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# The Distribution, Density and Economic Impact of Weeds in the Australian Annual Winter Cropping System

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**Front Cover:** Wildradish (top left), Wild oats (top right) and Paterson's curse (bottom).
Photos: Dr Richard Medd, NSW Agriculture

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# 1. Introduction

Weeds are an issue of significant economic importance in Australian farm production systems. Weeds impose costs on producers through yield and quality reduction, the input requirements for control and in extreme weed-affected situations the cost of adjustment to new production systems. The costs of yield reductions have broader economic significance if many producers are affected because of possible variations in supplies and the effect on product prices, which then ultimately impact upon consumers. Spreading weeds also impose external costs on both the farm sector and the broader environment where the aggregate level of private weed control is less than that which could be justified by society. Consequently, estimates of the economic costs of weeds provide an economic basis for establishing the status of plants as weeds, for rationalising the weed control program of producers and governments and for directing weeds research programs (Vere, Jones and Griffith 1997).

Despite the acknowledged significance of the cost of weeds in annual winter cropping systems in Australia, there have been few attempts to adequately quantify the extent of this problem. Combellack (1987) estimated the financial losses due to weeds through their direct and indirect costs on agricultural cropping systems. The estimated total financial loss of $1,271 million per annum was comprised of $592 million from cultivation costs, $137 million from herbicides, $34 million from herbicide application, $422 million in yield losses and $86 million in product contamination costs. In addition, Combellack estimated the financial losses due to weeds in pastures, horticulture and non-crop areas to be $494 million, $213 million and $119 million respectively. Due to a lack of available data, Combellack had to make a number of coarse assumptions regarding weed effects and consequently the results can not be extrapolated to present day values with any confidence. In another study, Medd and Pandey (1990) estimated that for the 1987/88 season the annual cost of wild oats was approximately $42 million, consisting of almost $30 million expenditure on herbicides and over $12 million due to reduced grain production. This estimate was considered conservative as it did not include the cost of contamination, disease hosting or of managing herbicide resistance.

A shortcoming of these analyses is that only the financial impacts on producers are considered and other economic costs and the broader industry implications are largely ignored. For example, it is possible there are important industry-wide price effects from both the presence and control of cropping weeds. Weeds restrict crop production and so impose economic costs on producers in terms of the value of production foregone. Costs may be imposed on consumers in terms of higher prices paid for the reduced level of crop production. Alternatively, widespread weed control increases production that, under competitive market conditions (as are faced by the Australian cropping industries), is likely to result in lower prices to both producers and consumers. Thus a comprehensive analysis of the costs of weeds in cropping systems needs to consider not only the financial and the opportunity costs of foregone production, but also the losses and gains of producer and consumer welfare.

This paper reports on an analysis of the costs of weeds in Australian annual winter cropping systems. The method of analysis adopted in the study to determine the distribution and density of all the major weeds that affect Australian crop production is outlined in section 2. Presented also in this section is the economic framework adopted for measuring weed costs. The results of two surveys to collect information on weed distribution and density are presented in section 3. From the resulting information the financial and economic implications of weeds in cropping regions were determined and are presented in section 3.

# 2. Data and methods

## 2.1 The study area

This study considered the weed problem in 12 of the 17 agro-ecological zones which comprise three Grains Research and Development Corporation (GRDC) cropping regions. These agro-ecological zones represent the bulk of the area sown to annual winter crops in Australia. The individual agro-ecological zones are illustrated in Figure 1 (GRDC 1998).

The GRDC northern region is characterised by summer dominant but variable rainfall and hot climate (Webb et al. 1997). This region extends from central and south-eastern Queensland through to northern New South Wales west of the Great Dividing Range. In this study the NSW North East - Qld SouthEast and NSW NorthWest - Qld South West agro-ecological zones were considered.

The GRDC southern region comprises the southern part of NSW, Victoria and South Australia and is characterised by equi-seasonal or winter dominant rainfall and temperate climate. The agro-ecological zones included in this region are NSW Central, NSW Vic Slopes, Vic High Rainfall, SA Vic Bordertown-Wimmera, SA Vic Mallee and SA Midnorth-Lower Yorke Eyre.

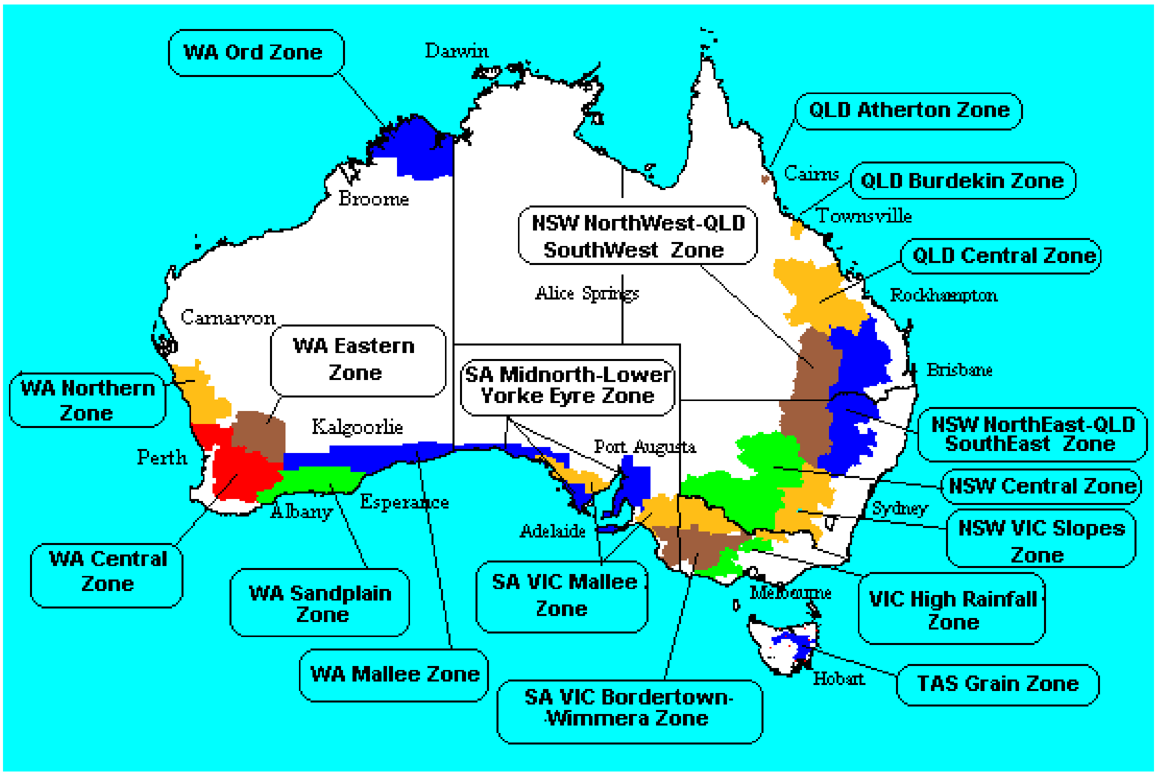
The GRDC western region covers the grain growing regions of Western Australia which have a true Mediterranean climate and low soil fertility. It extends from north of Geraldton to Esperance in the south (Martin and Madin 1993). The eastern limit of the agricultural area coincides closely with the 300 mm annual rainfall isohyet. WA Northern, WA Central, WA Eastern and the aggregated WA Mallee and Sandplain are the four agro-ecological zones in the region.

## 2.2 Assessing the distribution and density of weeds

### *2.2.1 Mail survey*

A mail survey of grain growers was conducted by TQA Research Pty Ltd. (TQA) on behalf of the Co-operative Research Centre for Weed Management Systems (CRC) and funded by the GRDC. Formal self-completion questionnaires were mailed individually to 10,000 grain growers out of which 1,040 useable surveys were returned. Farmers were requested to rank land management problems as they affect their farming enterprises and to

**Figure 1.** Agro-ecological zones



nominate the most difficult weeds to control in winter cropping. They were also asked to provide information, by crop and individual weed, on the area and density of the residual weed infestation after spraying, their perception on herbicide resistance and estimate of yield under the prevailing weed population and weed-free yield. Management practices in winter cropping such as weed control and crop rotations were also considered. The questionnaire is given in Appendix 1.

To adjust for non-response bias, the sample was weighted to reflect the 'true' representation of grain growers across Australia (TQA personal communication). The variables used to weigh the sample were total grain grower population in each of 12 agro-ecological zones across Australia and whether or not growers used specialist agronomic consultants. The sample base of 1,040 survey returns was adequate to ensure that conclusions drawn on key national issues were of high statistical accuracy[1].

Some survey data such as crop yields, soil preparation methods, and crop rotation practices showed large diversity between agro-ecological zones within a region. Aggregating such data on a regional basis would mask the specific characteristics of the agro-ecological zones.

Farmers' perception of yield loss due to weeds was analysed using a t-test in Genstat 5 Release 4.1 (Payne *et al.* 1997). The number of farmers and the mid-point of yield estimates of each crop were used to estimate mean and variance.

A listing of the major weeds identified is given in Table 1. The weeds are ranked in alphabetical order by common names and associated scientific names.

### *2.2.2 Field survey*

A field survey of weed assessment was conducted to validate the mail survey. To reduce the complexity of the field survey, only wheat paddocks were assessed. The field survey was undertaken in the period September to November of 1998, therefore, the data gathered represented the weed problem after weed control measures had been undertaken. This enabled the detection of problem weed species with identification being simplified due to most weed species being at a mature stage of development. Farmers whose paddocks were surveyed were also asked to complete a short questionnaire (a subset of the mail survey) which focused on the weed situation of the paddocks being surveyed. The field survey was undertaken in all agro-ecological zones with the exception of Vic High Rainfall, WA Mallee and Sandplain and WA Northern agro-ecological zones.

A total of 164 wheat fields were selected using a stratified random-sampling procedure with proportional allocation to strata (Cochran 1988) from three GRDC regions and nine agro-ecological zones. For the purpose of this survey each region and each agro-ecological zone was considered as primary and secondary stratum respectively. Major wheat growing areas (wheat district) were selected from each agro-ecological zone following discussion with researchers and agronomists. Lists of farmers from each wheat district were obtained from district agronomists. Ten farmers from each list were randomly picked and were contacted by phone. Five farms were then selected depending on accessibility from major or minor roads and farmers consent.

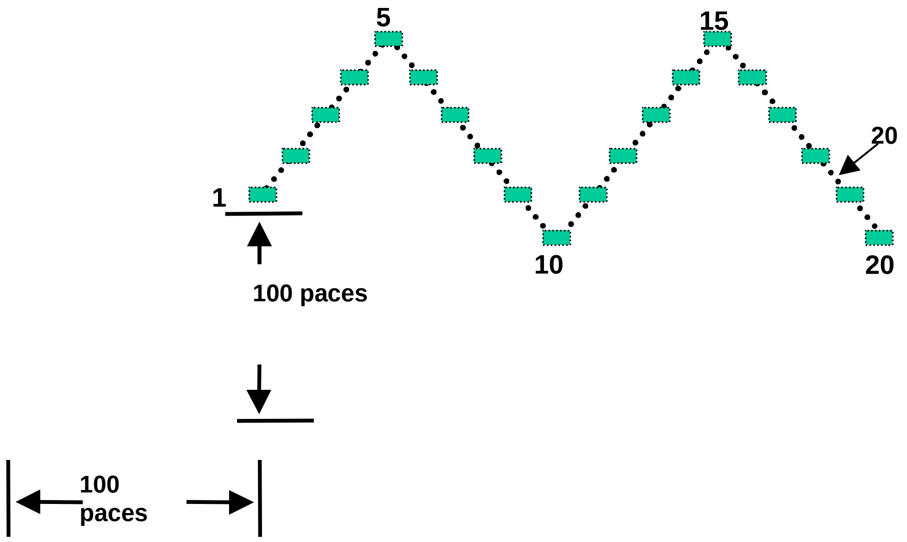
The position of each paddock surveyed was identified by region, state and agro-ecological zone and their easting, northing and height coordinates recorded using a hand-held GPS system. In each field weeds were counted in 20 1 $m^2$ quadrats located 20 metres apart and laid out in an inverted 'W' pattern (Thomas 1985) (Figure 2). The location of the pattern was determined by walking 100 paces along the edge of the field and then turning at a right angle and walking 100 paces into the field. The presence of each weed species was noted and its density recorded. However, if weed numbers were more than 20 per quadrat, densities were recorded in a logarithmic scale (see below). This differed to the mail survey where light-density infestations were considered scattered isolated plants, medium-density infestations were less than 1 plant/$m^2$ and high-density infestations were greater than 1 plant/$m^2$. The apparent crudeness of the infestation categories in mail survey was due to the difficulty in obtaining objective field data from a subjective farmer questionnaire.

| Weed number per quadrat | Rank |
|---|---|
| 1 – 6 | 1 |
| 7 - 20 | 2 |
| 21 – 60 | 3 |
| 61 – 190 | 4 |
| 190 – 600 | 5 |
| > 600 | 6 |

The data were entered into a database specifically designed for the survey. Tables and queries were used to manage and generate results. The field survey confirmed the existence of residual weed infestation ranging from zero to twenty (in few occasions up to 100) in all agro-ecological zones. Chi-square tests were undertaken on the responses and findings of the mail and field surveys to test for any differences. 2x2 contingency tables of counts were constructed for each response. The relationships between the two sets of data were then assessed using 'Pearson's Test' in Genstat 5 Release 4.1 (Payne *et al.* 1997). P values were used to evaluate the significance of the differences.

[1] Accuracy was ± 2% at a 95% confidence level (TQA personal communication).

**Figure 2.** Field sampling procedure




## 2.3 The economic cost of weeds framework

The impacts of weeds upon the production system can be demonstrated using the basic concept of the production function. The quantity of crop output (ie grain yield) is determined by the quantity of inputs (fixed or variable) into the production process. The algebraic representation of the production function is

$$Y = f(V,K) \quad (1)$$

where $Y$ is crop output, $V$ are variable production inputs (eg fertiliser, pesticides, water) and $K$ are fixed production inputs (eg land, labour, capital). The incidence of weeds will affect the parameters of this relationship so as to reduce output for any given level of input. This is illustrated in Figure 3 where two production functions $f_1(V,K)$ for "weed free" and $f_2(V,K)$ for "with weeds" are plotted. The important concept demonstrated by the use of production functions is that losses due to weeds are not a number or constant but a relationship, being smaller under low input-low output production methods (ab) than under more intensive systems (cd). The loss associated with weeds can be expressed as a reduction in output ($Y_0$ - $Y_1$ for low input-low output) or the additional input resources (excluding expenditure on weed control) to neutralise the effects of weeds ($V_1 - V_0$), or any combination of consequent output and revenue adjustments between the extremes.

The production function framework can be extending by introducing input variables specifically for weed control, ie

$$Y = f(V,H,K) \quad (2)$$

where $H$ is a weed control input variable (eg herbicide). Increasing inputs on weed control will reduce the production losses and result in a higher level of output for a given level of other production inputs $V$ and $K$. This is demonstrated in Figure 3 with two production functions $f_1(V,H,K)$ and $f_2(V,H,K)$ representing increasing levels of weed control input compared to no control inputs for the "with weeds" production function scenario.

Given that there are benefits from reducing output losses and costs are incurred in obtaining these benefits, from an economic perspective there is an optimal level of weed loss and weed control. McInerney (1996) demonstrated the concept of a loss-expenditure frontier for diseases in livestock that is equally applicable to weeds in annual winter crops. The term loss (L) is restricted to the direct effects caused by weeds in crops (eg yield loss, product contamination). The extra resources utilised as a consequence of weeds are termed expenditures (E) and include weed control inputs such as herbicides and cultivation. Together these two economic concepts define the costs of weeds (C) as the accounting identity

$$C = L + E \quad (3)$$

Weed management involves a choice between levels L and E, with the objective being to minimise C. The relationship between L and E is represented in Figure 4 (McInerney 1996). In the absence of any weed control expenditure, weed losses would equal to L′. With progressive increases in expenditure, losses decline but at a diminishing rate, with the line L′L″ representing an efficiency frontier defining the lowest weed losses attainable for any level of weed control expenditure. The lines $C_X$ and $C_M$ are iso-cost lines which indicate the weed loss and weed control expenditure

**Figure 3.** The effects of weeds on the crop production function

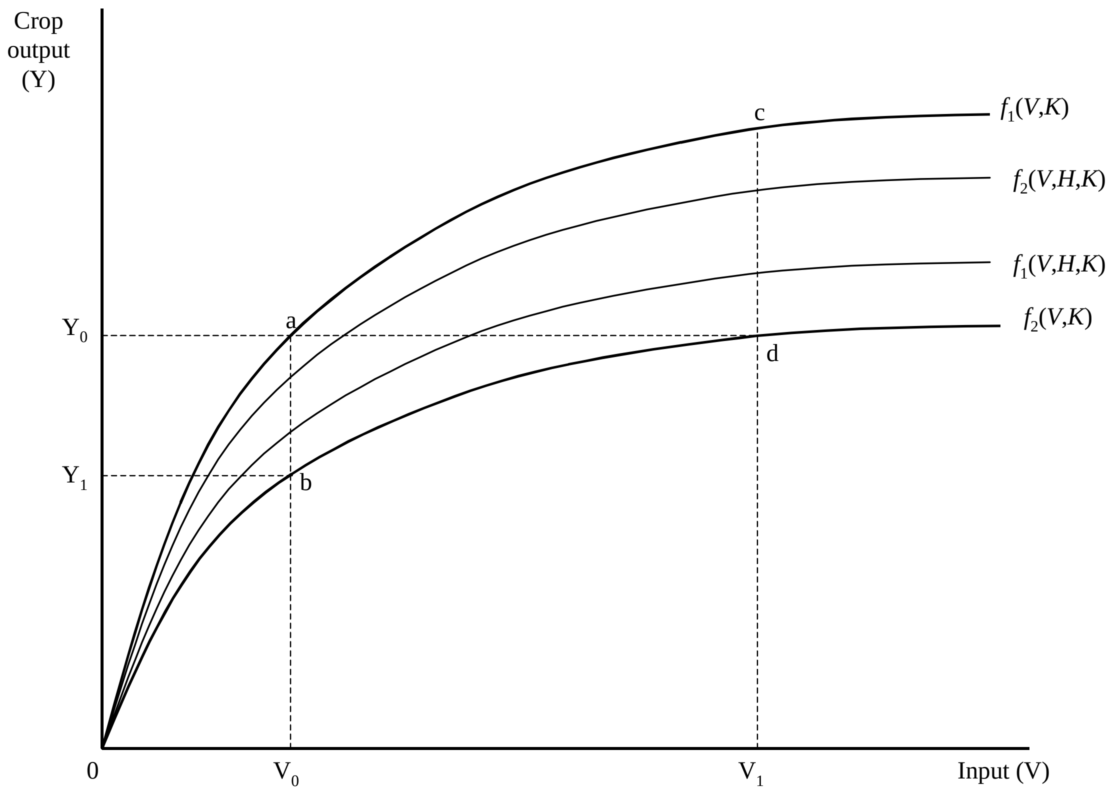
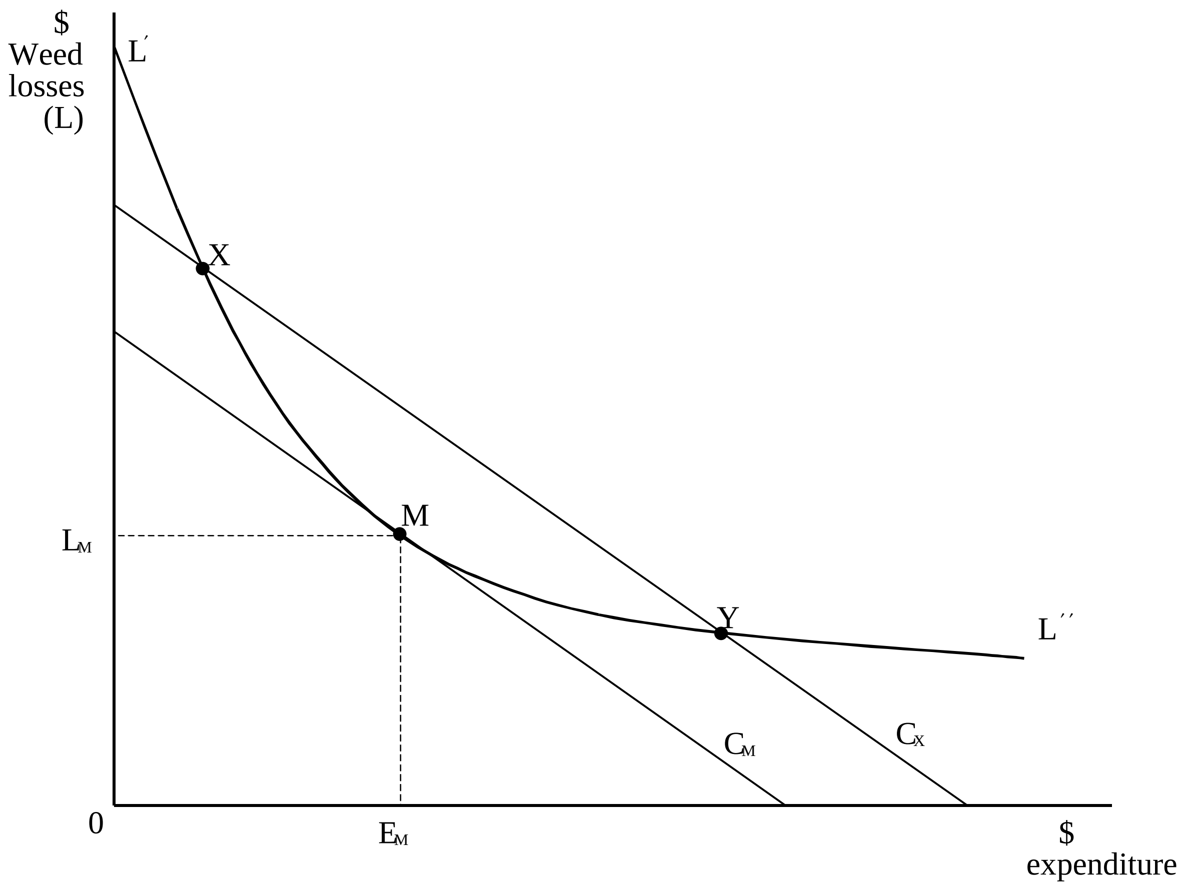



**Figure 4.** The weed loss-expenditure frontier



combinations that amount to the same total cost, ie any combination of L and E along the segment XY of $C_X$ results in the same weed cost. Note that combinations of L and E outside the segment XY of this iso-cost curve are infeasible. The points X and Y represent two contrasting situations; a low weed control and high weed loss scenario (X) and a high weed control and low weed loss scenario (Y). Increasing the level of weed control expenditure from X (ie towards Y) results in lower weed losses and reduces the total weed cost. The lowest weed cost is indicated by point M (ie $C_M$), which incurs a control expenditure $E_M$ and weed losses of $L_M$. At this point the equi-marginal condition is satisfied, ie the marginal cost from a unit of weed control equated the marginal benefit from a reduction in weed losses. Weed losses can be reduced further from point M, however, the benefits from doing so are not compensated by the large additional weed control expenditure required.

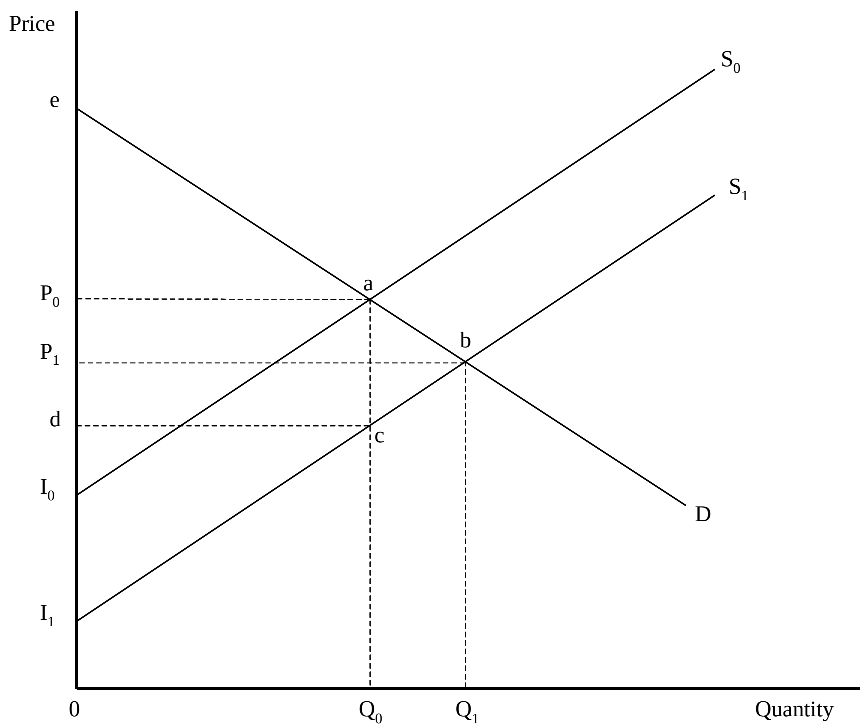
This framework for assessing the economic costs associated with weeds is valuable because it avoids the comparison of losses to a hypothetical (but usually unattainable) weed-free scenario (ie 0). On this point McInerney (1996 p308) states that (in the context of measuring the costs of disease losses) "…this highlights the meaninglessness of the conventional studies which seek to estimate the costs of a particular disease, as though that information had any relevance. Calculating large figures for 'the cost of disease', and inferring from them something about its importance or the case for taking action, implies that points represented by the origin … where no disease costs are incurred – are attainable". McInerney concludes "…it is the avoidable costs that should be measured (such as $C_X - C_M$)".

## 2.4 Economic surplus effects

The estimation of weed losses at an industry level is not realistically approximated by a calculation of change in quantity multiplied by price (such as by Combellack (1987)). For many industries a change in the quantity of a commodity produced can have market price effects, particularly where these industries have competitive structures. In addition, changes to the cost function due to the availability of a new control technology within an industry can have important market quantity and price effects. Therefore, the economic impact of weeds or weed control needs to be considered in terms of their effects upon social welfare. The general social benefit model, which incorporates the concept of economic surplus, provides an appropriate framework for assessing the social costs of weeds and the social benefits from weed control.

Economic surplus consists of two elements, consumers' surplus and producers' surplus (Figure 5). Consumers' surplus is defined as the extra amount a consumer (buyer) would have been prepared to pay (Currie, Murphy and Schmitz 1971) and is measured by the area below the demand curve and above the price line. The basic premise of consumers' surplus is that at a certain market price there are some consumers who would be willing to pay a higher price in order to obtain the same quantity, thus their utility is increased by obtaining the product at the lower price. The traditional measure of producers' surplus is the area above the product supply curve and below the price line.

**Figure 5.** Surplus distribution in the basic economic surplus model



This area represents the difference between what a producer (seller) actually receives for a sale and the minimum amount he would have been prepared to accept. Although Mishan (1968) and Currie, Murphy and Schmitz (1971), among others, prefer the term economic rent to producers' surplus, the latter term is used here for reasons of convention.

The standard economic surplus model presented by Alston (1991) for measuring the research benefits from a technical innovation is used to assess the economic impact of weeds. This model is similar to the single-process model presented by Lindner and Jarrett (1978) with modification by Rose (1980) and Lindner and Jarrett (1980). The approach taken here is to follow that of McInerney (1996) and measure the current weed losses (L) and control expenditure (E) and express these in terms of economic values. This is done by expressing these effects as a shift in the supply function.

The following simplifying assumptions are made. First, supply and demand curves are treated as being linear and any technical innovation would result in a parallel shift in the supply curve. Second, the model is considered as being static. Third, competitive price behaviour applies. Fourth, it is assumed that there are no spillover effects to other countries (Edwards and Freebairn 1981; Davis, Oram and Ryan 1987). Fifth, the model assumes a closed economy in a regional sense in that there are no spillover effects between agro-ecological zones. Finally, it is assumed that the commodities are non-endogenous substitutes, thus there are no cross-commodity effects.

The basic model is illustrated in Figure 5 (Vere, Jones and Griffith 1997). Demand for a homogenous product (eg wheat) is represented by the downward sloping demand curve D, and $S_0$ represents the supply function prior to the technical innovation (ie the current weed level scenario). The initial price and quantity equilibriums are $P_0$ and $Q_0$. Now consider a technical innovation that reduces the area or density of weeds in the annual winter cropping systems. The effect of this is to move the supply curve to the right from $S_0$ to $S_1$. The shift in the supply curve is an extension of the concepts presented by the production functions in Figure 3. The output per unit of resource input is increased with higher levels of weed control.

This rightward shift in the supply curve occurs for two reasons. First, as there are now fewer weeds to control, expenditure on weed control (eg herbicides and cultivation) is reduced or eliminated. This leads to a reduction in per unit production costs which is measured as the vertical distance between the supply curves. Consequently, the cost of producing a particular level of output (say $Q_0$) is lower than prior to the technical innovation. Second, the reduction in residual weeds results in a greater level of output from yield improvements with no additional inputs required. Thus, for a given price a higher quantity can be obtained.

The total benefit from a weed control is the sum of the benefits to consumers and producers in the form of the change in consumers' surplus and producers' surplus. Consumers' surplus prior to the technical innovation is the area $P_0$ae and after the innovation is area $P_1$be. Therefore, consumers have benefited from weed control by the area $P_0abP_1$. Producers' surplus prior to control is $P_0aI_0$ and after control is area $P_1bI_1$, therefore the benefit to producers is the difference between the two areas ie $P_1bI_1$ - $P_0aI_0$. Under the assumption of a parallel supply shift, where the vertical difference between the two curves is constant, area $dcI_1$ = area $P_0aI_0$. Therefore, the change in producer surplus is equal to the producer surplus on the increment to production from $Q_0$ to $Q_1$ that would be measured off either supply curve, ie $P_1bI_1 - dcI_1 = P_1bcd$.

The changes in the economic surplus areas from weed control can be estimated from the following equations (Alston 1991).

$$\Delta CS = P_0 Q_0 Z\left(1+\tfrac{1}{2}Z\eta\right) \tag{4}$$

$$\Delta PS = P_0 Q_0 (K - Z)\left(1+\tfrac{1}{2}Z\eta\right) \tag{5}$$

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K\left(1+\tfrac{1}{2}Z\eta\right) \tag{6}$$

where ΔCS, ΔPS and ΔTS are the changes in consumers' surplus, producers' surplus and total surplus respectively, K is the vertical shift in the supply function expressed as a percentage of initial price, Z is the percentage reduction in price arising from the supply shift and is defined as $Z = K\varepsilon/(\varepsilon+\eta)$, and η and ε are the absolute values for the elasticity of demand and the elasticity of supply. With estimates of these parameters the economic surplus equations can be solved for an individual commodity.

The assumption of a parallel shift in the supply function is critical in the above model. Such a supply shift guarantees that producers do not lose from research. With a divergent supply shift it is possible that producers may lose economic surplus while a convergent supply shift enhances gains in producers' surplus (Freebairn, Davis and Edwards 1982). The assumption of a standard industry wide parallel shift is problematic when one considers the diverse range of production regions that a technical innovation may apply. For instance, the supply shift resulting in yield improvement from a weed control technology in one agro-ecological zone (eg Vic high rainfall) may be quite different to another (eg WA northern) due to differences in climate, soil type and other production characteristics. Such problems have led to proposals to introduce kinks in the supply curve (Rose 1980). An alternative approach is to maintain the assumption of a parallel shift, but as suggested by Lindner and Jarrett (1980) to subdivide the production area into homogenous regions in terms of the technical innovation on yield and production costs.

Davis (1992) argues that this disaggregation issue has greater practical relevance than the debate on the appropriate geometric representation of the supply function. If a linear parallel shift assumption can be shown to be a reasonable approximation of the effect of a technical innovation, then empirical applications would be simpler and the risk of user error reduced. In presenting a framework for disaggregating supply into homogenous production environments, Davis (1992) accepted the principle that if firms operate in a homogenous set of production conditions then a parallel shift is a reasonable approximation. The framework presented by Davis (1992) in Figure 6 assumes a closed country commodity situation and consists of three homogenous production environments suitable for the production of the commodity. There is sufficient variability between the production environments to result in different cost conditions, and each of the aggregated individual production environments are approximated by a linear supply function (Figure 6(a), (b) and (c)). The national aggregated supply is drawn in Figure 6(d) and has three kinks at prices sufficient to encourage some production in each region. For simplicity demand is drawn only at the aggregate level, however, each homogenous region may have its own demand. In this study, demand for grain is likely to be at a national rather than regional level.

If a technical innovation occurs on a production constraint, such as weeds, relevant to and only affects the supply in production environment 3 (PE3), then only the supply of PE3 will shift. This is shown in Figure 6 with an outward shift in the supply function in PE3 (Figure 6(c)) resulting in a shift in aggregate national supply, but only over the top segment. Due to the aggregation process the vertical shift in the aggregate supply is smaller than the underlying regional supply. The welfare gain is given by the shaded area in Figure 6(d).

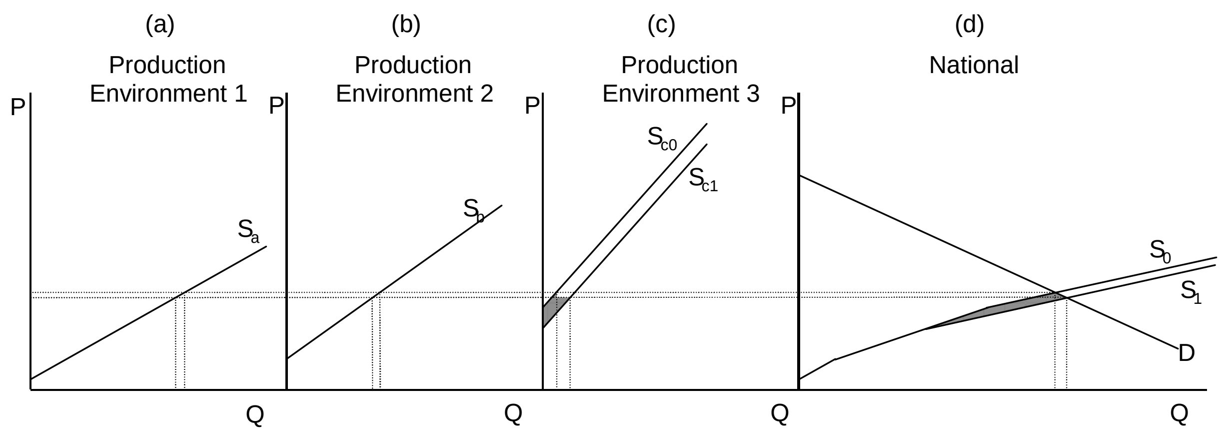
Although this can be estimated at the aggregate level, a simpler approach is to estimate the changes in consumers' and producers' surplus in each of the individual regions and then add the surpluses together. This approach is especially attractive when there are a large number of individual regions to consider (as in this study), and when there are quite diverse impacts upon supply in each of the individual regions from the technical innovation.

The approach taken in this study has been to identify homogenous regions on the basis of the agro-ecological zones. Changes in consumers' surplus and producers' surplus changes were then estimated for each agro-ecological zone. The changes in consumers' and producers' surpluses were summed to provide an estimate of the change in total economic surplus associated with weeds.

To undertake this analysis data were required for each agro-ecological zone on $P_0$, $Q_0$, K, η and ε. The initial equilibrium prices are those given in Table 5. Initial equilibrium quantities were derived from the mail survey and are presented in Table 12. To estimate the proportional vertical supply shift parameter, K, information is required on the absolute supply shift (ac in Figure 5) and the initial equilibrium price ($P_0$). The value of K is calculated as ac/ $P_0$. The values for η and ε were derived from a variety of sources and are given in Tables 13 and 14.

The estimated change in total economic surplus equated to the cost of weeds given by equation (3). The estimation of L and E was obtained from comparison of the values for losses and expenditure with a weed-free scenario, ie the origin in Figure 4. By using an economic surplus approach to estimate C, the weed cost in equation 3, the loss and expenditure values are converted from financial to economic values and therefore reflect any market price and quantity effects. It is important to note that the estimated value of C from this analysis does not represent the economic optimum level of weed loss and weed control. The estimated value simply represents one point in the upper north-east quadrant of Figure 4, bounded by the locusL′L″. The optimum level of weeds can only be determined from evaluation of a large number of weed loss and expenditure scenarios using this economic framework.

**Figure 6.** Supply disaggregation to three homogenous production environments



## 2.5 Measuring weed loss and weed control expenditure

The cost of weeds in annual winter cropping systems is a function of the weed losses due to reductions in yield from residual weeds after control and price penalties from grain contamination, plus expenditure upon weed control including herbicides (plus application costs) and cultivation. Weeds therefore have a direct financial impact from either reducing income through quantity or price effects, or through increasing production costs.

### 2.5.1 *Weed losses*

**Estimating yield losses due to residual weeds**

The loss in revenue of a particular crop is a function of the yield loss due to weed infestations and the commodity price. For each crop, weed and agro-ecological zone the yield loss was calculated as follows.

$$YL_{ijz} = \sum_{k=1}^{3} A_{ijkz} Y_{0iz} D_{ijk} \qquad (7)$$

where *YL* is the yield loss, *A* is the area of weed infestation, $Y_0$ is the weed-free yield, and *D* is the damage (yield loss) coefficient. The yield loss coefficient is a proportional variable and is bounded by zero and one. An increasing value for the yield loss coefficient for a given crop represents a greater yield damage due to higher weed densities.

The subscripts used in the study are defined as follows:

| | |
|---|---|
| *i* is crop, | *i* = 1,…,7 (ie 7 individual crops) |
| *j* is weed, | *j* = 1,…,15 (ie 15 individual weeds) |
| *k* is weed density, | *k* = 1,…,3 (ie 3 weed densities) |
| *z* is agro-ecological zone, | *z* = 1,…,12 (ie 12 agro-ecological zones) |

Cousens (1985) has argued that the appropriate form of a yield loss function for weeds of annual crops is the rectangular hyperbola. In this study, it is assumed that the appropriate yield loss coefficient lies in the initial linear section of any hyperbolic yield loss function. The reason for this is that the definition of medium density (<1 plant m$^{-2}$) and high density (>1 plant m$^{-2}$) is at the lower end of any yield loss curve. At these densities the competitive effect of each weed plant on the crop is additive. Yield loss parameters for the major weed species were estimated from studies undertaken to determine the relationships between weed density and yield loss. These studies were by Martin *et al.* (1987) and Poole and Gill (1987) for *Avena* spp, Medd *et al.* (1985) and Poole and Gill (1987) for *L. rigidum*, Cheam and Code (1998) for *R. raphanistrum*, Reeves and Lamb (1972) for *A. calendula*, Wells (1971) for *C. juncea* and Poole and Gill (1987) for *Bromus* spp. and *H. leporinum*.

Linear regressions were applied to those data to estimate the yield loss coefficients. The resulting regression coefficients (for wheat) along with the percentage of variance accounted for ($R^2$) and standard errors (s.e.) are given in Table 2. Given that yield loss coefficients were required for crops other than wheat, and for some weeds no reference source could be obtained to estimate yield loss, a competitive index approach was adopted to estimate the coefficients. A competitive index of a weed is the reciprocal of the number of plants that would have the same competitive effect as one reference plant. The competitive index of each crop relative to wheat and the competitive index of each weed relative to *R. raphanistrum* (for broadleaf weeds) and *H. leporinum* (for grass weeds) along with the methods used and rationale behind their estimation were peer reviewed (Table 3)[1] . The resulting yield loss coefficients calculated for each crop, weed and density combination are given in Table 4.

The loss in revenue due to weeds for each crop was calculated using the following equation.

$$RL_{ijz} = P_{iz} YL_{ijz} \qquad (8)$$

where *RL* is the revenue loss and *P* is the crop price (Table 5). Once the values for *RL* were determined it was then possible to obtain the loss in revenue in each agro-ecological zone for each crop or each weed.

$$TRL_{iz} = \sum_{j=1}^{15} RL_{ijz} \qquad (9)$$

$$TRL_{jz} = \sum_{i=1}^{7} RL_{ijz} \qquad (10)$$

where *TRL* is the total revenue loss. The total value of lost revenue due to weeds in the study region was obtained from the following equations.

$$TVL_i = \sum_{z=1}^{12} \sum_{j=1}^{15} RL_{ijz} \qquad (11)$$

$$TVL_j = \sum_{z=1}^{12} \sum_{i=1}^{7} RL_{ijz} \qquad (12)$$

$$TVL = \sum_{z=1}^{12} \sum_{j=1}^{15} \sum_{i=1}^{7} RL_{ijz} \qquad (13)$$

[1] The peer review was achieved by posting the derived competition indices to a CRC discussion list for comments. After carefully studying the comments and concerns of those who participated in the discussion, the final competition indices were determined.

where $TVL$ represents the total value of revenue loss. The above equations allowed for determination of the total revenue loss in the study region for each crop ($TVL_i$), for each weed ($TVL_j$), and for the summed total ($TVL$).

The complete weed area data ($A$) is not presented tabularly due to the magnitude of the data involved for all crops, weeds and agro-ecological zones. A summary of the areas of weeds by crop and density are given in Tables 18 and 19.

Weed free yields for each agro-ecological zone are given in Table 6. This data were obtained from the mail survey.

**Estimating losses from grain contamination**

The price penalty due to grain contamination with weeds was derived from the results of the mail survey. Growers were asked for each crop how many tonnes of grain were contaminated, the price reduction due to contamination, and the grading costs incurred due to contamination. The following equation was used to determine the total penalty from grain contamination in each agro-ecological zone.

$$PP_z = \sum_{i=1}^{7} NF_z pc_z \left( C_{iz} PR_{iz} + GC_{iz} \right) \qquad (14)$$

where $PP$ is the total price penalty, $NF$ is the number of farms in each agro-ecological zone affected, $pc$ is the proportion of farms penalised for weed contamination in crops, $C$ is the average tonnes of each crop contaminated, $PR$ is the average price reduction, and $GC$ is the average grading costs per farm for each crop. Details of the volume of grain contaminated with weeds for each crop and agro-ecological zone are given in Table 7 and the average price penalty from contamination is presented in Table 8.

### 2.5.2 Weed control expenditure

**Estimating herbicide costs**

The cost of herbicides was determined directly from the data provided by the mail survey. Average pre-emergent herbicide, post-emergent herbicide and treatment costs per farm were obtained for each crop. The resultant cost of herbicides for each agro-ecological zone was derived from the following equation.

$$HC_z = \sum_{i=1}^{7} NF_{iz} \left( Pe_{iz} + Po_{iz} + Tr_{iz} \right) \qquad (15)$$

Where $HC$ is the cost of herbicides, $NF$ is the number of farms treated with herbicides, and $Pe$, $Po$ and $Tr$ are the average farm pre-emergent herbicide, post-emergent herbicide and treatment costs. The average total crop herbicide costs per farm for each agro-ecological zone are given in Table 9.

**Estimating weed costs due to cultivation**

Although the need for weed control of early germinating cohorts is an important component of crop cultivation costs, there are other reasons for cultivation. Consequently, the approach taken in this study has been to take the arbitrary assumption that 75% of all cultivation costs are attributable to weed control. Data on the area of cultivation in each agro-ecological zone and the cultivation costs per hectare were obtained from ABARE (1999). These data are given in Tables 10 and 11.

# 3. Results

## 3.1 The distribution and density of weeds

### *3.1.1 Mail survey*

**Ranking of problems**

Of nine land management problems associated with cropping in Australia, weeds were ranked first by over 90% of farmers in each of the three regions (Table 15). The rank column reflects the importance of each of the land management problems, with a lower value representing a greater ranking. On this basis weeds were ranked the most important management problem by farmers in each region. Other land management problems that were considered important included crop diseases, insects/pests, saline soil and soil erosion. There was, however, a degree of regional variation with respect to the ranking of the remaining land management problems. For example, saline and acid soils were considered of significantly greater importance in the western region than in either the northern or southern regions, while soil erosion was considered important in the northern region but less so elsewhere.

A large proportion of farmers believed that the weed problem remains unchanged or is worsening. Compared with five years ago, 34%, 45% and 62% of farmers in the northern, southern and western regions considered that weed problems are worsening (Table 16). Only 29% and 25% of farmers in the northern and southern regions believed the weed problem was improving, while a significantly lower proportion of western region farmers (13%) believed this was the case. Very few farmers in any of the three regions surveyed felt that weeds have never been a problem.

**Difficult weeds to control**

Farmers' perceptions of the ten most difficult weeds to control in each region are listed in order of importance in Table 17. *Lolium rigidum* (Gaud) (annual ryegrass) was the most difficult weed to control in both the southern region and western region while it ranked sixth in the northern region. *Avena* spp. (wild oats) ranked first, second and third in the northern, southern and western regions respectively.

Most of the top ten weeds were common to all regions, however, some weeds showed regional propensity indicating the differences in importance of individual species from region to region. *Sonchus oleraceus* L. (sow or milk thistle), *Fallopia convolvulus* Adens. (black bindweed) and *Argemone mexicana* L. (Mexican poppy) were mentioned only in the northern region. *Chondrilla juncea* L. (skeleton weed) was only mentioned in the southern region and *Emex australis* Steinh. (spiny emex) only in the western region. Moreover, while *Brassica tournefortii* Gouan. (wild turnip) and *Phalaris paradoxa* L. (paradoxa grass) were ranked second and third respectively in the northern region they were considered far less important elsewhere with *P. paradoxa* being ranked tenth and *B. tournefortii* ranked ninth in the southern and western regions respectively.

**Residual weed infestation**

A summary of the area and density of the five major weeds in each region is presented in Table 18. The results in Table 18 largely agree with farmers' perceptions of the most difficult weeds to control reported in Table 17.

A more detailed breakdown of the area of the major weeds in each region by crop type is given in Table 19. This data indicates that the five major weeds across the three regions are, in order of importance, *L. rigidum* (5.9 million hectares), *R. raphanistrum* (2.7 million hectares), *Avena* spp. (2.4 million hectares), *A. calendula* (1.1 million hectares) and *B. tournefortii* (0.6 million hectares).

In the northern region, *Avena* spp. was by far the dominant weed in terms of infested area (0.6 million hectares), followed by *B. tournefortii* (0.4 million hectares) and *P. paradoxa* (0.3 million hectares). *L. rigidum* (2.5 million hectares) was the most significant weed in terms of area in the southern region, followed by *Avena* spp. (1.0 million hectares) and then to a much lesser extent *R. raphanistrum* (0.5 million hectares). In the western region the two major weeds were *L. rigidum* (3.1 million hectares) and *R. raphanistrum* (2.2 million hectares). These two weeds alone accounted for a significant proportion of the total crop area infested with weeds.

**Crop rotation practices**

The main crop rotation practised in the southern and western regions was mixed winter crops with a pasture phase, followed by a rotation of mixed winter crops (Table 20). There was very little use of opportunity cropping or continuous winter cereal rotations in these two regions. Owing to the prevailing climate in the southern and western regions (winter dominant rainfall), no rotational systems involving summer crops were recorded.

In the northern region the main rotation involved mixed winter and summer crops, followed by a rotation of mixed winter crops with a pasture phase. There was greater diversity of rotational options in the northern region with utilisation of rotations involving opportunity cropping and continuous winter cereals being also recorded.

**Methods used to control weeds**

The main methods of weed control in each region are reported in Table 21. Pre-emergent and post-emergent herbicides were the dominant control methods in all regions. Farmers in the northern region had a lower dependence upon herbicides than farmers in either the southern or western region, particularly regarding the usage of pre-emergent and post-emergent (grass) herbicides. Crop topping and spray topping appear to be regularly practiced in the southern and western regions, however, these technologies were infrequently used for weed control in the northern region. Long fallowing was rarely used for weed control in the western region, whereas there was moderate usage of this option in both the southern and northern regions. Early sowing and high crop density were practiced by farmers for weed control in all three regions, with a greater level of adoption in the western region.

Crop rotation was an important choice for weed control in all three regions. Although better weed control was considered by farmers as the major reason for rotational choice in each region, there was a range of other issues important in determining crop rotations (Table 22). Better disease control and managing soil fertility were considered important in each region, while moisture conservation and seasonal conditions were also important issues in the northern region.

**Herbicide resistance**

Farmers' perception of the problem of herbicide resistance varied greatly between the three regions (Table 23). Whilst only 17% and 35% of farmers believed herbicide resistance was either a serious or moderate problem in the northern and southern regions respectively, 60% of farmers in the western region considered the problem to be either serious or moderate. It is notable that only 11% of farmers in the western region were either unsure of the extent of the problem or considered it to be minor compared to 41% in the northern region and 28% in the southern region. This demonstrates the perceived extent of the problem in the western region.

**Weed management competency**

Farmers felt comfortable with their ability to manage weeds, with 10% or less of farmers in each region believing they were not competent in their weed management. Despite weeds being ranked as the number one problem affecting farming enterprises, and up to two thirds considering weeds to be a worsening problem, close to 90% of farmers in all regions believed that they were competent to deal with weed problems (Table 24).

### *3.1.2 Field survey*

The field survey largely supported the main findings of the mail survey in terms of the most difficult weeds to control (Table 17). In the northern region the most difficult weed to control was *Avena* spp. (60%) followed by *S. oleraceus* (40%). This differed to the mail survey where the second most difficult weed was *B. tornefortii* (46%). In the southern region the most difficult weeds were *L. rigidum* (74%) and *Avena spp.* (58%), consistent with the results of the mail survey. In the western region the two most difficult weeds were *L. rigidum* (100%) and *R. raphanistrum* (82%), again consistent with the mail survey findings.

The number of wheat paddocks surveyed that were infested with a given weed species and the number of farmers who indicated that their wheat paddocks had residual infestation (from a mail questionnaire undertaken as part of the field survey) are presented in Table 25. A chi-square test was used to test the hypothesis that the two sets of data were not statistically different for each weed species. Except for *S. oleraceus* in the northern region and *R. raphanistrum* in the western region, there were no significant differences between the results of the mail and field surveys. Importantly, a high degree of confidence can be attached to the results for the most important weeds identified from the mail survey, *L. rigidum* and *Avena* spp. in each region, and *R. raphanistrum* in the southern region. The insignificance of the result for *R. raphanistrum* in the western region could suggest that there is an over-estimate of the area of this weed by farmers in that region. However, the divergence of the results may partly be explained by the fact that the field survey did not include the northern part of the western region where there is a high prevalence of *R. raphanistrum*.

There was broad agreement in the results for crop rotation practices between the mail and field survey studies (Table 20). Some statistically significant differences were found in the northern region, however, this may be explained by the small sample size of the field survey in this region.

The results of the field survey were consistent with the mail survey for the main methods of weed control (Table 21). Only two results were statistically different, pre-emergent herbicides and crop topping/spray topping in the southern region. Likewise, there was broad agreement in the results for the reasons for crop rotation (Table 22), however, there were some statistically different responses.

There was broad agreement in terms of the results of the two surveys on farmers' perception of herbicide resistance (Table 23). The main divergence of the results involved the western region where the field survey estimated a higher proportion of farmers perceived the problem as being serious or moderate. Likewise, the results for farmers perception of their ability to manage weeds was similar for the two studies with the exception of the western region, where a higher proportion of farmers were recorded in the field survey as being competent in their management of weeds (Table 24).

## 3.2 Estimation of weed losses and weed control expenditure

### *3.2.1 Weed losses (L)*

**Losses due to yield loss by residual weeds**
The reduction in the yield of each individual crop due to the effect of residual weeds is given in Table 26. Wheat incurred the largest reduction in yield due to residual weeds (1.38 million tonnes), followed by malting barley, lupins and canola. To put the estimated wheat yield in perspective, the estimated national production of wheat for 1998-99 was 21.1 million tonnes (ABARE 1999) after existing weed control measures. Therefore, there is approximately a 6.2% reduction in the volume of the national wheat crop due to weed competition after existing weed control costs have been incurred.

The financial yield losses for each crop due to residual weeds is given in Table 27. The estimated total loss of $380 million was largely due to wheat ($241 million), canola ($57 million), lupins ($26 million), and malting barley ($26 million). The largest loss due to residual weeds occurred in the western region ($175 million), followed by the southern region ($143 million) and then the northern region ($62 million). Losses in the WA Central agro-ecological zone ($139 million) were significantly higher than the remaining agro-ecological zones. This reflects the large yield losses in wheat, malting barley and lupins recorded for this region (Table 26).

The financial yield losses due to residual weeds by each weed in each region is given in Table 28. The major weeds according to yield loss from residual weeds are *L. rigidum* ($140 million), *Avena* spp. ($131 million) and *R. raphanistrum* ($72 million). These three weeds in fact account for about 90% of the yield losses due to residual weeds indicating their importance to cropping systems. There was regional variation in terms of the importance of these weeds with *Avena* spp. by far being the dominant weed in the northern region, while *L. rigidum* was the most important weed in the southern and western regions. In the southern region *Avena* spp. was the second most important weed followed by *R. raphanistrum*, while this order was reversed in the western region where the losses due to *R. raphanistrum* were significantly higher than *Avena* spp.

**Losses due to grain contamination**
The losses due to price penalties from grain being contaminated with weeds was calculated at $25 million (Table 29). Wheat incurred the largest loss ($11 million), followed by pulses ($5 million) and malting barley ($5 million). The largest losses from grain contamination occurred in the southern region ($11 million) followed by the western region ($8 million).

### *3.2.2 Weed control expenditure (E)*

**Herbicide costs**
The total herbicide cost of $583 million (Table 30) included $225 million for pre-emergent herbicides, $253 million for post-emergent herbicides and $105 million for treatment costs. The southern region ($287 million) contributed the most to the total herbicide cost, followed by the western region ($197 million) and the northern region ($99 million). The total herbicide cost is broken down by crop in Table 31. This information illustrates that application of herbicides to wheat ($308 million) accounted for more than half of the total herbicide expenditure on annual winter crops.

The resulting herbicide costs derived from the survey process were compared to herbicide costs calculated from data collected by ABARE (1999). The alternative herbicide costs were derived from multiplying the herbicide material and application costs per hectare (ABARE 1999) by the crop areas collected from the mail survey. The resultant total herbicide cost was $633 million, made up of chemical costs of $524 million and treatment costs of $109 million.

There was a $50 million difference between the two approaches, or 7.8%. On the basis of this analysis an estimated cost of herbicides of around $600 million would appear a reasonable approximation.

**Cultivation costs**
The cultivation costs incurred for weed control were estimated at $206 million (Table 32). The costs of cultivation in wheat ($131 million) contributed a large proportion of the total cultivation cost for weed control. The costs of cultivation for the individual regions were estimated at $95 million for the southern region, $73 million for the western region and $38 million for the northern region.

### *3.2.3 Weed costs (C)*

The combined weed losses of $405 million plus weed control expenditure of $806 million resulted in a financial weed cost of $1,195 million for the 1998-99 season (Table 33). The southern region accounted for $537 million of this total, followed by the western region with $453 million and the northern region with a $205 million income loss.

To obtain an understanding of the significance of the weed impact the per unit (area) weed costs are presented in Table 34. The per unit costs are calculated by dividing the total weed costs for each crop by the respective total crop area. The resulting value reflects the increase in the gross margin per hectare of crop if weeds were eliminated from the cropping system. Therefore, this value represents the maximum financial benefits that could be obtained for each crop from additional and effective weed control. There was significant variation in the per unit weed cost from $37.9 per hectare to as high as $106.3 per hectare. The average per unit weed cost for wheat was $66.8 per hectare, however, this was as high as $96.2 per hectare in the Vic High Rainfall agro-ecological zone. There was significant regional variation in the unit weed cost with the western region, mostly, incurring the greatest proportional weed cost for each commodity with the exception of canola and pulses.

## 3.3. The economic cost of weeds

The estimated values for the proportional vertical supply shift in the supply curve (K) due to current weed infestations are given in Table 35. These were obtained by, first, dividing the per unit weed cost (Table 34) by the average weed free yield (Table 6) to derive an absolute cost reduction in terms of the cost per tonne and, second, dividing this value by the equilibrium price (Table 5). The results given in Table 35 suggest that the supply shift due to the presence of weeds is a significant factor in constraining crop production in the agro-ecological zones studied. The range in the estimated K parameter varied from 0.07 to 0.58, however two thirds of all values lie between 0.10 and 0.20, including all wheat values. There were a large number of values of K estimated at values between 0.20 and 0.58, particularly in the northern and western regions for feed barley, canola, pulses and lupins.

The estimated economic surplus effects due to the presence of weeds in Australian annual winter cropping systems are presented in Tables 36 to 38. The reduction in economic surplus, resulting from weed losses and weed control expenditure, from weeds at current infestation levels was estimated at $1,133 million for the 1998-99 season.

The largest economic cost due to weeds occurred with wheat production ($666 million), primarily due to wheat being the dominant crop in the annual winter cropping systems. Significant economic costs also occur in the production of canola ($138 million) and malting barley ($109 million). If weeds were significantly reduced or eliminated from these production systems, the southern region would be the largest beneficiary in terms of improved economic surplus ($513 million) followed by the western region ($421 million) and the northern region ($198 million).

The loss in total economic surplus for each agro-ecological zone indicates that some agro-ecological zones (eg WA Central) would realise significant gains in economic surplus by the removal of weeds from the production systems.

The breakdown of the total economic surplus loss between consumers and producers is presented in Tables 37 and 38. The most notable observation from these results is that producers appropriate the bulk of the economic welfare gains from any technology that reduces the economic impact of weeds. The loss in producers' surplus of $1,073 million accounts for 95% of the total loss in economic surplus. Consumers, however, do gain to a small extent from any reduced market price resulting from increased production due to weed control.

# 4. Discussion

The response rate from the mail survey (10.4% useable response) was lower than desired, but adequate to draw statistically significant conclusions. The diversity of the questionnaire, given that it included a large number of questions relating to non-weed issues and its complexity in relation to detailed weed management issues may have contributed to the higher non-response rate than the 35-50% that normally would be expected from mail surveys (TQA, personal communication). The response rate of the farmer questionnaire component of the field survey (78%) was much higher than the TQA mail survey, primarily because each grower was contacted at the time of the survey and follow up contact was made to non-responses.

Responding farmers in all regions regarded weeds to be the most important on-farm management problem of winter cropping activities. Compared with the other regions, farmers in the western region believed that weed problems were worse now than five years ago. Despite the widespread use of several weed control methods, including herbicides and cultural practices such as crop rotation and high crop density, and despite the high proportion of farmers (90%) who believe that they are competent enough to manage weeds, the major weed species still persist. This is in line with the general world-wide trend that weed control measures are having marginal effects on suppressing weed populations (Watson 1992, Medd 1997). One of the reasons for this could be herbicide resistance, especially in the western region where 60% of farmers considered that herbicide resistance is either a serious or moderate problem. Herbicide resistance has also been reported to affect up to 10% of the cropping area nationally and is expected to be an increasingly important problem requiring integrated solutions (GRDC 1998).

*L. rigidum*, *Avena* spp. and *R. raphanistrum*, in that order, were the most important weeds nationally and these species coincide with the CRC target weeds in its cropping systems program. The other species showed regional and zonal propensity. One of the unexpected results from the mail survey was that *L. rigidum* appears to be a significant problem in the northern region. It was fourth in terms of area infested in the northern region, ahead of *P. aviculare, S. oleraceus, Rapistrum rugosum* L. (turnip weed) and *Silybum marianum* L. (variegated thistle) all of which were rated higher by Martin *et al.* (1988). It is noteworthy that a population of *L. rigidum* in a winter/summer crop rotational system has recently been reported in the northern region as being resistant to glyphosate following selection by more than 30 applications of the herbicide since 1992 (A. Storrie, personal communication).

Generally there was close agreement with the ranking of weeds in this study and that of earlier studies of parts of the southern region. It is noteworthy that *Bromus* spp, *Phalaris* spp. and *R. raphanistrum* have all apparently increased in ranking in the southern region compared with the findings of Velthuis and Amor (1982/83), Taylor and Lill (1986) and Lemerle *et al.* (1996). Conversely to those studies, a number of previously highly ranked other species (such as *Juncus bufonius* L. (toad rush), *Crassula* species, *Fumaria* species, *Rumex* species and *Trifolium subterraneum* L. (subterranean clover)) did not rate highly in the present study. The higher incidence of *Arctotheca calendula* (L.) Levyns (capeweed) and *Vulpia* spp. (silver grasses), generally regarded as pasture weeds (Wallace 1998), in the southern and western regions compared with the northern region probably reflects the higher prevalence of the rotation of winter crops with pasture comprised of annual species in those regions.

The results of the mail survey regarding species distribution were consistent with the findings of the field survey with few exceptions. The distribution of *S. oleraceus* in the field was much higher than farmers perceived in the northern region. Conversely, the field distribution of *R. raphanistrum* was lower than that of farmer's perception in the western region. It is likely recent changes resulting from control measures (Amor and Kloot 1987, Lemerle *et al.* 1996, Medd 1987, 1997) might have caused these 'floristic shifts'. Gavin *et al.* (1999) found in-crop weed floras varied due to tillage practices in the northern region along with an increase in wind-dispersed species, especially *S. oleraceus*, which has ingressed from occurring on about one third of farms (Martin *et al.* 1988) to having almost ubiquitous occurrence. It is possible that the increase in *S. oleraceus* has been promulgated by the combined adoption of reduced tillage practices and sulfonylurea herbicides and not yet noticed by farmers. The reason for the lower field distribution of *R. raphanistrum* could be that field assessment was not done in the northern part of the western region where its prevalence is thought to be high.

The study also reinforced the presumption that herbicides are the main form of weed control used by farmers. Non-chemical control methods appear to be also regularly used by farmers, and there were clear regional trends as to the methods used. For instance, while fallow was a common practice in the southern and northern regions, it was rarely used in the western region. Whilst there is still room for much greater adoption of high crop density and early sowing for weed control, crop rotation is common practice. This implies that for any adoption by farmers of weed control technologies involving changes in rotational practices, there needs to be greater understanding of the broader farming system effects (such as managing soil fertility and crop diseases) of any change.

Herbicide resistance was perceived to be a far more significant problem by farmers in the western region than those in the eastern states. This reflects the advanced state of herbicide resistance in Western Australia. It is most likely that the proportion of farmers in the northern and southern region who consider herbicide resistance to be either a slight or not a problem will be dramatically reduced as resistance further develops in the eastern states.

This study has extended the economics of disease control framework presented by McInerney (1996) by incorporating supply and demand elasticities and capturing the market price and quantity effects of a change in supply of a commodity. The estimated change in economic surplus explicitly includes both the weed loss and weed control expenditure components required in the weed cost calculation of equation (3). Although the resulting economic cost is useful in itself in order to understand the magnitude of the problem, the real power of the weed cost estimate comes from providing a benchmark from which to determine the economic benefits from any weed control technology that influences weed losses and control expenditure. This approach reinforces the concept of measuring the "avoidable costs" rather than some unattainable zero weed scenario.

The change in producer surplus accounts for the bulk of the change in economic surplus from any technology that reduces weed costs. This result is not surprising given that prevailing world market conditions heavily influence the prices of each of the commodities studied and, consequently, the elasticities of demand are quite high. Such conditions generally imply limited domestic market effects from increases in domestic production, resulting in the incidence of the cost of weeds falling almost wholly on producers.

The nature of the elasticity estimates for supply and demand were largely responsible for the financial and economic costs of weeds results being largely equivalent. Such an outcome can occur when the elasticity of demand is highly elastic and the elasticity of supply is inelastic. For industries with higher supply elasticities and which have a large domestic consumption component and demand elasticities are less elastic than that for Australian grain industries, a financial analysis can considerably overestimate the true economic value.

The study has ignored any cross-commodity effects from any technical innovation that reduces weeds from the annual winter cropping systems. Hence, the economic surplus results reported here are likely to overestimate to some extent the benefits from weed control. However, any such overestimate is likely to be tempered by the conservative yield loss assumptions also made in the study.

# 5. Summary

It is concluded from this study that weeds are a significant management problem to winter crop production across all grain regions in Australia. The findings indicated the weed problem is increasing nationally and there was evidence that the major weeds are persisting despite the range of measures utilised for control. The statistical analysis on the relationships between the mail survey and field survey (including attitudinal and density) indicated that the two sets of data were not significantly different with few exceptions. This implies that a properly designed and conducted mail survey can generate reliable data, therefore justifying the approach used.

The most significant weeds were determined to be *L. rigidum*, *Avena* spp. and *R. raphanistrum* in that order. The financial weed cost of $1,195 million was comprised of weed losses of $385 million and weed control expenditure of $789 million. The per unit weed cost ranged from $28.40 per hectare to $358.80 per hectare. On average across the nation, the presence of weeds reduces the gross margin for wheat by $66.80 per hectare through a combination of yield losses and weed control expenditure.

Incorporating an economic surplus model to account for market price and quantity effects from changes in commodity supply as a result of weed infestations or weed control extended the standard loss-expenditure analysis. The resulting loss in economic surplus due to weeds was estimated at $1,133 million.

This study identified that the cost of weeds was largely borne by producers and, consequently, producers would be the main beneficiaries from any program that reduced the weed burden in the annual winter cropping systems. Consumers only benefited by $59.7 million out of the total $1,133 million (or 5.3%) gain in economic surplus from weed removal. This suggests that the costs of any research, development and extension for weed control should be borne by the primary beneficiary, producers. Consequently, there would appear to be little role for government apart from providing a mechanism for research levies to be collected.

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# Tables

**Table 1**. Major weeds identified in the study

| **Common name** | **Scientific name** | **Common name** | **Scientific name** |
|---|---|---|---|
| Annual ryegrass | *Lolium rigidum* Gaudin | Sow (Milk) thistle | *Sonchus oleraceus* L. |
| Barley grass | *Hordeum leporinum* Link | Spiny emex | *Emex australis* Steinh. |
| Black bindweed | *Fallopia convolvulus* L. | Vulpia | *Vulpia* spp. |
| Brome | *Bromus* spp. | Wild mustard | *Sisymbrium officinale* L. |
| Cape weed | *Arctotheca calendula* Levyns. | Wild oats | *Avena* spp. |
| Mexican poppy | *Argemone mexicana* L. | Wild radish | *Raphanus raphanistrum* L. |
| Paterson's curse | *Echium plantagineum* L. | Wild turnip | *Brassica tournefortii* Gouan |
| Phalaris | *Phalaris paradoxa* L. | Wire weed | *Polygonum aviculare* L. |
| Skeleton weed | *Chondrilla juncea* L. | | |

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**Table 2**. Linear yield loss coefficients

| | Estimate | s.e. | $R^2$ |
|---|---|---|---|
| *Avena* spp. | 0.77 | 0.035 | 0.970 |
| *L. rigidum* | 0.37 | 0.023 | 0.945 |
| *R. raphanistrum* | 0.40 | 0.008 | 0.985 |
| *A. calendula* | 0.30 | 0.030 | 0.636 |
| *Bromus* spp. | 0.35 | 0.019 | 0.956 |
| *H leporinum* | 0.23 | 0.013 | 0.960 |
| *C. juncea* | 0.28 | 0.033 | 0.787 |
| *E. australis* | 0.44 | 0.070 | 0.416 |

**Table 3**. Competition indices for crops and weeds

| Crop competition indices[1] | | Weed competition indices | |
|---|---|---|---|
| Oats | 0.70 | *B. tournefortii*[2] | 0.75 |
| Malting barley | 0.80 | *P. aviculare*[2] | 0.20 |
| Feed barley | 0.80 | *S. oleraceus*[2] | 0.20 |
| Canola | 1.10 | *E. plantagineum*[2] | 0.50 |
| Pulses | 1.25 | *S. officinale*[2] | 0.75 |
| Lupins | 1.25 | *P. paradoxa*[3] | 1.00 |
| | | *Vulpia* spp.[3] | 0.90 |

[1] Reference point wheat
[2] Reference point *R. raphanistrum*
[3] Reference point *H. leproinum*

**Table 4**. Yield loss coefficients

| Weed | Density | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|---|
| *Avena* spp. | High | 0.39 | 0.27 | 0.32 | 0.31 | 0.41 | 0.48 | 0.48 |
| | Medium | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.05 | 0.05 |
| | Low | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *L. rigidum* | High | 0.16 | 0.11 | 0.13 | 0.13 | 0.17 | 0.20 | 0.20 |
| | Medium | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *R. raphanistrum* | High | 0.26 | 0.19 | 0.22 | 0.21 | 0.28 | 0.32 | 0.32 |
| | Medium | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 |
| | Low | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| *A. calendula* | High | 0.13 | 0.10 | 0.11 | 0.11 | 0.15 | 0.17 | 0.17 |
| | Medium | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *B. tournefortii* | High | 0.20 | 0.14 | 0.16 | 0.16 | 0.21 | 0.24 | 0.24 |
| | Medium | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *P. aviculare* | High | 0.05 | 0.04 | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 |
| | Medium | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *P. paradoxa* | High | 0.15 | 0.11 | 0.13 | 0.12 | 0.17 | 0.19 | 0.19 |
| | Medium | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *S. oleraceus* | High | 0.05 | 0.04 | 0.04 | 0.04 | 0.06 | 0.06 | 0.06 |
| | Medium | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *E. plantagineum* | High | 0.13 | 0.09 | 0.11 | 0.10 | 0.14 | 0.16 | 0.16 |
| | Medium | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Bromus* spp. | High | 0.16 | 0.11 | 0.13 | 0.13 | 0.18 | 0.20 | 0.20 |
| | Medium | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *H. leporinum* | High | 0.12 | 0.09 | 0.10 | 0.10 | 0.13 | 0.15 | 0.15 |
| | Medium | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *C. juncea* | High | 0.20 | 0.14 | 0.16 | 0.16 | 0.21 | 0.24 | 0.24 |
| | Medium | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *S. officinale* | High | 0.20 | 0.14 | 0.16 | 0.16 | 0.21 | 0.24 | 0.24 |
| | Medium | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Vulpia* spp. | High | 0.11 | 0.08 | 0.09 | 0.09 | 0.12 | 0.13 | 0.13 |
| | Medium | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *E. australis* | High | 0.18 | 0.13 | 0.15 | 0.15 | 0.20 | 0.22 | 0.22 |
| | Medium | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| | Low | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table 5**. Farm gate crop prices ($/tonne)

| | | | |
|---|---|---|---|
| Wheat | 175 | Feed Barley | 118 |
| Oats | 112 | Canola | 359 |
| Malting Barley | 157 | Pulses | 240 |
| | | Lupins | 162 |

Source: ABARE (1999)

**Table 6**. Weed free yields derived from mail survey (tonnes/hectare)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 3.2 | 2.9 | 3.3 | 3.5 | 2.0 | 1.7 | 1.7 |
| NSWNW/QldSW | 2.9 | 3.5 | 3.0 | 2.0 | 1.8 | 1.6 | 1.5 |
| NSW Central | 3.4 | 3.0 | 2.8 | 3.6 | 2.2 | 1.8 | 2.1 |
| NSW/Vic Slopes | 4.1 | 3.0 | 3.6 | 3.4 | 2.5 | 2.3 | 2.1 |
| Vic High Rainfall | 3.9 | 3.8 | 4.0 | 4.0 | 2.3 | 2.5 | 2.3 |
| SA/Vic Bordertown-Wimmera | 3.4 | 3.3 | 3.3 | 3.3 | 2.0 | 2.3 | 1.9 |
| SA Vic Mallee | 2.1 | 2.3 | 2.1 | 2.1 | 1.5 | 1.3 | 1.6 |
| SA Midnorth-Lower Yorke, Eyre | 3.1 | 3.5 | 3.3 | 3.1 | 1.9 | 2.0 | 1.7 |
| WA Mallee and Sandplain | 2.9 | 3.8 | 2.8 | 3.1 | 1.6 | 1.5 | 1.8 |
| WA Central | 2.5 | 3.0 | 2.5 | 2.5 | 1.5 | 1.3 | 1.4 |
| WA Northern | 2.3 | 2.0 | 2.4 | 2.7 | 1.3 | 1.3 | 1.5 |
| WA Eastern | 1.8 | 1.9 | 1.9 | 2.3 | 1.1 | 1.1 | 1.2 |

**Table 7**. Grain contamination in each agro-ecological zone derived from mail survey ('000 tonnes)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | PulsesNote: |
|---|---|---|---|---|---|---|
| NSWNE/QldSE | 25.4 | 0.0 | 39.3 | 0.0 | 0.0 | 36.7 |
| NSWNW/QldSW | 87.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NSW Central | 8.3 | 0.0 | 20.5 | 22.2 | 18.5 | 0.0 |
| NSW/Vic Slopes | 34.3 | 0.0 | 13.9 | 0.0 | 3.3 | 0.0 |
| Vic High Rainfall | 0.0 | 0.0 | 5.5 | 0.0 | 0.0 | 1.9 |
| SA/Vic Bordertown-Wimmera | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 59.7 |
| SA Vic Mallee | 11.4 | 0.0 | 8.3 | 0.0 | 0.0 | 2.4 |
| SA Midnorth-Lower Yorke, Eyre | 56.4 | 0.0 | 34.8 | 16.0 | 0.0 | 48.1 |
| WA Mallee and Sandplain | 0.0 | 0.9 | 0.0 | 5.0 | 0.0 | 0.0 |
| WA Central | 120.0 | 0.0 | 95.3 | 123.0 | 35.1 | 0.0 |
| WA Northern | 43.3 | 0.0 | 0.0 | 40.7 | 30.5 | 0.0 |
| WA Eastern | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Note: Lupin values are included with pulses.

**Table 8**. Average price penalty per tonne of grain contaminated ($/tonne)

| Zone | Wheat | Malting Oats | Feed Barley | Barley | Canola | Pulses |
|---|---|---|---|---|---|---|
| NSWNE/QldSE | 13 | | 10 | | | 80 |
| NSWNW/QldSW | 18 | | | | | |
| NSW Central | 10 | | 28 | 12 | 15 | |
| NSW/Vic Slopes | 15 | | 40 | | 18 | |
| Vic High Rainfall | | | 40 | | | 10 |
| SA/Vic Bordertown-Wimmera | | | | | | 20 |
| SA Vic Mallee | 30 | | 35 | | | 28 |
| SA Midnorth-Lower Yorke, Eyre | 63 | | 28 | 14 | | 14 |
| WA Mallee and Sandplain | | 6 | | 5 | | |
| WA Central | 18 | | 13 | 10 | 14 | |
| WA Northern | 17 | | | 10 | 35 | |
| WA Eastern | 10 | | | | | |

Note: Lupin values are included with pulses

**Table 9**. Herbicide costs per farm ($'000)

| | Pre-emergent herbicides | Post-emergent herbicides | Treatment cost | Total cost |
|---|---|---|---|---|
| NSWNE/QldSE | 21.8 | 24.4 | 9.7 | 55.9 |
| NSWNW/QldSW | 16.0 | 28.7 | 8.8 | 53.5 |
| NSW Central | 11.3 | 21.3 | 6.9 | 39.5 |
| NSW/Vic Slopes | 14.3 | 17.4 | 6.5 | 38.3 |
| Vic High Rainfall | 9.0 | 12.5 | 6.4 | 28.0 |
| SA/Vic Bordertown-Wimmera | 11.1 | 15.4 | 6.6 | 32.9 |
| SA Vic Mallee | 11.6 | 18.0 | 7.9 | 37.5 |
| SA Midnorth-Lower Yorke, Eyre | 15.9 | 18.9 | 6.8 | 41.6 |
| WA Mallee and Sandplain | 25.7 | 24.5 | 10.1 | 60.3 |
| WA Central | 29.3 | 25.7 | 9.7 | 64.8 |
| WA Northern | 34.3 | 30.6 | 14.3 | 79.2 |
| WA Eastern | 37.2 | 40.8 | 13.7 | 91.7 |

**Table 10**. Cultivation area ('000 hectares)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 1,521 | 79 | 110 | 162 | 31 | 137 | 5 |
| NSWNW/QldSW | 1,024 | 43 | 12 | 4 | 10 | 61 | 11 |
| NSW Central | 876 | 105 | 135 | 44 | 114 | 21 | 22 |
| NSW/Vic Slopes | 699 | 113 | 102 | 42 | 395 | 19 | 85 |
| Vic High Rainfall | 32 | 20 | 15 | 0 | 19 | 11 | 4 |
| SA/Vic Bordertown-Wimmera | 577 | 168 | 427 | 33 | 244 | 419 | 55 |
| SA Vic Mallee | 1,092 | 67 | 369 | 191 | 29 | 156 | 22 |
| SA Midnorth-Lower Yorke, Eyre | 795 | 81 | 217 | 263 | 81 | 200 | 21 |
| WA Mallee and Sandplain | 108 | 12 | 51 | 43 | 48 | 9 | 23 |
| WA Central | 2,492 | 151 | 388 | 36 | 347 | 75 | 275 |
| WA Northern | 787 | 7 | 39 | 13 | 58 | 21 | 275 |
| WA Eastern | 337 | 7 | 22 | 1 | 10 | 3 | 53 |

Source: ABARE (1999)

**Table 11**. Cultivation costs ($/hectare)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 16.00 | 9.07 | 19.75 | 7.50 | 19.80 | 19.80 | 19.80 |
| NSWNW/QldSW | 16.00 | 9.07 | 19.75 | 7.50 | 19.80 | 19.80 | 19.80 |
| NSW Central | 19.00 | 19.00 | 19.00 | 19.00 | 13.00 | 12.34 | 12.34 |
| NSW/Vic Slopes | 19.00 | 19.00 | 19.00 | 19.00 | 13.00 | 12.34 | 12.34 |
| Vic High Rainfall | 19.00 | 19.00 | 19.00 | 19.00 | 13.00 | 12.34 | 12.34 |
| SA/Vic Bordertown-Wimmera | 13.00 | 10.00 | 13.00 | 13.00 | 17.00 | 7.00 | 7.00 |
| SA Vic Mallee | 17.00 | 11.00 | 17.00 | 17.00 | 17.00 | 10.00 | 10.00 |
| SA Midnorth-Lower Yorke, Eyre | 15.88 | 13.23 | 9.92 | 9.92 | 16.78 | 12.83 | 12.83 |
| WA Mallee and Sandplain | 13.92 | 13.20 | 13.00 | 13.20 | 16.30 | 12.00 | 12.00 |
| WA Central | 18.17 | 17.99 | 17.99 | 17.99 | 18.35 | 11.30 | 15.50 |
| WA Northern | 18.17 | 17.99 | 17.99 | 17.99 | 18.35 | 11.30 | 15.50 |
| WA Eastern | 13.62 | 13.44 | 13.62 | 13.62 | 14.34 | 13.62 | 12.00 |

Source: ABARE (1999)

**Table 12**. Initial quantity equilibrium $Q_0$ ('000 tonnes)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 4,705 | 224 | 350 | 558 | 59 | 220 | 8 |
| NSWNW/QldSW | 2,854 | 149 | 35 | 5 | 9 | 91 | 16 |
| NSW Central | 2,918 | 312 | 368 | 143 | 244 | 38 | 45 |
| NSW/Vic Slopes | 2,727 | 330 | 358 | 139 | 914 | 44 | 156 |
| Vic High Rainfall | 117 | 72 | 55 | 0 | 43 | 27 | 9 |
| SA/Vic Bordertown-Wimmera | 1,908 | 546 | 1,383 | 109 | 482 | 956 | 102 |
| SA Vic Mallee | 2,253 | 149 | 766 | 392 | 42 | 196 | 34 |
| SA Midnorth-Lower Yorke, Eyre | 2,362 | 277 | 692 | 792 | 144 | 375 | 33 |
| WA Mallee and Sandplain | 300 | 45 | 138 | 131 | 74 | 13 | 40 |
| WA Central | 5,672 | 439 | 914 | 86 | 482 | 91 | 295 |
| WA Northern | 1,717 | 13 | 89 | 32 | 70 | 27 | 380 |
| WA Eastern | 573 | 13 | 41 | 2 | 11 | 3 | 60 |

**Table 13**. Demand elasticities ($\eta$)

| | | | |
|---|---|---|---|
| Wheat | -6.17 | Canola | -2.20 |
| Oats | -2.20 | Pulses | -2.20 |
| Malting Barley | -2.20 | Lupins | -2.20 |
| Feed Barley | -2.20 | | |

Source: Myers, Piggot & MacAulay (1985)

**Table 14**. Supply elasticities ($\varepsilon$)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 0.33 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| NSWNW/QldSW | 0.33 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| NSW Central | 0.33 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| NSW/Vic Slopes | 0.24 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| Vic High Rainfall | 0.24 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| SA/Vic Bordertown-Wimmera | 0.26 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| SA Vic Mallee | 0.26 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| SA Midnorth-Lower Yorke, Eyre | 0.26 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| WA Mallee and Sandplain | 0.23 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| WA Central | 0.23 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| WA Northern | 0.23 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| WA Eastern | 0.23 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |

Source: ABARE (1999)

**Table 15**. Farmers' ranking of nine land management problems (% of farmers nominating)

| | Northern region | | Southern region | | Western region | |
|---|---|---|---|---|---|---|
| Problem | % of farmers | Rank | % of farmers | Rank | % of farmers | Rank |
| Weeds | 92 | 2.1 | 92 | 1.9 | 93 | 2.0 |
| Crop diseases | 61 | 4.0 | 74 | 3.6 | 78 | 3.9 |
| Insect/pests | 67 | 3.7 | 76 | 4.1 | 77 | 4.5 |
| Fertiliser | 51 | 4.8 | 40 | 5.0 | 44 | 5.9 |
| Lack of appropriate varieties | 38 | 5.7 | 40 | 6.1 | 46 | 6.9 |
| Saline soil | 9 | 7.1 | 20 | 6.7 | 67 | 4.6 |
| Soil sodicity | 22 | 6.7 | 28 | 6.5 | 21 | 7.2 |
| Acid soil | 12 | 7.0 | 41 | 5.4 | 69 | 4.5 |
| Soil erosion | 66 | 4.1 | 41 | 5.8 | 54 | 5.7 |

**Table 16**. Farmer's perception on the standing of the weed problem compared to five years ago in each region (%)

| | Northern region | Southern region | Western region |
|---|---|---|---|
| Getting worse | 34 | 45 | 62 |
| Getting better | 29 | 25 | 13 |
| Unchanged | 33 | 28 | 23 |
| Never a problem | 3 | 3 | 2 |

**Table 17**. Most difficult weeds to control as ranked by farmers in each region (% of farmers nominating)

| Northern region | | | Southern region | | | Western region | | |
|---|---|---|---|---|---|---|---|---|
| Weed | % farmers | | Weed | % farmers | | Weed | % farmers | |
| | Mail | Field | | Mail | Field | | Mail | Field |
| *Avena* spp. | 65 | 60 | *L. rigidum* | 78 | 74 | *L. rigidum* | 92 | 100 |
| *B. tournefortii* | 46 | 34 | *Avena spp.* | 51 | 58 | *R. raphanistrum* | 81 | 82 |
| *P. paradoxa* | 27 | 31 | *A. calendula* | 35 | 40 | *Avena* spp. | 56 | 77 |
| *S. oleraceus* | 26 | 40 | *R. raphanistrum* | 33 | 32 | *A. calendula* | 44 | 68* |
| *P. aviculare* L. | 25 | 34 | *Vulpia* spp. | 22 | 17 | *Vulpia* spp. | 34 | 55 |
| *L. rigidum* | 24 | 26 | *P. aviculare* | 17 | 17 | *Bromus* spp. | 31 | 27 |
| *F. convolvulus* | 22 | 0* | *C. juncea* | 16 | 23 | *H. leporinum* | 28 | 32 |
| *R. raphanistrum* | 20 | 9 | *Bromus* spp. | 15 | 23 | *E. australis* | 28 | 27 |
| *A. mexicana* | 15 | 3* | *H. leporinum* Link. | 13 | 9 | *B. tournefortii* | 12 | 0* |
| *A. calendula* Levyns. | 6 | 3 | *P. paradoxa* | 11 | 8 | *P. aviculare* | 5 | 5 |

* Significantly different responses.

**Table 18.** Area of the five major weeds by density in each region ('000 hectares)

| | High density | Medium density | Low density | Total |
|---|---|---|---|---|
| **Northern region** | | | | |
| *Avena* spp. | 192.5 | 218.9 | 217.7 | 629.1 |
| *Brassica tournefortii* | 9.8 | 192.6 | 194.6 | 397.0 |
| *Phalaris paradoxa* | 45.3 | 126.5 | 131.2 | 303.0 |
| *Lolium rigidum* | 72.8 | 115.9 | 94.8 | 283.5 |
| *Sonchus oleraceus* | 47.1 | 56.3 | 145.3 | 248.7 |
| **Southern region** | | | | |
| *Lolium rigidum* | 589.9 | 709.9 | 1.242.6 | 2.542.4 |
| *Avena* spp. | 173.7 | 282.8 | 572.1 | 1.028.6 |
| *Raphanus raphanistrum* | 73.0 | 130.8 | 252.6 | 456.4 |
| *Arctotheca calendula* | 48.5 | 114.2 | 288.9 | 451.6 |
| *Bromus* spp. | 45.1 | 108.0 | 181.8 | 334.9 |
| **Western region** | | | | |
| *Lolium rigidum* | 1,054.4 | 805.6 | 1.279.6 | 3.139.6 |
| *Raphanus raphanistrum* | 468.3 | 685.8 | 1.056.2 | 2.210.3 |
| *Avena* spp. | 184.0 | 189.5 | 392.5 | 766.0 |
| *Arctotheca calendula* | 59.5 | 129.7 | 472.0 | 661.2 |
| *Emex australis* | 30.4 | 25.8 | 136.7 | 192.9 |

**Table 19.** Area of the five major weeds by crop in each region ('000 hectares)

| Northern region | *Avena spp* | *Brassica tournefortii* | *Phalaris paradoxa* | *Lolium rigidum* | *Sonchus oleraceus* |
|---|---|---|---|---|---|
| Wheat | 473.9 | 247.0 | 245.5 | 209.6 | 181.5 |
| Oats | 7.1 | 13.7 | 5.4 | 23.6 | 0.0 |
| Malting Barley | 31.6 | 23.3 | 29.3 | 4.6 | 15.3 |
| Feed Barley | 29.8 | 13.4 | 6.2 | 6.2 | 11.5 |
| Canola | 9.9 | 2.7 | 2.7 | 18.1 | 6 |
| Pulses | 73.8 | 96.9 | 13.9 | 6.4 | 37.7 |
| Lupins | 2.9 | 0.0 | 0.0 | 15.0 | 2.1 |
| Total | 629.1 | 397.0 | 303.0 | 283.5 | 248.7 |

| Southern region | *Lolium Rigidum* | *Avena spp* | *Raphanus raphanistrum* | *Arctotheca calendula* | *Bromus spp.* |
|---|---|---|---|---|---|
| Wheat | 1,338.0 | 639.3 | 187.5 | 170.1 | 167.6 |
| Oats | 192.3 | 67.8 | 21.1 | 76.0 | 4.6 |
| Malting Barley | 307.5 | 86.3 | 52.7 | 46.3 | 71.3 |
| Feed Barley | 204.1 | 37.8 | 46.2 | 14.8 | 56.4 |
| Canola | 254.9 | 131.7 | 64.5 | 109.7 | 11.7 |
| Pulses | 200.5 | 37.4 | 55.9 | 4.3 | 20.3 |
| Lupins | 45.1 | 28.3 | 28.5 | 30.4 | 3.0 |
| Total | 2,542.4 | 1,028.6 | 456.4 | 451.6 | 334.9 |

| Western region | *Lolium Rigidum* | *Raphanus raphanistrum* | *Avena spp* | *Arctotheca calendula* | *Emex australis* |
|---|---|---|---|---|---|
| Wheat | 1,894.5 | 1,381.7 | 615.5 | 407.5 | 140.0 |
| Oats | 65.8 | 42.5 | 0.3 | 26.1 | 1.8 |
| Malting Barley | 251.3 | 154.9 | 39.9 | 29.6 | 5.7 |
| Feed Barley | 55.6 | 26.4 | 1.8 | 10.7 | 0.0 |
| Canola | 265.2 | 88.0 | 34.6 | 35.7 | 1.5 |
| Pulses | 33.6 | 38.1 | 6.0 | 3.0 | 9.5 |
| Lupins | 573.6 | 478.7 | 67.9 | 148.6 | 34.4 |
| Total | 3,139.6 | 2,210.3 | 766.0 | 661.2 | 192.9 |

| Total | *Lolium Rigidum* | *Raphanus raphanistrum* | *Avena spp* | *Arctotheca calendula* | *Brassica tournefortii* |
|---|---|---|---|---|---|
| Wheat | 3,442.1 | 1,616.0 | 1,728.7 | 577.6 | 356.5 |
| Oats | 281.7 | 67.8 | 75.2 | 102.1 | 31.0 |
| Malting Barley | 563.4 | 214.3 | 157.8 | 75.9 | 35.7 |
| Feed Barley | 265.9 | 72.6 | 69.4 | 25.5 | 32.2 |
| Canola | 538.2 | 152.5 | 176.2 | 145.4 | 6.6 |
| Pulses | 240.4 | 94.0 | 117.2 | 7.3 | 119.5 |
| Lupins | 633.7 | 507.2 | 99.1 | 179.0 | 0.8 |
| Total | 5,965.5 | 2,724.4 | 2,423.7 | 1,112.8 | 582.3 |

**Table 20**. Crop rotation practices in each region (% of farmers nominating)

| Rotation practice | Northern region Mail | Northern region Field | Southern region Mail | Southern region Field | Western region Mail | Western region Field |
|---|---|---|---|---|---|---|
| Continuous winter cereal | 15 | 14 | 2 | 4 | 4 | 0 |
| Continuous winter and summer cereal | 5 | 40* | 0 | 0 | 0 | 0 |
| Mixed winter crops | 8 | 11 | 29 | 26 | 28 | 32 |
| Mixed winter crops with pasture phase | 23 | 14 | 52 | 64 | 59 | 68 |
| Mixed winter and summer crops | 31 | 6* | 2 | 0 | 0 | 0 |
| Fallow every second year | 1 | 11* | 3 | 0 | 2 | 0 |
| Opportunity cropping | 12 | 3 | 4 | 4 | 1 | 0 |
| Other | 2 | 0 | 7 | 2 | 5 | 0 |

* Significantly different responses.

**Table 21**. The main weed control methods used in each grain region (% of farmers nominating)

| Weed control method | Northern region Mail | Northern region Field | Southern region Mail | Southern region Field | Western region Mail | Western region Field |
|---|---|---|---|---|---|---|
| Pre-emergent | 58 | 57 | 84 | 94* | 89 | 100 |
| Post-emergent (Broadleaf) | 88 | 94 | 89 | 91 | 88 | 100 |
| Post-emergent (Grass) | 52 | 51 | 71 | 68 | 81 | 82 |
| Early sowing | 29 | 20 | 22 | 28 | 30 | 50 |
| High crop density | 25 | 17 | 35 | 43 | 40 | 32 |
| Long fallow | 26 | 40 | 21 | 26 | 2 | 5 |
| Crop topping/spray topping | 11 | 9 | 52 | 75* | 73 | 86 |
| Crop rotation | 50 | 37 | 62 | 70 | 73 | 91 |
| Herbicide resistant crops | 3 | 3 | 13 | 11 | 20 | 32 |
| Others | 7 | 9 | 11 | 9 | 12 | 9 |

* Significantly different responses.

**Table 22**. Reasons for crop rotation where farmers nominated crop rotation as a weed control method (% of farmers nominating)

| Reason | Northern region Mail | Northern region Field | Southern region Mail | Southern region Field | Western region Mail | Western region Field |
|---|---|---|---|---|---|---|
| Better weed control | 78 | 60* | 80 | 83 | 81 | 91 |
| Better disease control | 58 | 83* | 78 | 83 | 71 | 82 |
| Moisture conservation | 44 | 43 | 30 | 26 | 19 | 27 |
| Management of soil fertility | 60 | 63 | 81 | 19* | 76 | 91 |
| Opportunity cropping | 39 | 37 | 24 | 15 | 25 | 14 |
| Seasonal conditions | 50 | 43 | 22 | 15 | 18 | 0* |
| Other | 9 | 3 | 8 | 6 | 11 | 5 |

* Significantly different responses.

**Table 23**. Farmers' perception of the magnitude of the herbicide resistance problem (%)

| Extent of problem | Northern region | | Southern region | | Western region | |
|---|---|---|---|---|---|---|
| | Mail | Field | Mail | Field | Mail | Field |
| Serious | 3 | 6 | 11 | 15 | 26 | 41 |
| Moderate | 14 | 20 | 24 | 19 | 34 | 45 |
| Slight | 42 | 43 | 35 | 45 | 29 | 14 |
| Not a problem | 29 | 29 | 18 | 15 | 8 | 0 |
| Not sure | 12 | 3 | 10 | 6 | 3 | 0 |

**Table 24**. Farmers' perception of their ability to manage weeds (%)

| Degree of competence | Northern region | | Southern region | | Western region | |
|---|---|---|---|---|---|---|
| | Mail | Field | Mail | Field | Mail | Field |
| Very competent | 17 | 14 | 14 | 32 | 12 | 9 |
| Fairly competent | 71 | 77 | 76 | 60 | 77 | 91 |
| Not competent | 10 | 9 | 8 | 8 | 10 | 0 |

**Table 25**. Number of wheat paddocks (field survey) with weed infestation and the number of farmers (mail survey) which indicated that their wheat paddocks had residual weed infestation

| | | Field survey | | Mail survey | | |
|---|---|---|---|---|---|---|
| | | Yes | No | Yes | No | P value |
| Northern | *Avena* spp. | 23 | 29 | 1771 | 2759 | .451 |
| | *S. oleraceus* | 31 | 21 | 794 | 3736 | <.001 |
| | *L. rigidum* | 12 | 40 | 1105 | 3225 | .688 |
| | *P. paradoxa* | 13 | 39 | 847 | 3683 | .247 |
| | *B. tournefortii* | 5 | 47 | 869 | 3661 | .081 |
| Southern | *L. rigidum* | 47 | 22 | 9035 | 6048 | .165 |
| | *Avena* spp. | 30 | 39 | 5215 | 9868 | .121 |
| | *R. raphanistrum* L. | 6 | 63 | 2321 | 12762 | .124 |
| | *A .calendula* Levyns. | 23 | 46 | 3609 | 11474 | .068 |
| | *Bromus* spp.. | 9 | 60 | 1114 | 13964 | .074 |
| Western | *L. rigidum* | 35 | 8 | 3114 | 937 | .484 |
| | *Avena* spp. | 21 | 22 | 1746 | 2305 | .450 |
| | *R. raphanistrum* L. | 9 | 34 | 2462 | 1589 | <.001 |
| | *A. calendula* Levyns. | 5 | 38 | 725 | 3326 | .285 |
| | *E. australis* | 2 | 41 | 450 | 3601 | .179 |

'Yes' indicates presence of weed and 'No' indicates absence. Chi-square was used to test the hypothesis that the two sets of data were not statistically different for each weed species. The given P values are the result of this test. P values les than .05 indicate significant difference.

**Table 26**. Yield loss from residual weeds ('000 tonnes)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 162.4 | 5.0 | 12.7 | 9.0 | 3.0 | 12.5 | 0.3 |
| NSWNW/QldSW | 115.2 | 1.3 | 0.6 | 2.9 | 8.7 | 7.1 | 0.3 |
| NSW Central | 59.9 | 3.2 | 10.3 | 15.1 | 7.2 | 0.1 | 1.4 |
| NSW/Vic Slopes | 138.4 | 9.2 | 9.3 | 3.9 | 73.2 | 0.1 | 22.1 |
| Vic High Rainfall | 7.6 | 4.0 | 5.5 | 0.0 | 0.3 | 0.3 | 0.0 |
| SA/Vic Bordertown-Wimmera | 53.8 | 8.2 | 25.7 | 0.4 | 6.0 | 7.3 | 2.2 |
| SA Vic Mallee | 39.8 | 5.1 | 9.3 | 8.8 | 1.9 | 6.6 | 0.9 |
| SA Midnorth-Lower Yorke, Eyre | 102.2 | 6.4 | 24.3 | 23.1 | 10.0 | 25.3 | 2.6 |
| WA Mallee and Sandplain | 13.1 | 0.2 | 5.0 | 2.3 | 3.0 | 0.1 | 1.7 |
| WA Central | 558.0 | 14.3 | 55.7 | 4.4 | 38.7 | 6.7 | 90.5 |
| WA Northern | 92.9 | 0.7 | 4.3 | 3.0 | 5.0 | 0.6 | 32.0 |
| WA Eastern | 33.1 | 0.5 | 0.6 | 0.0 | 0.5 | 0.0 | 3.9 |
| Northern region | 277.6 | 6.3 | 13.3 | 11.9 | 11.7 | 19.5 | 0.7 |
| Southern region | 401.8 | 36.2 | 84.4 | 51.4 | 98.7 | 39.6 | 29.3 |
| Western region | 697.1 | 15.6 | 65.7 | 9.8 | 47.2 | 7.4 | 128.1 |
| Total yield loss | 1,376.5 | 58.1 | 163.4 | 73.1 | 157.6 | 66.6 | 158.1 |

**Table 27**. Weed loss due to residual weeds by crop ($ million)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins | Total |
|---|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 28.4 | 0.6 | 2.0 | 1.1 | 1.1 | 3.0 | 0.13 | 6.1 |
| NSWNW/QldSW | 20.2 | 0.1 | 0.1 | 0.3 | 3.1 | 1.7 | 0.1 | 25.6 |
| NSW Central | 10.5 | 0.4 | 1.6 | 1.8 | 2.6 | 0.0 | 0.2 | 17.1 |
| NSW/Vic Slopes | 24.2 | 1.0 | 1.5 | 0.5 | 26.3 | 0.0 | 3.6 | 57.1 |
| Vic High Rainfall | 1.3 | 0.4 | 0.9 | 0.0 | 0.1 | 0.1 | 0.0 | 2.8 |
| SA/Vic Bordertown-Wimmera | 9.4 | 0.9 | 4.0 | 0.0 | 2.1 | 1.8 | 0.4 | 18.7 |
| SA Vic Mallee | 7.0 | 0.6 | 1.5 | 1.0 | 0.7 | 1.6 | 0.2 | 12.5 |
| SA Midnorth-Lower Yorke, Eyre | 17.9 | 0.7 | 3.8 | 2.7 | 3.6 | 6.1 | 0.4 | 35.2 |
| WA Mallee and Sandplain | 2.3 | 0.0 | 0.8 | 0.3 | 1.1 | 0.0 | 0.3 | 4.8 |
| WA Central | 97.7 | 1.6 | 8.7 | 0.5 | 13.9 | 1.6 | 14.7 | 138.7 |
| WA Northern | 16.3 | 0.1 | 0.7 | 0.4 | 1.8 | 0.1 | 5.2 | 24.5 |
| WA Eastern | 5.8 | 0.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.6 | 6.7 |
| Northern region | 48.6 | 0.7 | 2.1 | 1.4 | 4.2 | 4.7 | 0.1 | 61.8 |
| Southern region | 70.3 | 4.1 | 13.3 | 6.1 | 35.4 | 9.5 | 4.7 | 143.4 |
| Western region | 122.0 | 1.7 | 10.3 | 1.2 | 17.0 | 1.8 | 20.8 | 174.7 |
| Total | 240.9 | 6.5 | 25.6 | 8.6 | 56.6 | 16.0 | 25.6 | 379.8 |

**Table 28**. Weed loss due to residual weeds by weed and region ($ million)

| Weed | Northern region | Southern region | Western region | Total |
|---|---|---|---|---|
| *Avena* spp. | 44.9 | 51.3 | 34.5 | 130.6 |
| *L. rigidum* | 7.1 | 58.7 | 73.9 | 139.7 |
| *R. raphanistrum* | 0.4 | 14.9 | 56.5 | 71.8 |
| *A. calendula* | 0.0 | 5.4 | 4.3 | 9.7 |
| *B. tournefortii* | 3.1 | 2.5 | 0.3 | 5.9 |
| *P. aviculare* | 0.0 | 0.2 | 0.0 | 0.2 |
| *P. paradoxa* | 4.6 | 0.5 | 0.0 | 5.1 |
| *S. oleraceus* | 1.6 | 0.0 | 0.0 | 1.6 |
| *E. plantagineum* | 0.0 | 1.2 | 0.0 | 1.2 |
| *Bromus* spp. | 0.0 | 3.3 | 0.0 | 3.3 |
| *H leporinum* | 0.0 | 0.4 | 2.5 | 2.9 |
| *C. juncea* | 0.0 | 2.5 | 0.0 | 2.5 |
| *S. officinale* | 0.0 | 2.1 | 0.0 | 2.1 |
| *Vulpia* spp. | 0.0 | 0.4 | 0.3 | 0.7 |
| *E. australis* | 0.0 | 0.0 | 2.5 | 2.5 |
| Total | 61.8 | 143.4 | 174.7 | 379.8 |

**Table 29**. Weed loss due to grain contamination ($ million)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins | Total |
|---|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 0.3 | 0.0 | 0.4 | 0.0 | 0.0 | 3.1 | 0.0 | 3.8 |
| NSWNW/QldSW | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 |
| NSW Central | 0.1 | 0.0 | 1.2 | 0.3 | 0.3 | 0.0 | 0.0 | 1.8 |
| NSW/Vic Slopes | 0.6 | 0.0 | 0.6 | 0.0 | 0.1 | 0.0 | 0.0 | 1.2 |
| Vic High Rainfall | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.3 |
| SA/Vic Bordertown-Wimmera | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 |
| SA Vic Mallee | 0.8 | 0.0 | 0.3 | 0.0 | 0.0 | 0.1 | 0.0 | 1.1 |
| SA Midnorth-Lower Yorke, Eyre | 3.6 | 0.0 | 1.0 | 0.2 | 0.0 | 0.7 | 0.0 | 5.5 |
| WA Mallee and Sandplain | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WA Central | 2.2 | 0.0 | 1.4 | 1.2 | 0.6 | 0.0 | 0.0 | 5.3 |
| WA Northern | 1.1 | 0.0 | 0.0 | 0.8 | 1.1 | 0.0 | 0.0 | 3.0 |
| WA Eastern | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Northern region | 2.3 | 0.0 | 0.4 | 0.0 | 0.0 | 3.1 | 0.0 | 5.8 |
| Southern region | 5.0 | 0.0 | 3.2 | 0.5 | 0.4 | 2.1 | 0.0 | 11.2 |
| Western region | 3.3 | 0.0 | 1.4 | 2.1 | 1.6 | 0.0 | 0.0 | 8.4 |
| Total | 10.7 | 0.0 | 5.0 | 2.6 | 2.0 | 5.1 | 0.0 | 25.3 |

Note: Lupin values are included with pulses.

**Table 30**. Pre-emergent and post-emergent herbicide costs ($ million)

| Zone | Pre-emergent | Post-emergent | Treatment cost | Total |
|---|---|---|---|---|
| NSWNE/QldSE | 25.3 | 28.6 | 14.1 | 68.0 |
| NSWNW/QldSW | 10.7 | 15.0 | 5.3 | 31.0 |
| NSW Central | 11.2 | 17.4 | 6.3 | 34.8 |
| NSW/Vic Slopes | 26.1 | 28.8 | 11.6 | 66.5 |
| Vic High Rainfall | 1.3 | 1.9 | 1.0 | 4.2 |
| SA/Vic Bordertown-Wimmera | 25.6 | 37.3 | 16.0 | 78.9 |
| SA Vic Mallee | 12.9 | 17.2 | 10.2 | 40.3 |
| SA Midnorth-Lower Yorke, Eyre | 23.9 | 28.4 | 10.5 | 62.8 |
| WA Mallee and Sandplain | 4.0 | 3.4 | 1.5 | 9.0 |
| WA Central | 62.7 | 54.2 | 20.3 | 137.2 |
| WA Northern | 16.0 | 14.4 | 6.4 | 36.8 |
| WA Eastern | 5.7 | 6.3 | 1.8 | 13.8 |
| Northern region | 36.0 | 43.6 | 19.4 | 99.0 |
| Southern region | 101.0 | 130.9 | 55.5 | 287.4 |
| Western region | 88.4 | 78.4 | 30.0 | 196.8 |
| Total | 225.4 | 252.9 | 105.0 | 583.3 |

**Table 31**. Herbicide costs by crop ($ million)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins | Other |
|---|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 47.5 | 1.4 | 3.6 | 6.8 | 1.0 | 6.5 | 0.3 | 1.0 |
| NSWNW/QldSW | 25.6 | 0.8 | 0.6 | 0.2 | 0.3 | 3.1 | 0.1 | 0.3 |
| NSW Central | 20.5 | 1.7 | 3.3 | 1.8 | 5.4 | 0.7 | 1.0 | 0.3 |
| NSW/Vic Slopes | 26.5 | 2.9 | 4.0 | 2.2 | 21.9 | 1.0 | 3.8 | 4.3 |
| Vic High Rainfall | 1.3 | 0.5 | 0.5 | 0.1 | 0.8 | 0.5 | 0.2 | 0.4 |
| SA/Vic Bordertown-Wimmera | 24.2 | 3.1 | 14.0 | 1.2 | 14.3 | 17.0 | 2.5 | 2.7 |
| SA Vic Mallee | 19.4 | 0.8 | 6.3 | 4.6 | 1.1 | 5.6 | 1.0 | 1.6 |
| SA Midnorth-Lower Yorke, Eyre | 26.4 | 2.3 | 9.0 | 7.2 | 4.0 | 11.7 | 1.0 | 1.3 |
| WA Mallee and Sandplain | 2.6 | 0.2 | 1.3 | 1.6 | 2.0 | 0.3 | 1.0 | 0.1 |
| WA Central | 82.5 | 2.7 | 14.1 | 0.7 | 18.0 | 4.4 | 14.7 | 0.1 |
| WA Northern | 21.9 | 0.2 | 1.2 | 0.7 | 2.8 | 1.0 | 8.9 | 0.1 |
| WA Eastern | 9.7 | 0.2 | 0.8 | 0.0 | 0.6 | 0.2 | 2.1 | 0.2 |
| Northern region | 73.1 | 2.2 | 4.1 | 6.9 | 1.3 | 9.6 | 0.4 | 1.3 |
| Southern region | 118.2 | 11.2 | 37.1 | 17.0 | 47.5 | 36.4 | 9.5 | 10.5 |
| Western region | 116.7 | 3.3 | 17.4 | 3.0 | 23.3 | 5.8 | 26.9 | 0.5 |
| Total | 308.0 | 16.7 | 58.7 | 26.9 | 72.1 | 51.9 | 36.7 | 12.3 |

**Table 32**. Cultivation costs ($ million)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins | Total |
|---|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 18.3 | 0.5 | 1.6 | 0.9 | 0.5 | 2.0 | 0.1 | 23.9 |
| NSWNW/QldSW | 12.3 | 0.3 | 0.2 | 0.0 | 0.1 | 0.9 | 0.2 | 14.0 |
| NSW Central | 12.5 | 1.5 | 1.9 | 0.6 | 1.1 | 0.2 | 0.2 | 18.0 |
| NSW/Vic Slopes | 10.0 | 1.6 | 1.5 | 0.6 | 3.9 | 0.2 | 0.8 | 18.4 |
| Vic High Rainfall | 0.5 | 0.3 | 0.2 | 0.0 | 0.2 | 0.1 | 0.0 | 1.3 |
| SA/Vic Bordertown-Wimmera | 5.6 | 1.3 | 4.2 | 0.3 | 3.1 | 2.2 | 0.3 | 17.0 |
| SA Vic Mallee | 13.9 | 0.6 | 4.7 | 2.4 | 0.4 | 1.2 | 0.2 | 23.3 |
| SA Midnorth-Lower Yorke, Eyre | 9.5 | 0.8 | 1.6 | 2.0 | 1.0 | 1.9 | 0.2 | 17.0 |
| WA Mallee and Sandplain | 1.1 | 0.1 | 0.5 | 0.4 | 0.6 | 0.1 | 0.2 | 3.0 |
| WA Central | 34.0 | 2.0 | 5.2 | 0.5 | 4.8 | 0.6 | 3.2 | 50.3 |
| WA Northern | 10.7 | 0.1 | 0.5 | 0.2 | 0.8 | 0.2 | 3.2 | 15.7 |
| WA Eastern | 3.4 | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.5 | 4.4 |
| Northern region | 30.5 | 0.8 | 1.8 | 0.9 | 0.6 | 2.9 | 0.2 | 37.9 |
| Southern region | 51.9 | 6.0 | 14.1 | 5.9 | 9.6 | 5.8 | 1.7 | 95.0 |
| Western region | 49.3 | 2.3 | 6.5 | 1.1 | 6.3 | 0.9 | 7.1 | 73.4 |
| Total | 131.7 | 9.2 | 22.4 | 8.0 | 16.5 | 9.6 | 9.0 | 206.4 |

**Table 33**. Weed costs due to weed losses and expenditure on weed control ($ million)

| Zone | Yield loss | Grain contamination | Herbicides | Cultivation | Total |
|---|---|---|---|---|---|
| NSWNE/QldSE | 36.1 | 3.8 | 68.0 | 23.9 | 131.8 |
| NSWNW/QldSW | 25.6 | 2.0 | 31.0 | 14.0 | 72.6 |
| NSW Central | 17.1 | 1.8 | 34.8 | 18.0 | 71.7 |
| NSW/Vic Slopes | 57.1 | 1.2 | 66.5 | 18.4 | 143.2 |
| Vic High Rainfall | 2.8 | 0.3 | 4.2 | 1.3 | 8.6 |
| SA/Vic Bordertown-Wimmera | 18.7 | 1.2 | 78.9 | 17.0 | 115.8 |
| SA Vic Mallee | 12.5 | 1.1 | 40.3 | 23.3 | 77.2 |
| SA Midnorth-Lower Yorke, Eyre | 35.2 | 5.5 | 62.8 | 17.0 | 120.6 |
| WA Mallee and Sandplain | 4.8 | 0.0 | 9.0 | 3.0 | 16.8 |
| WA Central | 138.7 | 5.3 | 137.2 | 50.3 | 331.6 |
| WA Northern | 24.5 | 3.0 | 36.8 | 15.7 | 80.0 |
| WA Eastern | 6.7 | 0.0 | 13.8 | 4.4 | 24.9 |
| Northern region | 61.8 | 5.8 | 99.0 | 37.9 | 204.5 |
| Southern region | 143.4 | 11.2 | 287.4 | 95.0 | 537.1 |
| Western region | 174.7 | 8.4 | 196.8 | 73.4 | 453.3 |
| Total | 379.8 | 25.3 | 583.3 | 206.4 | 1,194.8 |

**Table 34**. Per unit weed cost ($/hectare)

| | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 62.2 | 31.7 | 69.2 | 53.8 | 81.7 | 106.5 | 77.9 |
| NSWNW/QldSW | 58.6 | 28.5 | 68.7 | 136.2 | 358.8 | 93.8 | 29.9 |
| NSW Central | 49.7 | 33.7 | 59.8 | 101.6 | 82.1 | 44.6 | 65.9 |
| NSW/Vic Slopes | 87.6 | 48.9 | 73.1 | 77.0 | 132.0 | 63.4 | 96.1 |
| Vic High Rainfall | 96.2 | 60.8 | 122.6 | - | 58.7 | 65.0 | 53.0 |
| SA/Vic Bordertown-Wimmera | 67.9 | 31.5 | 52.0 | 46.6 | 80.3 | 52.9 | 56.5 |
| SA Vic Mallee | 37.6 | 28.4 | 34.5 | 42.4 | 75.0 | 53.7 | 61.4 |
| SA Midnorth-Lower Yorke, Eyre | 72.1 | 46.9 | 71.0 | 45.9 | 106.0 | 101.9 | 76.5 |
| WA Mallee and Sandplain | 55.8 | 29.7 | 49.8 | 53.2 | 75.6 | 42.9 | 66.9 |
| WA Central | 86.8 | 41.7 | 75.9 | 82.9 | 107.3 | 88.1 | 118.5 |
| WA Northern | 63.5 | 54.0 | 62.2 | 155.1 | 111.2 | 64.4 | 63.0 |
| WA Eastern | 56.1 | 44.0 | 52.2 | 57.4 | 84.0 | 61.5 | 60.7 |
| Northern region | 60.7 | 30.6 | 69.1 | 55.8 | 149.3 | 102.5 | 44.9 |
| Southern region | 60.3 | 38.4 | 53.5 | 51.4 | 105.4 | 65.1 | 76.0 |
| Western region | 78.2 | 41.5 | 71.1 | 79.0 | 104.0 | 79.0 | 87.4 |
| Total | 66.8 | 37.9 | 59.2 | 55.4 | 106.2 | 73.0 | 83.8 |

**Table 35**. Estimated K parameters

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins |
|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 0.11 | 0.10 | 0.13 | 0.13 | 0.11 | 0.26 | 0.28 |
| NSWNW/QldSW | 0.12 | 0.07 | 0.15 | 0.58 | 0.56 | 0.24 | 0.12 |
| NSW Central | 0.08 | 0.10 | 0.14 | 0.24 | 0.10 | 0.10 | 0.19 |
| NSW/Vic Slopes | 0.12 | 0.15 | 0.13 | 0.19 | 0.15 | 0.11 | 0.28 |
| Vic High Rainfall | 0.14 | 0.14 | 0.20 | - | 0.07 | 0.11 | 0.14 |
| SA/Vic Bordertown-Wimmera | 0.11 | 0.09 | 0.10 | 0.12 | 0.11 | 0.10 | 0.18 |
| SA Vic Mallee | 0.10 | 0.11 | 0.10 | 0.17 | 0.14 | 0.17 | 0.24 |
| SA Midnorth-Lower Yorke, Eyre | 0.13 | 0.12 | 0.14 | 0.13 | 0.16 | 0.21 | 0.28 |
| WA Mallee and Sandplain | 0.11 | 0.07 | 0.11 | 0.15 | 0.13 | 0.12 | 0.23 |
| WA Central | 0.20 | 0.12 | 0.19 | 0.28 | 0.20 | 0.28 | 0.52 |
| WA Northern | 0.16 | 0.24 | 0.17 | 0.49 | 0.24 | 0.21 | 0.26 |
| WA Eastern | 0.18 | 0.21 | 0.18 | 0.21 | 0.21 | 0.23 | 0.31 |

**Table 36**. Loss in total economic surplus by crop due to weeds ($ million)

| Zone | Wheat | Oats | Malting Barley | Feed Barley | Canola | Pulses | Lupins | Total |
|---|---|---|---|---|---|---|---|---|
| NSWNE/QldSE | 93.0 | 2.5 | 7.5 | 8.8 | 2.5 | 14.4 | 0.4 | 128.9 |
| NSWNW/QldSW | 58.7 | 1.2 | 0.8 | 0.4 | 2.0 | 5.5 | 0.3 | 69.0 |
| NSW Central | 43.2 | 3.6 | 8.0 | 4.2 | 9.2 | 0.9 | 1.4 | 70.6 |
| NSW/Vic Slopes | 59.1 | 5.4 | 7.3 | 3.2 | 48.5 | 1.2 | 7.2 | 131.8 |
| Vic High Rainfall | 2.9 | 1.2 | 1.7 | 0.0 | 1.1 | 0.7 | 0.2 | 7.8 |
| SA/Vic Bordertown-Wimmera | 38.7 | 5.3 | 22.0 | 1.5 | 19.6 | 22.2 | 3.1 | 112.2 |
| SA Vic Mallee | 40.9 | 1.9 | 12.7 | 8.0 | 2.1 | 8.2 | 1.3 | 75.1 |
| SA Midnorth-Lower Yorke, Eyre | 55.9 | 3.8 | 15.1 | 11.9 | 8.1 | 19.5 | 1.5 | 115.7 |
| WA Mallee and Sandplain | 5.8 | 0.4 | 2.5 | 2.3 | 3.5 | 0.4 | 1.5 | 16.3 |
| WA Central | 201.2 | 6.1 | 28.0 | 2.9 | 34.8 | 6.2 | 25.6 | 304.8 |
| WA Northern | 48.2 | 0.4 | 2.3 | 1.9 | 6.1 | 1.3 | 16.2 | 76.4 |
| WA Eastern | 18.2 | 0.3 | 1.1 | 0.1 | 0.8 | 0.2 | 3.1 | 23.8 |
| Northern region | 151.7 | 3.7 | 8.3 | 9.1 | 4.5 | 19.9 | 0.7 | 197.9 |
| Southern region | 240.7 | 21.0 | 66.7 | 28.8 | 88.6 | 52.7 | 14.8 | 513.3 |
| Western region | 273.5 | 7.2 | 34.0 | 7.1 | 45.2 | 8.1 | 46.3 | 421.4 |
| Total | 665.9 | 31.9 | 109.0 | 45.0 | 138.3 | 80.7 | 61.9 | 1,132.7 |

**Table 37**. Loss in consumers' surplus, producers' surplus and total economic surplus by crop due to weeds ($ million)

| Crop | Consumers' Surplus | Producers' Surplus | Total Surplus |
|---|---|---|---|
| Wheat | 27.5 | 638.4 | 665.9 |
| Oats | 2.4 | 29.5 | 31.9 |
| Malting Barley | 8.0 | 101.0 | 109.0 |
| Feed Barley | 4.0 | 41.0 | 45.0 |
| Canola | 7.6 | 130.7 | 138.3 |
| Pulses | 7.3 | 73.4 | 80.7 |
| Lupins | 3.0 | 58.9 | 61.9 |
| Total | 59.7 | 1,073.0 | 1,132.7 |

**Table 38**. Loss in consumers' surplus, producers' surplus and total economic surplus by agro-ecological zone due to weeds ($ million)

| Zone | Consumers' Surplus | Producers' Surplus | Total Surplus |
|---|---|---|---|
| NSWNE/QldSE | 9.8 | 119.1 | 128.9 |
| NSWNW/QldSW | 4.4 | 64.6 | 69.0 |
| NSW Central | 6.0 | 64.6 | 70.6 |
| NSW/Vic Slopes | 4.1 | 127.7 | 131.8 |
| Vic High Rainfall | 0.2 | 7.6 | 7.8 |
| SA/Vic Bordertown-Wimmera | 7.4 | 104.8 | 112.2 |
| SA Vic Mallee | 4.4 | 70.7 | 75.1 |
| SA Midnorth-Lower Yorke, Eyre | 7.0 | 108.7 | 115.7 |
| WA Mallee and Sandplain | 0.7 | 15.6 | 16.3 |
| WA Central | 11.7 | 293.1 | 304.8 |
| WA Northern | 3.0 | 73.5 | 76.4 |
| WA Eastern | 0.9 | 22.9 | 23.8 |
| Northern region | 14.2 | 183.7 | 197.9 |
| Southern region | 29.2 | 484.1 | 513.3 |
| Western region | 16.3 | 405.1 | 421.4 |
| Total | 59.7 | 1,073.0 | 1,132.7 |

# Appendix 1

# Weeds and Soil Grower Survey 1998

TQA RESEARCH — Marketing and Social Research Consultants

GRDC Grains Research & Development Corporation

WEEDS AND SOIL
GROWER SURVEY 1998

## We need your help

By completing this important survey, you will help us learn a great deal more about weeds, soil and land degradation problems across the grain belts of Australia.

The survey is an initiative of the Grains Research and Development Corporation and information from it will be used to set strategies for research to assist grain growers across Australia. By carefully completing the survey, you will assist in providing information which is not currently available. Your time and effort will certainly be appreciated and none of your information will be passed on to any third party.

Return your completed survey in the reply-paid envelope provided, or address



TQA Research Pty. Ltd.
Reply Paid 3
Weed and Soil Survey
28-30 Station Street
Sandringham, Vic. 3191

**NO STAMP(S) REQUIRED**

Instructions

Simply circle the relevant answer code(s), or write in the space or box provided.

Example:

Do you grow winter crops?

YES __________ ①
NO __________ 2

# SECTION A - GENERAL

**Q1.** What is the total area of your farm in hectares (not acres)?.............................................................................. [ ] ha

(1 HA = 2.5 acres)

**Q2.** How many hectares of winter crop will you grow in the 1998 season (all winter crops)?........................................ [ ] ha

**Q3.** So far this season, which of the following (ifany) have affected your crops? (Circle any which apply)

Flood damage (in growing season so far) .......................................... 1
Hail damage (in growing season so far) .............................................. 2
Drought (in growing season so far) .................................................... 3
None of the above ................................................................................. 4

**Q4.** To what extent do you believe the following are problems on your property? *(Circle one code for each problem).*

| Problem | Extent of Problem: Serious Problem | Moderate Problem | No Problem at all | Don't Know |
|---|---|---|---|---|
| Acid soils | 1 | 2 | 3 | 4 |
| Saline soils | 1 | 2 | 3 | 4 |
| Soil sodicity (sodic soils) | 1 | 2 | 3 | 4 |
| Soil erosion | 1 | 2 | 3 | 4 |
| Weeds (in cropping paddocks) | 1 | 2 | 3 | 4 |
| Fertiliser management (specification, application rates, etc.) | 1 | 2 | 3 | 4 |
| Crop diseases (including plant and root diseases) | 1 | 2 | 3 | 4 |
| Insects and pests | 1 | 2 | 3 | 4 |
| Lack of appropriate crop varieties | 1 | 2 | 3 | 4 |

**Q5.** How would you rank the same nine problems as they affect your farming enterprise? Place a 1 in the box beside the problem you perceive is greatest; 2 in the box beside the problem you perceive is second greatest, etc. Place a ranking number (1 to 9; no "dead heats" please) in each box, even if the problem does not exist.

| | Ranking of Problem |
|---|---|
| Acid Soils ........................................ | |
| Saline Soils ........................................ | |
| Sodic Soils (Sodicity Problem) ........................................ | |
| Soil Erosion ........................................ | |
| Weeds ........................................ | |
| Fertiliser Management ........................................ | |
| Crop Diseases ........................................ | |
| Insects and Pests ........................................ | |
| Lack of Varieties ........................................ | |

**Q6.** Compared to five years ago, would you say the following problems are getting better, getting worse, have remained unchanged or have not been a problem at all on your property? (*Circle one code for each problem*)

| | **Your perception - now versus five years ago** | | | |
|---|---|---|---|---|
| **Problem** | Getting Worse | Getting Better | Unchanged | Never Really a Problem |
| Acid soils | 1 | 2 | 3 | 4 |
| Saline soils | 1 | 2 | 3 | 4 |
| Sodic soils (sodicity problem) | 1 | 2 | 3 | 4 |
| Soil erosion | 1 | 2 | 3 | 4 |
| Weeds (in cropping paddocks) | 1 | 2 | 3 | 4 |
| Fertiliser management (specification, application rates, etc.) | 1 | 2 | 3 | 4 |
| Crop diseases (including plant and root diseases) | 1 | 2 | 3 | 4 |
| Insects and pests | 1 | 2 | 3 | 4 |
| Lack of crop varieties | 1 | 2 | 3 | 4 |

**Q7.** Thinking of your main winter crop this year, which one of the following best describes your crop preparation method?
*(Read all before circling)*

Direct drill into standing stubble, no burning, no tillage except for sowing process .......... 1
Direct drill with removal of stubble prior to sowing by late burning or grazing .......... 2
Minimum tillage, no burning of stubble, no more than two workings of soil .......... 3
Conventional cultivation, stubble worked into soil, more than two workings of soil .......... 4
Conventional cultivation with removal of stubble by burning early/heavy grazing early then ploughing .......... 5

Other (specify) ..........

**Q8.** Which one of the following best describes your past winter crop rotation practices (over the last 5 years)?
*(Read all,* before circling one)

Continuous winter cereal .......... 1
Continuous winter and summer cereal .......... 2
Mixed winter crops (eg. cereal/canola/pulse) .......... 3
Mixed winter crops with pasture phase .......... 4
Mixed winter and summer crops (eg. wheat/mungbeans/sorghum) .......... 5
Fallowing every second year .......... 6
Opportunity cropping .......... 7
Other (specify) .......... 8

**Q9a** On your property, what are the main reasons for crop rotation?
(Circle as many as apply in column 9a)

**Q9b** For each reason circled, please circle in column b whether this is a major reason or a minor reason for crop rotation on your property.

| Reason for Rotation | | Major reason | Minor reason |
|---|---|---|---|
| Better diesease control | 1 | 1 | 2 |
| Better weed control | 2 | 1 | 2 |
| Moisture conservation | 3 | 1 | 2 |
| Management of soil fertility | 4 | 1 | 2 |
| Opportunity cropping | 5 | 1 | 2 |
| Seasonal conditions | 6 | 1 | 2 |
| Other (specify) | 7 | 1 | 2 |

**Q10** What do you consider to be the 5 most difficult weeds to control in your winter crops? Please list in order. *(Neat writing appreciated)*

Office

1. ........................................................................................................
2. ........................................................................................................
3. ........................................................................................................
4. ........................................................................................................
5. ........................................................................................................

**Q11** Which of the following methods do you routinely use to control weeds in winter crops? *(Circle as many as apply)*

Pre-emergent herbicides ........................................................................................ 1
Pre-emergent herbicides - broadleaf weeds ........................................................ 2
Post-emergent herbicides - grass weeds ............................................................... 3
Early sowing ......................................................................................................... 4
High crop density ................................................................................................. 5
Long fallows ......................................................................................................... 6
Crop topping 1 spray topping ............................................................................... 7
Crop rotation (eg. pasture) .................................................................................... 8
Herbicide resistant crops ...................................................................................... 9
Other (specify) ..................................................................................................... 10

# SECTION B: WEEDS

This section is **very important** to us. Your care and accuracy is appreciated. It is best to answer Questions 12-14 for each crop grown (i.e. work across the page for each crop)

| CROP | Q12. How many hectares of this crop will you grow in the 1998/99 season? *(If don't grow crop, just leave blank and do next crop)* | FOR EACH CROP GROWN: Q13. Please nominate the weeds you have either sprayed for (pre-emergent or post-emergent) and which remain a residual problem after spraying | FOR EACH PROBLEM WEED IN EACH CROP (in Q13). Q14. What is the area in hectares of the residual weed problem being either high, medium or low density weed infestation (as per definitions of infestation below). Enter a number in each box for each weed. HIGH DENSITY/ CHRONIC INFESTATION (greater than 1 plant per m²) | MEDIUM DENSITY INFESTATION (less than 1 plant per m²) | LIGHT INFESTATION/ SCATTERED WEEDS (scattered isolated plants) |
|---|---|---|---|---|---|
| EXAMPLE 1. WHEAT | 850 Ha | WEED 1 Annual rye grass | 50 Ha | 75 Ha | 50 Ha |
| | | WEED 2 Wild oats | 75 Ha | 35 Ha | 10 Ha |
| | | WEED 3 | *This means there will be 50 Ha of wheat crop with high residual rye grass infestation* | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |
| EXAMPLE 2. MALTING BARLEY | 420 Ha | WEED 1 Wild radish | 0 Ha | 0 Ha | 0 Ha |
| | | WEED 2 | *This means there will be no residual of wild radish at all in the malting barley crop* | | |
| | | WEED 3 | | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |
| 1. WHEAT | ............ Ha | WEED 1 | | | |
| | | WEED 2 | | | |
| | | WEED 3 | | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |
| 2. OATS | ............ Ha | WEED 1 | | | |
| | | WEED 2 | | | |
| | | WEED 3 | | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |
| 3. MALTING BARLEY | ............ Ha | WEED 1 | | | |
| | | WEED 2 | | | |
| | | WEED 3 | | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |
| 4. FEED BARLEY | ............ Ha | WEED 1 | | | |
| | | WEED 2 | | | |
| | | WEED 3 | | | |
| | | WEED 4 | | | |
| | | WEED 5 | | | |
| | | WEED 6 | | | |

| CROP | Q12. How many hectares of this crop will you grow in the 1998/99 season?<br>*(If don't grow crop, just leave blank and go next crop)* | FOR EACH CROP GROWN:<br>Q13. Please nominate the weeds you have either sprayed for (pre-emergent or post-emergent) and which remain a residual problem after spraying. | FOR EACH PROBLEM WEED IN EACH CROP (in Q13).<br>Q14. What is the area in hectares of the residual weed problem being either high, medium or low density weed infestation (as per definitions of infestation below). Enter a number in each box for each weed | | |
|---|---|---|---|---|---|
| | | | HIGH DENSITY: CHRONIC INFESTATION (greater than 1 plant per m²) | MEDIUM DENSITY INFESTATION (less than 1 plant per m²) | LIGHT INFESTATION: SCATTERED WEEDS (scattered isolated plants) |
| 5. CANOLA | ............ Ha | WEED 1<br>WEED 2<br>WEED 3<br>WEED 4<br>WEED 5<br>WEED 6 | | | |
| 6. ALL PULSES (e.g. peas, beans, etc.) | ............ Ha | WEED 1<br>WEED 2<br>WEED 3<br>WEED 4<br>WEED 5<br>WEED 6 | | | |
| 7. LUPINS | ............ Ha | WEED 1<br>WEED 2<br>WEED 3<br>WEED 4<br>WEED 5<br>WEED 6 | | | |
| 8. WINTER FALLOW | ............ Ha | WEED 1<br>WEED 2<br>WEED 3<br>WEED 4<br>WEED 5<br>WEED 6 | | | |
| 9. ALL OTHER WINTER CROPS | ............ Ha | WEED 1<br>WEED 2<br>WEED 3<br>WEED 4<br>WEED 5<br>WEED 6 | | | |
| TOTAL | ............ Ha | No need to add up but you might like to just make sure totals 'about right' | | | |

**Q15. Complete for each of the following crops you will grow this year**

| Crop | Q15a. Given expected weed populations indicated in Q13-14, what crop yield would you expect from this paddock? *(Average across all paddocks where crop grown)* *(Tonnes per hectare to one decimal point)* | Q15b. What would you expect your average yield to be for this crop if paddocks were totally weed free? *(Tonnes per hectare to one decimal point)* |
|---|---|---|
| 1 Wheat | | |
| 2 Oats | | |
| 3 Malting Barley | | |
| 4 Feed Barley | | |
| 5 Canola | | |
| 6 Pulses (the pulse you will grow most of) | | |
| 7 Lupins | | |
| 8 Other (write in) | | |

**Q16. Overall, to what extent are weeds currently, or expected to be, a problem in winter fallow this year?** *(Circle one only)*

High density/chronic infestation (greater than 1 plant per m²) ........ 1
Medium density (less than 1 plant per m²) ........ 2
Light infestation/scattered weeds (scattered isolated plants) ........ 3
Not at all ........ 4
No winter fallow ........ 5

**Q17 We need to obtain an accurate fix on the cost of weeds and weed control.**
**For each of the following crops you will grow this season, can you provide a best estimate of:**
**(a) cost of herbicide applied (split pre-emergent and post-emergent) and**
**(b) cost of application (labour and fuel)**

| CROP | (a) COST OF HERBICIDE *(total, not per ha)* Estimated expenditure for season for pre-emergent and post-emergent herbicide (no decimal points or cents please) | | (b) COST OF TREATMENT |
|---|---|---|---|
| | PRE-EMERGENT | POST-EMERGENT | Best estimate of cost application including own labour at say $25 per hour and fuel (ignore equipment costs) |
| 1 Wheat | $ | $ | $ |
| 2 Oats | $ | $ | $ |
| 3 Malting Barley | $ | $ | $ |
| 4. Feed Barley | $ | $ | $ |
| 5 Canola | $ | $ | $ |
| 6 All pulses | $ | $ | $ |
| 7 Lupins | $ | $ | $ |
| 8 Winter fallow | $ | $ | $ |
| 9 All other(s) | $ | $ | $ |

**Q18** Just as a cross-check for us, how much do you think you will spend on herbicides that are applied this season? *(No decimal points or commas please).*

$________

**Q19a** Did you have any weed contamination in crops harvested last year?

Yes .......................................................................................... 1
No ........................................................................................... 2 Go to Q21

**Q19b** When selling your grain, were you penalised for having any weed contaminant?
*(ie. have to accept lower price or incur a grading cost?)*

Yes .......................................................................................... 1
No ........................................................................................... 2 Go to Q21

**Q20** For the crops where you paid a penalty for weed contamination; please specify the following in the table below:

a) What crops were contaminated with weed (eg. wheat, oats, malting barley etc.)
b) How many tonnes of this crop were contaminated?
c) What was the average price reduction (or penalty) per tonne caused by weed contamination?
*(It is not the price you sold at but the price penalty which should be written in the third column.)*
d) Did you incur any grading costs as a result of this weed contamination? Enter zero if nil.

a) Crop (specify) ..........................................................................
b) How many tonnes of this crop was contaminated with weed?
c) Price reduction per tonne due to contamination.
d) Grading costs incurred due to contamination.

| | Crop (specifiy) | How many tonnes of this crop was contaminated with weed | Price reduction per tonne due to contamination | Grading costs incurred due to contamination |
|---|---|---|---|---|
| 1. | ____________ | ______ tonnes | $_______ per tonne | $________ |
| 2. | ____________ | ______ tonnes | $_______ per tonne | $________ |
| 3. | ____________ | ______ tonnes | $_______ per tonne | $________ |

**Q21** To what extent do you believe herbicide resistance is a problem in your area? Would you say it is:

A serious problem ........................................................................ 1
A moderate problem ..................................................................... 2
A slight problem ........................................................................... 3
Not a problem at all ...................................................................... 4
Not sure ........................................................................................ 5

**Q22** How competent would you regard yourself in managing weed problems?

Very competent .......... 1
Fairly competent .......... 2
Not too competent .......... 3
Not at all competent .......... 4

# SECTION C - SALINITY

**Q23** Have you or any party on your behalf conducted soil tests over the last 3 years to measure soil salinity on your property?

Yes .......... 1
No .......... 2
Not sure .......... 3

**Q24** Which of the following statements bests summarises the salinity status of the soils on your property? *(Circle only one after reading all three)*

I definitely know that I have a salinity problem on my property .......... 1
I definitely know that I do not have a salinity problem on my property .......... 2 go to Q27
I'm not sure of the salinity status of my soil .......... 3 go to Q27

**Q25** Is the salinity problem on your property due to ...

Factors on your farm only .......... 1
Factors in the catchment area, but off your property .......... 2
Both of the above .......... 3
Not sure .......... 4

**Q26** Do you do any of the following to reduce salinity or reduce recharge of the water table?
*(Circle as many as apply, circle at least one code)*

Grow lucerne .......... 1
Grow perennial grasses .......... 2
Other (specify) .......... 3
No/nothing .......... 4

**Q27** Are you doing anything on your property to manage the water table?
*(Do not leave blank - circle NO if not doing anything or not applicable)*

Yes .......... 1
No .......... 2

**Q28a** Is the water table in your catchment (district)

Rising ........................................................................................ 1
Falling ........................................................................................ 2
Staying Steady ............................................................................ 3 go to Q29
Not sure ...................................................................................... 4 go to Q20

**Q28b IF RISING, OR FALLING:** By how much per year is the water table in your catchment (district) rising or falling (approximately)? Enter a number in one of the boxes, depending on measurement unit.

[ ] millimetres per year or [ ] metres per year

**Q29** If the soil on your property was mildly saline, but still cropable (ie. not totally "bald"), which of the following two statements would you tend to agree with most? *(Circle one only)*

It's better just to live with the mildly saline soil, it costs more to to treat it than you would get back in crop yield benefits ............................ 1

It is worth spending money to restore the soil to a normal nutrient balance and to neutralise soil salinity ............................................... 2

# SECTION D - ACIDITY

**Q30** Have you, or a consultant on your behalf, conducted soil tests to measure acidity over the last 3 years?

Yes ............................................................................................ 1
No .............................................................................................. 2
Not sure ...................................................................................... 3

**Q31** Do you have a soil acidity problem on your property?

Yes ............................................................................................ 1
No .............................................................................................. 2 go to Q33
Not sure ...................................................................................... 3 go to Q33

**Q32** What are you doing to manage your soil acidity problems?

Office [ ]

..................................................................................................
..................................................................................................
..................................................................................................
..................................................................................................

# SECTION E - SOIL SODICITY

**Q33** Do you have a reasonable idea of what soil sodicity is?

Yes ........................................................................................ 1
No ......................................................................................... 2

**Q34** Have you or a consultant measured the sodicity of your soil in the last 3 years?

Yes ........................................................................................ 1
No ......................................................................................... 2
Not sure ................................................................................. 3

**Q35** Do you have any sodic or "hostile" sub-soils on your property?

Yes ........................................................................................ 1
No ......................................................................................... 2
Not sure ................................................................................. 3

# SECTION F - EROSION

**Q36** Is there a need to control erosion on your property?

Yes ........................................................................................ 1
No ......................................................................................... 2 go to Q38

**Q37** What are you doing on your property to manage or control erosion? office

..........................................................................................
..........................................................................................
..........................................................................................

**Q38a** Do you believe contour banks are enough to counter or control erosion?

Yes ........................................................................................ 1 go to Q39
No ......................................................................................... 2

**Q38b** **IF NO:** What else to you believe is required? Office

..........................................................................................
..........................................................................................
..........................................................................................

**Q39** Do you believe soil erosion is? *(circle one)*

Worse on your property than most properties within a 50km radius ................................ 1
Better on your property than most properties within a 50 km radius ............................... 2
About the same on your property as most properties within a 50km radius .................. 3
I can't really say ........................................................................................................... 4

# SECTION G - GENERAL

**Q40** Please indicate whether you attend to AGREE or DISAGREE with the following statements? *(Circle one code for each statement)*

| | Agree | Disagree | No opinion Don't know |
|---|---|---|---|
| There is a link between weeds that grow and degradation of soil due to acidity or salinity | 1 | 2 | 3 |
| A soil pH level of 5.5 would have no significant effect on the yield of wheat crop, all other things being the same | 1 | 2 | 3 |

**Q41** If we exclude new varities of grains, how much improvement do you think you could make to your main crop yield over the next 3-4 years?

A great deal (say 30% or more) .................................................... 1
A fair amount (say 10 - 29%) ........................................................ 2
Not too much (say 1 - 9%) ............................................................ 3
Nothing at all ................................................................................... 4

**Q42** Do you use a specialist Agronomic Consultant or specialist Crop Advisor?

Yes ........................................................................................... 1
No ............................................................................................ 2 go to Q44

**Q43** Is this person...? *(Circle as many as apply)*

A private consultant ........................................................................ 1
A government department officer ............................................... 2
Agronomist employed by retailer ................................................. 3
Some other (specify) ....................................................................... 4

**Q44** Are you an active member of any of the following groups? *(Circle as many as apply)*

Landcare ........................................................................................... 1
Top Crop ........................................................................................... 2
Other (specify) ................................................................................. 3
None ................................................................................................. 4

# SECTION H - CLASSIFICATION QUESTIONS

**Q45** Into which of the following age groups do you belong?

Under 36 years .......... 1
36-45 years .......... 2
46-55 years .......... 3
over 55 years .......... 4

**Q46** Would you regard your farming enterprise as ...? *(one only)*

Very profitable .......... 1
Fairly profitable .......... 2
Not too profitable .......... 3
Not profitable at all .......... 4

**Q47** In which postcode area is your property? *(Very important we have this)*

postcode ____________

**Q48** In which State or Territory is your property?

NSW .......... 1
VIC .......... 2
QLD .......... 3
SA .......... 4
WA .......... 5
OTHER .......... 6

Thank you very much for your assistance.
It is of great value.

Returning your questionnaire - fold and place in reply-paid envelope provided, or address to:

TQA Research Pty. Ltd.
Reply Paid 3
Weed and Soil Survey
28-30 Station Street
Sandringham, Vic. 3191

**NO STAMP REQUIRED**

For Grains Research and Development Corporation

# Appendix 2

# Results of Mail and Field Surveys by Agro-ecological Zones

## Contents