EVALUATION OF DATA COLLECTED FROM CEREAL TRIALS USED FOR HERBICIDE EVALUATION – FACTORS AFFECTING GRAIN YIELD LOSS

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Summary Herbicides are an important part of weed management in cereal crops reducing the competitive effects of weeds on yield. Large amounts of data have been accumulated by agrichemical companies in the process of herbicide registration. These unpublished trials were conducted on cereals, primarily wheat, in all cereal growing areas of Australia from 1967 to 1989. Data from each trial, including details on site, weed populations, level of weed control and yield, were collected and combined into a readily accessible database.

This paper presents a summary of the data collected on eight major weeds occurring alone or as the dominant species in trials. Factors causing a yield loss were identified with particular attention to the influence of weed density on yield.

The presence of weeds in most trials resulted in yield loss. Weed density relationships were found for the most competitive weeds (*Raphanus raphanistrum* L., *Avena* spp., *Lolium* spp., *Sisymbrium* spp., *Brassica* spp. and *Fallopia convolvulus* (L.) A.Love). Unexplained variation contributed significantly to these relationships and the data from *Arctotheca calendula* L., *Oxalis pes-caprae* L. and *Phalaris* spp. for which significant regressions were not found.

Seasonal conditions, time of herbicide application and location were found to have a significant effect on yield and for some weeds were a more important determinant of yield than weed density.

The general suitability of herbicide efficacy trials for description of weed density/yield relationships is discussed.

INTRODUCTION

Weeds are a major cause of yield loss in cereal crops and selective herbicides have been an important part of weed management over the past 40 years. Herbicides are costly inputs but if used correctly can result in increased returns to farmers and more efficient production which is essential to the survival of farming enterprises. The prediction of yield loss due to different species and density is an important part of the economic analysis of weed control thresholds. Agrichemical companies have been evaluating herbicides over the past 40 years and the collected data has primarily been used for herbicide registration.

This paper presents an analysis of efficacy data obtained from agrichemical companies with the aim of developing yield responses from controlling individual weed species and producing predictive models to aid farmer weed control decision making. Additionally the importance of other factors affecting yield was investigated.

MATERIALS AND METHODS

All agrichemical companies manufacturing and marketing cereal herbicides in Australia were approached to provide information from trial work conducted on registered and unregistered products (Table 1). Selected information was entered into a database constructed using Microsoft Works.

Data from 1295 trials conducted between 1967 and 1989 provided information on efficacy for various rates, timings and phytotoxicity. All trials contained untreated controls. More than one weed occurred in most trials but data in this paper was restricted to trials in which only one major weed occurred. A summary of the crops from which the trial data was collected is given in Table 2. The trials from which the data has been collected were primarily conducted on wheat (Table 2). Minor cereal crops were barley, oat and triticale.

For each trial, weed species, density and other factors, if available were collated including: postcode, variety, crop, sowing date, sowing rate, soil colour, texture and pH, application stage, date of application, year, weed stage at spraying and seasonal conditions. Weed densities were taken from either pre-spray counts or counts conducted during the assessment of weed control.

The grain yield in each trial collected was measured as t ha^{-1} for the untreated and the herbicide treated plots. Only trials where 90–95% weed control was achieved as measured subjectively by apparent abundance and without causing any crop phytotoxicity were included. In this paper the yield is expressed as a percentage of the untreated (no weed control). Regression analyses were conducted on transformed data ($\log_{10}$) from each weed species.

Multivariate stepwise regression analysis (factor analysis) was also conducted on the 23 factors using Genstat V5.

RESULTS AND DISCUSSION

The average weed density was generally very high as trial sites were selected to evaluate herbicide efficacy.

Weed density and yield response relationships (Figure 1) were found for *Avena* spp. (*A. fatua* L., *A. sterilis* ssp. *ludoviciana* (Dur.) Gillet & Magne), Lolium spp. (*L. rigidum* Gaudin, *L. perenne* L., *L. multiflorum* Lam.), *Raphanus raphanistrum* L., *Sisymbrium* spp. and *Brassica* spp. (*S. officinale* (L.) Scop., *S. orientale* L., *B. tournefortii* Gouan, *B. sinapistrum* Boiss.) and *Fallopia convolvulus* (L.) A.Love. The general linear regression equations explained 10–35% of yield variation. The slopes of the regression lines can be used as a general indication of specific weed competitiveness however the data spread does not afford a high level of confidence. The regressions however can be used to develop economic weed threshold models.

Significant yield responses to weed density relationships were not found for *Arctotheca calendula* L., *Oxalis pes-caprae* L. and *Phalaris* spp. (*P. aquatica* L., *P. canariensis* L., *P. minor* Retz., *P. paradoxa* L.). Although density/yield response relationships were not found for these weeds, control usually resulted in yield response increases in the general range of 0–100%.

Table 1. Co-operating companies.

Company	Number of trials
Bayer Australia Ltd.	3
Ciba-Geigy Australia Ltd.	81
Cyanamid Australia Pty. Ltd.	4
Du Pont (Australia) Ltd.	315
Hoechst Australia Ltd.	516
ICI Australia Operations Pty. Ltd.	150
Nufarm Ltd.	24
Rohm and Haas Australia Pty. Ltd.	17
Rhone-Poulenc Rural Pty. Ltd.	90
Sandoz Crop Protection	20
Shell Chemical Pty. Ltd.	71
Shionogi and Co. Ltd.	2

Table 2. Crops on which trials were conducted.

Crop	Number of trials
Wheat	1134
Barley	144
Oat	3
Triticale	9

The generally low fit of regressions and variability in the data has been caused by in part environmental factors affecting crop growth masking the effects of weed density on yield, the data set being biased to high weed densities, undetected crop phytotoxicity, less than complete weed control (Rerkasem *et al*. 1980), crop density and nutrition and other unknown factors. The unknown variability may have been reduced had all trials contained a complete description of all the above.

Herbicide efficacy trials have been used to estimate the competitive effects of weeds by Streibig *et al.* (1989) and Jensen (1991) who also found significant variability in yield estimates calculated from trials conducted over different locations over many years and seasonal conditions. Each weed is represented by a large number of trials which cover geographic and seasonal variations. The number of weed species reflects the herbicides which were being evaluated by the agrichemical companies and to a lesser extent their occurrence in cropping land.

Using factorial analyses weed density was seldom identified as the primary source of variation in cereal yield (Table 3). This was the case in only two analyses – *Avena* spp. and *A. calendula*). Weed density was significant in *Lolium* spp. and *R. raphanistrum*, having a 4–10% influence on yield. This does not provide evidence of the unimportance of weeds, but rather draws attention to the compounding which is present among the variables, for example, between year and weed density.

The year of conducting trials was an important source of variation in cereal yield with 'year' accounting for approximately 50–80% of variation in cereal yield for *Lolium* spp., *R. raphanistrum*, *O. pes-caprae*, and *Sisymbrium* spp./*Brassica* spp. (Table 3). Year also accounted for 8% variation of cereal yield as affected by *Avena* spp.

Seasonal conditions were important sources of yield variation in one case (*A. calendula*), accounting for approximately 80% of yield variation through weed density and autumn seasonal conditions (dry, average or wet). This would suggest the regression may have practical predictive worthiness for decision support for spraying against *A. calendula*. Year or seasonal variation or seasonal rainfall was also found to explain the major source of yield in New South Wales wheat crops by Wynen (1984).

Weed stage at spraying and date of application were identified as important only for *Phalaris* spp. For *Phalaris* spp. the 76% of variation accounted for at the 'date of application' probably relates to the type of herbicide used in controlling the weed (pre- or post-emergent).

Location was found to be an important secondary factor for *O. pes-caprae* and *F. convolvulus.* explaining 15% of the variation in these weeds. This indicates that

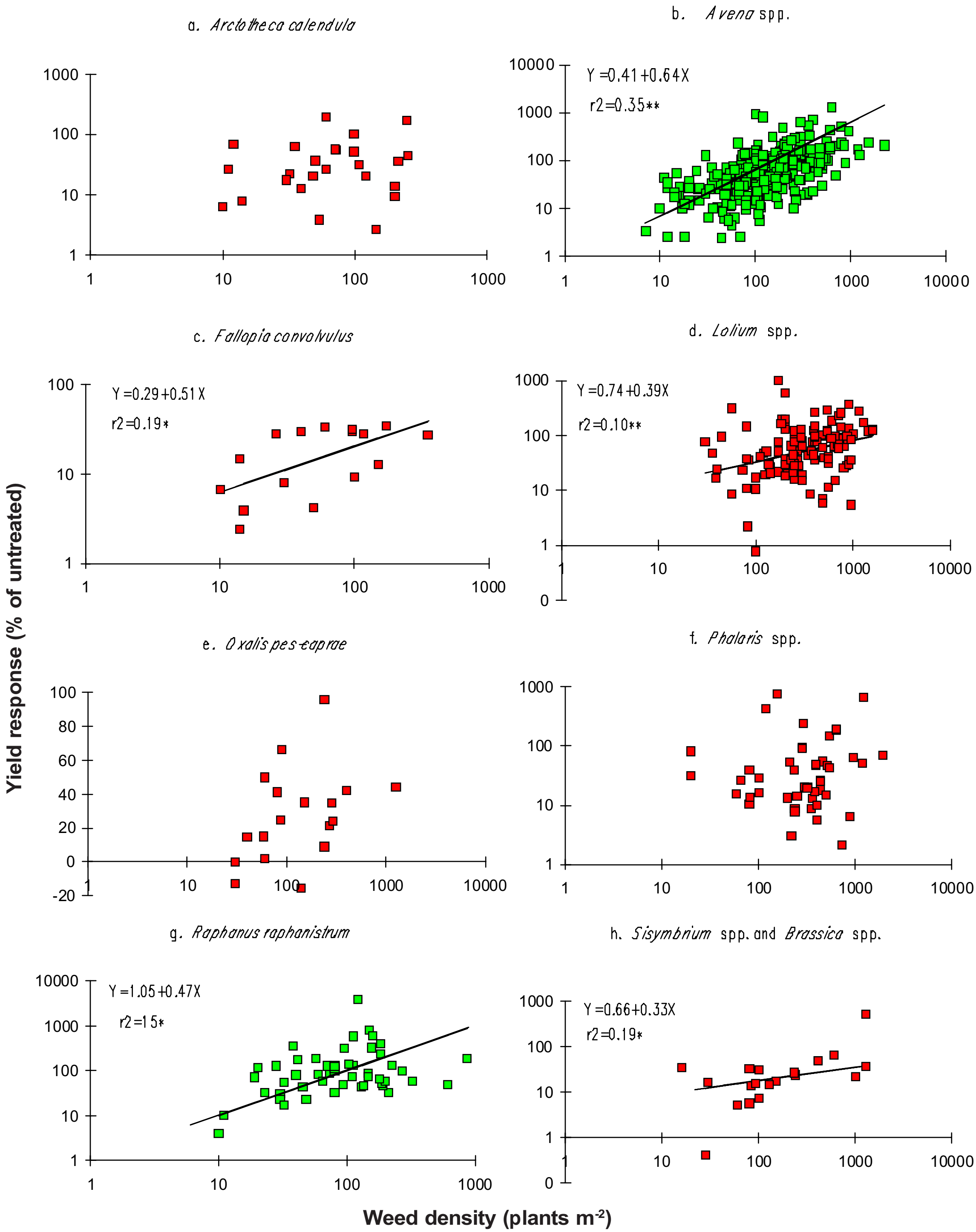

Figure 1. Weed Density and Yield response relationships for a) *A. calendula*, b) *Avena* spp., c) *F. convolvulus*, d) *Lolium* spp., e) *O. pes-caprae*, f) *Phalaris* spp., g) *R. raphanistrium*, h) *Sisymbrium* spp. and *Brassica* spp.

Table 3. Summary of multivariate analysis – significant factors contributing to the yield response.

Weed	n[A]		Regression factor and co-efficients of determination (r^2)			
Arctotheca calendula	28	Y=f:	Log (w.d.) 0.342	Autumn 0.455	Spring 0.067	DOA 0.015 (ns)
Avena spp.	348	Y=f:	Log (w.d.) 0.275	Year 0.080	Spring 0.017	Weed stage 0.011 (ns)
Lolium spp.	130	Y=f:	Year 0.873	Log (w.d.) 0.041	Weed stage 0.001 (ns)	
Phalaris spp.	54	Y=f:	DOA 0.757	Winter 0.045 (ns)		
Oxalis pes-caprae	21	Y=f:	Year 0.585	Location 0.146	DOA 0.039 (ns)	
Fallopia convolvulus	21	Y=f:	Soil texture 0.689	Location 0.152	Year 0.124	Sowing date 0.035[A]
Raphanus raphanistrum	56	Y=f:	Year 0.482	Log (w.d.) 0.095	Soil texture 0.153	Weed stage 0.067 (ns)
Sisymbrium spp. + *Brassica* spp.	23	Y=f:	Year 0.832	Soil texture 0.166[B]		

[A] n=number of trials in which the weed occurred as a sole weed or as the major weed, w.d.=weed density, DOA=date of application, [B] insufficient degrees of freedom to fit further terms.

these weeds primarily occur in specific areas because of adaptation of climate and soil type. *O. pes-caprae* being found predominantly in South Australia and *F. convolvulus* in north-west New South Wales and Queensland are adapted to specific regional areas.

CONCLUSIONS

The presence of weed species in most trials resulted in yield loss. Weed density/yield response relationships were established for *Avena* spp., *Lolium* spp., *Sisymbrium* spp., *Brassica* spp., *R. raphanistrum* and *F. convolvulus* and these may assist in establishing thresholds in weed control management.

A yield advantage was generally obtained from controlling the other weed species studied (*A. calendula*, *O. pes-caprae* and *Phalaris* spp.) however no significant density/relationships were found.

The main sources of variation affecting yield and for most species were identified by multivariate regression to be year and weed density.

This method of evaluating a large number of efficacy trials over many seasons and locations has not provided to be particularly useful due to substantial variation in the pooled data. Consequently it has not been possible to develop robust yield loss relationships.

Closer monitoring of agrichemical trials to provide a more complete data on environmental and crop factors could improve the usefulness of this information for development of weed density/yield loss relationships.

ACKNOWLEDGMENTS

The authors are grateful for funding provided by GRDC, agrichemical companies for access to trial information and Dr. R. Medd for guidance and assistance in the preparation of this paper.

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