by a later application of nicosulfuron.

An efficient management strategy for control of a weed must address the reproduction phase of its life cycle. This is critical in the case of broom corn millet for several reasons. The seed is more persistent in the soil than most other grass species and growers have reported the weed appearing after ploughing more than 5 years since it was last seen in that field. Khan *et al.* (1991) concluded that the black colouration of broom corn millet seed aided persistence of the seed in the soil and found that these seeds were still viable after 5 years in the soil. We are currently verifying this through a buried seed trial in which we have buried seed at two depths in eight locations throughout New Zealand. The longevity of the seed in the soil makes it imperative to minimise seed set and to minimise or eliminate spread between fields.

Minimising seed set involves making the best use of all the tools available to control the weed. Thus in addition to herbicides, stale seed beds and post-emergence cultivation should also be considered when designing a management program. In the stale seed bed technique, the seedbed remains untilled for about 2 weeks prior to sowing and the emerging weeds are controlled soon after sowing with an application of glyphosate. The glyphosate can be applied in a tank mix with a pre-emergence herbicide. This method is one way to control the broom corn millet seedlings, which germinate early and are not adequately controlled by the pre-emergence herbicide.

Although broom corn millet is found in many regions of New Zealand, it is usually confined to fields that have been or currently are in sweet corn production. This is mostly due to the seed being spread from field to field via the sweet corn harvesting equipment. Also, the sweet corn residue is frequently removed for animal fodder and it is possible that the seed could easily be carried along with it. The greatest danger is if the residue is fed out fresh and no steps are taken to remove the seed. However, our recent studies have shown some effective ways of killing broom corn millet seed. On arrival at the McCains Foods processing plant, the whole sweetcorn plant is passed through a wilter, which is a steam-heated, 15 m long, enclosed conveyor belt. Test packets of seed were passed through the wilter in the absence of sweet corn (2 min duration) and with sweetcorn (7 min duration). Ten separate packets of seed, each containing 200 broom corn millet seeds, were passed through the wilter and subsequent germination tests showed that all seed were killed. Similar packets of seed placed in ensiled maize and ensiled grass were also all killed within 3 months as was seed placed in wrapped balage. Placement within the stack or bale, adjacent to the plastic lining or wrapper or towards the centre, produced similar results. This shows that there are effective means of killing the seed before using the sweetcorn residue as animal feed.

DISCUSSION

Although a recent problem for New Zealand farmers, broom corn millet is a serious weed in many countries around the world. With our maritime climate and the well distributed rainfall, it has the potential to spread more rapidly. The current weed management practices for maize and sweet corn crops are not conducive for its containment. Our research program, in cooperation with maize growers and the horticultural industry, has provided much needed information on broom corn millet biology under local growing conditions. This information will be utilised in devising practical and effective management strategies for this weed. Although some pre-emergence herbicides showed better efficacy than others, none provided effective control of broom corn millet. Future research needs to concentrate on post-emergence herbicide options and the most appropriate time to use them. In addition, any other measures that reduce the size of the soil seedbank should be included in management plans for this weed.

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