COMMENT

Influence of spatial distribution on weeds on crop yield loss

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Summary

Crop yield/weed density functions generally show a decreasing rate of yield loss with increasing weed density (i.e. they are strictly convex functions). We demonstrate the influence of spatial distribution of weeds on crop yield for generalized convex function and give a numerical example for barnyard grass (*Echinochloa crus-galli* var. *oryzicola*) in rice. Plants generally display some degree of contagious or clumped distribution. Where this occurs in crop weeds, estimates of yield loss, based on mean densities over large areas, will usually be over-estimates.

Introduction

Crop yield/weed density models generally indicate a decreasing rate of yield loss with increasing weed density (Cousens 1985), i.e. strictly convex functions (see Figure 1). Estimates of crop loss are typically obtained by estimating the mean weed density for a large area, e.g. 1 ha or a field of many hectares. However, mean loss values for similar weed densities often vary widely and thus there is difficulty in establishing economic thresholds with precision (Auld *et al.* 1987). This may be partly explained by the influence of uneven spatial distribution of weeds, as plants frequently have clumped or contagious distributions (Kershaw 1973).

General derivation

Suppose that an area under study is divided into 1-m² quadrats and that weed density is uniform within each quadrat. Let $f(w)$ represent the yield in a quadrat as a function of its weed density. Furthermore, let n be the number of different weed densities observed in relation to all the quadrats making up the field.

If p_i represents the proportion of a field of a size of Am² with a weed density of w_i, total yield is

$$Y=\sum_{i=1}^{n} p_i A f(w_i) \qquad (1)$$

$$\text{and } \Sigma p_i = 1 \qquad (2)$$

Average yield m^{-2} is:

$$y=Y/A=\sum_{i=1}^{n} p_i f(w_i) \qquad (3)$$

If all the w_i are not equal (i.e. if weed density m^{-2} is not uniform) and since $f(w)$ is strictly convex, it follows that

$$\sum_{i=1}^{n} p_i f(w_i) > f\left\{\sum_{i=1}^{n} p w_i\right\} \qquad (4)$$

(Hardy *et al.* 1934; Karlin 1959) i.e. non-uniformity of weed density compared to uniformity results in a greater estimate of yield on average m^{-2}.

This is illustrated in Figure 1. If weed density is uniformly distributed at $\bar{w}$ per square metre yield on every m² (and therefore on average m^{-2}) is Y_2. Now suppose that weed density in half the m² quadrats is w_1 and in the other half is w_2. In those square metres with a density of w_1 yield is Y_4 and in those with a density of w_2 yield is Y_1. Hence yield on average m² is

$$Y_3=0.5Y_4+0.5Y_1 \qquad (5)$$

Because of the strict convexity of $f(w)$ and as can be observed from Figure 1, $Y_3 > Y_2$, the yield obtained when weeds are uniformly distributed.

Hence, because the yield estimate is greater for clumped distributions, the yield loss estimate is lower. Thus the current assumption in crop loss models of an even distribution of weeds over-estimates yield loss.

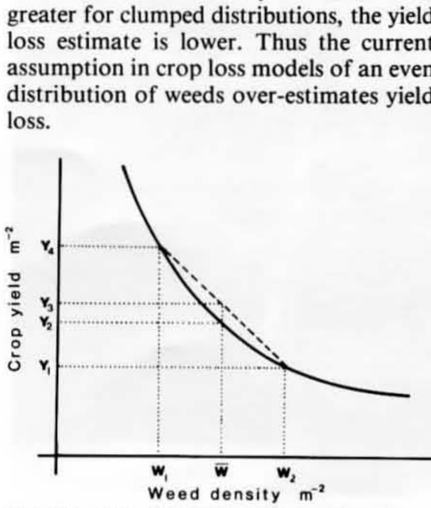

Figure 1 Generalized crop yield/weed density convex function $Y=f(w)$ (solid line).

A numerical example

Some appreciation of the impact on physical yield loss can be gained from a specific example. Chisaka (1977) presented a typical yield/weed density relationship which was specific for barnyard grass (*Echinochloa crus-galli* var. *oryzicola*) in rice (although he gave no data on distribution of the barnyard grass we will assume it to have been uniform). Using his function, let us consider two possible situations where the mean weed density over an area of 1 ha was one barnyard grass plant m^{-2}, i.e. the total weed population in each instance was 10 000 plants. In one case the weeds are distributed evenly so that one plant occurs in each m². In another case (ignoring edge effects) weeds are distributed in 100 discrete 1 m × 1 m patches each with 100 weeds. The predicted yield loss in the first case is 51 kg ha^{-1} and in the second it is 36 kg ha^{-1}.

Conclusion

Plants frequently display some degree of clumped or contagious distribution. Where this occurs with crop weeds, current estimates of crop yield loss based on mean densities per acre or hectare will usually be over-estimates; the more uneven the spatial distribution of weeds the greater the discrepancy. Consequently, the ability to determine crop loss functions with more precision and therefore economic thresholds would require data on weed distribution. In the absence of greater precision, uncertainty about weed distributions may influence decision making in weed control (Auld and Tisdell 1987). There is clearly a need to establish the magnitude of this distribution effect in field studies.

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