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Utilizing Conjoint Analysis to Develop Breeding Objectives for the Improvement of Pasture Species for Contrasting Environments When the Relative Values of Individual Traits Are Difficult to Assess

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Abstract

Despite the large number of active programs breeding improved forage plants, relatively little is known about the weightings that breeders consciously or sub-consciously give to specific traits when selecting individual plants, or that agronomists and producers use when assessing the relative merits of contrasting cultivars. This is in contrast to most modern animal breeding programs where the relative merits of novel genetics may be assessed against an index-based breeding objective. There are numbers of reasons why these technologies have not been used widely in plant breeding although applications in forest tree breeding are relatively common. A first step in defining breeding objectives for forage species can be to define the relative importance of specific traits and to interpret how these contribute to the relative potential advantage to a new plant or cultivar. One method of defining these weightings is through surveys of users followed by analyses of their combined experience. Therefore in this study, we have assessed the usefulness of discrete choice techniques in the development of weightings for specific traits in forage plant improvement based on views of both expert users (agronomists and farm consultants) and farmers who were asked to define their relative priorities when considering the renovation of a pasture. The surveys were conducted in three distinct regions of, or environments within, Australia of special relevance to meat production from beef and sheep (high rainfall, temperate (inland), and Mediterranean). In summary this study defines the focus of breeding objectives and selection criteria for different pasture species across production systems.

Keywords: pasture, breeding objectives, genetic gain, conjoint analysis

1. Introduction

The profitable production of meat, milk and wool from ruminants in Australia is based on grazing pasture. While most of the temperate species are bred outside of Australia, there are active breeding programs for several pasture plant species in Australia; in these programs, breeders are seeking to develop cultivars that are well-adapted to Australian conditions, and feature improvements in nutritive value, the distribution of seasonal forage yield or enhanced pest and disease resistance (e.g. Cunningham et al., 1994; Jahufer et al., 2002; Harris et al., 2008; Nie & Norton, 2009).

Despite these active breeding programs, the relative importance of specific traits when making breeding decisions is not well-defined. This is in contrast to animal breeding programs where breeding objectives based on the relative economic importance of specific traits within a production system (e.g. Amer & Fox, 1992; Solkner et al., 2008) are generally well-defined. In these situations, the relative importance of a genetic change in a trait is scaled by its estimated net or marginal value or net profit to the user.

There is increasing interest in the development of a more structured approach to the breeding and genetic improvement of pasture plants and the incorporation of novel traits into breeding programs including the application of breeding objectives (Smith et al., 2007; Smith & Fennessy, 2011). Breeding objectives are defined in terms of profit equations based on economic values which are generally derived from an economic model. The breeding objective (Smith & Fennessy, 2011) itself is expressed as the marginal change or response in profit from pasture which can be simply stated as a function of three factors:

Marginal Change in Profit due to use of an improved pasture species = (Increase in Kg Dry Matter (DM) harvested) + (Increase in Nutritive value of harvested DM) – (Increase in the Cost of pasture),

where the marginal change in profit refers to the difference in profit due to a change in the harvested yield or nutritive value or cost (such as costs of seed, of establishment or of maintenance fertiliser) due to the use of the new improved cultivar as compared with the original cultivar.

As noted by Smith and Fennessy (2011), forage plant breeders generally regard the derivation of breeding objectives as being too difficult in practice and hence they replace the optimal index approach with various methods involving family selection often utilizing the application of independent culling (e.g. culling for the presence of rust, low winter yield, etc).

In order to develop a breeding objective, it is necessary to develop the appropriate criteria on which plants should be evaluated or assessed as either the potential parents of new varieties to drive genetic gain or during the subsequent choice of cultivars by producers. Given the cost of developing formal economic models, there is considerable interest in alternatives; these include preference or choice methods to elicit the opinions of users as to the relative values of traits within a breeding objective.

Therefore we are interested in approaches that may be widely-applicable but which do not require the development of an economic model for each species in a breeding program. Of particular interest are options that canvas the opinions of users, such as *stated preference techniques* which seek to elicit consumer or farmer preferences by ascertaining their willingness to pay for goods or services; these have been applied in animal breeding (Tano et al., 2003; Wurzinger et al., 2006; Nielsen & Amer, 2007; Byrne et al., 2012).

Recently Smith and Fennessy (2011) utilised a conjoint analysis approach (Green & Srinivasan, 1978; Green et al., 2001; Tano et al., 2003), also known as a discrete choice experiment (McFadden, 1973) to help prioritise potential selection criteria for breeding programs in four perennial forage species. To achieve this, they applied the *1000Minds* software (Hansen & Ombler, 2009) via an expert survey to assess target traits. In this method, individual attributes that contribute to a complex outcome are given a weighting (part-worth utility) based on their relative importance. The Smith and Fennessy (2011) survey was the first part of a process to develop breeding objectives for pasture plant species. This paper reports the second part of the process, which also utilised the *1000Minds* software, in the development of relative economic values for the traits. This part involved a survey of farmers and their advisers (as users of pastures). In this case, the focus is on the perceptions of users around the relative economic value of seasonal feed supply and factors that contribute to costs of pasture replacement such as persistence.

The surveys were conducted to provide analyses representative of three distinctive regions of Australia of special relevance to meat production from beef and sheep (high rainfall, temperate (inland), Mediterranean).

2. Methods

This survey was designed to seek the views of farmers and their advisers with respect to issues that they considered when faced with the need to renovate or sow a pasture. The questions sought to elicit the opinions of respondents in terms of relative economic values for a range of traits.

Each survey comprised two separate, but linked, questionnaires. The survey requests were sent by email to potential participants in three regions (distinctive pasture environments) of Australia.

From the responses, the relative importance ('weights') that each respondent placed on each of the characteristics were derived using the PAPRIKA (Potentially All Pairwise RanKings of all possible Alternatives, Hansen & Ombler, 2009) method. Thus the software provided a method for the streamlined collection of, and the analysis of, data that minimised the time required by respondents to complete the survey and the time required by the survey team to analyse the data.

2.1 The Surveys

Specifically in each questionnaire, the participants were asked to consider the alternatives or options where the primary question was as follows: *Which combination of traits would you prefer when buying seed to sow a new pasture?*

In questionnaire 1 (Q1, Table 1), the individuals were asked a series of questions involving trade-offs between the value of an increase in the *yield of pasture* across the four seasons (spring, summer, autumn, winter) expressed in terms of its equivalent in tonnes of grain (one, two or three tonnes). The value of pasture was expressed in grain equivalents as this provides users with a readily-interpretable measure of potential benefit, as farmers are used to buying supplementary feed when pasture is in short supply. The major focus of questionnaire

2 (Q2, Table 2) was on traits that are generally not thought of in specific economic terms; these included *more persistent pastures* (0, 2, 4 or 6 years greater persistence than current pastures), increases in the *cost of establishment* (increases of \$150, \$100, \$50 or 0 above an indicative current cost of \$600 per hectare), and an *increased difficulty of grazing management* (compared with the current simple management system), and a series of aspects relating to *persistence*. These components of persistence which were expressed as contrasts with their respective current situation (*same as now*) were *Pest resistance - Extremely resistant to rust and insects*, *Survival - Always survives in adverse conditions (salt, aluminium, water-logging)*, or *Summer survival - Always survives a hot, dry summer*. The link between the questionnaires was achieved through the use of a common question relating to the value of an increased yield in autumn, expressed in terms of the financial value of the increase (\$250, \$500 or \$750). Thus in Q2, we generated relative economic values for traits by comparing their preference weightings directly with the monetary value of an increase in autumn yield. The link between Q1 and Q2 also requires that we assign a monetary value to an increase in yield which is expressed in tonnes in Q1; therefore we assigned a value of \$250 to one tonne of grain.

Table 1. The questions and criteria in Questionnaire 1

SPRING YIELD per HECTARE	
1.	NO CHANGE IN SPRING YIELD
2.	INCREASED SPRING YIELD equivalent to 1 Tonne of GRAIN
3.	INCREASED SPRING YIELD equivalent to 2 Tonne of GRAIN
4.	INCREASED SPRING YIELD equivalent to 3 Tonne of GRAIN
SUMMER YIELD per HECTARE	
1.	NO CHANGE IN SUMMER YIELD
2.	INCREASED SUMMER YIELD equivalent to 1 Tonne of GRAIN
3.	INCREASED SUMMER YIELD equivalent to 2 Tonne of GRAIN
4.	INCREASED SUMMER YIELD equivalent to 3 Tonne of GRAIN
AUTUMN YIELD per HECTARE	
1.	NO CHANGE IN AUTUMN YIELD
2.	INCREASED AUTUMN YIELD equivalent to 1 Tonne of GRAIN
3.	INCREASED AUTUMN YIELD equivalent to 2 Tonne of GRAIN
4.	INCREASED AUTUMN YIELD equivalent to 3 Tonne of GRAIN
WINTER YIELD per HECTARE	
1.	NO CHANGE IN WINTER YIELD
2.	INCREASED WINTER YIELD equivalent to 1 Tonne of GRAIN
3.	INCREASED WINTER YIELD equivalent to 2 Tonne of GRAIN
4.	INCREASED WINTER YIELD equivalent to 3 Tonne of GRAIN

Table 2. The questions and criteria in Questionnaire 2

YIELD

NO CHANGE IN AUTUMN YIELD in each YEAR

INCREASED AUTUMN YIELD PER HECTARE equivalent to \$250 of BOUGHT-IN GRAIN each YEAR

INCREASED AUTUMN YIELD PER HECTARE equivalent to \$500 of BOUGHT-IN GRAIN each YEAR

INCREASED AUTUMN YIELD PER HECTARE equivalent to \$750 of BOUGHT-IN GRAIN each YEAR

PERSISTENCE

PASTURE LASTS the SAME TIME as now

PASTURE is MORE PERSISTENT and LASTS 2 YEARS LONGER than now

PASTURE is MUCH MORE PERSISTENT and LASTS 4 YEARS LONGER than now

PASTURE is FAR MORE PERSISTENT and LASTS 6 YEARS LONGER than now

COST OF ESTABLISHMENT (about \$600 per hectare currently)

INCREASES \$150 per Hectare

INCREASES by \$100 per Hectare

INCREASES by \$50 per Hectare

DOES NOT INCREASE

SURVIVAL

PASTURE SURVIVAL in ADVERSE CONDITIONS (salt, aluminium, water-logging) is SAME AS NOW

PASTURE ALWAYS SURVIVES in ADVERSE CONDITIONS (salt, aluminium, water-logging)

MANAGEMENT

GRAZING MANAGEMENT is MUCH MORE DIFFICULT THAN NOW

GRAZING MANAGEMENT is SAME AS NOW

PEST RESISTANCE

RESISTANCE to RUST and INSECTS is SAME AS NOW

PASTURES are EXTREMELY RESISTANT to RUST and INSECTS

SUMMER SURVIVAL

PASTURE SURVIVAL in HOT DRY SUMMER is SAME AS NOW

PASTURE ALWAYS SURVIVES in HOT DRY SUMMER

3. Results

3.1 Derivation of the Breeding Objective

In order for these data to be used in the derivation of a breeding objective, the specific criteria are incorporated into the profit equation below:

Marginal Change in Profit due to use of an improved pasture species = *Increase in nutrient yield* – *Increase in the Cost of pasture*.

In this survey, we generated the function *Increase in nutrient yield* which combined both *DM yield* and *Nutritive value* as grain equivalents (ex Q1) in a single function that combined both Increase in Kg DM harvested and an Increase in Nutritive value of harvested DM. The *Increase in the cost of pasture* comprises two terms being *Persistence* (years) and the *Cost of establishment* (ex Q2).

3.2 Overall Preference Weightings for Pasture Yield (DM and Nutritive Value)

The survey results for Questionnaire 1 for the three environments or regions are presented in Table 3. There was no evidence of any departure from linearity for the weightings in any season or region. The mean preference weightings per tonne are presented in Table 4. Given these data, the relative overall weightings for seasonal yield for inclusion in the breeding objective can be generated. Thus the equations for the Yield (component of) the

objective (expressed as the relative importance across the four seasons) for each of the three regions generated from the mean values are:

High rainfall: *Increase in nutrient yield* = $0.07\delta\text{SpY} + 0.29\delta\text{SuY} + 0.33\delta\text{AY} + 0.32\delta\text{WY}$

Temperate (inland): *Increase in nutrient yield* = $0.10\delta\text{SpY} + 0.24\delta\text{SuY} + 0.30\delta\text{AY} + 0.36\delta\text{WY}$

Mediterranean: *Increase in nutrient yield* = $0.04\delta\text{SpY} + 0.16\delta\text{SuY} + 0.47\delta\text{AY} + 0.33\delta\text{WY}$

where each coefficient represents the relative importance of a change in Spring yield (δSpY), Summer yield (δSuY), Autumn yield (δAY) and Winter yield (δWY). The summary data are presented in Table 4 to enable the reader to assess the data in a simplified format. The analyses indicate significant differences in coefficients between regions with little emphasis on improved Spring yield in any of the three regions. The responses highlight the relative emphasis that ideally should be placed on genetic improvement in yield across seasons and environments.

Table 3. Mean preference weightings (%) (\pm standard deviation derived from the individual responses) for the traits and criteria in Questionnaire 1

<i>Region</i>	High rainfall	Temperate (inland)	Mediterranean
SPRING YIELD per HECTARE			
NO CHANGE IN SPRING YIELD	0.0	0.0	0.0
INCREASED SPRING YIELD equivalent to 1 Tonne of GRAIN	3.0 (7.0)	4.3 (3.6)	1.2 (0.8)
INCREASED SPRING YIELD equivalent to 2 Tonne of GRAIN	4.7 (4.4)	6.5 (5.5)	2.4 (1.5)
INCREASED SPRING YIELD equivalent to 3 Tonne of GRAIN	7.0 (5.5)	9.7 (8.5)	4.8 (3.1)
Mean per tonne of grain	2.5	3.4	1.4
SUMMER YIELD per HECTARE			
NO CHANGE IN SUMMER YIELD	0.0	0.0	0.0
INCREASED SUMMER YIELD equivalent to 1 Tonne of GRAIN	13.2 (9.5)	9.5 (5.1)	7.7 (6.2)
INCREASED SUMMER YIELD equivalent to 2 Tonne of GRAIN	22.0 (9.8)	18.0 (8.8)	10.9 (7.7)
INCREASED SUMMER YIELD equivalent to 3 Tonne of GRAIN	27.9 (10.8)	24.0 (9.5)	15.6 (7.8)
Mean per tonne of grain	10.5	8.6	5.7
AUTUMN YIELD per HECTARE			
NO CHANGE IN AUTUMN YIELD	0.0	0.0	0.0
INCREASED AUTUMN YIELD equivalent to 1 Tonne of GRAIN	15.1 (5.6)	12.1 (6.7)	20.2 (10.7)
INCREASED AUTUMN YIELD equivalent to 2 Tonne of GRAIN	23.7 (9.1)	21.7 (8.4)	34.6 (8.3)
INCREASED AUTUMN YIELD equivalent to 3 Tonne of GRAIN	33.1 (14.2)	29.7 (12.1)	44.7 (8.1)
Mean per tonne of grain	12.0	10.6	16.6
WINTER YIELD per HECTARE			
NO CHANGE IN WINTER YIELD	0.0	0.0	0.0
INCREASED WINTER YIELD equivalent to 1 Tonne of GRAIN	13.1 (5.4)	13.6 (7.5)	13.9 (4.4)
INCREASED WINTER YIELD equivalent to 2 Tonne of GRAIN	25.5 (9.3)	26.2 (12.8)	21.7 (6.4)
INCREASED WINTER YIELD equivalent to 3 Tonne of GRAIN	32.1 (12.2)	36.6 (19.1)	34.9 (13.4)
Mean per tonne of grain	11.8	12.7	11.8

Table 4. Mean preference weightings (%) and ratio (to autumn) per tonne of grain

<i>Region</i>	High rainfall	Temperate (inland)	Mediterranean	High rainfall	Temperate (inland)	Mediterranean
	Mean preference weightings (%) per tonne of grain			Mean preference weightings relative to autumn within each region		
SPRING YIELD	2.5	3.4	1.4	0.21	0.33	0.11
SUMMER YIELD	10.5	8.6	5.7	0.84	0.81	0.35
AUTUMN YIELD	12.0	10.6	16.6	1.00	1.00	1.00
WINTER YIELD	11.8	12.7	11.8	0.97	1.23	0.78
	Relative preference weightings through the seasons			Means & comparisons across environments, & seasons		
SPRING YIELD	0.07	0.10	0.04	Mean of 0.07: Proportional differences but spring is relatively much less important than other seasons		
SUMMER YIELD	0.29	0.24	0.16	Mean of 0.23: Relatively more important in High rainfall zone, and less important for Mediterranean		
AUTUMN YIELD	0.33	0.30	0.47	Mean of 0.36: Mediterranean is different, reflecting the relative difference across seasons		
WINTER YIELD	0.32	0.36	0.33	Mean of 0.34: No differences		

3.3 Overall Preference Weightings for Other Traits in Relation to Autumn Yield

The results for Questionnaire 2 for the three environments/regions are presented in Table 5. The relative values per 1% change in preference weightings for autumn yield were the virtually the same across the three regions (\$29.1, \$29.2 and \$27.5 for the High rainfall, Temperate (inland) and the Mediterranean regions respectively). While the absolute values are only important in the context of relativities within the survey, the fact that they are consistent gives confidence that the respondents were well aware of the value of additional yield. There was also no evidence of any departure from linearity for the weightings in any season or region. The mean preference weightings and the monetary value derived from the relative ranking calculated from the value of additional Autumn yield are presented in Table 6. The relative overall weightings for the non-yield components in relation to autumn yield are the values that are designed for inclusion in the breeding objective. Thus the equations for the non-yield components for each of the three regions have been generated from the means for each region, such that the increase in cost can be off-set against an increase in persistence (hence the negative sign for an additional year of persistence):

High rainfall: **Increase in the Cost of pasture (\$)** = $1.86\delta C - \$119\delta P$

Temperate (inland): **Increase in the Cost of pasture (\$)** = $1.92\delta C - \$96\delta P$

Mediterranean: **Increase in the Cost of pasture (\$)** = $2.23\delta C - \$54\delta P$

where δC is the change in the relative value of the **annual** increase in yield required to justify the **(one-off) increase** in the Cost of establishment (dollars) and δP is the Increase in Persistence (years). Thus for the *High rainfall* region, a saving of \$1.86 is required each year to justify an additional \$1.00 in the cost of establishment (\$186 in Table 6). The analyses indicate some relative differences in coefficients between regions.

Table 5. Mean preference weightings (%) (\pm standard deviation derived from the individual responses) for the traits and criteria in Questionnaire 2 expressed in terms of value per hectare per year

<i>Region</i>	High rainfall	Temperate (inland)	Mediterranean
AUTUMN YIELD per HECTARE			
NO CHANGE IN AUTUMN YIELD in each YEAR	0	0	0
INCREASED AUTUMN YIELD PER HECTARE equivalent to \$250 of BOUGHT-IN GRAIN each YEAR	9.6 (6.0)	10.2 (5.3)	10.8 (4.0)
INCREASED AUTUMN YIELD PER HECTARE equivalent to \$500 of BOUGHT-IN GRAIN each YEAR	18.1 (8.4)	17.3 (9.3)	19.5 (6.3)
INCREASED AUTUMN YIELD PER HECTARE equivalent to \$750 of BOUGHT-IN GRAIN each YEAR	23.9 (9.9)	23.9 (12.3)	24.3 (6.2)
Mean percentage preference per \$100 of grain	3.4	3.4	3.6
PERSISTENCE			
PASTURE LASTS the SAME TIME as now	0	0	0
PASTURE is MORE PERSISTENT and LASTS 2 YEARS LONGER than now	8.8 (4.5)	7.4 (4.4)	4.0 (2.0)
PASTURE is MUCH MORE PERSISTENT and LASTS 4 YEARS LONGER than now	16.2 (8.7)	13.2 (5.9)	8.1 (2.9)
PASTURE is FAR MORE PERSISTENT and LASTS 6 YEARS LONGER than now	24.3 (10.9)	19.0 (9.5)	11.3 (4.9)
Mean percentage preference per year of persistence	4.1	3.3	2.0
COST OF ESTABLISHMENT (about \$600 per hectare currently)			
INCREASES \$150 per Hectare (or alternatively does not change)	0	0	0
INCREASES by \$100 per Hectare (or alternatively reduces by \$50)	3.9 (3.9)	3.3 (4.2)	3.5 (2.9)
INCREASES by \$50 per Hectare (or alternatively reduces by \$100)	6.1 (4.5)	6.8 (8.2)	8.1 (7.7)
DOES NOT INCREASE (or alternatively reduces by \$150)	9.2 (6.4)	9.6 (8.4)	12.8 (11.3)
Mean percentage preference per \$100 change in cost of establishment	6.4	6.6	8.1
SURVIVAL			
PASTURE SURVIVAL in ADVERSE CONDITIONS (salt, aluminium, water-logging) is SAME AS NOW	0	0	0
PASTURE ALWAYS SURVIVES in ADVERSE CONDITIONS (salt, aluminium, water-logging)	7.2 (2.8)	10.5 (8.2)	7.5 (4.4)
MANAGEMENT			
GRAZING MANAGEMENT is MUCH MORE DIFFICULT THAN NOW	0	0	0
GRAZING MANAGEMENT is SAME AS NOW	10.1 (8.5)	15.3 (9.6)	16.3 (3.0)
PEST RESISTANCE			
RESISTANCE to RUST and INSECTS is SAME AS NOW	0	0	0
PASTURES are EXTREMELY RESISTANT to RUST and INSECTS	7.2 (5.3)	9.3 (8.0)	11.3 (11.7)
SUMMER SURVIVAL			
PASTURE SURVIVAL in HOT DRY SUMMER is SAME AS NOW	0	0	0
PASTURE ALWAYS SURVIVES in HOT DRY SUMMER	18.2 (8.7)	12.4 (11.7)	16.5 (15.5)

Table 6. Mean preference weightings (%) and the monetary value derived from the relative ranking calculated from the value of additional Autumn yield, expressed on a per hectare basis

Region		High rainfall	Temperate (inland)	Mediterranean	
Co-efficients required for the breeding objective					
AUTUMN YIELD per HECTARE	\$ value per 1% preference per year	\$29.1	\$29.2	\$27.5	No difference
PERSISTENCE	Percentage preference & the annual \$ value per an additional year of persistence	4.1% \$119	3.3% \$96	2.0% \$54	Relatively less important in Mediterranean
COST OF ESTABLISHMENT	Percentage preference & the annual \$ value required per \$100 (one-off) change in cost	6.4% \$186	6.6% \$192	8.1% \$223	Relatively more important in Mediterranean?
Other co-efficients not directly incorporated into the Breeding Objective					
SURVIVAL in ADVERSE CONDITIONS	Percentage preference & the annual \$ value of guaranteed survival	7.2% \$209	10.5% \$306	7.5% \$206	Relatively more important in Temperate
MANAGEMENT	Percentage preference & the \$ decline in annual value recognising increased difficulties of management	10.1% \$294	15.3% \$446	16.3% \$448	Relatively less important in High rainfall
PEST RESISTANCE	Percentage preference & the annual \$ value of guaranteed resistance to pests	7.2% \$209	9.3% \$271	11.3% \$310	Relatively less important in High rainfall
SUMMER SURVIVAL	Percentage preference & the annual \$ value of guaranteed survival over summer	18.2% \$510	12.4% \$347	16.5% \$433	All environments are perceived as different but relatively more important in High rainfall

3.4 Comparison of Responses From Different Regions or Production Systems

The breeding objectives expressed as profit functions for each region/environment are presented below. In order to combine the data from the two questionnaires it is necessary to assign a monetary value to an increase in yield of one tonne of grain – this has been taken as \$250 per tonne (as per the Materials and methods). The profit function is expressed per one unit change: thus yield is per one tonne of grain equivalent (at a value of \$250), the cost of establishment is per \$1 and persistence is per one year.

High rainfall: Change in Profit = \$250[0.21δSpY + 0.84δSuY + 1.00δAY + 0.97δWY] - [1.86δC - \$119δP]

Temperate (inland): Change in Profit = \$250[0.33δSpY + 0.81δSuY + 1.00δAY + 1.23δWY] - [1.92δC - \$96δP]

Mediterranean: Change in Profit = \$250[0.11δSpY + 0.35δSuY + 1.00δAY + 0.78δWY] - [2.23δC - \$54δP]

4. Discussion

In this survey we applied the *1000Minds* software system to elicit views as to the relative economic weights for a number of specific criteria or traits (for both benefits and costs) which could constitute important traits within a breeding objective. Thus the *1000Minds* approach used here provides a useful method to help develop a breeding objective. In developing the survey, we made two specific assumptions that:

1. There is a likely trade-off between improved annual/seasonal productivity of a pasture and lifetime performance, as reflected in persistence of the pasture (a proxy for the need for pasture renewal);
2. Pasture and grain are inter-changeable at a grain price of \$250 per tonne.

We were particularly interested in the perspectives of users around the importance of persistence. Hence in addition to the specific question relating to the value of extra years of persistence, we also looked at components of

persistence. Specific issues that became evident in discussion, with both farmers and seed company representatives, were the potential increases in the cost of establishment (higher seed costs, etc) and any increases in the complexity of pasture management.

4.1 Interpretation

The value of an increased yield of pasture differs according to the time/season of the year and the farming environment. For example, the high relative importance of autumn feed and the lower importance of summer feed in the Mediterranean region are in contrast to those in the other two regions. The interpretation of outputs of the model requires further consideration, especially in respect of the components of persistence; essentially the outputs provide one axis of the **attractiveness – feasibility** matrix that a plant breeder might consider when considering the focus of selection in a breeding program. In this respect, we can interpret the data presented for the **high rainfall region** in Table 6 as follows.

1. I would be willing to embrace a much more complex pasture management system if the increased yield was equivalent to \$294 per year (equivalent to 1.17 tonnes of grain) in each autumn.
2. If you could guarantee me the following benefits, I would be prepared to trade-off a gain in annual pasture productivity thus:
 - a. guaranteed survival in adverse conditions (salt, aluminium, water-logging) of \$209 or the equivalent of 0.84 tonnes of grain;
 - b. extremely resistant to rust and pests of \$209 or the equivalent of 0.84 tonnes of grain;
 - c. guaranteed survival in a hot, dry summer of \$529 or the equivalent of 2.12 tonnes of grain.
3. Hence these reflect my expectation that the value of:
 - a. guaranteed survival in adverse conditions (salt, aluminium, water-logging) is that pasture will persist for a further 1.8 years ($\$209/\$119 = 1.8$ years);
 - b. extreme resistance to rust and pests is that pasture will persist for a further 1.8 years ($\$209/\$119 = 1.8$ years);
 - c. guaranteed survival in hot, dry summer is that pasture will persist for a further 4.4 years ($\$529/\$119 = 4.4$ years).

4.2 Developing the Breeding Objective

Omitting a trait because it is difficult to measure is not appropriate as such a trait can change through correlated responses. Sometimes, defining the economic value for a trait is quite difficult for a variety of reasons – the extent of pasture ground cover may be an example. Under such circumstances, a common approach is to either simply monitor the trait, or alternatively, apply selection pressure so that it either does not change or at least remains within acceptable bounds in the next generation. However some traits may not be appropriate for inclusion in the breeding objective and may be better dealt with as independent traits; for example, susceptibility to rust is simply not acceptable in the market, so that no matter how good a plant may be in other aspects, this susceptibility represents a fatal flaw, so the plant will be culled.

Table 7 provides expressions of the relative emphasis derived from the survey that should be applied in a breeding program to yield (per tonne) against persistence (per year) to maximise profit.

Table 7. Mean preference values (percentage & monetary) and expressions of the relative emphasis that should be applied in a breeding program to yield (per tonne) against persistence (per year) to maximise profit; yield is the estimated value of an increase in yield from one tonne of grain equivalent (valued at \$250 or one tonne of grain in autumn)

	Mean preference values (%) for seasonal yield expressed per tonne of grain equivalent			Mean preference values (\$) for seasonal yield expressed per tonne of grain equivalent			Relative emphasis on seasonal yield (per tonne) compared with persistence (per year)		
	High rainfall	Temperate	Mediterranean	High rainfall	Temperate	Mediterranean	High rainfall	Temperate	Mediterranean
SPRING YIELD	2.5	3.4	1.4	\$51	\$81	\$21	0.43	0.84	0.39
SUMMER YIELD	10.5	8.6	5.7	\$219	\$203	\$86	1.84	2.11	1.60
AUTUMN YIELD	12.0	10.6	16.6	\$250	\$250	\$250	2.09	2.60	4.67
WINTER YIELD	11.8	12.7	11.8	\$246	\$301	\$177	2.06	3.12	3.31

4.3 Study Technique and Methodology

We have previously applied conjoint analysis or discrete choice experiments (McFadden, 1973) using the *1000Minds* software (Hansen & Ombler, 2009) to determine the views of experts as to the likely importance of a range of traits in forage plants in the future; these covered plants ability to tolerate abiotic and biotic stresses, the importance of nutritive value, and a range of agronomic traits and yield (Smith & Fennessy, 2011).

The *1000Minds* approach facilitates this process by allowing survey participants to respond online to provide their perspectives as to the relative importance of various criteria through survey criteria that have been developed by the survey team. However the critical difference in the *1000Minds* methodology as compared with more conventional survey approaches is that the actual form of the questionnaire is re-defined as the survey process takes place (based on how respondents answer questions) in order to minimise the actual numbers of questions asked.

4.4 Applications

While the survey was developed to facilitate the development of Breeding Objectives, it also has direct value for the following applications:

- for seed companies and agronomists to describe the relative value of pasture cultivars in contrasting environments;
- for breeders and research-funding agencies to assess the relative value of new traits in breeding programs based on their effect on the components of the breeding objective or through re-analysis of their relative merit to existing traits; and
- for producers in assisting them to make choices between two cultivars that have been described in terms of their relative performance for traits in the breeding objective.

5. Conclusion

The potential utility of discrete choice experiment techniques, and specifically the *1000Minds* methodology, in the development of breeding objectives for pasture species based on the views of farmers and their advisers has been demonstrated in this paper. This method of estimating economic weightings for difficult to measure parameters for commodities such as pastures that are not traded directly but rather are inputs into traded agricultural commodities offers great potential to facilitate the discrimination between pasture cultivars by producers and also for breeders to balance trait weightings in complex breeding programs.

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