The Adoption of Lupins In Western Australia: Did Extension Make A Difference?

Sally P. Marsh, David J. Pannell and Robert K. Lindner

Contributed Paper Presented to
39th Annual Conference of the Australian Agricultural Economics Society
University of Western Australia, Perth, Western Australia, 14 – 16 February 1995

THE ADOPTION OF LUPINS IN WESTERN AUSTRALIA: DID EXTENSION MAKE A DIFFERENCE?

Sally P. Marsh, David J. Pannell and Robert K. Lindner*

The growth of the sweet white lupin industry in Western Australia is a classic case of the adoption and diffusion of a new innovation in agriculture. In 1979, following the release of the cultivar Illyarrie, and the development of effective agronomic practices, the Western Australian Department of Agriculture (DAWA) commenced a major extension campaign to promote lupins. Between 1978 and 1992 the area of lupins grown increased from 39,000 to 822,000 hectares. However, the pattern of adoption varied widely between regions, with differences in starting time, rate and ceiling levels of adoption. In this paper we examine regional differences in the adoption process, and estimate the impact of various factors using multivariate regression analysis. Results suggest that both DAWA extension activities and the presence of private consultants contributed to earlier start times of the adoption process.

1. INTRODUCTION

The adoption and diffusion of innovations has an extensive literature history. Lindner (1987) classified the literature into studies principally concerned with adopter characteristics (adoption studies) and those concerned principally with innovation characteristics (diffusion studies), with each category having both cross-sectional and temporal studies. While the literature has expanded considerably in the intervening years, as reviewed by Feder and Umali (1993), the essential dichotomy described by Lindner (1987) still exists, albeit assisted by an increasingly sophisticated set of mathematical and econometric techniques. Lindner (1987) described the contradictory results typically associated with adoption studies, and pointed to methodological problems associated with these studies. He considered the most powerful method of empirical research for adoption/diffusion was a temporal study of the diffusion process, as it addresses "*both the static issue of ultimate adoption levels as well as the determinants of the dynamic rate of adjustment to this new equilibrium state*" (p 147).

Griliches's (1957) study of the diffusion of hybrid corn is the classic agricultural temporal diffusion study. By fitting logistic functions to curves which plotted the area planted to hybrid corn over time in different states of the U.S., he was able to estimate parameters which described the start time, rate and ceiling level of the adoption

* Marsh is Research Officer, Agricultural and Resource Economics, University of Western Australia.
Pannell is Senior Lecturer, Agricultural and Resource Economics, University of Western Australia.
Lindner is Executive Dean, Faculty of Agriculture, University of Western Australia.
The authors appreciate contributions to the work discussed in this paper by various people: notably Bryan Gorddard, who conceived the original project, Russel John, and Mike Perry.

process. His methodology has since been used for many studies of this type, although in recent years dynamic models have been used in an attempt to adjust for the limiting assumptions of the logistic model.[1] As noted by Feder and Umali (1993):

> *Diffusion has been modelled to account for changing equilibrium populations, changing technologies, changing rates of adoption, spatial differences, and the rate of abandonment. However it is apparent that no general model perfectly fits all situations and that in some cases different diffusion models can describe a single event effectively* (p 226).

Griliches's (1957) results have been re-worked[2] using refinements of the general logistic model, but have generally stood the test of time. His results emphasised the overriding importance of profitability, determined in his work by yield and acreages planted, in accounting for differing rates and ceiling levels of adoption. Results which have represented for a long time a convincing win for the economists at the expense of the sociologists.

This paper discusses some of the results obtained from a temporal diffusion study of a crop innovation that has been rapidly and successfully adopted in Western Australia. The particular brief of this RIRDC-funded study was to investigate the impact of agricultural extension on the adoption process. Few empirical studies of this nature have been attempted, because of the time-consuming and difficult nature of the data collection involved. The study involves district-level comparisons of the adoption of sweet white lupins (*Lupinus angustifolius*) by farmers in W.A., using a methodology similar to that pioneered by Griliches (1957) to estimate start times, rates and ceiling levels of adoption in different districts. These estimates were then used as dependent variables in multivariate regression analysis in an attempt to determine factors influencing the adoption process.

Using data provided by the Australian Bureau of Statistics, production data for lupins, including total area sown to lupins, percentage of crop sown to lupins, and tonnes produced, has been collated on a shire-level basis over time. Additionally, the number of farmers growing lupins has been collated by shire and by year. An effort has been made to quantify and classify soil types suitable for lupins on a shire basis, as the availability of suitable soil types affects both the maximum area of lupins that can be grown and the profitability of the lupin enterprise. Yields and yield variance for individual shires have been ascertained. These factors, as well as the profitability of competing enterprises, can be expected to influence adoption rates of lupins. Rather than the usual aggregate data on national or state-level extension expenditures, the study has attempted to disaggregate extension activities related to lupins to a shire level, in both physical and financial terms. Data on detailed extension and field-research activities undertaken by the Department of Agriculture W.A. (DAWA) has been collated for 43 shires in the northern and central wheatbelt[3]. Additionally, extension activities undertaken by private sector agencies operating in these areas has been incorporated into the data set.

---

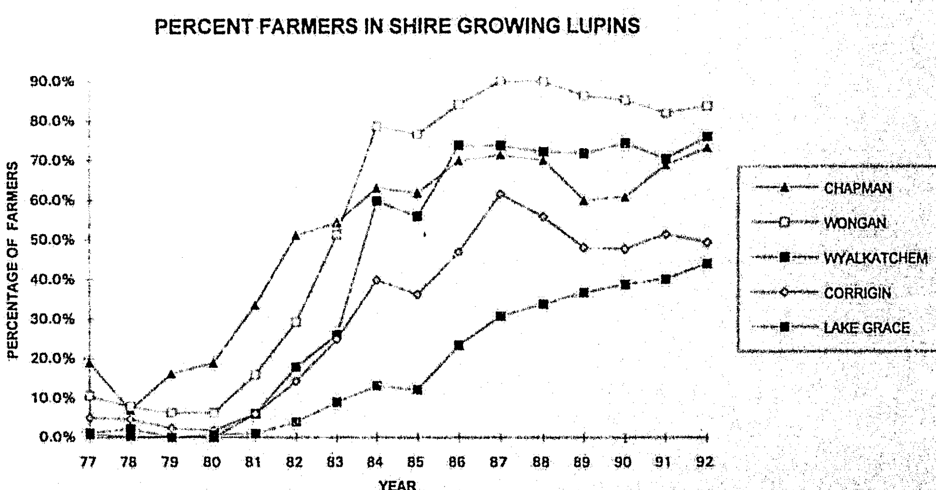
[1] For an explanation of these assumptions see Mahajan and Peterson (1985).
[2] e.g. Dixon (1980) and Valente (1993).
[3] Geraldton, Three Springs, Moora, Northam, Merredin and Lake Grace DAWA advisory districts.

2. BACKGROUND

Few new industries have been taken up so rapidly and successfully as the lupin industry in Western Australia. The area planted to sweet narrow-leafed lupins (*Lupinus angustifolius*) in W.A. has grown from less than 100,000 hectares in 1980 to a peak of 877,000 hectares in 1987, and plantings in 1992 of 822,000 hectares. The first sweet white lupin (cultivar Uniwhite) was released in 1967[4], and promoted as a legume crop especially suitable for sandplain soils in the heavier rainfall areas of the northern wheatbelt. By 1973 the area planted to lupins was 120,000 hectares, but a combination of poor management practices by farmers and droughts in 1976 and 1977 saw lupins lose favour. By 1978 the area planted had fallen to 40,000 hectares. In 1979, a higher yielding cultivar (Illyarrie) was released and a major extension effort commenced in the northern wheatbelt area by DAWA's Geraldton district office. This contributed to the rejuvenation of the lupin industry during the 1980s as described above, and this story has been documented by Nelson (1987).

The uptake of the new crop varied widely between regions. Figure 1 shows the percentage of farmers in the shire growing lupins over time for five shires in the W.A. wheatbelt, from Chapman Valley in the north, then progressively southeast through Wongan-Ballidu, Wyalkatchem, Corrigin and Lake Grace. All the shires illustrated,

Figure 1



except Lake Grace, appear to have gone through a complete diffusion process, and reached a ceiling level of adoption. This is the case for the majority of the 43 shires in the study. The shires shown in Figure 1 illustrate differences in the adoption of lupins that can be seen in different areas of the state. For each of the five shires there are differing times when the adoption process commenced, differing ceiling levels of adoption reached and differing rates of adoption to reach the ceiling. Obviously, a

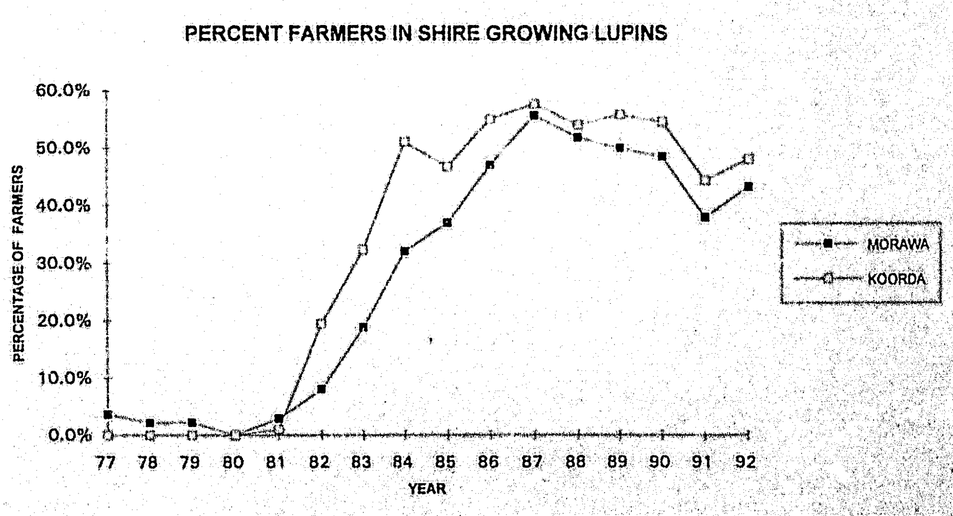
[4] For a history of the development of the sweet white lupin see Gladstones (1982).

great number of factors influence these differences, and one of the purposes of this study was to attempt to segregate and quantify the effect of extension activities on the rate of adoption.

Qualitatively, at least, it would seem that there is some evidence that extension effort was instrumental in influencing the start time of the adoption process. The influence of the major extension effort in the Geraldton region (northern wheatbelt) in 1979 can be seen in the data for Chapman Valley shire, which is served by the Geraldton DAWA office. For Chapman, and other high rainfall northern wheatbelt shires, the percentage of farmers in the shire growing lupins increased in 1979. Despite the amount of general information on lupins available to farmers throughout the state, this was not the case for shires in the central and eastern wheatbelt. As can be seen in Figure 1, the percentage of farmers growing lupins in Wongan, Wyalkatchem and Corrigin shires did not start to increase until 1981. It was not until 1981 that trials and extension activities in the Merredin region (eastern wheatbelt) set out to demonstrate that lupins could play a valuable role in farming systems in drier areas, previously thought "unsuitable" for lupin production. Considerable interest in these trials was shown by farmers and private consultants from higher rainfall central shires where little district-specific lupin extension had been undertaken and lupins were not yet grown to any great extent.[5] The data suggests that shires such as Wongan (central wheatbelt) were influenced by the extension program conducted by DAWA's Merredin office, whereas the earlier program in the northern wheatbelt had had little impact in this region.

Figure 1 illustrates the one to two year earlier adoption of lupins that occurred in a northern wheatbelt shire, Chapman, over a similar rainfall central wheatbelt shire, Wongan Hills. Figure 2 then illustrates how this situation is reversed for lower

Figure 2



rainfall shires, Morawa and Koorda, in the northern and eastern wheatbelt,

[5] S. Trevenen and M. Ewing, DAWA, pers. comm.

respectively. Lupins were not extended in the northern region as a crop for dryland areas until a meeting in eastern Mullewa in 1982. Nelson's (1987) documentation of the lupin extension effort in the Geraldton region shows that whilst recognising the value of lupins in rotation farming, the extension effort emphasised the potential value of lupins as a cash crop, the rationale being that current varieties and agronomic knowledge were sufficient to grow high yielding lupin crops. In contrast, extension in the Merredin region emphasised the role of lupins as a legume in the farming system, despite the problem of low and variable yields in low rainfall areas. Hence Morawa, although closer to Geraldton but considered too dry for lupins as a cash crop, lagged behind eastern wheatbelt "dry" shires where lupins were extended as part of a profitable farming system from 1981.

The impact of DAWA's Merredin office extension effort of lupins for dryland farming may also be reflected in figures such as the following comparison between adjoining wheatbelt shires Koorda (Merredin DAWA district) and Wongan (Moora DAWA district). Wongan is now one of the largest lupin producing areas and has production statistics far superior to the drier Koorda shire (1982-90 average yield - Wongan 1.06T/ha, Koorda 0.68T/ha). However, in 1982 and 1983 Koorda had lupin plantings that were approximately 20% and 55% of peak 1987 plantings, whereas plantings in Wongan were approximately 10% and 27%.

Qualitative evidence such as the above encouraged us to use the lupin adoption data to see if some quantitative support could be obtained for the impact of extension activities on adoption.

3. METHODOLOGY

3.1 Estimation of parameters describing the diffusion data

The cumulative adoption patterns for individual shires approximated the classical S-shaped curve associated with diffusion data, with parameters that can be estimated using a logistic model. A standard logistic function, Gompertz function and Richards function were fitted to the data for individual shires (see Appendix 1), giving estimates of the ceiling level of adoption attained, the intrinsic rate of adoption, and the time at which the maximum rate (i.e. the point of inflection in the curve) of adoption is reached. The data was described well by both the standard logistic and Gompertz functional forms, with R^2 being, in most cases, in excess of 0.9. Based on the work done by Dixon (1980) it was decided to use the Gompertz estimates, as his reworking of the Griliches (1957) data suggests that the Gompertz function, with its earlier point of inflection and longer tail, better describes the diffusion of agricultural technologies.

3.2 Estimation of dependent variables

The parameters obtained from fitting a Gompertz function to the diffusion data, were used to estimate the start time, rate and ceiling level of adoption for the shires in the study area. The function describes the number of farmers ,y, growing lupins at time, t:

$$y = A + C/(_{e} + e^{-b(t-m)})$$

with parameters defined as -

- C - the ceiling (or maximum) level of adoption attained,
- b - the intrinsic rate of adoption, and
- m - the time at which the maximum rate (ie. the point of inflection in the curve) of adoption is reached.
- A - the residual number of farmers growing lupins before the commencement of the diffusion process

Additionally, estimates of start time and rate were calculated directly from the data. These various estimates of start, rate and ceiling were used as the dependent variables (in turn) for multivariate regressions that expressed, for example, the start time of adoption as a function of cropping intensity, soil type, rainfall, previous experience, DAWA extension, etc. The estimates of start times of the adoption process were made as follows:

SG10 The time in years when 10% of the ceiling estimate (as calculated by the parameters of the Gompertz function) of percent farmers in the shire growing lupins was reached. Calculated by substituting y = .1*(A+C) in the Gompertz function and solving for t.[6]

SA10 The time in years when the percentage of farmers in the shire growing lupins was equal to a level calculated as the minimum percentage of farmers growing lupins[7] plus 10% of the difference between that minimum and the maximum percentage of farmers that grew lupins. This was calculated by substituting for y, as calculated, in the function describing the straight line between two known data points, each describing the percentage of farmers growing lupins in a given year.

All start times are expressed in year fractions (e.g, a start time of 80.45 means a time between 1980 and 1981). This was done partly because the range of start time differences in the study region were only a matter of three to four years, and the fractional expression of start times enabled a greater differentiation to be made. Technically speaking, the actual planting of a crop occurs only once in a specific year, but a start time expressed as a continuous variable could be said to recognise the information gathering and decision making processes that occur before the actual planting decision is carried out.

3.3 Explanation of independent variables

[6] The estimates of start times by this method for 3 shires - Greenough, Irwin and Westonia - were not used. The nature of the fitted curve for these shires was such that the start times estimated were clearly absurdly early. For these shires, the minimum level A_1 was taken from the real data and 10% of the difference between the estimated ceiling C and A_1 was added to A_1 to give a value for y. This was then used to read visually a value for t from the fitted curve.

[7] Many shires had a residual number of farmers still growing lupins following the release, adoption and then disadoption of early varieties in the 1970s.

A considerable number of possible independent variables have been investigated. Only those used in the regression analyses with start time as the dependent variable are detailed here. It was hypothesised that factors affecting start times would be those that reflected the agronomic suitability of the shire for lupins such as rainfall, the percentage of soils suitable for lupins, and the relative importance of cropping in the shire; and those that reflected awareness of the innovation either through early experience with growing lupins in the 1970s, or closeness to, and amount of, district-specific information. It was suspected that the activities of private consultants could also be a significant factor in some regions.

Variables described in sections i and ii are intended to capture the potential profitability of the new crop in the region. The results obtained by Griliches (1957), illustrating the importance of profitability on the rate and ceiling level of adoption, have been supported by other work. For example, Ruttan's (1977) review of the adoption of high yielding rice varieties indicated that they were adopted more rapidly in areas where they were more profitable. Similarly, Feder and Umali (1993), report that recent studies of complete adoption patterns for high yielding rice varieties indicate that the production environment was the most important factor in explaining differential adoption patterns. Variables pertaining to the yield characteristics of lupins in different areas were not used in the adoption start time analyses, as these variables were calculated over time (e.g. average yields and associated variances). It was considered that these variables would impact on rate and ceiling level of adoption, rather than start times.

Variables considered at various times in the multivariate regression analyses conducted were:

i) Estimates of percentage of soils suitable for lupins in the shire

S4 Estimate of percentage of suitable lupins soils[8].
Expected sign - negative.

ii) Measures of climatic variability

RM Estimate of shire rainfall in mm. This measure has inherent difficulties as some shires (e.g. Mullewa) have widely varying rainfall within the shire.
Expected sign - negative.

RF A dummy variable intended to capture shires with very low rainfall. All shires with approximately 50% or more of their area outside the 350mm rainfall isohyet were scored as 1.
Expected sign - positive.

---

[8] All soil estimates were based on the classification of Northcote *et al.* (1960). The S4 estimate adjusted some shires using an adaptation of the Northcote data done by Wilkinson (1994), and had the highest correlation of all the estimates with the estimated ceiling level (i.e. R^2 of 0.16, compared with R^2 of less that 0.03 for the S1, S2 and S3 estimates).

NS A dummy variable intended to capture the shorter growing season in the northern wheatbelt. All shires north of a line running east-west through the bottom of Dandaragan shire were scored as 1.
Expected sign - negative.

iii) Variables to capture extent of cropping intensity in shires

This variable was included to capture the relative importance of cropping, and hence the profitability of competing grazing enterprises, in different shires.

CLD1 The percentage of farmland in a shire that is cropped, averaged for the years 1980 to 1984.
Expected sign - negative.

iv) Variable to capture farmer experience with growing lupins

Farmers in some shires (mostly in the northern wheatbelt) grew lupins in the 1970s after the initial release of Uniwhite and other early cultivars. Poor seasons and management problems led to disadoption of lupins in the late 1970s. This variable is intended to capture the experience and knowledge gained by those farmers. Feder and Slade (1984) briefly review studies that support the conclusion that level of knowledge is important in explaining adoption behaviour. Although most studies emphasise the benefit of the accumulation of favourable experiences, which was not generally the case for farmers who grew the early lupin varieties, it was hypothesised that experience gained would shorten the re-adoption decision once farmers were convinced that agronomic problems had been overcome. The model developed by Feder and Slade (1984) suggested that a certain critical level of cumulative information must be attained before adoption takes place. Farmers who grew the early lupin varieties had already accumulated much of the technical knowledge needed, and only needed to be convinced of the superiority of the new variety and alternative management techniques.

LF The percentage of farmers in the shire growing lupins in 1978 (prior to the release of higher yielding varieties).
Expected sign - negative.

v) Measures of distance from information sources

Distance from information sources has been shown to be a significant factor influencing adoption. In their study of the adoption of trace element fertilisers, Lindner *at al.* (1982) concluded that distance to the source of the innovation was a barrier to adoption. They debated whether advances in communication technology would make distance irrelevant, but suspected that potential adopters would still face problems relating to distance from information source when trying to assess whether innovations were suitable for their specific area. Both DAWA district offices and research stations are treated as information sources. The former being the base location of research officers and advisers with district-specific information, and the latter being the location of much district-specific trial work. Griliches (1960) explains some of the unexpected deviations in his data in terms of the contributions made by specific agricultural research stations.

DO Distance in km of the shire from the DAWA district office to which the shire belongs. In most cases this has been measured from an approximate midpoint of the shire except where there is reason to do otherwise (e.g. eastern shires such as Yilgarn where much of the shire is outside the agricultural area).
Expected sign - positive.

DRS Distance in km of the shire from the nearest DAWA Research Station - measured as before. (Only Chapman, Wongan Hills, Badgingarra, Merredin and Newdegate Research Stations are considered as the annexes attached to Chapman and Merredin Stations - i.e. East Mullewa and South Carrabin - were not operational until the mid-1980s).
Expected sign - positive.

vi) Measures of DAWA extension activities

These variables capture a range of activities conducted by DAWA, including Research Station trials and on-farm trials[9] (more technically speaking information sources - but used as a focus for field days and field walks), field days, seminars and meetings, and Agmemo[10] information. Additionally, some variables measure the number of advisers working in different areas, both as related to the number of farmers in that area and the distances they have to travel to service farmers in the district.

These variables are intended to capture variation in information available to farmers in different areas through the activities of extension personnel. Most of the information measures are cumulative, to capture the on-going exposure of farmers to information. This is in recognition that adoption is essentially a dynamic learning process as described by Lindner (1987). As an individual accumulates information, they are able to reassess their beliefs about an innovation and review their decision of whether or not to adopt. As mentioned previously, work by Feder and Slade (1984) suggests that a certain critical level of cumulative information must be attained before adoption takes place.

Extension workers have been found to be influential in providing information to farmers. Feder *et al.*(1987) report that there has been an acceptable rate of return to investment in intensified extension (a training and visit system in northwest India), and that this is largely because of the increased availability of farmers to extension

[9] On-farm trials are those conducted by DAWA on farmers' properties. Mostly these are conducted by DAWA advisers working out of individual district offices, but some are conducted by research staff from DAWA's head office. Some use the farmer's machinery, but most use DAWA's machinery suitable for working small replicated plots. Crop variety trials (i.e. those evaluating different cultivars of a crop) are conducted from DAWA's head office, and have not been counted as on-farm trials, even when they occur on farmers' properties.
[10] Agmemos are published regularly by individual DAWA district offices, and give brief timely district-specific information. They are sent by mail to all farmers within the advisory district.

agents. Similarly Hussain *et al.* (1994) report that training and visit systems in Pakistan have increased the quantity of extension contact, and this has increased farmers' knowledge and adoption of technology. Polson and Spencer (1991) report that the activities of extension workers in Nigeria were significant in the early adoption process. Strauss *et al.* (1991) report on a Brazilian study that attempted to measure the quality of extension personnel by measuring their experience, and concluded that there was benefit in investing in the human capital of extension workers.

The impact on adoption of farmers' participation in trials and field days is less well established. Harper *et al.* (1990) concluded that farmers' attendance at specific field days was significant in the adoption of insect management technologies. Abler *et al.* (1992) were unable to say whether farmers' participation in field trials had any affect on adoption of new technologies in Swaziland, although Grimsley (1994) concluded that on-farm trials may be an effective, but limited method for diffusing new varieties in Uganda.

Variables used in the start time analyses were:

ADR79 This is a measure of DAWA adviser density in the shire for the year 1979. It has been calculated by simply dividing the number of farmers in the DAWA district by the number of advisers working in the district office. Officers-in-Charge and advisers, but not Research Officers, veterinarians and technical support staff, have been counted as advisers for this purpose.
Expected sign - positive.

ADVD79 This is a measure that attempts to account for the interaction between number of advisers servicing a district and the distances they have to cover to service the farmers in their area. It has been calculated by dividing the distance of the shire from the district office by the number of advisers working in that district (for the years 1979).
Expected sign - positive.

F80 This is a cumulative measure of field days, meetings and seminars held in the shire which featured lupins either wholly or partly upto and including the year 1980. This variable attempts to measure the level of extension activity about lupins in a shire in the form of DAWA field days, DAWA meetings and seminars, and DAWA Research Station field days. All these activities have been tabulated separately in the database, but numbers are small, hence it was necessary to aggregate, especially for start time analysis. Research Station field days are counted for the shire in which the Research Station is located plus all directly adjoining shires. In the start time analyses, this variable has been squared (**SQF80**), to give more weight to shires which have had more than a few extension activities, in recognition that a number of information opportunities has potential to have a greater than linear impact.
Expected sign - negative.

TN78 This is a cumulative count by year of the number of on-farm lupin trials in the shire conducted by DAWA for the year 1978. Trials have been counted as

having a value of 1 in the shire in which they were located, and as having a value of .75 in adjoining shires. This is to attempt to account for information leakage across shire boundaries.
Expected sign - negative.

TN80 A cumulative count by year of the number of on-farm lupin trials conducted by DAWA for the year 1980.
Expected sign - negative.

RST78 A cumulative count of the number of Research Station trials for the year 1978. The trials are counted for the shire in which the Research Station is located plus adjoining shires.
Expected sign - negative.

RST80 A cumulative count of the number of Research Station trials for the year 1980.
Expected sign - negative.

RSN A dummy variable for shires with, or adjacent to a shire with, a Research Station within their boundaries.
Expected sign - negative.

GER A dummy variable intended to capture the major extension effort by DAWA in the Geraldton district. All shires in the DAWA Geraldton district are scored as 1 except Morawa and Mullewa. These two shires have large areas with low rainfall, and were not considered suitable for lupin production in the initial years of the extension effort in the Geraldton district.
Expected sign - negative.

MER A dummy variable intended to capture the major extension effort by DAWA in the Merredin district. All shires in the DAWA Merredin district, plus Tammin and Wyalkatchem (from the Northam district), are scored as 1. Material from interviews with DAWA personnel who worked in Merredin at this time frequently mentioned that farmers from Tammin and Wyalkatchem shires travelled to field days in the Merredin area and were visited (unofficially) by DAWA advisers and research officers based in the Merredin area.
Expected sign - negative.

vii) Measures of private extension activity

In the late 1970s and early 1980s a number of private farm management consultants were active in some shires (far fewer than are operating today). Survey and anecdotal data indicated that they were actively promoting lupins in the areas they serviced. There is little work on the impact of private extension consultants on adoption, although Lazenby *et al.* (1994) report that evidence from W.A. suggests that farmers employing private consultants adopt new varieties about twice as quickly as those who do not use consultants.

CON A dummy variable. Shires with more than 20 farmers using a consultant (in the late 1970s/early 1980s) are scored as 1[11].
Expected sign - negative.

KS This is a dummy variable to account for the activities of a private consultant working in the Dowerin and Cunderdin shires. Merredin DAWA personnel mentioned (in taped interviews) that this particular consultant was in regular contact with them with regard to information about lupins.
Expected sign - negative.

4. RESULTS

The data was analysed by multivariate regression analysis using MICROFIT®.

Both SG10 and SA10 were used as dependent variables. Considerably better values for R^2 were obtained using SA10. Although a cursory glance at the start times estimated by the two methods suggests that they are quite similar, some Gompertz estimates are considerably earlier. This usually occurred when the estimate for A (i.e. the residual number of farmers growing lupins before the start of the diffusion process) was negative. Only results using SA10 as the dependent variable are reported here.

Variables which appear in a number of final models are LF, CLD1, F80, ADVD, ADR79, GER, KS, MER, CON. The most consistently appearing significant variables (not including dummy variables) are LF, F80 and ADVD. Real data values for F80 were very small (ranging from 0 in many shires to a maximum of 3 in 1980), so to give more weight to the impact in shires where a number of extension activities had occurred, this variable was squared and called SQF80. The decision to include F80 or SQF80 was subjected to non-nested tests. Results for some final models are given in Table 1.

Models 1 and 2 compare models with F80 and SQF80 respectively. All variables except CLD1 are significant at 10% or lower, and coefficient signs are as expected. Non-nested tests show that Model 2 (with SQF80 replacing F80) is preferred to Model 'ested tests indicate that CLD1, despite it being an insignificant variable, should dropped from Model 2. Model 4 shows results for this model without the three ..y variables included. Values for R^2 are only 0.1 lower, and the coefficients appear to have behaved as might be expected, taking on more impact to compensate for the absence of the dummy variables. CLD1 becomes significant at 1% in this model.

Model 3 shows results when a different approach was taken, substituting the F80 variable with ADR79, the variable that describes the ratio of farmers to DAWA advisers working in the area. These two variables have, as might be expected, a high

[11] Some guesswork has been involved here as some prominent consultants working at this time refused to give details on the location of their clientele.

Table 1 - Sample size 40

Regressors	Coefficient	T-Ratio	Regressors	Coefficient	T-Ratio
Model 1: $R^2 = 0.84$ R-bar$^2 = 0.80$			**Model 2:** $R^2 = 0.85$ R-bar$^2 = 0.82$		
CLD1	-1.4684	-1.5260	CLD1	-1.5452	-1.6822
LF	-3.7991	-3.4776 ***	LF	-4.5024	-4.2265 ***
F80	-0.2251	-1.9614 *	SQF80	-0.11179	-2.7009 **
ADVD	0.017679	2.2091 **	ADVD	0.017340	2.2816 **
GER	-1.4585	-5.4475 ***	GER	-1.2784	-4.6471 ***
KS	-0.67502	-2.1929 **	KS	-0.70137	-2.3828 **
MER	-0.43980	-2.4407 **	MER	-0.43609	-2.5616 **
Model 3: $R^2 = 0.82$ R-bar$^2 = 0.79$					
LF	-2.8338	-2.7313 ***			
ADVD	0.016462	2.2625 **			
GER	-1.6534	-6.8837 ***			
KS	-0.78760	-2.5421 **			
MER	-0.73366	-3.2680 ***			
ADR79	0.0023756	1.7313 *			
Model 4: $R^2 = 0.72$ R-bar$^2 = 0.68$			**Model 5:** $R^2 = 0.42$ R-bar$^2 = 0.37$		
CLD1	-3.8539	-3.7319 ***	LF	-4.2067	-2.3986 **
LF	-6.5301	-5.5142 ***	ADVD	0.015736	1.2557
SQF80	-0.21283	-5.3186 ***	ADR79	0.0025423	1.6337
ADVD	0.021370	2.1708 **			

*** Significant at 1%
** Significant at 5%
* Significant at 10%

Table 2 - Sample size 33

Regressors	Coefficient	T-Ratio	T-Ratio (White's Adjusted)
Model 6: $R^2 = 0.54$ R-bar$^2 = 0.41$			
CLD1	-1.6128	-0.9430	-1.0837
LF	-5.5216	-1.1201	-1.0204
SQF80	-0.13676	-0.91796	-1.4468
ADVD	2.1652	0.80136	0.55675
GER	-0.56141	-0.49697	-0.71414
KS	-1.0229	-2.1478 **	-4.5684 ***
MER	-0.73247	-2.4321 **	-2.4899 **
Model 7: $R^2 = 0.38$ R-bar$^2 = 0.29$			
CLD1	-3.4247	-2.0845 **	
LF	-2.4026	-0.48828	
SQF80	-0.1816	-2.8956 ***	
ADVD	1.6457	0.56334	
Model 8: $R^2 = 0.57$ R-bar$^2 = 0.51$			
ADR79	0.00464	2.2513 **	2.1443 **
SQF80	-0.20176	-3.6020 ***	-4.9208 ***
CON	-1.0632	-3.4790 ***	-3.7910 ***
MER	-1.5457	-4.3893 ***	-3.8713 ***

*** Significant at 1%
** Significant at 5%

negative co-variance. This model was first run with CLD1 included, but nested tests indicated that it should be dropped from the function. Non-nested tests indicate that Model 3 is actually a preferred model to Model 2, despite a slightly lower value for R^2. However, when this model is run without the three dummy variables (see Model 5 in Table 1), the value for R^2 drops considerably, and both ADVD and ADR79 become insignificant variables. Model 2 seems to be the most stable description of factors that impact on the start times of the adoption of lupins in different areas. Diagnostic test indicted that heteroscedasticity and functional form[12] were not problems for any of the models described in Table 1.

The estimations highlight the importance of prior experience in influencing the start time of adoption. The value for LF (i.e. the percentage of farmers in the shire growing lupins in 1978) has a big impact for shires where it is high. It is consistently the most significant variable (in the sense of having the highest T-ratio). To further test the stability of the model, it was estimated with a data set in which shires with large values for LF had been removed. Seven shires had values for LF greater than 0.1[13], and an additional 10 had values for LF greater than 0.05. The seven shires with LF greater than 0.1 were removed from the data set and the analysis conducted on the remaining 33 shires. Results are given in Table 2.

Models 6 and 7 correspond with Models 2 and 4 in Table 1 respectively. Values for R^2 have fallen considerably. This is to be expected because much of the variation in the data set that the model was explaining has been removed. The earliest start times were associated with shires that had previously grown considerable areas of lupins in the 1970s and so had the highest values for LF. Looking at Model 7, with dummy variables excluded, coefficients remained correctly signed and, except for ADVD and LF, of comparable magnitude. CLD1 and SQF80 remained significant variables. It could be expected that LF would no longer be a significant variable, as the shires where this variable was high have been removed from the data set. ADVD becoming insignificant was unexpected, and this must cast some doubt on the validity of the statistical significance of this variable. When dummy variables were added to the regression, KS and MER became the only significant variables, indicating the importance of the Merredin extension effort for the shires which had not grown lupins in the 1970s.

Model 8 is a different approach, to try and account for the different information sources in these shires. This approach should be valid as diagnostic tests show a structural break between the two data sets, but sample sizes are possibly too small to test this. As LF and GER could be expected to have less impact on the regression (three of the five shires in the GER dummy have been excluded from the data set), these were omitted as variables. Private consultants were active in a number of shires in the restricted data set, so the CON variable was used instead of the more specific KS variable. The absence of private consultants from the Geraldton area, with the earliest starts, had prevented this variable from featuring in the original regressions. Variables describing extension activity, distances covered by advisers and the

[12] Based on the regression of squared residuals on squared fitted values for heteroscedasticity, and Ramsey's RESET test (which uses the square of the fitted values) for functional form.

[13] These were Greenough, Irwin, Mingenew, Dandaragan, Moora, Coorow and Three Springs.

farmer/adviser ratio (i.e. F80, ADVD and ADR79) were included. It was hypothesised that farmers in these areas would be more dependent on knowledge gained from adviser activity, rather than their previous experience growing lupins. ADVD and CLD1 were not significant variables, and a variable deletion test showed that they could be dropped. As shown in Table 2, all other variables were significant in Model 8 were significant.

Models 6 and 8 had significant heteroscedasticity at 10%. The T-ratios were recalculated using White's heteroscedasticity-consistent Standard Errors[14], and are also shown in Table 2. For Model 6, T-ratios associated with SQF80 and KS increased substantially, although SQF80 was still not significant. For Model 8, there was some change in T-ratios but the level of significance of the variables remained unchanged.

5. DISCUSSION

Did extension make a difference? Our work suggests that there is evidence to suggest that extension did make a difference, of about 1 to 2 years, in the start time of the adoption of lupins. Approximately 70% of the variability in start time has been accounted for by four variables, two of which (SQF80 and ADVD) are measures of extension activity. A third variable, LF, describes the percentage of farmers with previous experience of the technology. The remaining variable, CLD1, is a measure of the profitability of cropping in the area compared to alternative grazing enterprises. All variables are significant at 5%. The addition of three dummy variables which take account of major DAWA extension efforts in the Geraldton and Merredin areas, and the activities of a private consultant, result in the model describing over 80% of the variability in start time. The significance of these variables suggests that concerted extension activity from either the public or private sector, as occurred in these areas, does influence adoption start times.

The acquisition of knowledge, either through previous experience or the activities of extension agents, seems to be important in influencing the start time of the adoption process. This supports previous findings, as outlined in Section 3. The inclusion of the variable ADVD suggests that distance from information sources can be overcome with the addition of more extension personnel, but distance from information sources remains a barrier to early adoption. This could have implications as cutbacks in funding and restructuring of State Departments of Agriculture occur throughout Australia.

No evidence was found to suggest that on-farm or research station trials influenced the start time of the adoption process. A study of the data for these variables shows that many trials take place in areas, not especially suited to lupins, with specific production problems (e.g. potash rates required on poor coastal sands).

[14] This still uses OLS to estimate the coefficients and the variance, but does so with a consistent estimator of the variance-covariance matrix.

Although not reported in this paper, our results show that extension was not a factor influencing ceiling levels of adoption of lupins. Significant variables in this analysis were those describing yields, rainfall and percentage of the shire cropped. These are all variables which measure the production environment, and impact on profitability. These findings are also supported by previous research. Analysis of the rate of adoption is currently in progress.

The study has some major limitations. The question of how to measure extension is intrinsically difficult. Records of extension activities conducted by regional DAWA offices are often incomplete, and activities such as field walks, which agents claim are one of their most effective for extending information, have been unable to be counted. Data for field days in the early 1980s has been difficult to collate, because of less than adequate records. The breakdown of data by shire is essentially artificial, and we expect that there would be significant information leakages across these artificial boundaries. We have major reservations about the validity of the soil estimates, as the Northcote classification is essentially ill-suited to this type of breakdown. Unfortunately, it is the only classification covering the entire area of the study able to be broken down quanititatively on a shire basis.

The sample size (43 shires) is small, and this must cast some doubt on the validity of the statistical analysis. Collinearity between independent variables is another problem, although this does not affect the validity of the statistical test, but reduces its power. Statistical difficulties also arise when estimates (with associated standard errors) are used as dependent variables.

6. ACKNOWLEDGMENT

This project is funded by a grant from the Rural Industries Research and Development Corporation.

REFERENCES

ABLER, David, G., RAUNIYAR, Ganesh P. and GOODE, Frank M., 1992, "Field Trials as an Extension Technique: The Case of Swaziland", *Northeastern Journal of Agricultural and Resource Economics*, 21 (1), pp 30-35.

DIXON, Robert, 1980, "Hybrid Corn Revisited", *Econometrica*, 48 (6), pp 1451-1461.

FEDER, Gershon, LAU, Lawrence J. and SLADE, Roger H., 1987, "Does Agricultural Extension Pay? The Training and Visit System in Northwest India", *American Journal of Agricultural Economics*, 69(3) , pp 677-686.

FEDER, Gershon and SLADE, Roger, 1984, "The Acquisition of Information and the Adoption of New Technology", *American Journal of Agricultural Economics*, 66 (4), pp 312-320.

FEDER, Gershon and UMALI, Dina L., 1993, "The Adoption of Agricultural Innovations: A Review", *Technological Forecasting and Social Change*, 43, pp 215-239.

GLADSTONES, J.S., 1982, "Breeding Lupins in Western Australia", *Journal of Agriculture - Western Australia*, 23: pp 73-76.

GRILICHES, Zvi, 1957, "Hybrid Corn: An Exploration in the Economics of Technological Change", *Econometrica*, 25 (4), pp 501-522.

GRILICHES, Zvi, 1960, "Hybrid Corn and the Economics of Innovation", *Science*, 132, pp 275-280.

GRISLEY, W., 1994, "Farmer-to-farmer transfer of new crop varieties: an empirical analysis on small farms in Uganda". *Agricultural Economics*, 11, pp 43-49.

HARPER, Jayson K., RISTER, Edward M., MJELDE, James W., DREES, Bastiaan M. and WAY, Michael O., 1990, "Factors Influencing the Adoption of Insect Management Technology", *American Journal of Agricultural Economics*, 72 (4), pp 997-1005.

HUSSAIN, Syed Sajidin, BYERLEE, Derek and HEISEY, Paul W., 1994, "Impacts of the training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan", *Agricultural Economics*, 10, pp 39-47.

LAZENBY, A., BARTHOLOMAEUS, M., BOUCHER, B., BOYD, W.R., CAMPBELL, A., CRACKNELL, R., EAGLES, H., LEE, J., LUKEY, G. and MARSHALL, B., 1994, *Trials and Errors: A Review of Variety Testing and Release Procedures in the Australian Grains Industry*, Grains Research and Development Corporation, Canberra.

LINDNER, R.K., 1987, "Adoption and Diffusion of Technology: An Overview", in *Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics*, Eds. Champ, B.R., Highley, E. and Remenyi, J.V., ACIAR, Proc No 19, pp 144-151.

LINDNER, R.K., PARDEY, P.G. and JARRETT, F.G., 1982, "Distance to Information and the Time Lag to Early Adoption of Trace Element Fertilisers", *Australian Journal of Agricultural Economics*, 26 (2), pp 98-113.

MAHAJAN, V. and PETERSON, R., 1985, *Models for Innovation Diffusion*, Sage Publications.

NORTHCOTE, K.H., BETTENAY, E., CHURCHWARD, H.M. and McARTHUR, W.M., 1960, *Atlas of Australian Soils: Explanatory Data for Sheet 5*, CSIRO, Melbourne University Press.

NELSON, P., 1987, "Changing Farming Systems in the Geraldton Area - A Case Study in Extension", paper presented to the Australasian Extension Conference, Brisbane.

POLSON, Rudulph, A. and SPENCER, Dunstan, S.C., 1991, "The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in Southwestern Nigeria", *Agricultural Systems*, 36, pp 65-78.

RUTTAN, V., 1977, "The Green Revolution: seven generalizations", *International Development Review*, 19, pp 16-23.

STRAUSS, John, BARBOSA, Mariza, TEIXEIRA, Sonia, THOMAS, Duncan and GOMES JUNIOR, Raimundo, 1991, "Role of education and extension in the adoption of technology: a study of upland rice and soybean farmers in Central-West Brazil", *Agricultural Economics*, 5, pp 341-359.

VALENTE, Thomas W., 1993, "Diffusion of Innovations and Policy Decision-Making", *Journal of Communication*, 43 (1), pp 30-45.

WILKINSON, Claire E.C., 1994, "Reforms of the European Common Agricultural Policy and the implications on the West Australian lupin industry - A whole-farm mathematical modelling approach", A dissertation submitted in partial requirement of the requirements for the Bachelor of Science (Agriculture) in the Faculty of Agriculture, University of Western Australia.

Paper presented at the 39th Annual Conference of the Australian Agricultural Economics Society, University of Western Australia, February 14-16, 1995.

APPENDIX 1

The statistical package GENSTAT® was used to fit functional forms to the data. GENSTAT ® fitted three different variations of the logistic curve to the data as follows:

- A standard logistic function - $y = A + C/(1 + e^{-b(t-m)})$

This function describes a symmetrical curve, with a maximum rate of adoption (point of inflection) when 50% of the final ceiling level is reached (or in this case A+C/2 percent).

- A Gompertz function - $y = A + C/(e + e^{-b(t-m)})$

This function describes an asymmetrical curve that reaches its maximum rate of adoption earlier in the diffusion process, when approximately 37% of the final ceiling level is reached (or in this case when the percent of farmers adopting is A + C/e).

- A generalised logistic function (Richards) - $y = A + C/(1 + Te^{-b(t-m)})^{1/T}$

This function describes a more flexible asymmetrical curve that has a point of inflection at a variable point determined by the interaction of parameters b and T. As $T \rightarrow 0$, the function tends to the Gompertz.[15]

In all cases y is the percent of farmers growing lupins in year t. The other parameters are described as:

- C - the ceiling (or maximum) level of adoption attained,
- b - the intrinsic rate of adoption, and
- m - the time at which the maximum rate (ie. the point of inflection in the curve) of adoption is reached.

Because many shires had a residual number of farmers still growing lupins following the release, adoption and then disadoption of early varieties in the 1970s, it was necessary to estimate a fourth parameter:

- A - the residual number of farmers growing lupins before the commencement of the diffusion process

Without this parameter the fitted curve was constrained to pass through the origin, resulting in poor fits for many shires.

Getting a good fit to the data depended for many shires on a judicious selection of the years to be analysed. For years prior to 1979 ,the percentage of farmers growing lupins was actually declining following the adoption and disadoption of early lupin varieties in the 1970s. For most shires a starting year of 1979 seemed appropriate, and produced satisfactory results. Selecting a finish year for the purpose of the analysis proved more difficult. Ideally the data should be run through to the present, but in a fair proportion of shires, the percentage of farmers growing lupins has either fallen since 1987 to 1992 (by up to 20%), or fell sharply in 1988, 89 and 90 before recovering to 1987 levels. In this situation, if data is analysed over the time period to the present, a slower adoption rate is estimated and the estimated curve misses the peak adoption. For the purposes of this study we are interested in the sometimes rapid rate of adoption that occurred in the early 1980s, and wish the parameters to reflect this. Our subjective selection of the years to analyse has been done with this purpose in mind.

---

[15] $\lim_{n \to \infty} (1 + x/n)^n \rightarrow e^x$