A survey of weeds in dryland cotton cropping systems of sub-tropical Australia. 2. Economic cost of weeds

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Abstract:

Economic losses and costs associated with weeds in dryland cotton production are important for growers, weeds researchers, and rural industry funding bodies when making decisions about research priorities and research and development funding. A survey was conducted to provide information on weed types and control strategies, from which estimated costs to growers were derived. We used information from the survey to estimate conventional financial losses due to weeds, and as a basis for evaluating aggregate economic (society) impacts. An economic surplus model was used to estimate the aggregate societal impact of weeds for the main cotton production region in sub-tropical Australia. The annual economic costs associated with weeds were estimated to be $19.6 million, and the on-farm financial costs were $24.7 million. While these are past (sunk) costs, and based on a total removal of weeds, the approach outlined here can be used to begin evaluating likely future returns from technologies or management improvements for different agricultural problems. Estimates are presented of sampling errors associated with survey-derived estimates as they relate to the true population parameters. The use of 'economic cost' as a basis for project funding decisions should be avoided, but the economic framework can provide a valuable measure of relative merit that can be applied to funding proposals.

Introduction

The focus of agricultural research and development (R&D) by public sector agencies and industry funding bodies continues to be important. The survey reported by Walker et al. (2004) was conducted with the aim of providing direction and priorities for future research to improve weed management in crop production systems which include dryland cotton. The results reported in that paper illustrate the main weed problems, the importance of various control methods and the cropping system context in which research priorities need to be considered. This paper extends that work by estimating the financial and economic costs that are currently imposed by these weeds, which can be used in the process of evaluating potential benefits from future R&D.

In thinking about such priority setting, considerations of the size of potential benefits from alternative R&D allocations can provide one idea of relative merit. Other issues are important in the decision making process, including research capacity or potential for success, links with other projects or programs, and grains industry perceptions of R&D priorities. Potential benefits are can be measured in economic terms.

In determining priorities as a basis for R&D funding decisions, the 'economic cost' associated with some problem is sometimes mentioned (McInerney 1996). There are two issues with such an approach – the first involves how to properly measure economic cost, and the second relates to the use of that information in determining R&D priorities. Vere et al. (2002) have presented the conventional economic framework for measuring the economic cost of weeds in agricultural systems, and that methodology is applied here to weeds in dryland cotton systems. The second issue can be addressed by analysis of potential gains from specific R&D proposals for weed technologies from alternative R&D allocations. Any such analysis is beyond the scope of this paper, but a framework for analysis is presented. It is the potential gains from specific project proposals that are important for R&D managers, rather than the total economic cost of the problem.

Another issue addressed in the paper is the analysis and interpretation of survey results. The nature of the sampling approach and other potential errors in sampling and processing mean that there are sampling errors associated with the derivation and interpretation of survey estimates. The sampling errors involved in deriving estimates from the survey are presented, together with implications for interpretation.

A distinction is made between the financial and economic costs of weeds. The on-farm (or financial) costs of weeds arise from both the application of direct control measures and yield losses (i.e. opportunity costs). The effects of weeds thus constrain aggregate crop production, with potential implications beyond the farm gate for crop processors, manufacturers and consumers. Jones et al. (2003) estimated the economic costs of different weeds for Australian annual winter cropping systems. This paper, together with the companion paper (Walker et al. 2004), reports the results of a scoping study similar to theirs, which was conducted for farming systems involving dryland cotton in sub-tropical Australia. This study examined weed issues and their economic impact to better understand weed management in regions growing dryland cotton.

Approach used for the study

There are a number of weeds issues for cotton growers and weed scientists resulting from the dryland farming system and constraints within the region. Residual herbicides used in rotational crops may damage cotton, in particular the sulfonylurea and triazine herbicides. Equally, a number of the common cotton herbicides have long plant-back withholding periods to either winter cereals or other summer cereals used in rotation with dryland cotton. To preserve soil moisture many dryland growers have adopted minimum or zero tillage systems that are almost solely reliant on herbicides for weed control. Control measures therefore must be flexible to allow last minute changes in the crops grown due to soil moisture limitations or price fluctuations, and need to provide adequate levels of protection against weeds in the chosen crop. This has led to a greater reliance on glyphosate for widespread weed control in minimum or zero till systems. This increased use has, in turn, led to recent concerns over the development of resistance within some weed species.

The aims of the scoping study were to determine:

- Dominant and difficult-to-control weed species in each crop and fallow component of the different crop rotations used for dryland cotton production in the region;
- Weed management practices, both non-chemical and chemical, being used for weed control in these systems;
- Economic impact of these weeds; and
- Current practices exacerbating the weed problems.

The analysis in this paper was conducted in two parts. The financial (on-farm) costs of weeds were estimated on an average per ha basis for each crop and fallow type, including potential yield losses. Average costs per rotation were estimated and the financial costs of weeds in dryland cotton were aggregated. An economic analysis of the impacts of weeds was also conducted, in which the impacts of weeds on cotton production beyond the farm gate were included. Industry groups such as processors and manufacturers, and consumers can be affected in this way. One region was identified for analysis based on dryland cotton production patterns in northern NSW (comprising the Macquarie, Namoi and Gwydir river valleys) and southern Queensland (centred on the Darling Downs). This region includes the main cotton production areas in Australia.

Materials and Methods

Due to the variety of cropping rotations used in dryland cropping systems, the assessment of weed problems was studied in the context of crop sequences. Details of weed types and densities were collected within these management contexts. The scoping study consisted of four components, starting with a postal survey of dryland cotton growers, followed by detailed grower interviews and extensive field surveys of a select number of growers who responded to the mail survey. Finally, financial and economic analyses were conducted from the survey data and other sources. This paper reports results of the latter analyses.

Postal survey

The postal survey was sent to 286 growers of dryland cotton in the region. The list of growers was derived from industry sources, and represented all known producers of dryland cotton. Growers were asked to provide information on their crop rotations, farming practices for weed control used in each component of the rotation, specific information on herbicides used for the main weeds of each crop and fallow, costs incurred, and estimates of the impact of weeds on crop production. As well, specific details of troublesome weeds within the cropping systems were requested. It is also possible for weed contamination to impact the price received for a crop, and a question about weed contamination was included in the postal survey. However, few problems of weed contamination in grain or cotton sold were reported.

Reliability of survey estimates

The survey was conducted to find information about the whole group (or population within the region) of farmers with cropping systems that included dryland cotton. Efforts were made to consider the errors associated with using a survey estimate to represent a true population parameter. There are two types of errors associated with using sample surveys to develop estimates of underlying population parameters – non-sampling and sampling errors. The former can be minimised by careful questionnaire design and testing to avoid ambiguous or misleading questions, minimising the possibility of transcription or other processing errors, and preliminary data analysis to ensure the required information is derivable.

Sampling errors arise because estimates of a parameter of interest will vary with repeated sampling, even if the sample proportion of the population is 'large'. If a sample survey is used to generate information about a population of interest to a researcher, any estimate derived from the sample should have an associated standard error to indicate the degree of confidence in that estimate. The alternative approach is to classify the information as a case study, with the results being representative of only the group of survey respondents rather than the whole population or industry.
Sample means and associated standard deviations (SD) were estimated from the survey responses. Standard statistical *t*-tests (Greene 1995) were used to signify whether survey means were significantly different from zero.

Financial and economic impacts

The on-farm financial impact of weeds was determined from the survey estimates of expenditure on direct control costs and the yield loss due to weeds for each of the crops. Jones *et al.* (2003) adapted McInerney's (1996) representation of the trade-off between production losses and control expenditure (for livestock disease expenditure), to conceptualise the total cost of weeds. The costs of weeds comprise control expenditure (herbicide and tillage costs) plus crop losses due to the direct weed effects (yield loss and product contamination). This framework emphasises the presence of opportunity costs, and the loss and expenditure calculations require an estimate of the weed-free situation, even if that is hypothetical. The level of costs with current management practices can provide an important reference point for determining the value of weed management practices and technologies.

The average weed cost in dryland cotton was expressed as a percentage of total crop variable costs, and then used in estimating the aggregate economic impacts if the weed constraint could be removed by R&D. The economic evaluation is distinguished from the on-farm financial analysis by estimating likely changes in industry prices and quantities based on potential changes in aggregate production if the effects of weeds were removed.

Economic surplus modelling

The economic cost of weeds was evaluated with the standard industry supply and demand representation, as described by Vere *et al.* (2002). Economic surplus concepts are widely used in evaluating the social welfare effects of agricultural productivity changes (Alston *et al.* 1995). The supply and demand functions of a commodity represent its value to producers and consumers. Economic welfare is measured as consumer's surplus, the difference between the willingness to pay (demand) and price for consumption, and as producer's surplus, the difference between price and the marginal costs of production (supply). These were evaluated as an inward shift in the industry supply curve from the case of a weed-free environment for dryland cotton production.

The change in supply is represented by a percentage change in the minimum average variable costs of production per unit of output. This is in accordance with economic theory of supply representing marginal costs of production. The change in total economic surplus is the sum of the change in consumer surplus and producer surplus, as shown graphically be Vere *et a*l. (2002).

Demand and supply elasticities

Estimates of industry demand and supply elasticities were required for the analysis. Hill *et al.* (1996) reviewed Marshallian demand elasticities from previous studies and used their own judgement to develop an own-price domestic cotton demand elasticity of -0.2 and a cotton supply elasticity of 1.5. Clements and Lan (2001) quoted an own-price cotton demand elasticity of -0.14. Supply elasticities vary according to the length of run in the decision period, since production responses to price changes are more limited in the short term. Demand for cotton will also vary according to the length of the value chain between producer and final consumer. The longer the value chain the more inelastic is the derived demand that the producer faces, but the demand also varies according to whether there are substitutes in manufacturing. In the analysis, demand and supply elasticities of -1.5 and 0.8, respectively, were used in the analysis to estimate the aggregate economic effects of weed costs in dryland cotton. These represented a 'medium term' case.

These numbers were considered in the context of dryland cotton production in Australia. Over 90% of Australian cotton is exported for processing. It is also important to consider the size of the industry being considered. Because dryland cotton is such a small proportion of the industry, and because of the strong export orientation it was considered that dryland cotton producers are price takers and that changes in production would have no effect on price. Therefore we assumed demand to be perfectly elastic. This has implications for economic surplus gains from potential improvements in weed management.

Physical and economic characteristics of the industry

For the region defined above, irrigated and dryland cotton production was 2.3 million and 196 thousand bales respectively in 2000-01 (Cotton Yearbook 2001). Average yields were 7.5 and 2.8 bales/ha respectively. Areas of dryland cotton production in that year were 28 000 ha and 41 200 ha in southern Queensland and northern NSW respectively. The dryland proportion was 8% of the total cotton crop in that year.
Dryland crop yields, prices and variable costs for the 2000-01 year are shown in Table 1. These were derived from published gross margin budgets (Scott 2001, Lucy 2002, Lucy *et al.* 2002). While these figures are from synthetic budgets based on 'best management practice', they are considered useful as a guide for the analysis. The farm-gate prices are considered the most relevant measures to which farmers throughout the industry would be likely to respond. The estimates of average variable costs are used for all costs on an enterprise basis.

Results

Results are presented in two ways. First, average costs on a $/ha basis from the survey responses are calculated, with associated sampling errors. Second, aggregated financial and economic cost figures for the industry are presented. Then follow discussion and conclusion sections.

Rotations including dryland cotton

Due to the nature of the cropping systems used in north-eastern Australia, dryland cotton may be grown in combination with a number of other winter and summer crops, and fallows. From the postal survey results the main crops grown with cotton were winter cereal only (predominantly wheat but also some barley), summer and winter cereal (sorghum and wheat or barley), long fallow, summer cereal only (sorghum), winter cereal and pulse (chickpea), and summer cereal plus winter cereal plus pulse (see Table 1 of Walker *et al.* 2004). These results reflect soil types and management preferences of the farmers.

This information has implications for the financial and economic analyses carried out for this study. The financial costs can be calculated for each crop and fallow, and these results are presented. The weed costs can also be summed to develop an average control cost for any specified crop sequence, provided that double counting was avoided. Similarly the framework used for the economic analysis allows the industry impacts of weeds to be evaluated for each crop type. However, aggregation of financial or economic benefits over crop rotations has not been undertaken here because information on other crop areas (than dryland cotton) was not collected.

Reliability of survey estimates

The mean and SD estimates of direct control costs for crops in the rotations from the postal survey are presented in Table 2. Using a *t*-test, the estimates of direct weed control costs in wheat crops were found to be not significantly different from zero. The estimates of yield losses in Table 2 were considered to suffer from possible non-sampling errors, due to reliance on farmer perceptions of weed-free crop yields rather than recorded costs. Therefore no sampling error was estimated for the yield loss estimates, and so the likely sampling errors associated with the total ($/ha) costs of weeds in Table 2 were not derived.

Financial analysis

The average direct cost of controlling weeds in each crop grown in rotation with dryland cotton include the cost of herbicides, application costs, cultivation, and manual chipping where appropriate. The low wheat cost in Table 2 reflects the fact that there were few winter grass weeds for wheat; however, the sorghum and cotton costs are surprisingly large.

The estimated direct cost of weeds in cotton was $220/ha in both northern NSW and southern Queensland. Given the similarity in production systems this outcome is not surprising. In general the direct weed control costs in Table 2 might be considered quite high, especially in comparison with the average variable costs in Table 1. Although the cost due to yield loss is not considered in financial budgets, even the direct control costs of $220/ha are relatively high. It must be remembered that there is substantial variability associated with these estimates, and the wheat control cost estimates are associated with very large errors.

Growers were also asked in the postal survey to provide details of the potential reduction in crop yield due to weeds. The reported yield losses were averaged for each of the crops across the regions and are presented as the percentage yield loss due to weeds in Table 2. This percentage loss was converted into dollar equivalents using current prices for the crops and the average yield for each region for each crop. The total cost of weeds for each crop was calculated taking into account the impact of weeds on yield and the costs of weed control for each crop.

The aggregated financial costs of weeds in dryland cotton crops is estimated from Table 2 (total $/ha cost of weeds) and the total areas of dryland cotton production (quoted above) to be $24.7 million in the region.

Weed control in summer and winter fallows relies primarily on knockdown herbicides and some cultivation. As water conservation is of upmost importance to dryland growers, the use of cultivation for weed control is likely to be minimal. The transition of many growers to minimum or zero tillage for soil and water conservation thus places a great deal of reliance on knockdown herbicides as the primary means for weed management in summer and winter fallows. Average weed control cost in fallows was $36 per ha and $34 per ha for summer and winter respectively (Table 2). Average weed management costs included operational costs (cultivations), chemicals (herbicides) and spray applications. Spot spraying cost more that usual spraying. The average spray cost was $4 per ha which includes the spot spraying.

The average total cost of weeds over each rotation type ($/ha/year) was estimated and the results are in Table 3. The crop rotations were identified in the survey. Total control costs from Table 2 were used in the calculations. Even though the SDs were relatively large in some cases (especially wheat), the survey estimates were used to calculate average weed costs in the absence of better information. Average weed costs varied from $220/ha/year to around $150/ha/year. Although no errors could be calculated for these figures, comparisons between them should be made with caution because they are ultimately derived from survey processes.

Even if the numbers in Table 3 were error-free any interpretation needs to be considered carefully. From Table 1 in Walker *et al.* (2004) a large proportion of dryland cotton rotations were with winter cereal only. Even if the weed cost of $224 was known to be higher than for the other rotations, any interpretation of the figures would need to be compared with the relative returns from each rotation to obtain an idea of comparative profitability for a better view of the importance of weed costs.

Economic analysis

The economic analysis was conducted to evaluate the losses from weeds in dryland cotton crop within the region. The analysis was based on farm survey estimates of weed costs (direct control costs and yield losses) and total crop cost figures from synthetic budgets. For dryland cotton, the total cost of weeds from Table 2 was expressed as a percentage of average variable costs (Table 1) to derive a cost reduction of 31%. This proportion were used to represent the restrictions to crop supply deriving from the effects of all weeds that influence the cotton yield.

For dryland cotton, estimates of changes in producer and consumer surplus for the region were derived using the supply and demand elasticities, a conversion of production and price from a bale to a tonne basis (227 kg bale weights standard in Australia), and equations involving initial prices and quantities, the percentage cost reductions associated with weed removal, and the percentage reduction in price from the supply shift. The loss in producer surplus associated with all weeds in cotton for the region was estimated to be $19.6 million. There are no changes in consumer surplus because of the price taking assumption for dryland cotton producers.

For other crops, analysis is dependent on obtaining the annual production figures for those crops when grown in rotation with dryland cotton. These production estimates were not available, so similar analyses were not possible.

Discussion

The focus of this paper has been on the potential for using financial and economic analysis of crop survey data in an R&D priority-setting process. The underlying methodologies are well known to economic analysts, but the application to weeds in Australian dryland cotton crop rotations is new.

Several points arise from the survey results. First, we have calculated the standard errors associated with some survey estimates and found them to be quite large. The use of surveys and interpretation of survey results seems relatively widespread, but seldom is there any acknowledgement of the possibility, or implications, of sampling errors associated with these types of analyses. Straight comparisons of estimates derived from survey processes may lead to invalid conclusions. The size of errors can be reduced by stratifying the population to increase sampling efficiency. There are also likely to be substantial non-sampling errors associated with the use of self-administered surveys and response bias.

The estimates of weed control costs presented in the paper appear to be substantial compared to total costs, and so in general terms there may be scope for gains from weed productivity advances. However, care should be used in drawing any conclusions for payoffs from weeds R&D without more detailed evaluations of potential gains from specific proposals for weed and other (eg fertiliser, insect pests) problems.

The aggregated estimates of financial and economic costs associated with current weed infestations were substantial; and as expected the economic estimates were larger. The financial estimates are derived by applying an estimated per ha cost to a fixed area of production. The economic analysis, characterising as it does the costs associated with weeds as impacting on aggregate supply, is a normative (what should be) analysis which assumes a supply response to the additional costs. Intuitively, it is expected that the economic could outweigh the financial effects because off-farm effects are included in the former.

The economic cost estimated here relates to total weed costs (including yield losses). By itself this figure is not very useful in an R&D priority-setting context because it is unlikely that ll weed costs can be mitigated. However, the estimation framework itself can be used to evaluate potential payoffs from particular R&D proposals, and this is the main point to be taken from the paper.

To fully utilise this methodology for priority setting, several potential R&D projects could be analysed using this framework to provide a ranking according to likely net benefits. Changes in potential crop yield losses associated with different technologies (where relevant) should be included in R&D evaluations. The framework also allows an allocation of benefits between producers, processors and consumers (both domestic and export), which can have implications for who should fund the research. Such analyses would need to consider assumptions about patterns and rates of technology adoption by industry. Software packages (eg DREAM, Wood *et al.* 2001) can be used for this purpose. Analyses with such packages can show the benefits from further uptake of existing technology versus development of completely new technologies, which may have uncertain adoption by industry.

Conclusions

The analysis of weed costs in crop rotations with dryland cotton has shown substantial potential benefits from the removal or reduction of weeds. While the scenario of complete weed removal is unrealistic, the methodology can be used to evaluate the returns from future R&D on a more valid and consistent basis. Research workers need to be careful about the collection, analysis and interpretation of survey data when drawing implications for research priorities.

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Table 1: Dryland crop production, prices and variable costs used in the analysis

Crop	Mean crop yield Cotton bales/ha		Farm-gate price $/cotton bale, $/t		Average variable costs $/ha	
	Northern NSW	Southern QLD	Northern NSW	Southern QLD	Northern NSW	Southern QLD
Cotton	3.0	3.9	480	430	1236	986
Sorghum	3.3	4.6	170	170	210	140
Wheat	2.8	2.9	115	115	305	208
Chickpea	1.6	1.6	400	350	295	172

Source: Scott (2001), Lucy (2002) and Lucy *et. al* (2002)

Table 2: Estimated direct weed control costs for each main crop and fallow, and costs due to uncontrolled weeds on crop yield based on the production and prices for2000-01 season

Crop or fallow	Direct control cost $/ha		Yield loss due to weeds		Total cost of weeds $/ha
	Mean	Standard deviation	%	$/ha	
Cotton	220	62	7.0	137	357
Sorghum	60	27	6.6	34	93
Wheat	20	35	3.7	18	37
Chickpea	37	29	8.6	56	95
Summer fallow	36	10	-	-	-
Winter fallow	34	11	-	-	-

Table 3: Estimated total costs of weeds in the main rotations with dryland cotton

Crop rotations								Cost of weeds
Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	$/ha/yr
Cotton	Wheat	Fallow	Fallow					224
Cotton	Wheat	Fallow	Wheat	Fallow	Fallow			174
Cotton	Fallow	Fallow	Wheat	Fallow	Fallow			173
Cotton	Fallow	Fallow	Wheat	Fallow	Wheat	Fallow	Fallow	148
Cotton	Fallow	Sorghum	Fallow	Fallow	Fallow			191
Cotton	Wheat	Fallow	Fallow	Sorghum	Fallow	Fallow	Fallow	161
Cotton	Fallow	Sorghum	Chickpea	Fallow	Wheat	Fallow	Fallow	177
Cotton	Fallow	Fallow	Fallow					223