Competitive effects of field bindweed (*Convolvulus arvensis* L.) in wheat, barley and field peas

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Summary

In the same field, the yields of wheat in 1989, barley in 1990 and field peas in 1991 were related to the density of field bindweed stems, using a quadrat assessment technique. At the highest densities of stems that were recorded in wheat (140 m^{-2}), barley (65 m^{-2}) and field peas (100 m^{-2}) there were yield reductions of approximately 56%, 92% and 74% respectively compared with quadrats where there were no field bindweed stems. Explanations are suggested for these differences. The relationships between field bindweed stem density and yield were equally well described by an exponential decay model, a hyperbolic model or a model combining both.

Introduction

Field bindweed (*Convolvulus arvensis* L.) is a herbaceous, deep rooted, twining perennial that is considered to be one of the world's ten worst weeds (Holm *et al.* 1977). Its extensive root system can penetrate to considerable depths (Derscheid 1978) and competes effectively for limited soil moisture (Mitich 1991). Eradication of field bindweed is unlikely as its seeds have been reported to survive in soil for at least 30 years (Timmons 1949). In addition to infestations in perennial horticulture crops, in South Australia bindweed is a major problem in some intensively cropped fields, especially on heavy red-brown earths receiving more than 450 mm rainfall in areas north of Adelaide. The use of tyned cultivation implements that break up the root system and drag roots may have increased the rate of spread of the weed – fragments of roots as small as 5 cm can regenerate (Swan and Chancellor 1976). Also, field bindweed is readily eaten by sheep (personal observations) and cattle (Sa'ad 1967). The trend to more intensive cropping and, consequently, less grazing in these areas may have increased the opportunities for field bindweed to spread and increase in density.

Few published data appear to be available about crop losses from field bindweed in wheat, barley and field peas, the three principal rotation crops used in the areas of South Australia where field bindweed is a problem. It is important for farmers who are affected by field bindweed to have knowledge of the effects of the weed on the crop yield potential, in order to provide an incentive for them to stop ingress of the weed into their fields. These yield effects are not intuitively obvious, as field bindweed stems emerge from perennial rootstock in early to mid-spring in South Australia, long after crops have been established and after selective herbicides have been applied to control annual weeds.

In this paper we present data describing the relationship between field bindweed stem density and the yield of wheat, barley and field peas, taken from assessments in the same field but in different years.

Materials and methods

A field at Freeling, 50 km NNE of Adelaide, which had been invaded by field bindweed and which had patchy infestations, was chosen for the assessments. It had been continuously cropped with cereals and grain legumes over a period of at least 10 years. The soil type was a cracking red-brown earth of pH 8.3. In 1989 the paddock was sown with wheat cv. Machete, in 1990 with barley cv. Galleon and in 1991 with field peas cv. Dun. In all years selective herbicides had been applied to the crop to control annual broadleaf and grass weeds, well before field bindweed stems had emerged. The herbicide programs consisted of 19 g ha^{-1} chlorsulfuron in 1989, 4 g ha^{-1} metsulfuron-methyl and 375 g ha^{-1} diclofop methyl in 1990, and 170 g ha^{-1} metribuzin and 35 g ha^{-1} haloxyfop in 1991. In our judgement, these selective herbicide programs did not appear to affect the emergence or vigour of the bindweed stems.

In 1989 and 1990 in the wheat and barley crops at harvest, 1 m × 1 m quadrats were deliberately placed in areas of varying field bindweed stem density. The number of field bindweed stems were recorded and the hand-harvested cereal plants were placed in separate containers and threshed and cleaned at the Northfield Research Laboratories. In 1991 the same methodology was used for field peas, but a 2 m × 2 m quadrat was used. Because pea crops intertwine and are relatively prostrate at maturity, considerable care was taken to delineate the pea plants that were rooted within the quadrat. Different parts of the field were used in different seasons.

Field bindweed stem density was regressed against crop yield to define the mathematical relationship between the two parameters. Models suitable for one-sided, two-sided and combined competition (Tollenaar 1992) were used. For one-sided competition (dominance and suppression, normally light) a model based on the inverse yield law that produces a rectangular hyperbola, derived by Cousens (1985) and modified for absolute yield, was chosen:

$$Y_{BW} = Y_o\,(1+k_1BW)/(1+k_2BW) \qquad (1)$$

For two-sided competition (equal partitioning of the available resource, normally nutrients and water) an exponential decay model used by Tollenaar (1992), modified for variations in weed density only, was chosen:

$$Y_{BW} = Y_o e^{-k_3BW} \qquad (2)$$

Thirdly, a model derived by Tollenaar (1992) for describing the interaction between one-sided and two-sided competition, modified for variations in weed density only, was used:

$$Y_{BW} = Y_o e^{-k_3BW}/(1 + k_2BW) \qquad (3)$$

Y_{BW} is yield in kg ha^{-1} when field bindweed is present, Y_o is yield at nil field bindweed, BW is field bindweed stems m^{-2}, e is the base of natural logarithms and k_1, k_2 and k_3 are parameters to be estimated.

Results and discussion

All three models described the relationship between crop yield and field bindweed stem density equivalently in terms of equal final R^2 values to the second decimal place. We conclude that these data were insufficiently precise to allow a ranking of the models.

Figures 1(a), (b) and (c) show the data points and fitted curves for wheat, barley and field peas respectively. The curves are fitted from the exponential decay algorithm (2) as this is the simplest model and we believe that two-sided competition, i.e., for water and nutrients, is particularly important in explaining the marked yield reductions caused by field bindweed. Table 1 shows the respective values for Y_o and k_3, as well as R^2.

From the results it is clear that field bindweed markedly reduces field crop yields at high stem densities, despite late emergence in the crop. At the maximum bindweed stem densities recorded (140 m^{-2} in wheat, 65 m^{-2} in barley and 100 m^{-2} in

Table 1. Parameter estimates for the exponential decay model (2).

Parameter	Wheat	Barley	Field Peas
Y_o	3620	3920	3130
k_3	-0.00617	-0.0414	-0.0142
R^2	0.83	0.81	0.89

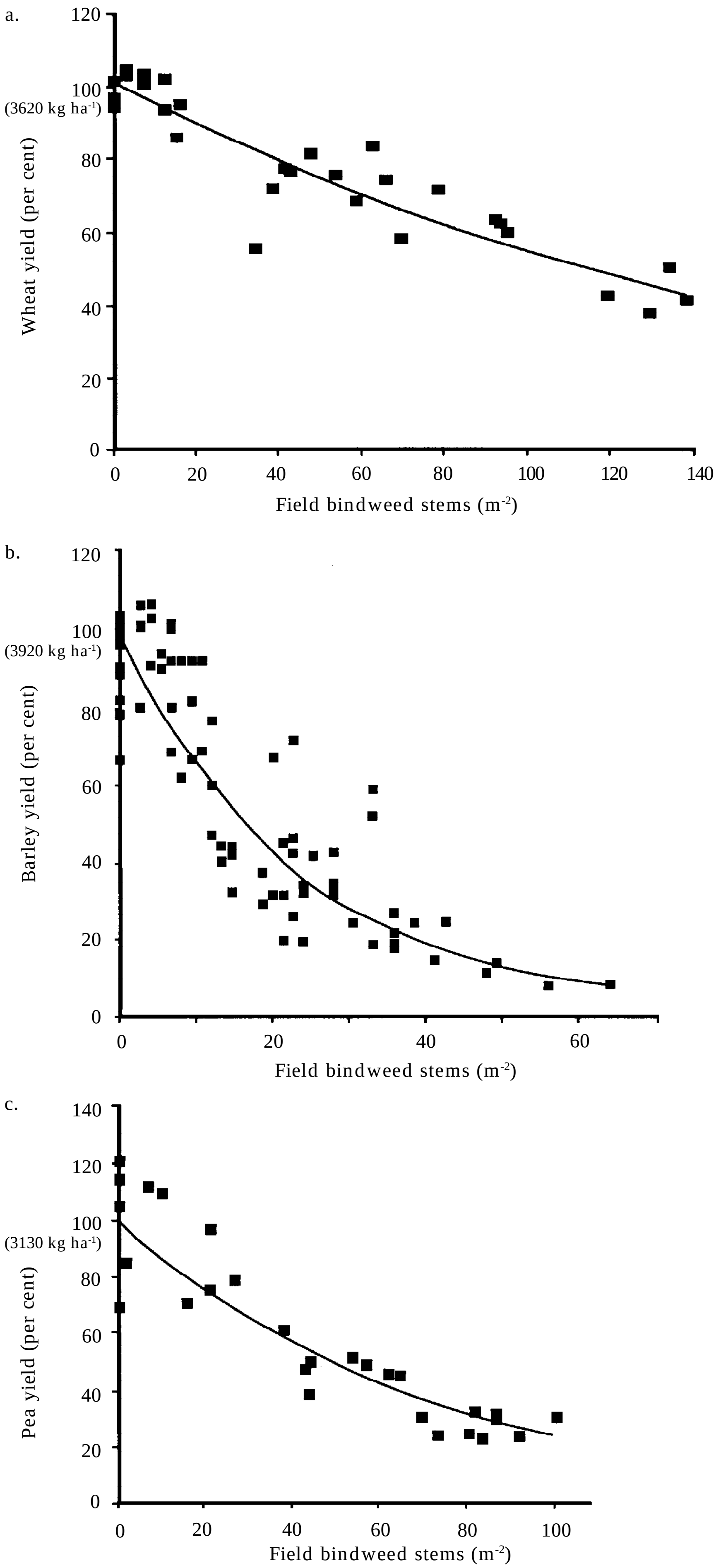

Figure 1. Data points and fitted curve for the relationship between field bindweed stem density and wheat (a), barley (b) and field pea (c) per cent yields in 1989, 1990 and 1991 respectively.

field peas) yield was reduced by approximately 56%, 92% and 74% respectively. We presume the perennial root system is taking up a high proportion of the water and/or nutrients potentially available to the crop.

We recorded a greater yield reduction than Swensen *et al.* (1987) for the same stem density. They found that 70 stems m^{-2} reduced wheat yield by 15% in Idaho, USA. In the results reported here 70 stems m^{-2} reduced wheat yield by 35%. We suggest that differences in population dynamics of field bindweed and wheat due to climate, edaphic and management factors account for much of the difference between their results and ours. In the Northern Hemisphere, Wiese and Rea (1959) suggested that winter wheat is a good competitor with field bindweed because it grows rapidly during early spring when field bindweed is not using soil moisture. In our much milder environment we think that field bindweed is using substantial quantities of available soil moisture and nutrients during early spring.

At the same stem density the yield reduction caused by field bindweed was markedly different in wheat, barley and field peas. For example, at 30 stems m^{-2} the yield reduction was 16%, 69% and 31% respectively. At 60 stems m^{-2} the yield reduction was 31%, 91% and 55% respectively. In North America, Derscheid (1978) also found that field bindweed reduced wheat yields less than those of barley, but the magnitude of the difference was much less compared with that shown in these data (a reduction in yield of 30% in wheat and 65% in barley). At normal sowing rates in South Australia the competitive ability of wheat and barley crops against annual weeds is similar (Black and Dyson 1993), but wheat is sown at a higher rate than barley, indicating that barley is the more competitive species. Most experiments worldwide have shown that barley is the better competitor with weeds (e.g., Cousens *et al.* 1987). Our data and those of Derscheid (1978) indicate that field bindweed competition results in an exception to this general finding. At maturity, a barley crop is of shorter stature than wheat and it could be that the twining stems of field bindweed are more easily able to access light, thus increasing the competitive ability of the weed in barley relative to wheat. The average field bindweed stem density in barley was much less than in wheat (Figure 1), indicating that field bindweed photosynthesis was more efficient in barley if the below-ground biomass of field bindweed in the two crops was similar.

The field peas data were intermediate in terms of the competitive effects of the field bindweed, as was the average density of field bindweed stems in the crop

(Figure 1). Substantially more rain fell during the April to October growing season in 1991 than the previous two years and greater moisture availability during grain filling may account for the reduced effect of the field bindweed in the peas compared to the barley. In addition, field peas have nitrogen directly available to the plant through N-fixing nodules, thus removing a potential growth limiting factor. Also, barley stems allow the field bindweed to more easily twine up them to gain access to light whereas peas have a prostrate habit at maturity, which reduces the opportunity for emerging field bindweed stems to twine and so increase light interception.

The practical conclusion from these results is that farmers should give a high priority to stop the ingress of field bindweed into cropping paddocks because the weed is so competitive and is very difficult to control in the long term. The only available chemicals that give effective long-term control of the perennial root system in South Australia are spraying with imazapyr (Matic and Black, submitted) or picloram plus 2,4-D when applied at high rates (Alcock and Dickinson 1974). Such rates leave residues that are toxic to crops for long periods. Therefore a spot spraying program over the summer period to stop ingress of the weed and to eradicate light infestations will give far more benefit, in terms of retaining the productivity of land, than eradication by boom spraying these chemicals once field bindweed is well established in a field.

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