Meeting producer knowledge requirements to enable 'successful' sub-tropical grass establishment and management

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Abstract. In the southern regions of New South Wales (NSW), Australia there is increasing interest in sub-tropical grasses in response to increased summer rainfall and declining temperate grass productivity. Producers across inland NSW were surveyed about their interest in and experience with growing these grasses. We found significant positive relationships between intention to sow new areas to sub-tropical grasses and a high level of awareness; possessing a sound knowledge of sub-tropical and general agronomy; highly rating their benefits; possessing a business focus; and concern about reduced temperate pasture persistence. While one-third of interested producers indicated their intention to sow sub-tropical grasses, most reported insufficient knowledge to 'successfully' establish these grasses. Around half of experienced producers reported insufficient knowledge to 'best' manage these grasses once established. We discuss the implications of these findings for extension planning around sub-tropical grasses, highlighting the need to meet the specific knowledge requirements based on producer experience.

Keywords: farmers, perennial tropical pastures, awareness, intention, experience, adoption.

Introduction

Tropical grasses are an important component of grazing systems globally, including Australia (Moser et al. 2004). In inland, northern New South Wales (NSW), sub-tropical grasses, including digit grass (*Digitaria eriantha*), Bambatsi panic (*Panicum coloratum var. makarikariense*) and Rhodes grass (*Chloris gayana*) are highly productive and persistent, responsive to summer rainfall events and nitrogen fertiliser (Boschma et al. 2015; Boschma et al. 2017). In the central and southern geographical regions of NSW there is increasing interest in these grasses to contribute to the forage supply for livestock over the summer-autumn period (Sinclair et al. 2021). This growing interest is a response to an increase in the frequency of rainfall events over summer together with a decline in the productivity of temperate grasses (Sinclair et al. 2021). These changes align with climate change projections and farm system modelling for south-eastern Australia (Cullen et al. 2009; CSIRO & BoM 2015; CSIRO & BOM 2018; Cullen et al. 2021).

The recently completed five-year multidisciplinary research project, "Increasing livestock production by integrating tropical grasses into farming systems" (Boschma et al. 2022) investigated the opportunity to increase the productivity of red meat production in southern Australia. Field experiments located across inland NSW evaluated sown sub-tropical grass species for their agronomic potential. Modelling assessed the potential distribution of these across south-eastern Australia and investigated the potential economic and other benefits of replacing temperate pastures with sub-tropical pastures. Social research studies focussed on understanding the adoptability of sub-tropical grasses, a new practice, across inland NSW.

Within the Australian agricultural adoption literature, a useful conceptual framework has been advanced by Pannell et al. (2006) within which adoption of a new practice can be explored. Those researchers concluded that a producer's decision to adopt a new practice is shaped by four key sets of interacting factors: their personal characteristics and circumstances, their wider social context, the attributes of the practice, and the support they receive through the adoption process. While belonging to networks and local organisations and having access to trusted and experienced extension agents are key avenues supporting producers to change, the other three sets of factors provide the context within which the adoption decision-making process is shaped. A producer's personal goals, values, motivations, capacity to invest and aversion to risk as well as property location and characteristics are important context considerations. A key consideration in the adoption decision-making process is for a new practice to have a perceived relative advantage, although attributes relating to learning and skill development of a new practice are also important (Pannell et al. 2006).

Relative advantage refers to the extent to which a new practice is perceived as being better than the existing practice (Rogers 2003). That is, for a new practice to be adopted there needs to be a net benefit particularly in terms of profitability although a range of economic, social and environmental factors can be important including its degree of complexity and compatibility with

existing practices (Pannell et al. 2006; Kaine & Wright 2022). Relative advantage is a key decisive factor in determining the ultimate extent a new practice is adopted (Kaine & Wright 2022).

Building knowledge, skills and confidence helps to inform a producer's decision to adopt a new practice while reducing uncertainty about that practice (Chavas & Nauges 2020). While learning and skill development is a unique process undertaken by individual producers in their adoption journey, Pannell et al. (2006) proposed a multi-phased process of adoption including awareness, non-trial evaluation, trial evaluation, adoption, review and modification, and dis-adoption. Non-adoption may be a sound decision for a producer, and adoption may not always be linear in that a new practice may be partly adopted or adopted for a short period and then rejected (Pannell & Classen 2020).

The CSIRO web-based tool ADOPT (Adoption and Diffusion Outcome Prediction Tool) is a quantitative forecasting model that has been developed by Kuehne et al. (2017) to predict the likely uptake of new agricultural practices and to estimate the influence of a range of variables on adoption decision making. The ADOPT tool recognises the relative advantage of a new practice and learning about the relative advantage as key drivers in the adoption decision process (Montes de Oca Munguia et al. 2021). The tool explicitly accounts for the interaction between the characteristics of a new practice and those of the adopter as emphasised by Pannell et al. (2006) among others (Montes de Oca Mungia & Llewellyn 2020). The tool has been found to be useful particularly in ex-ante adoption planning (i.e. assumes a hypothetical intention to adopt a practice) by extension practitioners (Montes de Oca Munguia et al. 2020). However, it is limited by the lack of specific data about the target population, particularly in acknowledging its heterogeneity and the specific learning needs within the target population which according to Vanclay (2004) are important for enabling effective change. It also does not consider external factors (i.e. climate change) that could potentially impact the adoption decision (Kuehne et al. 2007).

While the ADPOT tool employs a set of variables likely to influence the adoption of a new practice, for extension to be most effective in supporting producers' adoption decision making the information and the strategies employed must be targeted (i.e. must be location and audience specific) (Black 2000; Nettle et al. 2024). This requires the collection of descriptive information about the producer population and their farming context to identify different producer cohorts and their specific information requirements (Lewellyn 2011). At the same time, understanding the drivers and challenges to adopting the new practice in the design and implementation of extension programs is necessary, which requires resources in terms of cost, labour and time to gather, analyse and interpret the collected data.

In our social research studies, we had the budget and time allocated within the larger project to collect specific information about the targeted population. Firstly, we conducted a series of workshops with purposively selected producers to gather data about producers' experiences in establishing and managing sub-tropical grasses, and the support interested producers required to sow these grasses (Sinclair et al. 2019; Sinclair et al. 2021). A broad survey of producers was designed following the producer workshops as these workshops did not define where and to what extent producers had sown or were interested in sowing sub-tropical grasses. The survey set out to quantify the extent to which livestock producers have trialled and are managing sub-tropical grasses, and for those who have not trialled, their interest in trialling those grasses and to identify the key factors enabling or constraining trialling; and/or successfully managing sub-tropical grasses.

The focus of this paper is to describe key findings from the survey and to use these findings to identify and understand the factors influencing producer adoption intentions regarding sub-tropical grasses. The findings from the survey will contribute to the design and delivery of targeted extension plans to build the capacity of producers to make effective decisions about these grasses.

Method

Producer survey instrument

A draft survey instrument was developed based on the information gathered from the producer workshops (Sinclair et al. 2019; Sinclair et al. 2021) and prior research identifying influences on producer adoption decision making (Pannell et al. 2006; Montes de Oca Munguia et al. 2020). The draft instrument was pre-tested with six producers (three experienced with sub-tropical grasses and three interested in growing sub-tropical grasses), with amendments made to the survey following their feedback. The main topics in the survey included:

- Level of awareness, adoption intentions, and experience with sub-tropical grasses
- Knowledge about sub-tropical grass agronomy and general agronomy practices

- Benefits and concerns about growing sub-tropical grasses
- Farm structure and business enterprise
- Values attached to the property, long-term plans for the property, and issues of concern affecting the property and district.

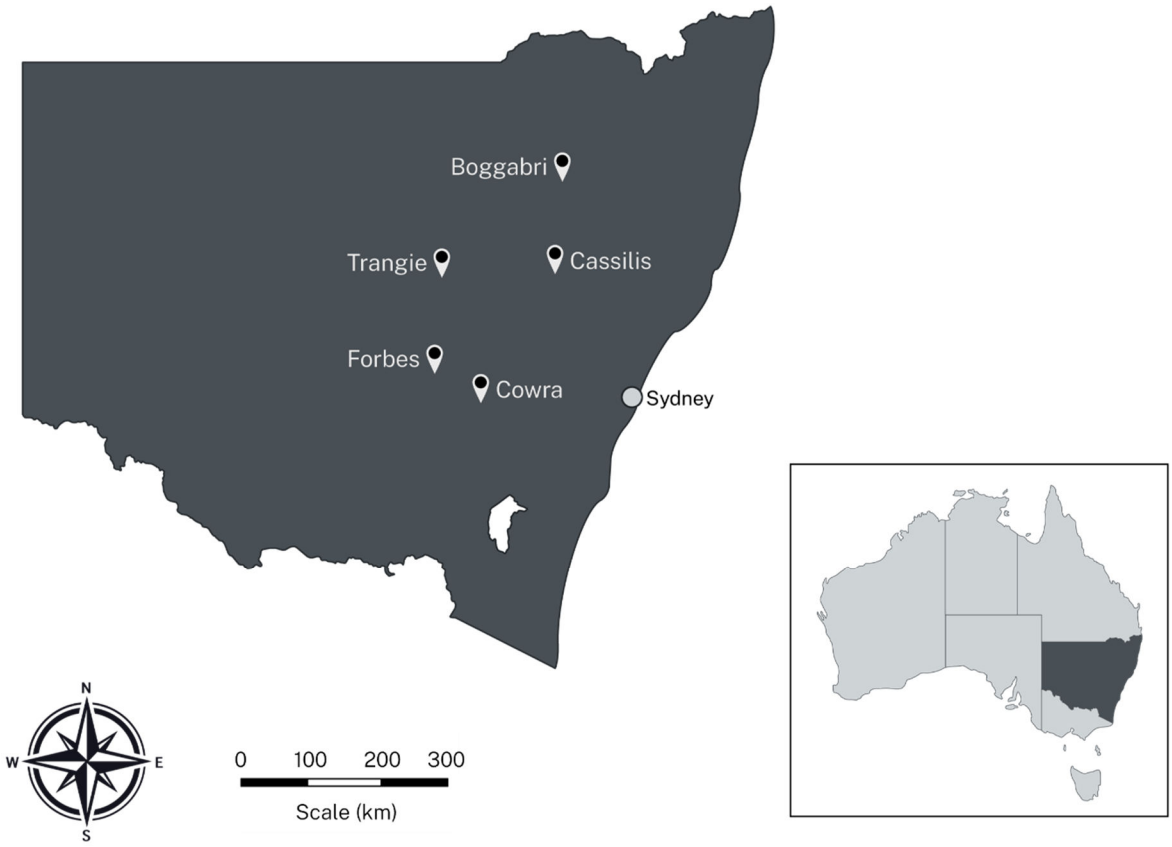
Response options in the survey included numeric responses (e.g. property size in hectares), binary responses (e.g. have or have not sown tropical grasses) and Likert-type response options with rating on a scale of 1 to 5 (e.g. 1 = not important to 5 = very important).

Survey distribution

Five districts in NSW centred on the towns of Boggabri, Cassilis, Trangie, Forbes and Cowra, were selected to be surveyed (Figure 1). In the Boggabri and Cassilis districts, located on the North West Slopes, sowing sub-tropical grasses is a well-established practice. The Forbes and Trangie districts, located on the Central West Slopes and Plains, and the Cowra district, located on the South West Slopes, are areas with limited sowings of sub-tropical grasses but with increasing producer interest in these grasses.

In early spring 2020, 200 printed surveys were delivered to property mailboxes along selected roads radiating out from each of the five towns listed above with 1000 surveys distributed in total. The mailbox address was recorded and two reminder/thank you cards mailed out following the process outlined by Dillman (1979) cited in (Curtis et al. 2005). With winter crop harvest approaching in these districts, the second survey mail out process was delayed until early 2021. The survey was also made available online to producers across NSW from February to mid-April 2021. There were 115 usable mail out surveys (response rate = 11.6%) and 45 usable online surveys totalling 160 usable surveys for analysis. The number of usable surveys was reasonably evenly distributed across districts: Boggabri (33), Cassilis (30), Trangie (41), Forbes (28) and Cowra (26). Survey respondents appear to be representative in that property size and enterprise mix across the five districts were as expected by NSW Department of Primary Industries and Regional Development staff.

Figure 1. Map of survey distribution



Data analysis

Descriptive statistics including median, means and frequencies were used to summarise the data. Statistical analyses (p = 0.05) were also conducted to determine differences between groups (e.g. experience with sub-tropical grasses). 'Experienced' producers were those respondents who reported they had trialled and/or were managing sub-tropical grasses while 'inexperienced' producers were those who have not trialled these grasses.

Kruskal-Wallis rank sum test was used to test differences (p = 0.05) on a 5-point Likert scale variable based on producer's experience. 'Not applicable/Don't know' and missing responses were removed from the statistical analyses.

Pairwise comparisons were used to test for relationships between individual survey items (independent variables) and the adoption/intention to adopt sub-tropical grasses (dependent variable, N = 160). The exceptions were for testing separately for relationships between the possible benefits and concerns survey items and the adoption intentions of the experienced and inexperienced producers, (n =81 and n = 79, respectively). Those results were used to identify those explanatory variables which are likely associated with the adoption decision-making process. Kruskal-Wallis test or Chi-squared test of independence were typically applied.

Results and key findings

Half of the survey respondents indicated they had sown and/or manage sub-tropical grasses (i.e. were 'experienced' producers), although the proportion differed significantly across the five districts. Producers in the more northern districts of Boggabri (52%), Cassilis (77%) and Trangie (54%) are significantly more likely to have sown sub-tropical grasses than those in the more southern districts of Cowra (36%) and Forbes (18%).

In this section, we present summary data tables for topics relating specifically to sub-tropical grasses based on producer's experience. These include:

- Awareness and intention - level of awareness, adoption intentions, and experience with sub-tropical grasses.
- Knowledge base – level of knowledge about sub-tropical grasses and general agronomic practices.
- Benefits and concerns - about growing sub-tropical grasses.

We also provide an interpretation of those data, including drawing upon the results of pairwise comparisons. For the remaining topics in the survey, we describe some of the highlights.

Awareness of and intention to sow sub-tropical grasses

Most of the producers irrespective of experience indicated they could name at least one species of sub-tropical grass, which suggests a high level of awareness (Table 1). While almost two-thirds of experienced producers had visited a trial or demonstration sites, only a quarter of the inexperienced cohort had done so.

While about one-third of the inexperienced cohort indicated they intend sowing for the first time over the next three years, the experienced cohort indicated they were more than likely to sow additional areas to sub-tropical grasses over that period (Table 1). This data suggests there is considerable interest in establishing sub-tropical grasses in the near-term and that once producers 'successfully' trial these grasses that experience improves their confidence to sow further areas.

Table 1. Sub-tropical grass awareness and producer adoption intentions by experience (*N* = 160)

Key Attributes	Experienced *n* = 81 %[#]	Inexperienced *n* = 79 %	
Before you received this survey, did you know the name of at least one of the commonly sown sub-tropical grasses?	99	81	*
Before you received this survey, had you read or viewed information about any of the commonly sown sub-tropical grasses?	97	60	*
Have you ever visited a small plot trial or demonstration site of sub-tropical grasses?	63	24	*
Do you intend to sow new or additional areas of sub-tropical grasses over the next 3 years	83	31	*

[#]Percentage of producers responding in the positive. *Significant difference between groups at p = 0.05.

There were significant (p < 0.05) positive relationships between the first three items exploring awareness in Table 1 and a producer's intention to sow new or additional areas to sub-tropical grasses in the short-term.

Knowledge base

A 5-point Likert type scale was employed for producers to self-assess their agronomic knowledge relating to sub-tropical grasses and general pasture practices. The knowledge response categories 1 to 6 were: "no knowledge", "very little knowledge", "some knowledge", "sound knowledge (sufficient to act)", "very sound knowledge (can give a detailed explanation)" and "not applicable". The responses "sound knowledge" and "very sound knowledge" (i.e. categories 4 and 5) are combined and that data is presented in Tables 2 and 3.

Sub-tropical grass knowledge

As would be expected, the experienced producers, compared to the inexperienced producers, reported significantly higher levels of agronomic knowledge for the eight sub-tropical grass practice items listed in the survey instrument and shown in Table 2. Of the experienced producers at least 70% indicated they had the knowledge to prepare the land, select suitable species and sow a sub-tropical grass pasture, compared to less than 15% of the inexperienced producers. However, around 50% of experienced producers reported insufficient knowledge to 'best' manage the fertility requirements of sub-tropical grasses. Fertility is a key driver of these grasses' productivity (Harris et al. 2014; Boschma et al. 2015; Boschma et al. 2017). There is a substantial knowledge deficit among the inexperienced producers with close to 90% reporting insufficient knowledge to act for each of the agronomic practice items in Table 2. At current knowledge levels, inexperienced producers are at risk of failing to achieve a 'successful' establishment when sowing for the first-time without support from extension agents.

Table 2. Producer self-assessed knowledge of sub-tropical grass practices by experience (*N* = 160)

Sub-tropical grass practices	Experienced *n* = 81 %[#]	Inexperienced *n* = 79 %[#]	
How to prepare land to establish sub-tropical grasses in your district	74	14	*
The main sub-tropical grasses best suited to the soil type(s) on your property	73	5	*
How to sow (e.g. timing and depth to sow, equipment needed) sub-tropical grasses (e.g. digit grass, Bambatsi panic and Rhodes grass) in your district	70	13	*
The potential role(s) of sown sub-tropical grasses (e.g. digit grass, Bambatsi panic and Rhodes grass) in grazing systems in your district	68	5	*
The benefits of combining sown sub-tropical grasses and legumes in a pasture	63	15	*
The grazing management (e.g. when, how often and how hard) to ensure the persistence of established sub-tropical grasses in your district	63	11	*
The fertiliser requirements (NPKS[##]) of at least one of the main sub-tropical grasses in your district	52	6	*
The timing and amount of nitrogen to be applied to boost the growth of sub-tropical grasses	44	9	*

[#]Percentage of producers responding with "Sound Knowledge" or "Very Sound Knowledge" combined.
[##]NPKS=nitrogen, phosphorus, potassium, sulphur. *Significant difference between groups at p = 0.05.

General agronomic knowledge

Overall, producers reported insufficient knowledge to act for four of the eight items on general agronomic knowledge listed in the survey instrument and shown in Table 3. That is, more than 50% self-assessed they did not have sound or very sound knowledge. These were associated with identifying soil constraints, interpreting soil test results, and preparing a feed budget and soil nutrient budget. However, they indicated they had sufficient knowledge to maintain ground cover to minimise soil erosion, establish temperate pastures and assess soil water and pasture quality This deficit suggests there is considerable scope to improve the capacity and capability of producers across topics related to pasture agronomy.

Experienced producers, compared to the inexperienced producers, reported significantly higher knowledge for all items listed in Table 3 apart from assessing soil water. Notably, both experienced and inexperienced producers reported managing soil fertility as their poorest knowledge item.

Table 3. Producer self-assessed knowledge of general agronomic practices, by experience (*N* = 160)

General agronomic practices	Experienced *n* = 81 %[#]	Inexperienced *n* = 79 %[#]	
Strategies to maintain ground cover to minimise erosion in your district	83	62	*
How to establish temperate perennial pastures (e.g. lucerne, phalaris, cocksfoot, fescue)	68	52	*
How to assess stored soil moisture	61	45	
How to assess pasture quality	63	42	*
How to identify the main soil constraints limiting productivity	58	39	*
How to interpret soil test results	52	37	*
How to calculate a feed budget for livestock for the next six weeks	52	35	*
How to prepare a soil nutrient budget to maintain pasture productivity at least cost	31	6	*

[#]Percentage of producers responding with "Sound Knowledge" or "Very Sound Knowledge" combined.
*Significant difference between groups at $p = 0.05$.

All sub-tropical grass practice knowledge items (Table 3) had significant ($p < 0.05$) positive relationships with intention to sow new or additional areas to sub-tropical grasses. Apart from two items (calculating a feed budget and assessing stored soil moisture), all general pasture agronomy practice items (Table 4) also had significant positive relations with intention to sow new or additional areas to these grasses. This suggests that intent to sow sub-tropical grasses is related to good pasture agronomy knowledge.

Benefits and concerns

Benefits of growing sub-tropical grasses

A 5-point Likert type scale was employed to assess the benefits of and concerns about growing sub-tropical grasses. The benefit response categories 1 to 6 were: "not important", "minimal importance", "some importance", "important", "very important" and "not applicable". The responses, "important" and "very important" are combined (i.e. categories 4 and 5) and presented in Table 4.

Of the nine possible benefit options listed in the survey instrument and in Table 4 for the experienced producers, more than 70% of these producers rated each benefit as important or very important. In comparison, fewer inexperienced producers rated their nine possible benefits (Table 4) as important or very important.

Table 4. Producer assessment of the possible benefits of sub-tropical grasses by experience (*N* = 160)

Possible benefits	Experienced *n* = 81 %[#]	Inexperienced *n* = 79 %[#]
Persist once established	96	70
Respond rapidly to summer rainfall	96	74
Drought tolerant[##]	96	N/A
Provide useful feed in, summer and autumn, filling part of the feed gap for stock grazing temperate pasture systems based on species, such as phalaris, cocksfoot, fescue and clover	93	73
Provide ground cover to prevent soil erosion in dry seasons or from intense storm events	91	78
Increase production on less fertile soils or degraded cropping land	87	70
Provide effective control of summer and difficult to control weeds (e.g. blue heliotrope and silverleaf nightshade)	81	69
Increased weight gain of livestock grazing pasture systems that include tropical grasses[##]	80	N/A
Reduced tillage compared to annual pastures and forage crops	73	63
Will increase the profitability of my farming system[###]	N/A	70
Ability to turn off livestock faster[###]	N/A	67

[#]Percentage of producers responding with "Important" or "Very Important" combined. [##]Items for experienced producers only. [###]Items for inexperienced producers only.

There were no significant relationships for experienced producers between the nine possible benefit items and intention to increase the area sown to sub-tropical grasses. This suggests that the experienced producers have realised the advantages in establishing and managing these grasses. There were, however, significant ($p < 0.05$) positive relationships for inexperienced producers for five of the nine possible benefit items and intention to sow for the first time. The five possible benefits related to increasing profitability, responding to summer rainfall events, providing useful feed in summer-autumn, persisting once established, and increasing productivity on poorer country.

Concerns about growing sub-tropical grasses

Of the 10 items listed in the survey instrument (Table 5) the experienced producers indicated they had concerns about several issues. While lack of knowledge about establishing and grazing these grasses was an important issue for around 45% of experienced producers, the ability to integrate a legume, managing grazing for pasture quality and managing soil fertility for productivity were more important issues.

Table 5. Experienced producers' assessment of possible issues with sub-tropical grasses (*n* = 81)

Possible issues	%[#]
Integrating legumes with sub-tropical grasses	79
Difficulty sourcing quality seed of a species of my choice at reasonable prices	74
Need to pay attention to grazing management to maintain pasture quality	63
Need to pay attention to fertiliser requirements to maintain productivity	56
Insufficient knowledge to make a choice between different sub-tropical grass species	56
Sub-tropical grasses can reduce runoff to dams	47
Lack of knowledge about how to establish sub-tropical grasses	46
Lack of knowledge about how to graze established sub-tropical grasses	43
Difficulty accessing quality and independent advice from agronomists	40
Not having ready access to other farmers with experience managing sub-tropical grasses	29

[#]Percentage of producers responding with "Important" or "Very Important" combined.

For the inexperienced producers, of the nine issues of concern listed in the survey instrument (Table 6), seven of these issues were of concern to more than 60% of producers. The three issues of most concern were associated with their lack of knowledge to select species matched to their soil type, the need for evidence that sub-tropical grasses will establish and persist at their location and the need for data supporting the economic returns of sowing sub-tropical grasses.

Table 6. Inexperienced producers' assessment of possible issues with sub-tropical grasses (*n* = 79)

Possible issues	%[#]
Insufficient knowledge to select sub-tropical grass species best suited to my soil type.	74
Need evidence that sub-tropical grasses will establish and persist in my district	72
Need evidence that adding sub-tropical grasses will increase economic returns	72
Availability of quality seed for a species of my choice at a reasonable price	65
Sufficient rainfall to establish sub-tropical grasses	65
Insufficient knowledge about how to manage sub-tropical grasses once established	61
Insufficient knowledge about how to establish sub-tropical grasses	60
Difficulty obtaining advice from knowledgeable agronomists I trust	47
I don't own or have access to suitable sowing equipment	34

[#]Percentage of producers responding with "Important" or "Very Important" combined.

A significant issue concerning both experienced and inexperienced producers is their ability to source seed. Specifically, their concerns related to seed quality, and availability and price of seed of a species they sought. This was evident in a significant ($p < 0.05$) positive relationship for both experienced and inexperienced producers between intention to sow new or additional areas to sub-tropical grasses and access to good quality seed. We acknowledge that our study was conducted during an extended drought when seed stores were depleted. However, the consistency of the concern across all interactions with producers (e.g. Sinclair et al. 2019; Sinclair et al. 2021) highlights the importance of the issue.

Apart from issues relating to seed, there were no other significant positive relationships between issues held by the experienced producers and their intention to increase the area sown to sub-tropical grasses. Among the inexperienced producers, three other concerns also had significant ($p < 0.05$) positive relationships with their intention to sow. These concerns related to sufficient rainfall for establishment, the lack of knowledge about how to establish sub-tropical grasses and the need to demonstrate that sub-tropical grasses will establish and persist at their location.

Additional variables positively related to sowing intention

There was a significant ($p < 0.05$) positive relationship between producers' intention to sow and their concern about the persistence of introduced temperate perennial pasture species. It suggests that producers are considering adding sub-tropical grasses to secure their summer-autumn forage supply in response to the reduced reliability of temperate grasses.

There were also significant ($p<0.05$) positive relationships between several property variables and producer intention to sow new or additional areas to sub-tropical grasses. Producers most likely to sow these grasses were those with larger properties, had purchased additional land since 2010, plan to purchase additional land, and/or plan to intensify their enterprise(s) or landuse. Experienced producers, compared to the inexperienced producers, had substantially larger properties (1,160 ha vs 485 ha, respectively, median property size) and were also more likely to have purchased additional land since 2010 (49% vs 29%, respectively). These relationships suggest scale and a strong farm business orientation are relevant to decisions about sowing sub-tropical grasses.

Discussion

In this discussion we examine the significant factors influencing the likely adoption of sub-tropical grasses and whether those factors are unique to the adoption of these grasses. We discuss the implications for extension planning around sub-tropical grasses. Finally, we reflect on the research approach used in this social research study.

Influences on adoption intentions around sub-tropical grasses

Adoption can be viewed as a dynamic learning process in which new knowledge and skills are acquired enabling a producer to make a more informed decision about a new practice (Abadi Ghadim & Pannell 1999). Our survey instrument was designed to explore factors influencing adoption decisions around sub-tropical grasses by experienced and inexperienced producers. Pairwise comparisons allowed us to identify those factors significantly and positively related to intention to sow new or additional areas to these grasses.

While we acknowledge adoption is often an iterative process and can be non-linear, it can be broken into recognised steps. Awareness is when a producer first hears or reads about a new technology and is assumed to be the first step in the adoption decision-making process (Pannell et al. 2006). In this study the significant positive relationships between the survey awareness items (i.e. naming a sub-tropical grass, seeking information and/or attending a demonstration /trial site) and intention to sow subtropical grasses confirms the importance of active and passive awareness raising activities.

A next step in the adoption decision-making process, is knowledge building (Pannell et al. 2006). Significant positive relationships between almost all survey knowledge items (specific to sub-tropical grasses and general agronomy) and intention to sow confirms the importance of knowledge as a precursor to action or influence on the decision-making process. In the case of sub-tropical grasses, the significant difference in self-reported agronomic knowledge between the experienced and inexperienced producers suggests sound agronomic knowledge is a precursor to the adoption of these grasses.

A critical step in the adoption decision-making process is evaluating the relative advantage of a new technology (Pannell et al. 2006; Kuehne et al. 2017). For the inexperienced producers there were significant positive relationships between those benefit items relating to profitability and productivity and their intention to sow. For these producers there were also significant positive relationships between their concerns relating to lack of knowledge and agronomic performance at their location and intention to sow.

While improved productivity and increased profitability are key enablers for adoption, any significant constraint relating to cost, risk and complexity must be reduced or eliminated (Pannell et al. 2006). A large proportion of the experienced and inexperienced producers reported difficulty accessing quality seed of a species of their choice at a reasonable price. This is an important constraint that needs to be addressed by the red meat industry. There is a significant relationship between this constraint and producer intention to sow new or additional areas to sub-tropical

grasses. It is currently limiting producers' ability to take advantage of the contribution that sub-tropical grasses can make to secure the forage supply for their livestock.

Implications for extension planning

The survey was designed to gather specific information about two populations of livestock producers: those with and those without experience in establishing and managing sub-tropical grasses. The findings from the survey indicate the two producer cohorts, experienced and inexperienced, have different knowledge and skill needs if they are to trial or sow additional areas of subtropical grasses. While we acknowledge the number of respondents in each producer cohort is small, the producer workshops also revealed the different knowledge and skill requirements (Sinclair et al. 2019; Sinclair et al. 2021). These distinct differences illustrate the importance of developing extension programs that are designed to address the specific needs of different populations.

For inexperienced producers, particularly those in the more southern regions, incorporating sub-tropical grasses into a temperate pasture-based forage system involves a significant change from the accepted establishment and management practices of temperate grass pastures. It is likely they need to be motivated to invest in the time and effort to acquire the necessary knowledge and skills to at least trial a small area to sub-tropical grasses (Kaine & Wright 2022). Producers surveyed indicated that with the reduced reliability of their temperate grasses adding sub-tropical grasses would reduce the risk to their summer-autumn forage supply. While a substantial proportion of the inexperienced producers surveyed expressed interest in establishing sub-tropical grasses, they also reported limited sound agronomic knowledge about these grasses. For this cohort, extension delivery should initially focus on the principles and practices required to achieve 'successful' establishment. This should include establishing species demonstration sites across a range of locations and soil types enabling producers to observe these grasses near their property.

An important aspect when promoting the value of sub-tropical grasses is for extension agents to understand those key factors driving producer interest in sowing these grasses. There should be an emphasis on those benefits identified by the inexperienced producers including, for example, the ability of sub-tropical grasses to fill the summer-autumn feedgap and to increase stocking rate enabling increased production per hectare. Establishing field experiments or demonstration sites in local districts will be important to allow the inexperienced producers to observe these grasses growing in their environment. Providing economic data or local producer testimonials of the economic benefits will also be important given this cohort identified improved profitability and increased productivity as key drivers.

Although a considerable proportion of the experienced producers indicated they intended to increase the area sown to sub-tropical grasses, the survey also indicated they believed they had insufficient knowledge and skills managing these grasses to reach their full productive potential. For this cohort to realise the productivity benefit of these grasses, the extension focus should be on the principles and practices associated with 'best' management soil fertility and grazing. In addition, it is likely that once the inexperienced group have established sub-tropical grass pastures they will also be seeking to learn about 'best practice' fertiliser and grazing management.

As with any engagement, extension agents need to acknowledge the heterogeneity of the farming community with producers operating within their own unique context (Vanclay 2004; Kuehne et al. 2007). Extension agents need to keep in mind that there are personal and property factors that are important influences on adoption decisions made by producers (Pannell et al. 2006). The findings from the survey suggest that those producers with a focus on building their farm business are more likely to consider sub-tropical grasses as an opportunity as they expand their business.

Research approach

With the funds made available and the amount of time allocated to the social component within this large multi-disciplinary project, we were able to explore the influences shaping producers' adoption of sub-tropical grasses. While the research approach included gathering qualitative and quantitative data, the cost and time incurred undertaking the survey probably expended at least 60% of the allocated budget and researchers' time. Despite our efforts following 'best practice' in encouraging the completion of the printed survey (i.e. the Dillman process) we achieved a response rate below 12%. The online equivalent survey was developed as an attempt to increase the number of usable surveys. When we reflected on the research approach the workshops with purposively selected producers provided significant insights that were later confirmed, expanded and quantified by the broader survey of producers. The workshops, however, provided no indication as to where and to what extent producers across inland NSW were either managing or interested in sub-tropical grasses. The survey findings enabled the sub-tropical grasses program

to focus the extension effort and the specific support required to be based on gathering evidence rather than our assumptions.

Conclusion

In this study we determined some key factors influencing producers' likely adoption decisions about sub-tropical grasses. The survey data revealed there is already a high level of awareness of sub-tropical grasses amongst the producers surveyed. Most experienced producers reported they intend to increase the area already sown to sub-tropical grasses and a sizable proportion of the inexperienced producers also reported they also intend to sow these grasses in that period. This suggests there is already existing interest in these grasses across inland NSW. Extension agents need to immediately respond to take advantage of producer interest to accelerate the rate of adoption of these grasses.

The survey data reinforces the importance for extension agents to distinguish between the specific knowledge and skills needs of the different cohorts in the design of extension materials and activities. The extension focus when engaging with inexperienced producers should be in supporting them to achieve a 'successful' establishment while the focus for the experienced producers is on the 'best' management practices enabling the productive potential of these grasses to be realised.

Producers surveyed identified important economic and environmental benefits from growing sub-tropical grasses. These are key enablers for change and should underpin extension efforts particularly at the awareness raising step. At the same time, extension agents need to address the concerns raised by producers including providing evidence about the performance of sub-tropical grasses in the local environment and for credible evidence supporting the business case for these grasses. The issue of most concern is the difficulty in accessing quality seed at a reasonable price. This is a significant constraint that is impeding producers' ability to take advantage of sub-tropical grasses.

Acknowledgements

We gratefully acknowledge Dr Allan Curtis for his valuable contribution to the design and development of the survey instrument, and the data analysis and interpretation. We would like to thank those producers who participated in our survey. We would like to thank Ian Toole, Warren Smith, Susan Langfield and Lyndell Boschma for their assistance with the survey mailout. This study was funded through the Livestock Productivity Partnership between NSW Department of Primary Industries and Meat and Livestock Australia Donor Company.

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