AN ECOLOGICAL BASIS FOR ESTIMATING PROBABILITIES OF COLONIZATION FOR WEED SEEDS CONTAMINATING IMPORTED PLANT PRODUCTS

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SUMMARY

A method is presented for estimating colonization probabilities associated with the importation of grapes contaminated by skeleton weed, a potential weed of cereal producing areas in New Zealand. The method utilizes field-based estimates of the probability of colonization from seed, in conjunction with estimates of the proportion of seed contaminants which is leaked to the environment. It is concluded that the colonization probabilities associated with the current maximum pest limit (MPL, 0.5%) are high. For example, colonization by skeleton weed is predicted to occur during 1 year in 5 in the Auckland region. Since the chances of colonization increase directly with the volume of imports, MPL's should vary accordingly.

INTRODUCTION

A major role of plant quarantine agencies is to prevent the introduction of weeds which have the potential to incur economic loss. The chances of introducing injurious plants can be reduced by setting limits on the amount of weed seed contamination which is permissible in imported plant products. At present, tolerances for weed seeds are generally very low because a paucity of data does not allow quantitative appraisals of risk. This conservative approach to risk is necessary in order to provide the required agricultural security when the risk cannot be quantified.

Skeleton weed (*Chondrilla juncea* L.) is an herbaceous perennial species which has become a major weed of cereal cropping in southern Australia (Panetta and Dodd 1987a). Although it is not naturalized in New Zealand (Esler 1987), skeleton weed could be expected to become a serious weed if introduced, on the basis of its breadth of climatic adaptation (Panetta and Dodd 1987b) and its impact upon cereal farming in North and South America, in addition to Australia (Panetta and Dodd 1987a). Routine broadleaf weed control methods in New Zealand cereal crops, while probably effective in controlling skeleton weed seedlings (Panetta 1989a), could be expected to achieve only a measure of suppression for established plants (Panetta and Dodd 1987b). Skeleton weed seeds are sometimes detected in consignments of table grapes imported from Australia. Since it is designated a quarantine pest, the maximum pest limit (MPL) for this weed is 0.5% (one seed per 200 bunches of grapes). This paper reports an analysis of the probability of colonization when grapes are imported according to the current limit for contamination by skeleton weed.

METHOD

The procedure for determining the probability of colonization was similar to a multiplicative model proposed for assessing risks associated with genetic engineering experiments (Subak-Sharpe *et al* 1978). This scheme involved assigning a numerical risk to individual gene manipulation experiments. The overall risk was calculated as a product of the risks associated with three independent factors, namely the probabilities that manipulated organisms would enter and persist in the human body, that the foreign gene would be translated into the protein product and secreted and that the gene product would cause physiological damage.

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In the model for skeleton weed, colonization of a site was defined as the occurrence of one reproductive plant. The probability of colonization by seed was calculated as the product of the probability of establishment and the probability of survival to the reproductive stage. Data used for such calculations came from a demographic study in the Western Australian wheatbelt (Panetta 1989a,b). The study comprised a series of sowings made over 2 years in annual pastures at two sites. Since the edaphic characteristics of one site were unfavourable to skeleton weed survival and were considered to be dissimilar to those in the grain producing areas of New Zealand, its data for probabilities of reproduction were not included in the analysis.

A third factor was introduced to the model in order to capture the immediate fate of seed contaminants of table grapes. "Leakage" was defined as the proportion of the seed contaminants which reached sites where germination and establishment could occur. Since most weed seeds contaminating table grape bunches would be removed by washing, would perish through ingestion or would be disposed of as domestic refuse, it was assumed that this factor would take on very low values, in the order of 10^{-3} or less. The probability of colonization from contaminated grapes was calculated, therefore, as the product of the leakage factor and the probability of colonization from seed.

It was considered that grape consignments with contamination levels at or above the MPL would be detected by current sampling procedure (inspection of 600 bunches) and would be rejected. Therefore, it was assumed that a contamination level equal to half the MPL (i.e. 1 seed per 400 bunches) applied to all accepted consignments at the ports of Auckland, Wellington and Christchurch. Import records were obtained from the New Zealand Agricultural Quarantine Service for the years 1987-1989. The total number of seeds imported through each port was determined by multiplying the total number of bunches (15 bunches per carton) imported by 0.25%. Seed numbers were multiplied by the upper limit of the 95% confidence interval for the probability of colonization from contaminated grapes (assuming a leakage factor of 10^{-3}) in order to estimate the frequency of colonization by skeleton weed in the region serviced by each port.

RESULTS AND DISCUSSION

The mean probability of colonization by seed for skeleton weed was approximately 0.07, with an upper limit to the 95% confidence interval of approximately 0.08 (Table 1). Calculations of the confidence intervals rested upon the assumption that the data for establishment and reproduction were normally distributed. While this assumption was justified for the establishment probabilities, the distribution for reproduction probabilities was highly skewed, owing to a large number of zero values (Panetta 1989a). Since confidence intervals are asymmetrical for skewed distributions, the interval employed for the latter parameter was possibly too small, effectively reducing the value for the limit to the confidence interval for probability of colonization.

In the interests of ecological realism, it would be preferable to obtain demographic data for skeleton weed in New Zealand. By taking simple precautions (Panetta 1989a,b), such information could be obtained with minimal risk of escape of the weed. Bearing in mind the following factors, however, the Western Australian data provide a legitimate basis for predicting colonization in New Zealand. Certain experimental conditions could have inflated the demographic estimates. For example, seed were

TABLE 1: Derivation of the probability of colonization of skeleton weed from seed.

Probability of establishment (n)	×	Probability of reproduction (n)	=	Probability of colonization
0.278 (204)		0.248 (385)		0.0689
0.300 ¹		0.281 ¹		0.0840 ²

¹ Upper limit of 97.5% confidence interval.

² Upper limit of 95% confidence interval.

lightly buried, which would promote germination and eliminate seed loss through predation (Panetta 1988). The effects of interspecific competition upon seedling survival were minimized, since in a number of cases annual weeds were removed prior to sowing, with few germinating subsequently (Panetta 1989a). Lastly, although few plants reproduced in their first year (Panetta 1989b), it was assumed that any juvenile plant which survived its first summer would reproduce eventually.

Factors which could have contributed to under-estimation of the probability of reproduction include the relatively harsh summer conditions of Western Australia compared to New Zealand and elevated levels of density dependent mortality resulting from high experimental rates of sowing. Since the major portion of plant mortality occurred during the growing season (Panetta 1989a), the first factor is not considered to be important. However, seeds were sown in densities far greater than could be expected at the earliest stages of colonization, and it is possible that a larger proportion of established plants would survive to reproduce at lower densities. In the balance of factors either promoting or inhibiting establishment and reproduction, it is considered that the demographic estimates are higher than might be obtained naturally in New Zealand. The use of such data is consistent with the conservative approach to risk appraisal required when information is lacking.

According to calculations based upon the recorded volume of grape imports and assumptions relating to the degree of contamination by skeleton weed seed, the probabilities relevant to the regions surrounding New Zealand ports ranged from 0.065 (Christchurch) to 0.205 (Auckland) over the years 1987-1989 (Table 2). These correspond to frequencies of colonization by skeleton weed of once every 15.4 and 4.9 years in the respective regions. Since Christchurch is situated in the major cereal producing region of New Zealand, it is perhaps fortunate that the predicted colonization frequencies are lowest here.

TABLE 2: Volumes of table grape imports (cartons x 10⁴) and estimated regional frequencies of colonization by skeleton weed if imports were contaminated at 50% MPL (0.25%) and leakage was 10⁻³.

Season	Auckland		Port Wellington		Christchurch	
	Volume	Frequency	Volume	Frequency	Volume	Frequency
1987	6.39	0.201	4.41	0.139	1.37	0.043
1988	8.10	0.255	4.04	0.127	3.29	0.104
1989	5.00	0.158	1.26	0.040	1.51	0.048
Mean	6.50	0.205	3.24	0.102	2.06	0.065

Although the inclusion of demographic data has provided a firmer basis for quantifying the risks associated with importing contaminated produce, several uncertainties remain. Foremost is the dimension of the leakage factor. If this were reduced by an order of magnitude, for example, the regional colonization probabilities (Table 2) would decrease in proportion. Unfortunately, the measurement of leakage poses considerable, possibly insurmountable, practical problems. In addition, since it is generally difficult to detect new skeleton weed infestations, validation of the estimated frequencies of colonization, even in the broadest sense, is problematic.

On the basis of the present analysis, it would be difficult to argue for a higher tolerance of skeleton weed seeds in imported table grapes. Indeed, many would be concerned that the regional probabilities of colonization could be as high as those estimated for Auckland, for example (Table 2). Obviously, acceptable levels of risk will vary according to the magnitude of the perceived hazard; Subak-Sharpe *et al.*, (1978) designated as highest risk those genetic engineering experiments entailing overall risks >10⁻⁶! Whatever the acceptable risk might be for skeleton weed, it is clear that the chance of colonization increases in proportion to the volume of grapes imported. Thus it is possible that different MPL's should apply according to different projected

volumes of import. Since it is not desirable (for administrative reasons) to set different MPL's for different ports, the MPL should be geared either to the volume handled by the busiest port or to the total volume of table grape imports from Australia.

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