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Nutritional Value of Bee Collected Pollens

A report for the Rural Industries Research and Development Corporation

by DC Somerville

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Researcher Contact Details
Douglas C Somerville
NSW Agriculture
159 Auburn St
PO Box 389
GOULBURN NSW 2580

Phone: 02 4828 6619
Fax: 02 4822 3261
Email: doug.somerville@agric.nsw.gov.au

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au
Website: http://www.rirdc.gov.au

Foreword

All enterprises relating to beekeeping activities in Australia require careful attention to the nutritional requirements of the developing bees.

Decision making concerning nutritional strategies by commercial beekeepers has been historically based on anecdotal evidence from field observations. Successful strategies, when repeated, may not always produce the same results in following seasons.

The qualitative measurement of bee collected pollen will allow beekeepers to improve the process on which decisions are made regarding various management strategies regarding the nutritional requirements of honey bees.

The need to improve beekeeping management practices, as they relate to nutritional needs of bee colonies, was highlighted by RIRDC at a workshop held in May 1998. The workshop titled, "Strategic Planning and Action Meeting for Honey Bee Nutrition", organised by Mr GJ Kleinschmidt, the then Chairman of HBRDC, recommended the analysis of pollens to gain further qualitative data on Australian pollens.

RIRDC have been able to facilitate this by providing funding for this project. This research report discusses the pollen qualities of 60 floral species which are presented in a convenient format ready to publish in industry journals and magazines, thus ensuring that beekeepers benefit from and increase their understanding of honey bee nutrition.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.
This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our Honeybee R&D program, which aims to improve the productivity and profitability of the Australian beekeeping industry.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
- purchases at www.rirdc.gov.au/eshop

Peter Core
Managing Director
Rural Industries Research and Development Corporation

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At various times assistance was coerced to assist in the sorting of pollen prior to sending to the chemistry laboratory. This was a particularly time-consuming and laborious task. These people include my wife, Annette Somerville; Catherine Langford; Dale Chalker; Troy French; Chris Toole; Jeff Casburn; and a few work experience students from local high schools.

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Executive summary

Crude protein, amino acid and fat levels of pollens collected by honey bees primarily in southern NSW.

Objective

To trap and analyse pollens from a range of floral species to determine their nutritional values for amino acids, crude protein and fat levels, as this relates to honey bee dietary requirements. In the process of the study, investigate the possible variation of qualities of pollen originating from the same species with a major focus on Paterson's curse *(Echium plantagineum)* pollen.

Method

The cooperation of interested beekeepers was coopted for the research. Each participant was supplied with at least one bottom fitting pollen trap and instructions on the harvesting and storing of pollen plus suspect flowers and buds from the probable source of the pollen. The pollen was stored at -5 to -10°C until sent to chemistry laboratories for analysis.

Identification of pollens was done microscopically with comparison of pollen from the anthers of unopened flowers. Chemical analysis was by a modified macro-Kjeldahl method for nitrogen, which is used to calculate the crude protein levels. Half the samples tested for amino acids were analysed by HPLC using pre-column derivatisation using Pico•Tag® system or by HPLC with a cation exchange analytical column and post-column ninhydrin reaction. The fat levels were determined by solvent extraction.

Results & Discussion

Many hundreds of pollen samples were gathered during the course of the research but, for a range of reasons, only 194 samples were analysed. Of these the principal researcher personally collected 53 samples, thus a significant contribution was made by cooperating beekeepers. A total of 60 pollen producing species are covered by this research, with 61 samples collected from the one species, Paterson's curse *(Echium plantagineum)* from 1995 to 1998.

The major points of interest as a result of this research are:

- Paterson's curse pollen is of a very high quality with consistent levels of crude protein above 30%. Combine this with the ample quantity of pollen available and it is strongly arguable that this is the single most important pollen source in southern NSW.

- The difference in quality over the three years for Paterson's curse pollen does not immediately give any conclusive evidence that there is a very high level of variability based on year or location. 1995 was a reasonably good spring, the following spring was dry and considered below average for yields of Paterson's curse honey. The average crude protein levels increased for 1996 and 1997 from 1995, although there were generally lower levels of amino acids in 1996 than in 1995; 1995 and 1997 were similar. Thus there is not a clear trend for both protein and amino acid values of pollen from the same species to decline or increase with wet or dry seasons.

- Pollens collected from hives located on the one site on two locations during the same season (four samples spread over one month) demonstrated a significant difference between sample qualities on each location, thus it is difficult to state from this research that qualities of pollen will significantly vary between locations for the same species, although there is a strong suggestion that this is the case. If bees are readily working a four kilometre radius in November during the

time of this research, then they will have access to 50 km^2. No doubt there is significant variation in this sized area for soil fertility, moisture and localised climatic variations to potentially have an impact on pollen quality.

- Pollens collected for this research could be loosely placed in one of four quality categories: poor, average, above average or excellent, primarily based on crude protein levels with a consideration for significant amino acid deficiencies.

POOR QUALITY POLLENS					
SPECIES	**CP %**	**SPECIES**	**CP %**	**SPECIES**	**CP %**
Buckwheat	11	Weeping willow*	15	Saffron thistle	18
Fireweed*	12	Nodding thistle	15	Silky hakea*	18
Black sheoak*	13	Flatweed*	16	Citrus	19
Sunflower	13	Black thistle*	17	Lavender*	20
Blueberry	14	Capeweed*	17	Eggs & bacon*	20
Maize	15				
AVERAGE QUALITY POLLENS					
Red ironbark	20	White box*	23	Apple box*	24
Yellow burr	21	Onion weed*	23	Canola	24
White mallee*	21	Swamp mahogany	23	Vetch	24
Sweet scented wattle	22	Turnip weed	23	River red gum*	24
Pussy willow	22	Skeleton weed*	23	Faba bean	24
Rough barked apple	22	Alpine ash	23	Sydney golden wattle	25
Hedge mustard	22	Grey box*	24	Red stringybark*	25
Red box*	22	Manna gum	24	Currawong wattle*	25
				Woollybutt*	25
ABOVE AVERAGE QUALITY POLLEN					
Almond	25	Christmas mallee*	27	Blakely's red gum*	29
Balansa clover	25	Bloodwood	27	Spotted gum*	29
White clover	26	Grey gum*	27	White stringybark*	29
Pear	26	Sydney blue gum*	28	Heath-leaved banksia*	29
Brittle gum*	26	Gorse	28		

EXCELLENT QUALITY POLLENS			
SPECIES	**CP %**	**SPECIES**	**CP %**
Scribbly gum	30	Lupin	34
Paterson's curse	33	Vipers bugloss	35
Saw banksia*	33		

* Deficient in one or more essential amino acids.

- The essential amino acid, Isoleucine was below the desired levels to meet honey bee dietary requirements in 42 of the samples tested or 74% of the eucalypt or related species in this trial. This supports previous research findings, suggesting that the lack of Isoleucine could pose a problem when honey bees are regularly working or relying on supplies of Eucalypt pollen. No other essential amino acid as required by honey bees was identified as significantly limiting in the bulk of the pollen samples.

- The results of the fat levels in pollens identify a few species that consistently contain relatively high levels of fat. These species include Canola, Hedge mustard, Turnip weed and Flatweed. It would appear that components associated or contained in the fat content of these pollens have a high capacity to attract bees. All pollens with high fat levels are readily collected by bees and often in preference to pollens with higher levels of protein or amino acids.

- As two chemistry laboratory providers were used to analyse pollens for this research, it was necessary to establish if the results received from both institutions were compatible in relation to comparison of amino acid, protein and fat levels for the one sample. Five samples were analysed by each laboratory and the results were satisfactory with a reasonable degree of confidence that results could be compared between labs for the same species. During the course of this research, it

became apparent this may not be the case with other providers of nutrient analysis. Thus when comparing the data from different research origins, a certain degree of caution is required due to possible variations in chemical analysis methods used to determine amino acid levels.

Outcomes

It is apparent from this research that pollen qualities vary within the one species. Each species may fall within one or two groupings, i.e., a pollen, when judged by its quality, may be either poor, average, above average or of excellent quality.

Beekeepers have traditionally observed that colonies may do well on one source of pollen but not on another. Also, the same source of pollen may not produce the same results each time it becomes available. What is possibly happening is a lack of knowledge of the adult body crude protein levels before going onto a new pollen source. Bees with high body crude protein levels will remain in reasonable condition and recover quickly if placed on an average pollen source after working a honey flow, whereas bees with very low body crude protein levels (e.g., coming off sunflowers) will run down very quickly if placed on a medium to heavy honey flow with average quality pollen support. Recovery of a colony after these circumstances could take as much as four months, to obtain a populous hive ready to work another honey flow.

Armed with the knowledge that different species contain different levels of nutrients, it should be possible for beekeepers to better manage their bees, paying more attention to the ongoing nutrition status of the colony.

Improved productivity, longer lived queens and workers, drones with high fertility and lower potential disease risks are all potential outcomes from beekeepers incorporating the knowledge of this research into their management strategies.

1. Introduction

Honey bees require a range of elements to satisfy their nutritional requirements. These elements include proteins, carbohydrates, minerals, fats (lipids), vitamins and water for normal growth and development. Pollen normally satisfies the dietary requirements for proteins, minerals, lipids and vitamins. The proteins are composed of a series of amino acids, ten of which (Threonine, Valine, Methionine, Isoleucine, Leucine, Phenylalanine, Histidine, Lysine, Arginine and Tryptophan) have been identified as being essential for honey bee nutritional requirements. (De Groot, 1953.)

Glycine, Proline and Serine were not essential for growth but did exert a stimulating effect at sub-optimal growth levels (DeGroot, 1953).

Availability of pollen, either stored or freshly gathered, is required for the feeding of larvae and young nurse bees up to the age of 15 to 18 days. The largest amount of pollen is consumed by 3 to 6 day old bees during spring breeding conditions, extending to 9 day old bees during summer. (Zherebkin, 1965.)

Ample protein promotes a high birth rate and long-lived bees, whereas protein deficient conditions minimise the birth levels and length of life of adult bees. (Kleinschmidt & Kondos, 1977.)

Adequate protein also has a major role in the rearing of drone bees. Nguyen (1999) found that drones with higher body protein levels reached sexual maturity earlier than those with lower body protein levels, also drones fed adequate protein produced higher numbers of spermatozoa than those fed low protein.

This has significant ramifications for the rearing and supply of mated queen bees for sale to apiarists. Drone mother hives should have access to high quality pollen, or the provision of protein supplements, to ensure dietary deficiencies are not placed on the colonies rearing drones for mating with virgin queens.

Fresh pollen is still regarded as the most ideal source of various nutritional substances for honey bees compared to stored pollen and certainly pollen supplements. Haydak (1961) demonstrated that fresh pollen is 100% effective in stimulating the development of the hypopharyngeal glands in worker bees, whereas pollen stored for one year had decreased its stimulating effect by 76%. Pollen stored for two years did not initiate brood food gland development at all.

The quantity of pollen a colony consumes will largely depend on the availability of pollen to foraging honey bees and the demands from the colony in the form of developing larvae and young adult bees.

Doull (1974) suggested that on average, 125 mg of pollen was consumed for every larvae reared in the colony. A strong colony with upwards of 200,000 bees in a year will require at least 25 kg of pollen per year. Doull also suggests this is an under-estimate for it does not take into consideration the pollen consumed by adult bees in the production of beeswax. Also, Doull has not included the amount of pollen young adult bees consume from when they hatch until two weeks of age or thereabouts, after which they largely consume only carbohydrate. Thus, a productive colony could have a need for 50 kg of pollen per year. If the production season is long and a commercial beekeeper is regularly moving bees onto honey flows and breeding conditions for much of the year, then again the amount of pollen required per annum could be higher than 50 kg.

The quality of this pollen is paramount to the success of a beekeeper maintaining populous hives with long-lived bees.

Kleinschmidt and Kondos (1976) concluded that pollens with less than 20% crude protein cannot satisfy colony requirements for optimum production. For every 10 grams of protein required by the colony for net production, it is necessary for about 48 grams of pollen containing 30% crude protein to be consumed. If the protein content of pollen is reduced from 30% to 20%, the colony will be forced to increase its pollen consumption from 48 grams to 72 grams in an attempt to maintain satisfactory levels of production.

Kleinschmidt and Kondos (1976) considered a strong colony would require about 55 kg of pollen per year and if the quality of pollen decreased, then a colony would have to increase the consumption of pollen to make up the shortfall.

Ten amino acids have been demonstrated by DeGroot (1953) as being essential for honey bee nutrition.

Table 1.: DeGroot's (1953) Essential Amino Acids for Satisfactory Honey Bee Nutrition

Essential Amino Acids to Satisfy Honey Bee Nutritional Requirements (DeGroot, 1953)	
Essential Amino Acids	Bee Requirements g/16g N
Threonine	3.0
Valine	4.0
Methionine	1.5
Isoleucine	4.0
Leucine	4.5
Phenylalanine	1.5
Histidine	1.5
Lysine	3.0
Arginine	3.0
Tryptophan	1.0

If a pollen is lacking in one or more of these essential amino acids, then the quantity of pollen consumed by the bees would need to be increased to obtain sufficient quantities of the amino acids required.

Pollens with low protein levels would expose bees to more severe amino acid deficiencies. Low protein and essential amino acid levels would be more of a problem to a colony when there is reduced quantities of pollen stored in combs around the brood and only low volumes of pollen are available in the field.

Thus, a colony needs to consume a lot less pollen that contains a high protein content with all the essential amino acids at or above DeGroot's recommended minimum levels, than it would if the protein level was lower or one or more of the essential amino acids was below the ideal levels.

Past research has focussed on the crude protein and amino acid levels in bee-collected pollen (Kleinschmidt, 1986; Stace, 1996; Muss, 1987; Rayner and Langridge 1985) and identified species in various areas of Australia that are below or are of a satisfactory value to meet honey bee nutritional requirements.

This has largely taken place in Victoria, Northern NSW and Southern Queensland, thus focussing on species providing pollen to bees in these areas. This research has demonstrated a very significant range of crude protein levels from 9% to 37%, and a significant variability of amino acid levels according to species. Very little information is available on fat % in bee collected pollens.

The research resulting in this publication set out to determine the more valuable pollen sources to honey bees with a particular interest in southern NSW. This research indicates a significant variability in pollens from different species, species growing in different locations and variations from one year to the next for the same species on the same sites. Another variable that needs to be considered is that differences in the results of chemical analysis can occur within laboratories, between laboratories and between methods used. When differences are apparent between laboratories and methods that have been used, this brings into question the comparability of published data, particularly for amino acid analysis, and adds another layer of complexity to data interpretation.

2. Objectives

1. To collect and analyse pollens from a range of floral species for crude protein, amino acids and fat levels.

2. To measure any yearly variations in the levels of crude protein and amino acids for the one species.

3. To utilise this information to inform beekeepers of appropriate management strategies.

3. Methods and Materials

3.2 Pollen Traps

Bottom fitting pollen traps, as manufactured by EC Tobin & Son, 77 Locke Street, Raglan via Bathurst NSW 2795 (manufacturers of beekeeping woodware) were supplied to cooperating beekeepers, mainly through branches of the NSW Apiarists' Association Inc. One or two traps were supplied to those beekeepers trapping pollen for the project, with collection bags, sticky labels and instructions to detail the date the sample was collected, date trapping started, list species in flower and the location and, where possible, flower buds were collected to verify the source of the pollen trapped. The principal researcher of the project was responsible for trapping 53 of the 194 pollen samples tested.

All pollen, once collected, was stored in a chest freezer at -5 to -10°C.

3.3 Identification and Preparation For Lab

Pollen was first identified by using 400X microscopic examination of pollen grains from the flowers collected and comparing this with the pollen pellets collected by the bees. Once the association had been established between the pollen from a particular species and that collected by the bees, the pollen pellets were sorted by colour differences. Tubes of single species pollen, approximately 7 grams in weight, were forwarded to the analytical chemistry laboratories.

3.4 Chemical Analysis

Pollen samples were forwarded to two chemistry laboratories:

NSW Agriculture Chemistry Section PMB Bruxner Highway Wollongbar NSW 2477	&	Agriculture Victoria State Chemistry Laboratory Cnr Sneydes & South Roads Werribee VIC 3030

NSW Agriculture processed 91 samples of pollen and Agriculture Victoria, 103 samples of pollen. It was necessary to change chemistry laboratory providers for this project after 1996, as NSW Agriculture was no longer capable of providing an amino acid analysis service for pollen. A description of the chemistry methods used to test pollens by the NSW Agriculture chemistry laboratories is as follows.

A modified macro Kjeldahl method for determining nitrogen was used, crude protein is calculated by mulitplying 6.25 by the %N. This is based on %N in 100 g protein. Amino acids were analysed using high-pressure liquid chromatography. The Pico•Tag® method was used, which employs phenylisothiocyanate to rapidly and quantitatively derivatise both primary and secondary amino acids in a simple, one-step reaction. Amino acids are separated on a C_{18} column and total analysis time is 20 minutes, with detection limits of one picomole (Cohen, Meys & Tarvin, 1989).

Due to the instability of Methionine and Cystine under acid hydrolysis conditions, the amino acids are converted to more stable derivatives by pre-oxidation prior to hydrolysis. Total fat levels in pollen were based on the extraction of fat with petroleum spirits. Results are expressed as a percentage with two decimal places.

A description of the chemistry methods used to test pollens by the Agriculture Victoria, State Chemistry Laboratory is as follows.

1. Amino acids: Sample is hydrolysed in 6N HCI, diluted to volume, an aliquot is taken for rotary evaporation, dried and amino acid dissolved in a sodium citrate buffer (pH 2.2). This solution is then injected into the HPLC. The HPLC is comprised of a strong cation exchange column, which separates out the individual amino acids on the basis of pH and sodium ion strength of the buffer and pKa's of the individual amino acids. A post-column ninhydrin reaction produces coloured derivatives, which can be monitored via a UV detector. The sulfur amino acids Methionine and Cystine require a pre-oxidation with performic acid prior to hydrolysis as above.

2. Crude protein: Samples are digested in concentrated sulfuric acid with a selenium catalyst. Organic nitrogen in the sample is reduced to ammonia, which remains in the solution as ammonium sulfate. The digest is made alkaline with sodium hydroxide, and the ammonia is steam distilled into boric acid solution and titrated against standardised hydrochloric acid. The nitrogen and protein are then calculated.

3. Fat: The fat is determined as crude fat from a solvent extract. A known amount of sample is weighed out, extracted in a Soxtherm apparatus with diethyl ether. Excess solvent is removed and the extracted fat is further "dried" in an oven. The weight of extracted fat is recorded and fat content is then calculated.

3.5 Statistical Analysis

An analysis of variance was conducted for the:

- variability between laboratory providers;
- the laboratory variability within the one pollen sample;
- variability of pollen collected from four species: Apple box *(Eucalyptus bridgesiana),* Flatweed *(Hypochoeris radicata),* Spotted gum *(Corymbia maculata),* Turnip weed *(Rapistrum rugosum)*;
- variability of variants in the one species (Paterson's curse) over four collection dates on two locations.

A Wald statistic test was used to test the differences in amino acids, crude protein and fat % on nine locations over a three year period for Paterson's curse pollen. For the Paterson's curse pollen the mean, median, standard deviation and co-efficient of variation for each year plus box plots to illustrate the differences for each variant over the three years have been supplied in the results.

4. Results

The results include all the information provided for amino acid, crude protein and fat % levels for 194 pollen samples analysed.

Table 2. **Amino Acid, Crude Protein and Fat % for all Pollen Samples Analysed.**
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Species	**Almond**	**Almond**	**Alpine ash**	**Apple box**	**Apple box**	**Apple box**	**Apple box**	**Apple box**
Amino Acid								
Aspartic acid	10.6	11.67	9.51	9.71	9.75	8.96	8.97	8.75
Threonine	4.52	4.47	3.68	3.81	3.64	4	3.74	3.74
Serine	5.3	5.73	3.69	3.6	3.45	5.22	4.82	4.91
Glutamic acid	10.44	10.35	11.8	11.51	11.87	10.79	11.36	10.23
Proline	11.28	12.49	18.84	15.8	15.67	15.91	14.57	15.31
Glycine	4.15	4.24	4.87	5.25	5.09	4.91	4.73	4.26
Alanine	5.25	5.4	5.36	5.8	5.57	5.55	5.19	5.03
Valine	5.11	4.83	5.83	6.26	6.05	5.09	4.94	4.84
Methionine	2.57	2.38	2.05	2.21	2.71	2.85	2	2.61
Isoleucine	4.31	4	4.86	5.13	4.99	4.24	3.52	3.86
Leucine	6.41	6.85	7.14	7.58	7.31	7.02	6.79	6.73
Tyrosine	3.12	3.3	2.96	3.01	2.72	2.83	2.71	3.12
Phenylalanine	3.88	4.15	4.33	4.27	4.17	3.98	3.89	3.96
Lysine	6.48	5.87	6.04	6.56	6.36	5.6	5.92	5.15
Histidine	1.94	1.82	2.27	2.35	2.49	2.43	2.61	1.59
Arginine	5.48	5.15	6.05	6.42	5.92	6.58	5.7	5.77
Cystine	2.15	1.95	1.76	1.87	2.27	2.24	1.18	1.96
Protein Recovery %	-	-	-	-	-	-	87.6	-
Original Moisture %	-	-	-	-	-	-	11.8	-
Crude Protein %	25.4	24.8	23	23	22.6	23.1	25.9	23.5
Fat %	2.74	1.89	1.87	1.26	1.72	0.43	1.1	0.57

Sample No	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Species	**Apple box**	**Balansa clover**	**Balansa clover**	**Black she-oak**	**Black she-oak**	**Black she-oak**	**Black thistle**	**Black thistle**
Amino Acid								
Aspartic acid	8.16	9.63	9.27	9.04	9.4	9.51	8.95	9.53
Threonine	3.61	4.7	4.58	3.19	3.67	4.16	3.63	4.06
Serine	4.64	5.48	5.39	4.67	5.13	4.81	3.77	5.28
Glutamic acid	10.23	10.51	10.46	9.21	10.21	10.11	9.27	10.64
Proline	12.66	16.74	14.52	19.02	21.8	13.18	17.31	15.03
Glycine	4.3	4.34	4.13	3.85	4.3	4.33	4.19	4.22
Alanine	4.92	5.59	5.27	4.57	4.74	4.8	5.76	5.72
Valine	4.84	5.66	5.27	3.3	4.17	4.74	5.09	4.72
Methionine	2.2	2.41	2.12	2.48	2.26	2.58	2.52	1.98
Isoleucine	3.55	5.13	4.34	2.71	3.4	3.91	4.54	4.1
Leucine	6.16	7.35	6.96	5.63	6.41	6.06	6.19	6.34
Tyrosine	2.54	3.12	3.05	2.64	3.06	2.69	2.58	3.07
Phenylalanine	3.67	4.43	4.35	2.86	3.57	3.44	3.52	3.72
Lysine	5.57	5.96	6.08	3.5	4.94	4.66	6.78	6.87
Histidine	2.18	2.41	2.48	1.59	1.91	1.68	3.13	3.43
Arginine	5.38	4.86	4.62	5.82	6.4	7.09	3.91	4.41
Cystine	1.34	2.09	1.12	2.39	2.4	2.56	2.56	1.61
Protein Recovery %	82.2	-	87.7	-	-	-	-	87.77
Original Moisture %	13.2	-	13.2	-	-	-	-	-
Crude Protein %	24.9	23.4	27.2	11.5	12.9	13.1	16.1	17.3
Fat %	1.1	2.31	1.5	3.25	1.38	1.15	2.59	3.7

Sample No	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Species	**Black thistle**	**Blakely's red gum**	**Bloodwood**	**Blueberry**	**Brittle gum**	**Brittle gum**	**Buckwheat**	**Canola**
Amino Acid								
Aspartic acid	9.39	9.94	10.11	9.32	8.57	7.86	9.85	8.09
Threonine	4.31	3.93	4.35	3.78	3.91	3.57	4.2	4.92
Serine	5.28	5.11	5.67	4.37	5	4.51	5.39	5.66
Glutamic acid	10.24	11.88	12.05	10.33	10.87	9.94	16.56	10.19
Proline	18.99	12.76	11.08	5.81	12.5	12.84	5.04	6.42
Glycine	4.57	5.25	5.27	4.37	4.59	4.25	3.91	4.62
Alanine	5.79	5.44	5.47	4.71	5.14	4.8	5.5	5.29
Valine	5.16	5.08	5.36	5.44	4.96	4.78	5.02	5.36
Methionine	2.38	2.28	2.31	2.29	2.43	2.18	1.98	2.64
Isoleucine	4.67	3.74	4.04	4.72	3.65	3.54	4.46	4.95
Leucine	6.71	7.16	7.28	6.65	6.57	6.17	6.83	6.95
Tyrosine	2.95	3	3.19	1.98	2.8	2.53	3.34	3.05
Phenylalanine	4.02	4.22	4.72	3.51	4.19	3.66	3.85	4.39
Lysine	6.86	6.26	6.6	6.37	6.09	5.61	6.89	8.38
Histidine	3.2	2.13	3.09	1.98	2.45	2.23	2.65	2.17
Arginine	4.32	6.45	7.74	5.64	5.95	5.55	4.32	5.09
Cystine	2.84	1.38	1.39	2.61	1.35	1.41	1.06	2.33
Protein Recovery %	-	96.2	96.4	-	87.2	81.5	86.83	-
Original Moisture %	-	9.4	13.5	-	12	11.1	-	-
Crude Protein %	17.6	28.8	26.9	13.9	28.1	24.3	11.4	22.1
Fat %	1.48	1.5	1.6	2.04	1.5	0.9	2.2	7.31

Sample No	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Species	**Canola**	**Canola**	**Canola**	**Canola (Oscar)**	**Cape weed**	**Christmas mallee**	**Citrus**	**Clover**
Amino Acid								
Aspartic acid	9.45	10.6	9.14	9.32	10.39	8.55	10.4	9.41
Threonine	4.82	5.11	3.93	5.03	4.16	3.49	4.44	4.57
Serine	6.36	6.35	5.02	5.98	5.35	4.52	5.57	5.47
Glutamic acid	11.11	11.64	10.85	10.71	8.81	10.42	11.67	10.2
Proline	5.94	8.2	12.69	6.94	10.13	11.31	12.6	14.38
Glycine	4.43	5.04	4.81	4.73	5.45	4.4	4.35	4.1
Alanine	5.27	5.78	5.19	5.41	5.22	4.67	5.43	5.38
Valine	4.9	5.57	5.15	5.49	4.34	4.5	5.33	5.27
Methionine	1.94	2.32	2.03	2.51	2.25	2	2.08	2.18
Isoleucine	4.34	4.47	3.82	5.03	3.74	3.36	4.22	4.44
Leucine	6.98	7.57	6.57	7.17	5.92	5.97	7.21	6.98
Tyrosine	2.91	2.69	2.77	3.14	2.84	2.52	3.18	3.12
Phenylalanine	4.21	4.03	3.78	4.47	3.89	3.57	4.28	4.28
Lysine	7.94	8.45	5.55	8.28	7.59	5.36	9.53	5.86
Histidine	2.1	2.72	2.52	2.19	3.77	2.49	2.3	2.49
Arginine	5.17	4.83	6.26	5.13	3.75	7.18	5.22	4.65
Cystine	1.22	1.51	1.27	2.41	1.57	1.39	1.17	1.13
Protein Recovery %	83.66	92.1	88.2	-	85.9	86.1	102.4	87.7
Original Moisture %	-	10.2	8.5	-	14.6	9.7	10.7	12.6
Crude Protein %	23.5	26.1	23.8	23.6	17.3	26.6	18.5	25.9
Fat %	7.3	6.9	1.8	6.82	3.4	1.8	3	2.5

Sample No	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
Species	**Currawong wattle**	**Eggs and bacon**	**Eggs and bacon**	**Eggs and bacon**	**Faba bean**	**Fire weed**	**Flat weed**	**Flat weed**	**Flat weed**
Amino Acid									
Aspartic acid	7.34	9.61	9.26	9.44	9.19	9.1	7.05	8.03	8.16
Threonine	3.01	4.06	3.85	3.95	4.57	4.04	3.24	3.7	3.7
Serine	3.92	5.04	4.84	4.94	5.18	5.19	4.8	4.93	4.91
Glutamic acid	9.04	10.06	9.59	9.82	9.85	8.32	7.45	8.04	8.04
Proline	10.59	10.94	10.53	10.73	18.65	11.47	11.8	14.29	13.95
Glycine	3.74	4.48	4.33	4.41	4.06	4.34	3.79	4.49	4.51
Alanine	3.93	5.17	4.98	5.07	5.08	5.07	4.17	4.64	4.64
Valine	4	5.03	4.89	4.96	5.22	4.08	3.41	3.92	3.91
Methionine	2.21	2.36	2.36	2.36	2.24	2.32	2.02	1.82	1.82
Isoleucine	2.94	3.83	3.72	3.77	4.83	3.57	3.13	3.39	3.36
Leucine	5.35	6.68	6.42	6.55	6.7	5.76	4.94	5.76	5.76
Tyrosine	2.18	2.8	2.67	2.74	3.07	3.05	2.18	2.49	2.51
Phenylalanine	3.21	3.9	3.79	3.84	4.15	3.39	3.06	3.61	3.59
Lysine	4.66	5.82	5.59	5.71	6.17	5.44	7.48	8.38	8.25
Histidine	2.36	2.69	2.69	2.69	2.11	3.2	3.84	4.42	4.32
Arginine	6.37	7.35	6.87	7.11	5.1	4.36	3.14	3.59	3.64
Cystine	1.21	1.34	1.34	1.34	1.75	2.38	1.46	1.4	1.4
Protein Recovery %	75.4	93.2	86.8	90	-	-	72.61	83.5	83
Original Moisture %	19.2	19	19	19	-	-	-	16	16
Crude Protein %	24.9	19.7	19.7	19.7	24.4	12.4	15.1	17	17
Fat %	0.9	1.7	1.7	1.7	1.72	2.41	5.9	6.6	6.6

Sample No	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**
Species	**Flat weed**	**Flat weed**	**Flat weed**	**Flat weed**	**Flat weed**	**Flat weed**	**Flat weed**	**Flat weed**
Amino Acid								
Aspartic acid	8.28	8.74	9.26	8.28	8.22	8.54	8.33	7.21
Threonine	3.71	4.06	4.08	3.81	3.05	4.17	3.85	3.17
Serine	4.9	5.57	5.33	5.13	5.02	5.1	5.34	6
Glutamic acid	8.03	8.63	8.6	8.15	7.73	8.88	8.3	6.76
Proline	13.61	15.15	13.59	15.08	15.91	16.81	16.92	7.01
Glycine	4.53	4.92	4.76	4.52	4.33	4.32	4.64	4.69
Alanine	4.64	5.06	4.89	4.77	4.61	5.07	5.04	4.82
Valine	3.9	4.27	4.27	4.17	2.98	4.55	4.46	3.84
Methionine	1.82	2.11	2.06	1.99	2.18	2.15	2.05	1.43
Isoleucine	3.33	3.63	3.51	3.62	2.7	4.27	3.77	3.15
Leucine	5.77	6.1	5.94	5.74	5.01	6.24	5.97	5.59
Tyrosine	2.52	2.74	2.77	2.57	2.53	2.76	2.46	2.42
Phenylalanine	3.57	4.1	3.9	3.76	3.05	3.86	3.56	3.04
Lysine	8.12	8.88	7.41	7.8	6.61	7.8	8.17	8.58
Histidine	4.22	4.9	4.4	4.18	3.75	3.27	3.84	3.12
Arginine	3.68	3.93	3.63	3.32	3.01	3.81	3.38	3.57
Cystine	1.4	1.57	1.48	1.41	2.55	2.4	1.48	2.18
Protein Recovery %	82.5	90.3	85.5	84	-	-	86.4	80.3
Original Moisture %	16	14.2	10.5	12.2	-	-	14	12.4
Crude Protein %	17	17.1	18.2	17.9	15.6	14.1	17.1	9.2
Fat %	6.6	7.4	8.5	9.2	7.43	5.26	8.2	11.2

Sample No	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**
Species	**Gorse**	**Grey box**	**Grey gum**	**Heath-leaved banksia**	**Lavender**	**Lupin**	**Lupin**	**Maize**
Amino Acid								
Aspartic acid	10.7	8.56	8	10.59	9.24	11.68	11.27	9.61
Threonine	4.51	3.92	3.5	4.2	4.17	4.36	4.99	5.11
Serine	5.6	4.94	4.52	5.79	4.61	5.3	6.05	6
Glutamic acid	10.86	11	9.55	13.05	10.24	10.71	11	9.6
Proline	11.81	10.09	12.74	10.19	18.13	15.2	13.87	13.55
Glycine	4.02	4.76	4.35	4.68	4.57	4.49	4.62	9.6
Alanine	5.08	5.16	4.84	5.38	5.25	5.38	5.57	6.59
Valine	5.14	5.11	4.76	4.47	4.54	5.35	5.72	5.9
Methionine	2.35	2.07	1.68	2.73	2.21	2.07	2.13	1.57
Isoleucine	4.43	3.77	3.45	3.75	3.59	4.44	4.91	4.84
Leucine	7.15	6.5	6.03	6.4	6.04	7.96	8.05	6.82
Tyrosine	3.39	2.75	2.58	3.22	3.11	3.09	3.71	3.18
Phenylalanine	4.39	3.85	3.51	3.83	4.11	4.24	5.06	3.84
Lysine	5.99	5.96	5.42	6	6.38	3.25	7.4	5.55
Histidine	2.26	2.38	2.26	2.98	3.67	2.22	2.8	1.86
Arginine	4.73	6.44	5.57	6.57	4.31	4.7	5.5	4.7
Cystine	1.86	1.27	1.05	2.88	1.67	1.22	1.15	1.53
Protein Recovery %	-	86.2	80.7	-	89.3	92.3	96.4	-
Original Moisture %	-	10.2	9.3	-	13.6	13	16	-
Crude Protein %	28.4	23.6	27.3	28.6	19.4	34.7	33.7	14.9
Fat %	2.08	3	2	2.45	2.9	3.1	2.7	1.8

Sample No	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**
Species	**Manna gum**	**Mustard**	**Mustard**	**Mustard**	**Nodding thistle**	**Onion weed**	**Pear**	**Pussy willow**
Amino Acid								
Aspartic acid	9.06	10.32	9.33	10.13	8.39	7.22	10.63	10.12
Threonine	3.75	5.06	4.23	4.66	3.78	3.53	4.42	4.5
Serine	3.9	6.23	5.68	4.72	4.65	4.11	5.69	5.92
Glutamic acid	11.02	10.92	9.19	10.35	9.05	8.01	10.76	12.29
Proline	15.45	8.82	8.03	9.93	20.98	39.38	5.73	4.96
Glycine	4.9	4.74	4.2	5.06	4.15	3.25	4.28	4.7
Alanine	5.34	5.68	5.04	5.59	5.47	5.04	5.37	5.43
Valine	5.62	5.34	3.27	5.7	4.78	4.06	5.4	5.51
Methionine	2.48	2.43	2.77	2.64	2.25	1.79	2.43	2.52
Isoleucine	4.74	4.92	3.14	5.34	4.19	3.22	4.11	4.75
Leucine	7.08	7.31	5.63	7.23	5.72	5.31	6.89	7.49
Tyrosine	2.76	3.25	2.58	2.8	2.83	2.24	2.8	3.16
Phenylalanine	3.94	4.51	3.21	4.2	3.44	3.06	4.15	4.39
Lysine	6.22	8.71	5.81	8.09	6.13	3.77	6.42	7.16
Histidine	2.47	2.25	1.79	2.67	3.61	1.64	2.64	2.28
Arginine	5.46	5.33	4.1	4.99	3.69	3.4	4.77	6.29
Cystine	2.14	2.28	2.6	2.53	3.18	1.02	1.32	2.18
Protein Recovery %	-	-	-	-	-	88.9	84.4	-
Original Moisture %	-	-	-	-	-	13.2	11.5	-
Crude Protein %	23.7	22	22.3	22.4	15.1	22.5	26.2	21.9
Fat %	0.48	5.68	6.39	5.4	2.25	4.5	1.8	3.1

Sample No	**66**	**67**	**68**	**69**	**70**	**71**	**72**
Species	**Red box**	**Red ironbark**	**Red stringy-bark**	**Red stringy-bark**	**Red stringy-bark**	**Red stringy-bark**	**River red gum**
Amino Acid							
Aspartic acid	8.73	8.88	8.48	9.11	9.39	9.76	9.94
Threonine	3.8	3.41	3.34	3.48	3.71	3.88	3.97
Serine	4.76	3.54	4.99	3.38	4.73	5.04	4.7
Glutamic acid	10.47	10.95	9.98	10.55	11.69	12.32	11.25
Proline	11.24	11.9	15.66	15.62	12.11	12.28	14.3
Glycine	4.66	4.69	4.66	4.71	4.67	5.01	4.8
Alanine	5.02	4.96	4.83	5.47	5.76	6.01	5.35
Valine	4.9	5.34	4.29	5.75	5.37	5.64	5.45
Methionine	2.24	2.51	2.23	2.11	2.11	2.22	2.99
Isoleucine	3.61	4.39	3.4	4.79	3.84	3.95	4.53
Leucine	6.39	6.63	6.12	6.86	6.86	7.25	6.86
Tyrosine	2.79	2.59	2.93	2.62	2.47	2.54	2.78
Phenylalanine	3.73	3.7	3.58	3.89	3.53	3.65	3.82
Lysine	5.66	5.58	5.14	6.24	6.07	6.34	5.87
Histidine	2.54	2.05	2.1	2.5	2.33	2.33	2.33
Arginine	6.23	6.5	5.59	5.65	5.49	5.57	6.48
Cystine	1.39	2.24	1.94	1.84	1.28	1.34	2.39
Protein Recovery %	86.4	-	-	-	88.1	91.4	-
Original Moisture %	14.8	-	-	-	8.5	13.2	-
Crude Protein %	22.4	20.5	24.2	22.1	26.9	26.2	22.6
Fat %	3.9	2.21	2.24	2.58	1	0	4.58

Sample No	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
Species	**River red gum**	**Rough-barked apple**	**Rough-barked apple**	**Rough-barked apple**	**Rough-barked apple**	**Rough-barked apple**	**Saffron thistle**	**Saw banksia**
Amino Acid								
Aspartic acid	9.12	8.86	11.18	9.32	8.56	8.94	10.04	9.72
Threonine	3.82	4.17	4.79	4.3	3.61	3.95	4.05	3.81
Serine	4.92	5.25	6.03	5.58	4.73	5.15	4.28	5.37
Glutamic acid	10.66	10.47	12.8	11.5	10.45	10.98	10.19	12.58
Proline	12	14.57	15.37	15.11	12.02	13.57	15.73	7.83
Glycine	4.61	4.72	5.65	4.93	4.49	4.71	5.14	4.22
Alanine	4.98	5.23	6.25	5.52	4.82	5.17	6.05	4.63
Valine	4.98	5.47	5.99	5.67	4.86	5.27	5.69	4.84
Methionine	2.52	2.34	2.06	2.14	2.14	2.14	2.55	2.27
Isoleucine	3.6	4.71	4.7	4.34	3.59	3.97	5.03	3.61
Leucine	6.46	7.19	8.67	7.38	6.65	7.02	6.94	5.77
Tyrosine	2.74	2.99	3.55	3.03	2.56	2.79	2.72	2.77
Phenylalanine	3.75	4.25	5.09	4.47	3.71	4.09	4.18	3.71
Lysine	5.49	5.57	6.62	6.06	5.34	5.7	6.77	5.49
Histidine	2.33	2.7	2.68	2.67	2.5	2.58	4.43	2.37
Arginine	6.23	6.07	7.02	6.44	5.74	6.09	4.48	7.24
Cystine	1.38	2.49	1.31	1.45	1.45	1.45	2.46	2.03
Protein Recovery %	86.7	-	103.1	95.2	83.4	89.3	-	87.6
Original Moisture %	9.5	-	17.5	17.4	17.4	17.4	-	8.8
Crude Protein %	25.6	21	22.9	22.3	22.3	22.3	18.1	33.3
Fat %	1.3	1.55	1.1	1.5	1.5	1.5	3.86	1.9

Sample No	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**
Species	**Scribbly gum**	**Silky hakea**	**Skeleton weed**	**Skeleton weed**	**Spotted gum**	**Spotted gum**	**Spotted gum**	**Spotted gum**
Amino Acid								
Aspartic acid	9.77	9.63	12.08	10.19	9.63	8.76	10.78	11.74
Threonine	4.11	4.26	4.67	3.68	3.83	3.68	4.15	4.4
Serine	5.28	5.32	4.85	5.11	5.2	4.67	5.27	5.65
Glutamic acid	11.19	12.07	12.43	10.07	11.03	9.68	12.26	13.54
Proline	11.26	15.67	4.83	7.32	11.35	11.7	13	13.84
Glycine	4.82	3.95	5.46	4.24	4.47	4.38	5.44	5.52
Alanine	5.35	4.68	5.94	5.12	5.13	4.84	5.55	5.71
Valine	5.2	4.78	7.19	3.8	4.74	4.72	5.16	5.44
Methionine	2.52	2.04	3.05	3.6	2.19	2.03	2.26	2.19
Isoleucine	3.88	3.93	5.77	3.1	3.87	3.63	3.88	4.09
Leucine	6.91	6.59	8.2	6.02	6.69	6.31	7.59	8.06
Tyrosine	2.82	2.9	3.58	2.85	2.72	2.58	2.99	3.09
Phenylalanine	4.13	3.81	5.17	3.41	3.89	3.77	4.4	4.54
Lysine	6.08	4.66	5.91	4.99	5.79	5.5	6.44	6.94
Histidine	2.5	2.4	2.96	2.2	2.65	2.55	2.74	2.9
Arginine	7.09	6.41	6.03	4.52	7.65	6.63	8.04	8.37
Cystine	1.47	2.95	2.54	3.02	1.36	1.41	1.49	1.39
Protein Recovery %	93.2	-	-	-	88.66	84.1	97.8	103
Original Moisture %	14.2	-	-	-	-	19.6	17	14.4
Crude Protein %	29.7	18.4	23.4	22.2	24.9	30.4	29.5	28.4
Fat %	2.3	2.82	2.59	3.43	1.5	1.4	1.1	1.3

Sample No	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**
Species	**Spotted gum**	**Spotted gum**	**Sun flower**	**Sun flower**	**Swamp mahogany**	**Sweet-scented wattle**	**Sydney blue gum**	**Sydney golden wattle**
Amino Acid								
Aspartic acid	11	11.58	9.25	9.32	8.82	10.78	9.98	10.13
Threonine	3.82	4.06	3.96	4.06	3.74	3.71	4	4.54
Serine	5.05	5.39	4.6	4.75	4.7	5.26	5.21	5.17
Glutamic acid	11.72	12.26	9.11	9.7	10.03	10.09	11.52	11.54
Proline	13.36	13.65	6.73	6.36	12.13	7.47	10.45	6.15
Glycine	5.04	5.44	4.95	4.79	4.46	3.86	5.34	4.17
Alanine	5.37	5.62	4.56	5.1	4.93	5.09	5.56	4.98
Valine	5.04	5.2	4.57	4.64	5.08	3.95	5.19	5.34
Methionine	2.25	2.29	2.24	1.82	2.46	2.84	1	2.74
Isoleucine	3.67	3.77	4.28	4	4	3.41	3.72	4.64
Leucine	7.26	7.57	6.61	6.41	6.64	6.38	7.26	7.15
Tyrosine	2.66	2.75	2.85	2.87	3.19	2.99	2.9	3.08
Phenylalanine	3.97	4.11	3.7	3.55	3.97	3.51	4.14	4.24
Lysine	6.01	6.2	5.75	6.21	5.29	5	5.89	6.19
Histidine	2.8	2.91	4.61	4.79	1.82	1.73	2.02	1.97
Arginine	7.13	7.84	3.71	3.98	5.99	4.66	6.65	5.45
Cystine	1.36	1.41	3.54	2.14	2.02	1.93	1.22	2.25
Protein Recovery %	93.8	98.4	-	80.8	-	-	94.3	-
Original Moisture %	13.3	13.8	-	-	-	-	20.6	-
Crude Protein %	29.1	28.7	13.8	12.9	22.6	21.7	27.6	24.6
Fat %	2	2	1.41	1.1	1.43	2.52	1.5	1.44

Sample No	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**104**
Species	**Turnip weed**	**Turnip weed**	**Turnip weed**	**Turnip weed**	**Turnip weed**	**Vetch**	**Vetch**	**Vipers bugloss**
Amino Acid								
Aspartic acid	8.61	9.19	9.96	10.03	8.95	9.14	10.14	12.62
Threonine	4.67	4.75	4.73	4.59	4.55	4.55	5	4.69
Serine	5.73	5.93	5.82	5.87	5.85	5.54	6.13	5.37
Glutamic acid	9.81	9.38	10.59	10.92	10.89	11.02	12.1	10.82
Proline	9.87	8.28	14.11	10.95	7.62	17.08	18.56	6.32
Glycine	4.64	4.47	4.42	4.54	4.5	4.06	4.46	4.79
Alanine	5.54	5.23	5.11	5.1	5.01	5.55	6.05	5.44
Valine	5.27	4.88	5.02	4.79	4.7	5.15	5.68	5.45
Methionine	2.29	2.61	2.54	2.31	1.85	2.39	2.36	2.28
Isoleucine	4.86	4.29	4.5	4.33	3.86	4.66	5.13	4.6
Leucine	7.05	6.83	6.97	6.97	6.51	7.02	7.8	7.03
Tyrosine	3.13	3.05	3.22	3.44	2.62	3.02	3.29	3.25
Phenylalanine	4.44	4.17	4.25	4.29	4.1	4.36	4.8	4.32
Lysine	8.47	6.58	6.46	6.8	6.96	6.74	7.37	5.08
Histidine	2.13	2.09	1.85	1.92	2.25	1.98	2.18	2.36
Arginine	5.09	5.11	5.58	4.79	4.78	4.72	5.24	4.89
Cystine	2.19	2.01	2.01	2.01	1.14	1.91	1.85	1.37
Protein Recovery %		-	-	-	81.6	-	-	86.1
Original Moisture %		-	-	-	10.6	-	-	14.4
Crude Protein %	21.6	22.7	21.8	22.9	24.6	24.1	24	34.9
Fat %	6.51	5.93	5.23	5.43	7	1.77	1.68	4.1

Sample No	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**
Species	**Wattle**	**White box**	**White box**	**White box**	**White box**	**White mallee**	**White mallee**	**White stringybark**
Amino Acid								
Aspartic acid	11.14	7.99	7.86	9.35	8.5	8.6	8.88	10.24
Threonine	4.63	3.41	3.78	3.87	3.86	3.6	3.65	4.02
Serine	5.76	4.69	4.85	4.88	4.83	4.63	4.85	5.11
Glutamic acid	12.18	9.88	11.21	11.11	10.42	10.07	10.76	10.88
Proline	13.05	12	11.72	13.46	11.57	12.69	12.08	12.23
Glycine	4.24	4.71	4.98	4.45	4.67	4.5	4.64	5.15
Alanine	5.29	5	5.24	4.92	5.01	4.87	4.81	5.44
Valine	5.49	4.28	5.3	4.74	4.92	4.85	4.78	5.03
Methionine	2.54	2.7	2.69	2.55	2.33	2.15	1.92	2.25
Isoleucine	4.56	3.38	4.2	3.77	3.59	3.54	3.52	3.68
Leucine	7.28	6	6.89	6.61	6.47	6.28	6.47	7.25
Tyrosine	3.34	2.88	3.17	3.17	2.84	2.61	2.7	2.97
Phenylalanine	4.08	3.44	3.9	3.89	3.8	3.64	4.08	4.24
Lysine	5.35	5.16	5.37	4.78	5.6	5.67	5.8	6.34
Histidine	2.12	1.95	2.3	1.73	2.61	2.46	2.84	2.78
Arginine	7.2	5.79	6.41	5.77	6.78	7.16	8.15	7.1
Cystine	1.85	2.47	2.47	2.08	1.35	1.43	1.46	1.3
Protein Recovery %	-	-	-	-	87.7	87.7	90.4	92.6
Original Moisture %	-	-	-	-	16.7	15.5	8.2	17.7
Crude Protein %	23.8	22.1	22.4	22.5	23.1	22.2	20.5	29.4
Fat %	1.2	2.51	2.61	2.27	4.2	1.9	1.4	1.2

`	113	114	115	116	117	118	119	120
Species	**Willow**	**Willow**	**Woolly-butt**	**Woolly-butt**	**Yellow burr**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	9.06	9.72	7.92	7.41	9.32	12.89	13.91	11.37
Threonine	3.41	3.89	3.67	3.46	4.2	4.51	4.61	4.37
Serine	5.24	5.71	4.7	4.96	6.12	5.03	5.29	5.14
Glutamic acid	10.22	11.02	10.25	10.74	10.43	10.97	11.71	10.98
Proline	5.51	5.24	15	15.47	15.59	6.48	8.08	7.86
Glycine	3.6	3.84	4.44	4.97	5.23	4.66	4.82	4.62
Alanine	4.09	4.57	4.9	5.33	5.67	5.28	5.5	5.34
Valine	3.93	4.52	4.75	4.49	4.94	5.42	5.67	5.33
Methionine	2.16	2.44	2.99	2.39	2.14	2.49	2.37	2.58
Isoleucine	3.28	3.9	3.84	3.5	4.52	4.94	5.17	4.83
Leucine	5.62	6.18	6.26	6.32	6.96	6.8	7.19	6.82
Tyrosine	2.7	2.86	2.66	2.96	3.07	3.12	3.2	3.19
Phenylalanine	3.29	3.57	3.72	3.54	3.96	4.19	4.41	4.21
Lysine	5.25	5.85	5.82	5.03	6.34	7.1	7.83	7.35
Histidine	1.8	1.99	1.84	1.75	3.74	2.42	2.41	2.3
Arginine	6.57	6.82	6.5	6.33	4.41	5.06	5.12	5.13
Cystine	2.4	2.26	2.46	2.1	1.87	2.22	2.14	2.59
Protein Recovery %	-	-	-	-	-	-	-	-
Original Moisture %	-	-	-	-	-	-	-	-
Crude Protein %	14.8	15.1	24.9	25.4	20.6	32.8	31.9	29.9
Fat %	1.54	2.07	-	2.41	2.83	1.68	2.09	1.76

Sample No	**121**	**122**	**123**	**124**	**125**	**126**	**127**	**128**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	14.23	13.77	13.49	12.42	11.45	13.7	13.57	13.22
Threonine	4.96	4.85	4.74	4.32	4	4.7	4.75	4.67
Serine	5.62	5.56	5.39	4.94	4.6	5.52	5.23	5.22
Glutamic acid	12.38	12.04	11.09	10.62	9.91	11.69	11.39	11.19
Proline	8.13	8.58	7.08	6.79	6.26	8.15	7.7	8.71
Glycine	5.2	5.21	4.84	4.48	4.16	4.74	5.13	5.1
Alanine	5.86	5.72	5.34	5.09	4.71	5.54	5.55	5.49
Valine	6.06	5.89	5.2	5.15	4.77	5.3	5.73	5.65
Methionine	2.6	2.59	2.29	2.56	2.48	2.49	2.92	2.38
Isoleucine	5.51	5.4	4.83	4.69	4.37	4.91	5.27	5.24
Leucine	7.63	7.45	6.9	6.52	6.13	7.13	7.25	7.32
Tyrosine	3.54	3.36	3.12	2.88	2.74	3.28	3.28	3.25
Phenylalanine	4.69	4.58	4.16	4.07	3.78	4.27	4.4	4.29
Lysine	8.26	7.61	6.67	6.97	6.69	7.38	6.96	6.41
Histidine	2.66	2.73	2.87	2.27	2.05	2.32	2.75	2.8
Arginine	5.58	5.43	5.14	4.78	4.44	5.42	5.14	5.49
Cystine	2.29	2.3	2.18	2.28	2.32	2.18	2.7	2.16
Protein Recovery %	-	-	-	-	-	-	-	-
Original Moisture %	-	-	-	-	-	-	-	-
Crude Protein %	29.9	28.9	32.4	29	31.5	30.9	29.4	30.6
Fat %	2.06	2.05	1.05	2.01	2	1.79	1.37	1.78

Sample No	129	130	131	132	133	134	135	136
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	11.6	13.08	12.97	13.49	11.11	14.49	13.94	14.41
Threonine	4.01	4.18	4.61	4.27	3.7	4.23	4.07	4.46
Serine	4.17	5.23	5.5	5.31	3.67	3.9	3.58	4.48
Glutamic acid	9.89	10.84	11.34	10.94	9.42	12	11.14	11.81
Proline	6.59	7.91	9.26	7.54	7.11	7.12	7.13	7.1
Glycine	4.55	4.65	4.76	4.78	4.35	5.5	5.26	5.28
Alanine	4.83	5.18	5.48	5.28	4.77	5.68	5.44	5.57
Valine	5.27	4.24	4.92	4.23	5.21	6.34	6.12	6.23
Methionine	2.79	2.76	3.08	2.14	2.69	2.73	2.71	2.89
Isoleucine	4.83	3.8	4.45	3.81	4.8	5.79	5.6	5.73
Leucine	6.54	6.22	6.92	6.29	6.36	7.3	7.08	7.26
Tyrosine	2.79	3.1	3.37	3.14	2.46	3.05	2.93	2.91
Phenylalanine	3.8	3.64	3.88	3.73	3.7	4.44	4.23	4.35
Lysine	5.93	5.99	5.88	6.1	5.8	7.12	7.02	7.44
Histidine	2.51	2.3	2.67	2.38	2.51	2.97	2.86	2.97
Arginine	4.51	4.67	5.13	4.66	4.3	5.13	5.02	4.83
Cystine	2.52	2.5	2.77	2.01	2.3	2.34	2.44	2.61
Protein Recovery %	-	-	-	-	-	-	-	-
Original Moisture %	-	-	-	-	-	-	-	-
Crude Protein %	32.1	30.2	32.6	32.1	29.5	32	31.4	29.9
Fat %	1.52	1.77	1.84	1.65	1.84	1.38	2.14	1.17

Sample No	**137**	**138**	**139**	**140**	**141**	**142**	**143**	**144**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	13.81	14.71	13.74	14.04	14.25	14.29	14.3	13.31
Threonine	4.13	4.36	4.58	4.09	4.16	4.51	4.51	4.56
Serine	3.86	4.07	4.69	3.52	3.7	4.3	4.42	5.19
Glutamic acid	11.39	11.8	10.86	11.3	11.5	11.38	11.56	11.13
Proline	7.05	7.22	7.71	7.1	7.17	7.72	6.98	7.25
Glycine	5.22	5.33	5.15	5.13	5.36	5.41	5.24	4.69
Alanine	5.39	5.49	5.4	5.54	5.53	5.7	5.5	5.17
Valine	5.95	6.18	6	6.18	6.13	6.25	6.1	5.48
Methionine	2.79	2.81	2.76	2.53	2.7	2.73	2.26	2.65
Isoleucine	5.46	5.64	5.47	5.67	5.61	5.74	5.61	4.89
Leucine	6.78	7.19	7.24	7.16	7.11	7.31	7.19	6.83
Tyrosine	2.79	3.01	2.87	2.81	2.91	2.96	3.04	3.31
Phenylalanine	4.17	4.31	4.21	4.29	4.27	4.4	4.25	3.96
Lysine	7.08	7.29	7.03	7.13	7.06	7.33	7.27	5.86
Histidine	2.94	2.9	2.94	2.63	2.97	3.03	2.87	2.52
Arginine	4.64	5.34	5.31	4.83	4.87	5.09	5.04	5.18
Cystine	2.41	2.44	2.37	2.33	2.54	2.46	2.17	2.4
Protein Recovery %	-	-	-	-	-	-	-	-
Original Moisture %	-	-	-	-	-	-	-	-
Crude Protein %	32.8	33.1	28.1	30.2	30.4	28.8	32.7	30.9
Fat %	1.24	1.48	2.46	1.48	1.7	2.46	1.13	0.98

Sample No	**145**	**146**	**147**	**148**	**149**	**150**	**151**	**152**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	13.16	11.67	14.07	13.79	12.69	12.11	12.65	12.15
Threonine	4.18	4.29	4.51	4.46	4.66	4.48	4.21	4.38
Serine	5.23	4.9	5.57	5.55	5.29	5.01	4.87	5.09
Glutamic acid	11.05	10.48	11.78	11.59	10.88	10.57	10.57	10.55
Proline	6.13	7.12	6.31	6.02	7.22	6.98	6.12	6.7
Glycine	4.22	4.35	4.55	4.44	4.72	4.55	4.42	4.66
Alanine	5.02	5.08	5.44	5.37	5.41	5.07	4.92	5.1
Valine	4.74	5.12	5.15	5.09	5.57	5.31	4.99	5.18
Methionine	2.18	2.63	2.18	2.2	2.2	2.41	2.33	2.32
Isoleucine	4.28	4.64	4.62	4.64	4.59	4.57	4.05	4.35
Leucine	6.58	6.49	7.09	6.99	6.98	6.77	6.49	6.71
Tyrosine	2.9	2.87	3.07	3.07	3.11	3.08	2.79	3.08
Phenylalanine	3.72	4.02	3.95	3.94	4.02	4.18	3.72	4.11
Lysine	6.57	7.05	7.07	6.78	6.16	6.15	5.8	6.75
Histidine	2.18	2.23	2.61	2.86	2.45	2.16	2.79	2.63
Arginine	4.87	4.87	5.36	5.23	5.03	4.85	4.67	4.87
Cystine	1.38	2.31	1.43	1.39	1.35	1.42	1.41	1.47
Protein Recovery %	82.74	-	89.4	88.36	95.5	84.8	84.4	86.9
Original Moisture %	-	-	-	-	10.1	10.5	10.9	14.3
Crude Protein %	31.6	29	29.9	32.4	35.2	34.2	34.9	34.4
Fat %	1.9	1.73	1.9	1.4	1.5	1.6	1.9	1.2

Sample No	**153**	**154**	**155**	**156**	**157**	**158**	**159**	**160**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	12.57	12.36	12.96	12.57	12.63	11.67	11.11	12.36
Threonine	4.51	4.44	4.67	4.66	4.61	4.27	4.07	4.52
Serine	5.2	5.15	5.41	5.45	5.4	4.97	4.68	5.25
Glutamic acid	10.71	10.63	11.03	10.78	11.02	10.24	9.9	10.65
Proline	6.48	6.59	6.49	6.91	6.84	6.95	6.53	6.38
Glycine	4.78	4.72	4.84	4.89	4.72	4.39	4.24	4.63
Alanine	5.2	5.15	5.28	5.25	5.3	4.92	4.67	5.18
Valine	5.22	5.2	5.25	5.26	5.37	5.01	4.69	5.3
Methionine	2.12	2.22	2.33	2.36	2.25	2.2	2.3	2.38
Isoleucine	4.45	4.4	4.39	4.42	4.43	4.15	3.99	4.41
Leucine	6.93	6.82	7.05	6.96	6.97	6.48	6.2	6.88
Tyrosine	3.23	3.15	3.29	3.31	3.13	2.87	2.95	3.04
Phenylalanine	4.21	4.16	4.48	4.37	4.07	3.8	3.97	4.02
Lysine	6.95	6.85	6.4	6.2	6.34	5.9	5.39	6.43
Histidine	2.71	2.67	2.82	2.83	2.62	2.54	2.01	2.57
Arginine	5.03	4.95	5.14	5.15	4.98	4.66	4.59	4.87
Cystine	1.31	1.39	1.43	1.41	1.44	1.45	1.43	1.46
Protein Recovery %	87.9	87.4	89.3	88.4	88.1	82.8	82.3	86.2
Original Moisture %	14.3	14.3	10.7	15.7	8.2	9.3	9.3	17.6
Crude Protein %	34.4	34.4	34.9	33.8	35.7	36.2	36	34.2
Fat %	1.2	1.2	1.3	1	1.6	1.8	1.1	0.6

Sample No	**161**	**162**	**163**	**164**	**165**	**166**	**167**	**168**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	12.33	11.9	12.12	12.34	13.22	11.47	12.59	12
Threonine	4.43	4.26	4.35	4.49	4.82	4.04	4.58	4.31
Serine	5.19	4.98	5.08	5.23	5.57	4.8	5.21	4.95
Glutamic acid	10.75	10.37	10.56	10.76	11.59	9.75	10.85	10.26
Proline	7.03	6.84	6.93	6.87	7.8	6.18	6.26	6.44
Glycine	4.54	4.37	4.45	4.57	4.85	4.17	4.66	4.46
Alanine	5.12	4.92	5.02	5.11	5.42	4.65	5.23	4.99
Valine	5.31	5.02	5.16	5.2	5.52	4.64	5.38	5.11
Methionine	2.34	2.34	2.34	2.26	2.44	2.38	2.46	2.35
Isoleucine	4.35	4.19	4.27	4.33	4.62	3.83	4.47	4.23
Leucine	6.82	6.46	6.64	6.72	7.17	6.2	6.86	6.53
Tyrosine	3.06	2.93	3	3.08	3.35	2.82	3.14	2.9
Phenylalanine	4.06	3.88	3.97	4.04	4.3	3.71	4.09	3.83
Lysine	6.03	5.78	5.9	6.3	6.67	5.58	5.72	5.87
Histidine	2.63	2.45	2.54	2.48	2.75	2.46	2.5	2.43
Arginine	4.85	4.68	4.76	4.83	5.24	4.51	4.89	4.66
Cystine	1.45	1.45	1.45	1.4	1.54	1.45	1.43	1.49
Protein Recovery %	86.1	82.8	84.4	85.6	91.8	79.2	87.9	83.1
Original Moisture %	8.2	8.2	8.2	12.2	9.8	8	7.7	9.6
Crude Protein %	36.1	36.1	36.1	34.4	33.9	36	34.1	31.9
Fat %	2	2	2	1.5	1.4	1.8	1.9	2.2

Sample No	**169**	**170**	**171**	**172**	**173**	**174**	**175**	**176**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	13.6	14.59	14.52	12.9	14.01	14.06	14.37	15.24
Threonine	4.45	4.62	4.6	4.29	4.53	4.5	4.56	4.75
Serine	5.65	5.32	5.45	5.43	5.28	5.25	5.19	5.62
Glutamic acid	11.37	11.68	11.63	10.92	11.45	11.38	11.33	12.24
Proline	6.54	6.81	6.91	5.69	6.57	6.9	7.15	7.75
Glycine	4.42	4.9	4.94	4.21	4.75	4.76	4.82	5.13
Alanine	5.38	5.46	5.51	5.05	5.27	5.29	5.43	5.72
Valine	5.1	5.35	5.45	4.83	5.21	5.12	5.31	5.73
Methionine	2.24	2.32	2.28	2.2	2.32	2.36	2.31	2.39
Isoleucine	4.6	4.32	4.46	4.37	4.25	4.18	4.33	4.66
Leucine	6.83	7.18	7.1	6.54	6.98	6.9	7.05	7.52
Tyrosine	3.16	3.04	3.1	2.96	3	3.01	3.02	3.19
Phenylalanine	3.83	4.03	4.02	3.67	3.94	3.91	3.99	4.17
Lysine	6.13	6.23	6.25	5.83	6	5.98	6.34	6.46
Histidine	2.77	3.02	2.99	2.54	2.92	2.88	2.81	3.2
Arginine	5.1	4.98	5.13	4.96	4.91	4.89	4.98	5.27
Cystine	1.33	1.38	1.36	1.32	1.38	1.43	1.36	1.42
Protein Recovery %	87.34	91.4	93.1	82.78	89.1	89.5	96.1	97
Original Moisture %	-	10.6	11.3	-	11.8	10.8	11.7	10.6
Crude Protein %	30.3	35	36.1	33.1	34.5	36	35.1	34.7
Fat %	0.9	1.3	1.3	1.1	1.1	1.1	2.5	1.4

Sample No	**177**	**178**	**179**	**180**	**181**	**182**	**183**	**184**
Species	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**	**Paterson's curse**
Amino Acid								
Aspartic acid	13.89	13.23	13.9	14.29	11.85	14.43	13.04	16.94
Threonine	4.55	4.38	4.4	4.37	4.38	4.62	4.2	4.38
Serine	5.69	4.95	4.97	4.98	4.97	5.29	4.83	5.09
Glutamic acid	11.62	11.22	10.97	10.96	10.25	11.74	10.64	11.71
Proline	5.96	6.78	6.1	6.8	6.77	6.98	6.95	6.54
Glycine	4.41	4.65	4.62	4.62	4.33	4.85	4.46	4.93
Alanine	5.36	5.25	5.26	5.2	4.94	5.28	4.89	5.68
Valine	5.14	5.28	5.2	5.17	5.12	5.26	4.91	5.52
Methionine	2.18	2.22	2.32	2.37	2.26	2.18	2.3	2.25
Isoleucine	4.6	4.3	4.22	4.18	4.34	4.38	4.01	4.47
Leucine	6.91	6.86	6.77	6.75	6.59	7.09	6.44	7.19
Tyrosine	3.09	2.93	2.92	2.86	3.08	3.15	2.88	2.76
Phenylalanine	3.95	3.84	3.78	3.78	4.09	4.21	3.86	3.72
Lysine	7.02	7.57	6.46	6.08	6.36	7.07	6.26	6.98
Histidine	2.99	3.33	2.87	2.83	2.52	3.13	2.95	2.78
Arginine	5.12	4.86	4.74	4.87	4.76	5.07	4.53	4.63
Cystine	1.39	1.4	1.45	1.41	1.47	1.37	1.45	1.44
Protein Recovery %	88.74	91.4	92.4	93.3	84.2	92.1	85.4	93.7
Original Moisture %	-	8.1	10	7.9	6.9	9.6	9.7	8.8
Crude Protein %	31.5	36.2	34.8	37.4	36.9	33.4	34.9	36.3
Fat %	1.5	1.7	1.3	1.6	1.4	1.5	1.6	1.9

(Species not confirmed)

Sample No	**185**	**186**	**187**	**188**	**189**
Species	**St John's wort**	**St John's wort**	**Pea flower**	**Brown pollen**	**Burr daisy**
Amino Acid					
Aspartic acid	11.42	9.62	11.09	9.49	8.38
Threonine	4.41	4.53	4.52	4.79	4.52
Serine	4.7	5.5	5.56	5.57	5.06
Glutamic acid	11.24	10.61	10.78	10.63	8.84
Proline	11.51	14.34	13.65	18.53	11.36
Glycine	4.9	4.62	4.04	4.47	4.36
Alanine	5.6	5.46	5.04	5.58	4.63
Valine	6.12	5.11	4.98	5.83	4.2
Methionine	2.97	2.54	2.72	2.52	1.81
Isoleucine	5.46	4.45	4.25	5.4	3.75
Leucine	7.84	6.66	7.39	7.87	5.41
Tyrosine	3.41	3.05	3.7	3.51	2.61
Phenylalanine	5.24	4.04	4.38	4.67	3.34
Lysine	6.74	6.55	5.65	6.04	6.09
Histidine	2.35	2.71	2.64	2.2	3.08
Arginine	5.78	4.25	4.89	4.91	3.7
Cystine	2.51	2.39	1.99	2.11	2.56
Protein Recovery %	-	-	-	-	-
Original Moisture %	-	-	-	-	-
Crude Protein %	17.2	19.9	17.1	21.9	12.4
Fat %	1.11	4.95	6.67	4.68	2.82

(Species not confirmed)

Sample No	**190**	**191**	**192**	**193**	**194**
Species	**Cootamundra wattle**	**Mt.Devil**	**Mallee**	**Eggs and bacon**	**Eggs and bacon**
Amino Acid					
Aspartic acid	-	10.13	13.49	9.45	9.61
Threonine	-	4.64	5.03	3.7	4.06
Serine	-	6.43	6.46	4.44	5.04
Glutamic acid	-	11.7	12.56	9.73	10.06
Proline	-	14.5	5.95	11.42	10.94
Glycine	-	5.45	5.22	3.98	4.48
Alanine	-	5.38	6.07	4.77	5.17
Valine	-	5.66	6.2	4.75	5.03
Methionine	2.71	2.32	1.96	1.99	2.36
Isoleucine	-	4.27	5.02	3.66	3.83
Leucine	-	7.37	8.68	6.33	6.68
Tyrosine	-	3.38	3.76	2.66	2.8
Phenylalanine	-	5.24	5.22	3.73	3.9
Lysine	-	5.59	7.61	5.59	5.82
Histidine	-	3.48	3.32	2.71	2.69
Arginine	-	6.51	6.23	7.05	7.35
Cystine	2.18	1.25	1.44	1.12	1.34
Protein Recovery %	-	98.5	101.7	84.9	93.2
Original Moisture %	-	12.6	7.7	19.1	19
Crude Protein %	-	23.1	21	23.3	19.7
Fat %	5.12	1.1	1.5	1.6	1.7

Table 3. Minimum, mean and maximum values for all 194 pollens tested.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

Amino Acid	Minimum	Mean	Maximum
Aspartic acid	7.05	10.76	16.94
Threonine	3.01	4.2	5.11
Serine	3.38	5.09	6.46
Glutamic acid	6.76	10.7	16.56
Proline	4.83	10.66	39.38
Glycine	3.25	4.66	9.6
Alanine	3.93	5.23	6.59
Valine	2.98	5.1	7.19
Methionine	1	2.34	3.6
Isoleucine	2.7	4.28	5.79
Leucine	4.94	6.76	8.68
Tyrosine	1.98	2.95	3.76
Phenylalanine	2.86	4	5.24
Lysine	3.25	6.36	9.53
Histidine	1.59	2.64	4.9
Arginine	3.01	5.35	8.37
Cystine	1.02	1.82	3.54
Protein Recovery %	72.61	88.48	103.1
Original Moisture %	6.7	12.14	20.6
Crude Protein %	9.2	25.85	37.4
Fat %	0	2.52	11.2

Table 4. Common name, scientific name, location and date pollen collected and chemistry laboratory pollen analysed.

No.	Common Name	Scientific Name	Location Collected	Date Collected	Chem. Lab.
1	Almond	Prunus dulcis	Darlington Pt	20-Aug-95	NSW
2	Almond	Prunus dulcis	Mildura, Vic.	01-Sep-96	NSW
3	Alpine ash	*Eucalyptus delegatensis*	Tumbarumba	20-Feb-96	NSW
4	Apple box	*Eucalyptus bridgesiana*	Burra Ck.	22-Mar-96	NSW
5	Apple box	*Eucalyptus bridgesiana*	Ironmungie	04-Mar-96	NSW
6	Apple box	*Eucalyptus bridgesiana*	Bombala	12-Mar-96	NSW
7	Apple box	*Eucalyptus bridgesiana*	Bombala	12-Mar-96	VIC
8	Apple box	*Eucalyptus bridgesiana*	Williamsdale	12-Mar-96	NSW
9	Apple box	*Eucalyptus bridgesiana*	Collector	Feb-97	VIC
10	Balansa clover	*Trifolium balansae*	Wagga Wagga	17-Oct-95	NSW
11	Balansa clover	*Trifolium balansae*	Ariah Park	04-Oct-96	VIC
12	Black she-oak	*Casuarina littoralis*	Sussex Inlet	14-Jun-96	NSW
13	Black she-oak	*Casuarina littoralis*	Sussex Inlet	25-Jun-96	NSW
14	Black she-oak	*Casuarina littoralis*	Millingandi	Jun-96	NSW
15	Black thistle	*Cirsium vulgare*	Taralga	Feb-96	NSW
16	Black thistle	*Cirsium vulgare*	Collector	Feb-97	VIC
17	Black thistle	*Cirsium vulgare*	Black Springs	02-Feb-96	NSW
18	Blakely's red gum	*Eucalyptus blakelyi*	Jugiong	05-Dec-96	VIC
19	Bloodwood	*Corymbia gummifera*	Nowra	24-Mar-97	VIC
20	Blueberry	*Vaccinium species*	Gunning	Sep-95	NSW
21	Brittle gum	*Eucalyptus mannifera*	Bungonia	24-Mar-97	VIC
22	Brittle gum	*Eucalyptus mannifera*	Oberon	16-Apr-97	VIC
23	Buckwheat	*Fagopyrum esculentum*	Black Springs	10-Jan-98	VIC
24	Canola	*Brassica napus*	Darlington Pt	28-Aug-95	NSW
25	Canola	*Brassica napus*	Darlington Pt	28-Aug-95	VIC
26	Canola	*Brassica napus*	Woodstock	Sep-97	VIC
27	Canola	*Brassica napus*	Stockinbingal	Nov-96	VIC
28	Canola (Oscar)	*Brassica napus*	Ariah Park	12-Sep-95	NSW
29	Cape weed	*Arctotheca calendula*	Dubbo	09-Sep-96	VIC
30	Christmas mallee	*Eucalyptus socialis*	Weethale	23-Dec-96	VIC
31	Citrus	*Citrus species*	Paynters Siding	10-Nov-97	VIC
32	Clover	*Trifolium repens*	Candelo	01-Nov-96	VIC
33	Currawong wattle	*Acacia doratoxylon*	Dubbo	07-Oct-96	VIC
34	Eggs and bacon	*Dillwynia species*	Nowra	26-Sep-97	VIC
35	Eggs and bacon	*Dillwynia species*	Nowra	26-Sep-97	VIC
36	Eggs and bacon	*Dillwynia species*	Nowra	26-Sep-97	VIC
37	Faba bean	*Vicia faba*	Darlington Pt	28-Aug-95	NSW
38	Fireweed	*Senecio madagascariensis*	Nowra	03-Sep-96	NSW
39	Flatweed	*Hypochoeris radicata*	Oberon	03-Jan-98	VIC
40	Flatweed	*Hypochoeris radicata*	Bungonia	10-Nov-97	VIC
41	Flatweed	*Hypochoeris radicata*	Bungonia	10-Nov-97	VIC
42	Flatweed	*Hypochoeris radicata*	Bungonia	10-Nov-97	VIC
43	Flatweed	*Hypochoeris radicata*	Goulburn	24-Dec-98	VIC
44	Flatweed	*Hypochoeris radicata*	Molong	16-Nov-96	VIC
45	Flatweed	*Hypochoeris radicata*	Tarago	27-Jan-96	VIC
46	Flatweed	*Hypochoeris radicata*	Black Springs	02-Feb-96	NSW

No.	Common Name	Scientific Name	Location Collected	Date Collected	Chem. Lab.
47	Flatweed	*Hypochoeris radicata*	Amaroo	Jan-96	NSW
48	Flatweed	*Hypochoeris radicata*	Bathurst	Jan-98	VIC
49	Flatweed	*Hypochoeris radicata*	Weethale	14-Jan-97	VIC
50	Gorse	*Ulex europaeus*	Collector	27-Aug-96	NSW
51	Grey box	*Eucalyptus microcarpa*	Flagstaff	26-Mar-97	VIC
52	Grey gum	*Eucalyptus punctata*	Nowra SF	28-Jan-97	VIC
53	Heath-leaved banksia	*Banksia ericifolia*	Shoalhaven	26-Jun-96	NSW
54	Lavender	*Lavandula species*	Goulburn	24-Dec-98	VIC
55	Lupin	*Lupinus angustifolius*	Boree Ck	15-Sep-97	VIC
56	Lupin	*Lupinus angustifolius*	Sandigo	09-Sep-98	VIC
57	Maize	*Zea mays*	Darlington Pt	11-Jan-96	NSW
58	Manna gum	*Eucalyptus viminalis*	Nimmitabel	12-Mar-96	NSW
59	Mustard	*Sisymbrium officinale*	Goulburn	17-Nov-95	NSW
60	Mustard	*Sisymbrium officinale*	Tarago	Feb-96	NSW
61	Mustard	*Sisymbrium officinale*	Goulburn	12-Feb-96	NSW
62	Nodding thistle	*Caduus nutans*	Taralga	08-Feb-96	NSW
63	Onion weed	*Asphodelus fistulosus*	Carwarp, Vic.	Sep-96	VIC
64	Pear	*Pyrus connunis*	Goulburn Valley, Vic.	Oct-97	VIC
65	Pussy willow	Salix discolor	Lithgow	06-Sep-95	NSW
66	Red box	Eucalyptus polyanthemos	Bigga	26-Sep-96	VIC
67	Red ironbark	*Eucalyptus fibrosa*	Mogo	21-Feb-96	NSW
68	Red stringybark	*Eucalyptus macrorhyncha*	Nth Orange	Feb-96	NSW
69	Red stringybark	*Eucalyptus macrorhyncha*	Abercrombie Caves	Mar-96	NSW
70	Red stringybark	*Eucalyptus macrorhyncha*	Tumbarumba	25-Feb-98	VIC
71	Red stringybark	*Eucalyptus macrorhyncha*	Oberon	23-Feb-97	VIC
72	River red gum	*Eucalyptus camaldulensis*	Narrandera	22-Dec-95	NSW
73	River red gum	*Eucalyptus camaldulensis*	Darlington Pt	Dec-96	VIC
74	Rough-barked apple	*Angophora floribunda*	Bega	19-Jan-96	NSW
75	Rough-barked apple	*Angophora floribunda*	Bega	Jan-96	VIC
76	Rough-barked apple	*Angophora floribunda*	Bega	14-Jan-98	VIC
77	Rough-barked apple	*Angophora floribunda*	Bega	14-Jan-98	VIC
78	Rough-barked apple	*Angophora floribunda*	Bega	14-Jan-98	VIC
79	Saffron thistle	*Carthamus lanatus*	Taralga	08-Feb-96	NSW
80	Saw banksia	*Banksia serrata*	Nowra SF	28-Jan-97	VIC
81	Scribbly gum	*Eucalyptus sclerophylla*	Nowra SF	24-Mar-97	VIC
82	Silky hakea	*Hakea sericea*	Nowra	02-Aug-96	NSW
83	Skeleton weed	*Chondrilla juncea*	Yetholme	Jan-96	NSW
84	Skeleton weed	*Chondrilla juncea*	Leneva, Vic.	14-Feb-96	NSW
85	Spotted gum	*Corymbia maculata*	Moruya	Jul-97	VIC
86	Spotted gum	*Corymbia maculata*	Moruya	27-May-97	VIC
87	Spotted gum	*Corymbia maculata*	Nowra SF	09-Jul-97	VIC
88	Spotted gum	*Corymbia maculata*	Bermagui	18-Jun-97	VIC
89	Spotted gum	*Corymbia maculata*	Moruya	Jul-97	VIC
90	Spotted gum	*Corymbia maculata*	Narooma	Jul-97	VIC
91	Sunflower	*Helianthus annuus*	Griffith	20-Jan-96	NSW
92	Sunflower	*Helianthus annuus*	Griffith	16-Jan-97	VIC

No.	Common Name	Scientific Name	Location Collected	Date Collected	Chem. Lab.
93	Swamp mahogany	*Eucalyptus robusta*	Jervis Bay	03-Sep-96	NSW
94	Sweet-scented wattle	*Acacia suaveolens*	Shoalhaven	26-Jun-96	NSW
95	Sydney blue gum	*Eucalyptus saligna*	Termeil	06-Mar-97	VIC
96	Sydney golden wattle	*Acacia longifolia*	Nowra	24-Jul-96	NSW
97	Turnip weed	*Rapistrum rugosum*	Paynters Siding	30-Oct-95	NSW
98	Turnip weed	*Rapistrum rugosum*	Mildura, Vic.	01-Sep-96	NSW
99	Turnip weed	*Rapistrum rugosum*	Coonamble	Aug-96	NSW
100	Turnip weed	*Rapistrum rugosum*	Dirranbandi, Qld.	Aug-96	NSW
101	Turnip weed	*Rapistrum rugosum*	Walgett	21-Aug-96	VIC
102	Vetch	*Vicia species*	Boree Ck	28-Sep-95	NSW
103	Vetch	*Vicia species*	Sandigo	28-Sep-95	NSW
104	Vipers bugloss	*Echium vulgare*	Yetholme	Jan-96	VIC
105	Wattle	*Acacia species*	Murrah SF	22-Aug-95	NSW
106	White box	*Eucalyptus albens*	Blackville	29-Jun-96	NSW
107	White box	*Eucalyptus albens*	Carroll	10-Jun-96	NSW
108	White box	*Eucalyptus albens*	Carroll	Aug-96	NSW
109	White box	*Eucalyptus albens*	Bigga	07-Aug-96	VIC
110	White mallee	*Eucalyptus dumosa*	West Wyalong	12-Feb-97	VIC
111	White mallee	*Eucalyptus dumosa*	Dubbo	20-Feb-98	VIC
112	White stringybark	*Eucalyptus globoidea*	Nowra	26-Sep-97	VIC
113	Willow	*Salix species*	Tarana	12-Sep-95	NSW
114	Willow	*Salix species*	Goulburn	07-Sep-95	NSW
115	Woollybutt	*Eucalyptus longifolia*	Murrah SF	28-Jun-95	NSW
116	Woollybutt	*Eucalyptus longifolia*	Millingandi	Jun-96	NSW
117	Yellow burr	*Centaurea solstitialis*	Molong	28-Jan-96	NSW
118	Paterson's curse	Echium plantagineum	Junee	10-Nov-95	NSW
119	Paterson's curse	*Echium plantagineum*	Dubbo	17-Oct-95	NSW
120	Paterson's curse	*Echium plantagineum*	Bethungra	26-Oct-95	NSW
121	Paterson's curse	*Echium plantagineum*	Grenfell	31-Oct-95	NSW
122	Paterson's curse	*Echium plantagineum*	Leneva, Vic.	01-Nov-95	NSW
123	Paterson's curse	*Echium plantagineum*	Leneva, Vic.	21-Nov-95	NSW
124	Paterson's curse	*Echium plantagineum*	Narrandera	30-Oct-95	NSW
125	Paterson's curse	*Echium plantagineum*	Stockinbingal	15-Nov-95	NSW
126	Paterson's curse	*Echium plantagineum*	Bathurst	18-Nov-95	NSW
127	Paterson's curse	*Echium plantagineum*	Carcoar	Dec-95	NSW
128	Paterson's curse	*Echium plantagineum*	Breakfast ck	Dec-95	NSW
129	Paterson's curse	*Echium plantagineum*	Breakfast ck	Dec-95	NSW
130	Paterson's curse	*Echium plantagineum*	Canowindra	Nov-95	NSW
131	Paterson's curse	Echium plantagineum	Tarana	08-Nov-95	NSW
132	Paterson's curse	*Echium plantagineum*	SE Cowra	Dec-95	NSW
133	Paterson's curse	*Echium plantagineum*	Cowra	18-Nov-95	NSW
134	Paterson's curse	*Echium plantagineum*	Darlington Pt	07-Nov-95	NSW
135	Paterson's curse	*Echium plantagineum*	Candelo	14-Nov-95	NSW
136	Paterson's curse	*Echium plantagineum*	Wagga Wagga	11-Nov-95	NSW
137	Paterson's curse	*Echium plantagineum*	Jugiong	02-Nov-95	NSW
138	Paterson's curse	*Echium plantagineum*	Nth Cowra	06-Dec-95	NSW
139	Paterson's curse	*Echium plantagineum*	Greenthorpe	03-Nov-95	NSW
140	Paterson's curse	*Echium plantagineum*	Sth Cowra	06-Dec-95	NSW

No.	Common Name	Scientific Name	Location Collected	Date Collected	Chem. Lab.
141	Paterson's curse	*Echium plantagineum*	Nangus	04-Nov-95	NSW
142	Paterson's curse	*Echium plantagineum*	Greenthorpe	17-Nov-95	NSW
143	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	20-Nov-95	NSW
144	Paterson's curse	Echium plantagineum	Bathurst	15-Oct-95	NSW
145	Paterson's curse	*Echium plantagineum*	Bathurst	15-Oct-95	VIC
146	Paterson's curse	*Echium plantagineum*	Goulburn	17-Nov-95	NSW
147	Paterson's curse	*Echium plantagineum*	Goulburn	17-Nov-95	VIC
		Echium plantagineum			
148	Paterson's curse	*Echium plantagineum*	Darlington Pt	Sep-96	VIC
149	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	26-Nov-96	VIC
150	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	29-Nov-96	VIC
151	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	08-Dec-96	VIC
152	Paterson's curse	*Echium plantagineum*	Dubbo	15-Oct-96	VIC
153	" "	*Echium plantagineum*	" "	" "	VIC
154	" "	*Echium plantagineum*	" "	" "	VIC
155	Paterson's curse	*Echium plantagineum*	Narrandera	25-Oct-96	VIC
156	Paterson's curse	Echium plantagineum	W.A.	96	VIC
157	Paterson's curse	*Echium plantagineum*	Mingenew W.A.	Nov-96	VIC
158	Paterson's curse	*Echium plantagineum*	Goulburn	03-Nov-96	VIC
159	Paterson's curse	*Echium plantagineum*	Cowra	13-Dec-96	VIC
160	Paterson's curse	*Echium plantagineum*	Harden	21-Nov-96	VIC
161	Paterson's curse	*Echium plantagineum*	Canowindra-Eugowra	01-Dec-96	VIC
162	" "	*Echium plantagineum*	" "	" "	VIC
163	" "	*Echium plantagineum*	" "	" "	VIC
164	Paterson's curse	*Echium plantagineum*	Candelo	07-Nov-96	VIC
165	Paterson's curse	*Echium plantagineum*	Molong	16-Nov-96	VIC
166	Paterson's curse	*Echium plantagineum*	Cowra	15-Dec-96	VIC
167	Paterson's curse	*Echium plantagineum*	Stockinbingal	Nov-96	VIC
168	Paterson's curse	*Echium plantagineum*	Canowindra	13-Dec-96	VIC
169	Paterson's curse	Echium plantagineum	Henry Lawson Way	05-Nov-97	VIC
170	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	11-Nov-97	VIC
171	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	15-Nov-97	VIC
172	Paterson's curse	*Echium plantagineum*	Henry Lawson Way	19-Nov-97	VIC
173	Paterson's curse	*Echium plantagineum*	Bimby Rd	05-Nov-97	VIC
174	Paterson's curse	*Echium plantagineum*	Bimby Rd	11-Nov-97	VIC
175	Paterson's curse	*Echium plantagineum*	Bimby Rd	15-Nov-97	VIC
176	Paterson's curse	*Echium plantagineum*	Bimby Rd	19-Nov-97	VIC
177	Paterson's curse	*Echium plantagineum*	Jugiong	14-Nov-97	VIC
178	Paterson's curse	*Echium plantagineum*	Goulburn	16-Nov-97	VIC
179	Paterson's curse	*Echium plantagineum*	Narrandera	10-Nov-97	VIC
180	Paterson's curse	*Echium plantagineum*	Cowra	05-Nov-97	VIC
181	Paterson's curse	*Echium plantagineum*	Cowra	25-Nov-97	VIC
182	Paterson's curse	*Echium plantagineum*	Dubbo	20-Oct-97	VIC
183	Paterson's curse	*Echium plantagineum*	Woodstock	Oct-97	VIC
184	Paterson's curse	*Echium plantagineum*	Candelo	18-Nov-97	VIC

4.1 Variability of Paterson's Curse Pollens in 1995, 1996 and 1997 for 17 Amino Acids, Crude Protein and Fat %

A total of 61 pollen samples were obtained from Paterson's curse *(Echium plantagineum)*; 28 samples in 1995, 17 in 1996 and 16 in 1997.

The following three tables contain the means, median, minimum, maximum, standard deviation and coefficient of variation for the amino acids, protein and fat levels tested over three years. Individual box plots for each variant tested visually indicate the variability for each variant for the three year period.

Table 5. Summary of statistics for Paterson's curse pollen samples.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

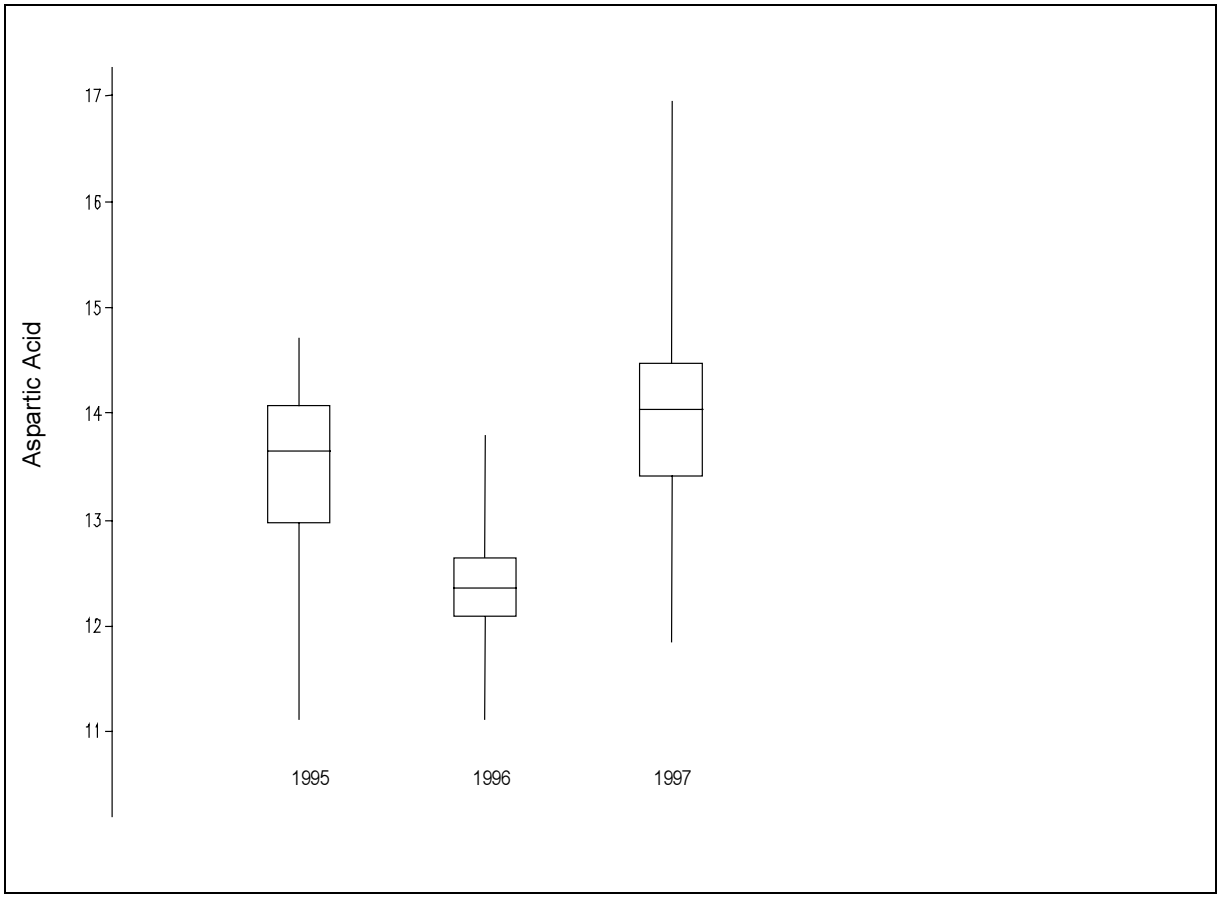
1995 (28 samples)						
	Mean	Median	**Minimum**	**Maximum**	**Standard Deviation**	**Coefficient Variation**
Aspartic Acid	13.35	13.63	11.11	14.71	1.01	7.59
Threonine	4.39	4.42	3.7	4.96	0.29	6.56
Serine	4.76	4.98	3.52	5.62	0.68	14.34
Glutamic Acid	11.19	11.25	9.42	12.38	0.66	5.87
Proline	7.38	7.15	6.13	9.26	0.74	10.03
Glycine	4.89	4.83	4.16	5.5	0.38	7.83
Alanine	5.36	5.44	4.71	5.86	0.28	5.22
Valine	5.53	5.56	4.23	6.34	0.59	10.72
Methionine	2.59	2.62	2.14	3.08	0.23	8.98
Isoleucine	5.05	5.06	3.8	5.79	0.56	11.14
Leucine	6.94	7.09	6.13	7.63	0.39	5.65
Tyrosine	3.04	3.05	2.46	3.54	0.23	7.55
Phenylalanine	4.15	4.21	3.64	4.69	0.27	6.59
Lysine	6.91	7.05	5.8	8.26	0.61	8.87
Histidine	2.62	2.65	2.05	3.03	0.28	10.83
Arginine	5.01	5.07	4.3	5.58	0.32	6.39
Cystine	2.3	2.33	1.38	2.77	0.29	12.97
Crude Protein %	30.82	30.75	28.1	33.1	1.43	4.65
Fat %	1.71	1.76	0.98	2.46	0.38	22.15

Fat % levels have a consistently high coefficient of variation. Fat levels varying by 0.3 or 0.4 when the mean is 1.71, 1.53 or 1.45 are interpreted as having a high degree of variability but this needs to be considered against the low levels found in the samples. It is probable that the lower the levels of a substance such as fat content, in this case, the harder or more difficult it will be to test for that substance accurately.

Table 5. (cont...)

1996 (17 samples)						
	Mean	**Median**	**Minimum**	**Maximum**	**Standard Deviation**	**Coefficient Variation**
Aspartic Acid	12.36	12.36	11.11	13.79	0.59	4.75
Threonine	4.44	4.46	4.04	4.82	0.2	4.5
Serine	5.16	5.19	4.68	5.57	0.24	4.65
Glutamic Acid	10.67	10.65	9.75	11.59	0.45	4.18
Proline	6.69	6.7	6.02	7.8	0.42	6.22
Glycine	4.57	4.57	4.17	4.89	0.19	4.35
Alanine	5.11	5.12	4.65	5.42	0.21	4.16
Valine	5.18	5.2	4.64	5.57	0.23	4.41
Methionine	2.31	2.33	2.12	2.46	0.09	3.79
Isoleucine	4.34	4.39	3.83	4.64	0.21	4.84
Leucine	6.74	6.82	6.2	7.17	0.27	3.97
Tyrosine	3.07	3.08	2.79	3.35	0.15	5.03
Phenylalanine	4.04	4.04	3.71	4.48	0.2	4.95
Lysine	6.19	6.16	5.39	6.95	0.44	7.13
Histidine	2.57	2.57	2.01	2.86	0.21	8.22
Arginine	4.88	4.87	4.51	5.24	0.21	4.28
Cystine	1.43	1.43	1.31	1.54	0.05	3.36
Crude Protein %	34.73	34.4	31.9	36.2	1.19	3.45
Fat %	1.53	1.5	0.6	2.2	0.41	26.44

1997 (16 samples)						
	Mean	**Median**	**Minimum**	**Maximum**	**Standard Deviation**	**Coefficient Variation**
Aspartic Acid	14.05	14.04	11.85	16.94	1.12	7.94
Threonine	4.47	4.47	4.2	4.75	0.14	3.18
Serine	5.25	5.27	4.83	5.69	0.27	5.15
Glutamic Acid	11.32	11.37	10.25	12.24	0.48	4.29
Proline	6.7	6.79	5.69	7.75	0.49	7.27
Glycine	4.67	4.7	4.21	5.13	0.26	5.47
Alanine	5.31	5.29	4.89	5.72	0.23	4.33
Valine	5.23	5.21	4.83	5.73	0.22	4.19
Methionine	2.28	2.29	2.18	2.39	0.07	2.89
Isoleucine	4.35	4.34	4.01	4.66	0.17	3.99
Leucine	6.92	6.91	6.44	7.52	0.27	3.97
Tyrosine	3.01	3.02	2.76	3.19	0.12	3.97
Phenylalanine	3.92	3.93	3.67	4.21	0.16	3.97
Lysine	6.44	6.3	5.83	7.57	0.48	7.43
Histidine	2.91	2.9	2.52	3.33	0.21	7.32
Arginine	4.91	4.94	4.53	5.27	0.19	3.96
Cystine	1.39	1.39	1.32	1.47	0.04	3.15
Crude Protein %	34.76	34.95	30.3	37.4	1.91	5.49
Fat %	1.45	1.4	0.9	2.5	0.38	26.17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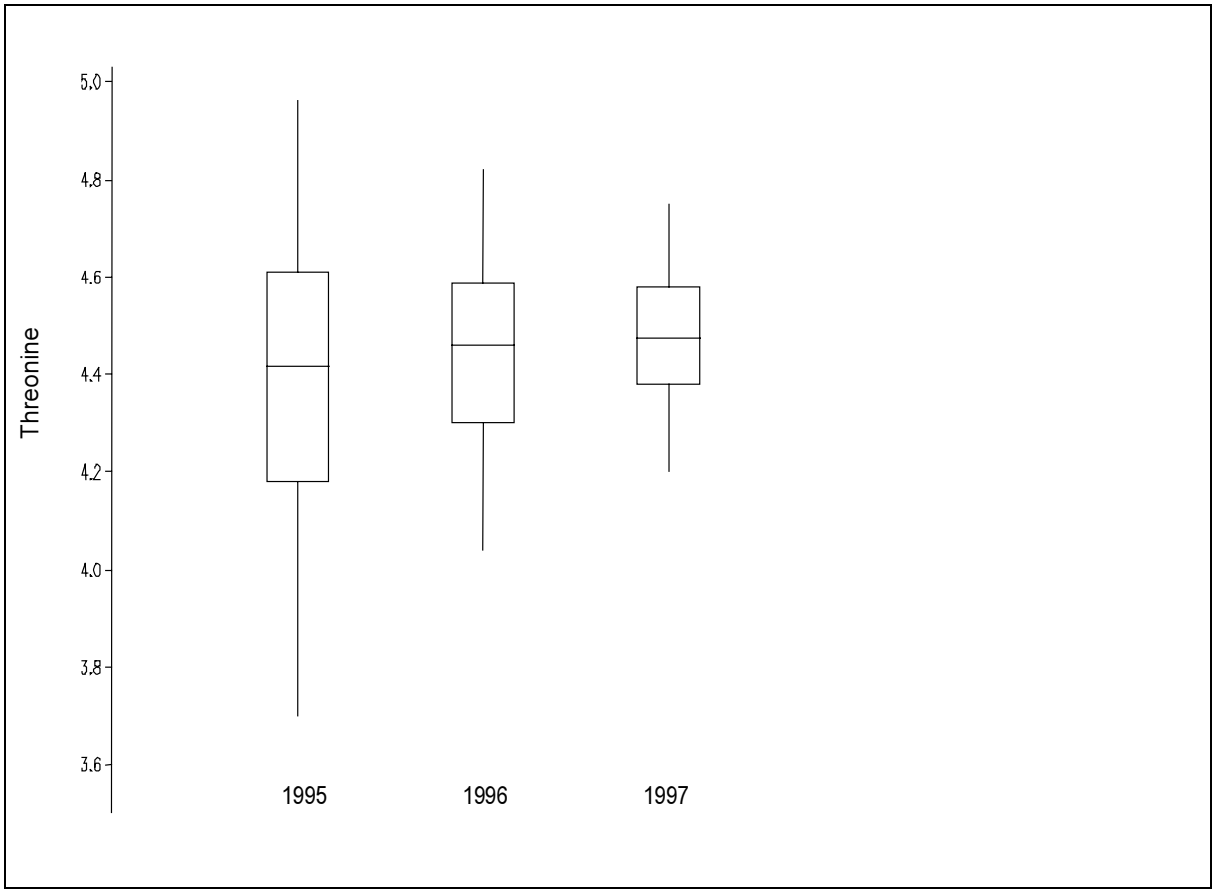
17
16
15
14
13
12
11
1995
1996
1997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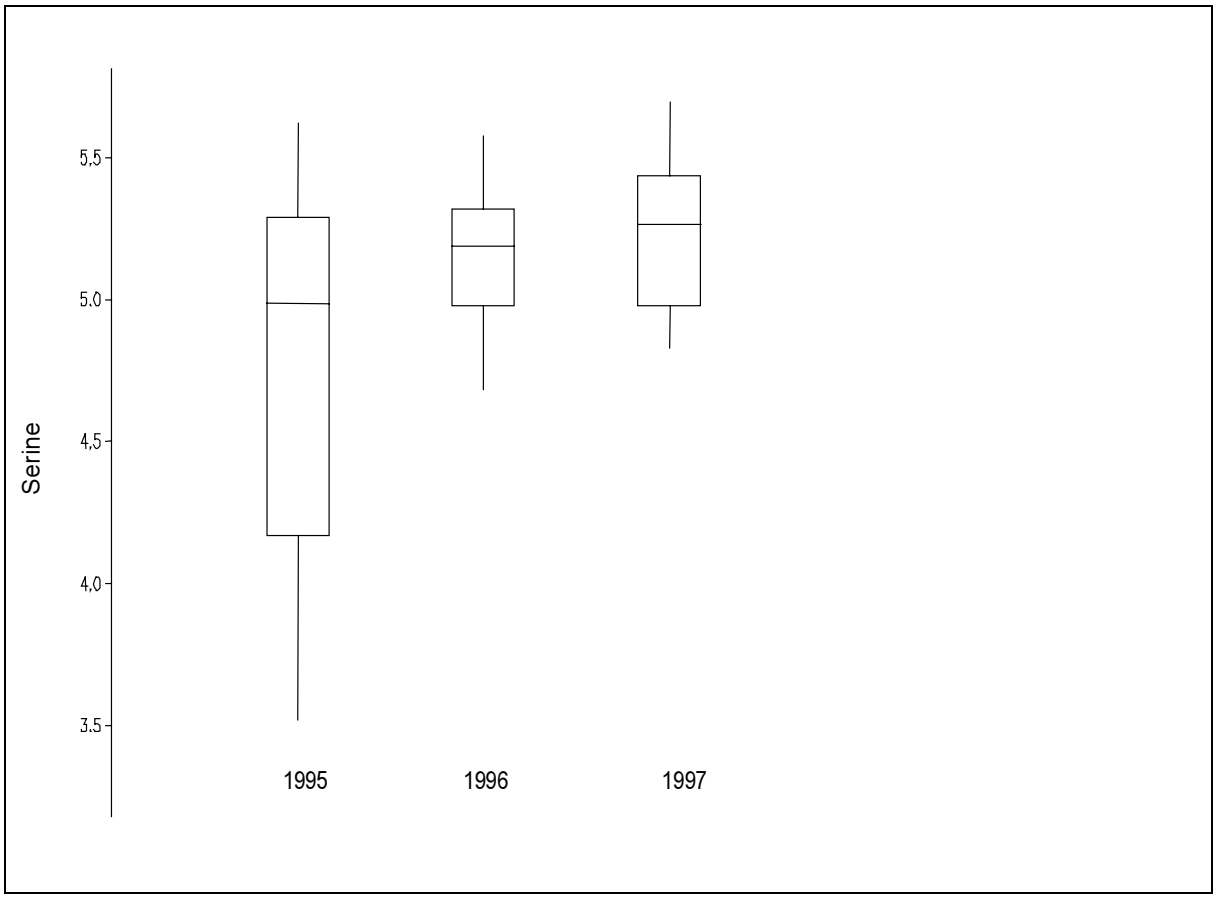
1995
1996
1997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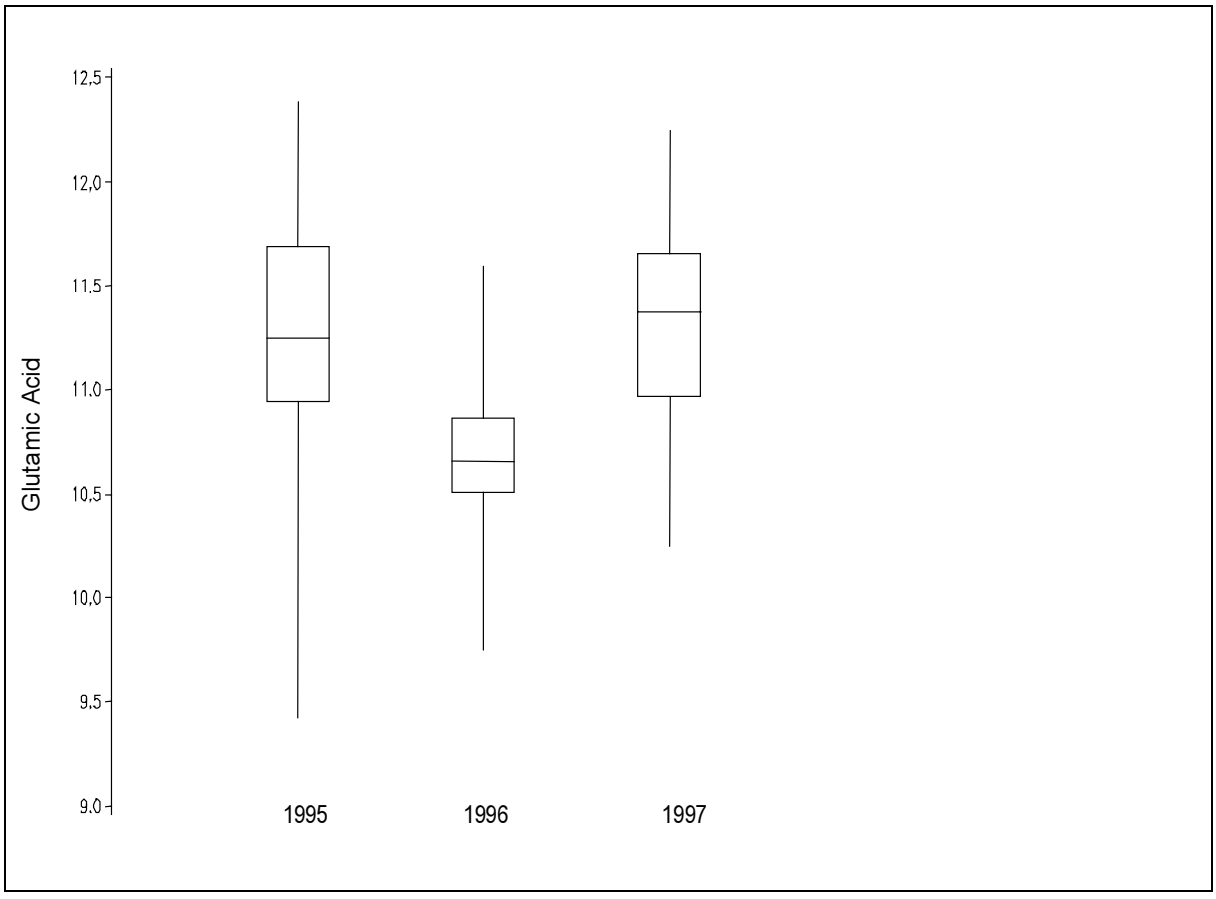
3.5
1995
1996
1997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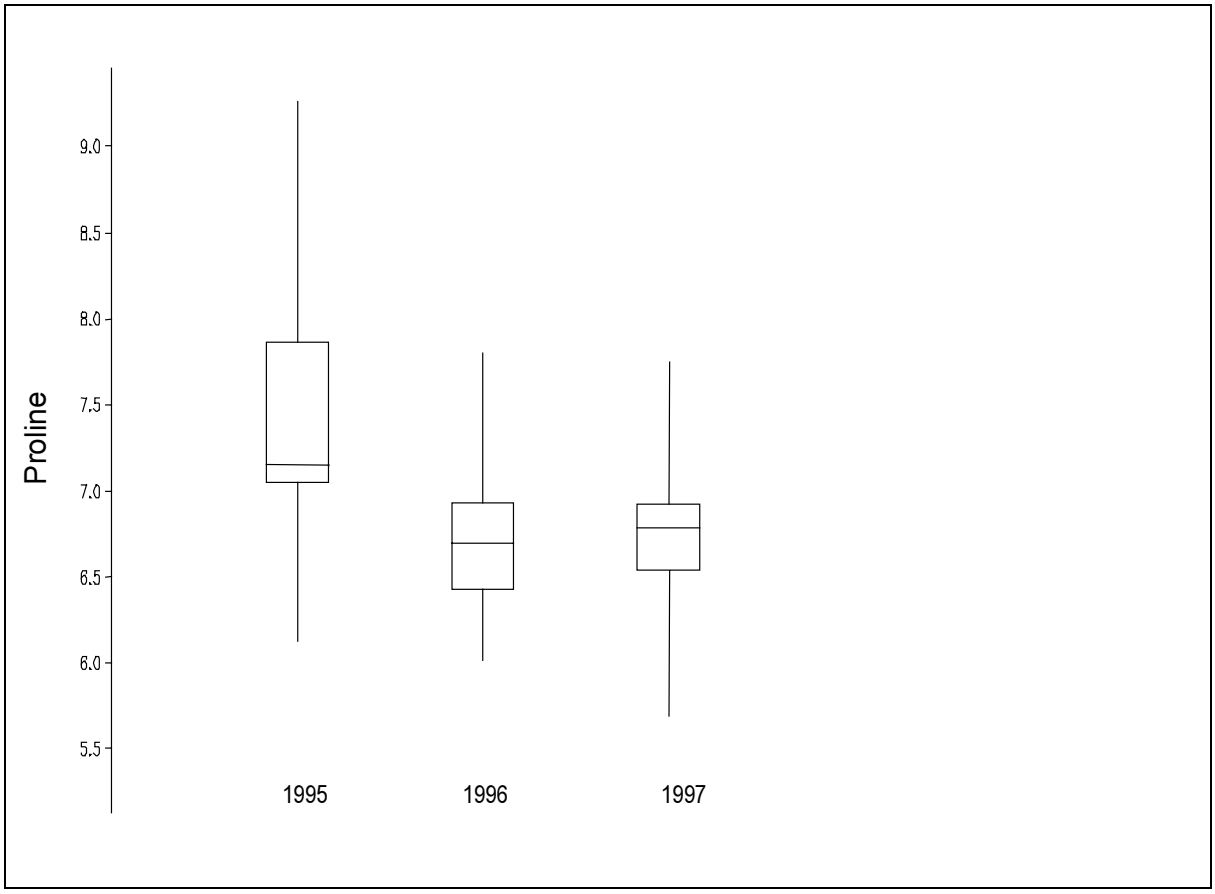
10.0
9.5
9.0
1995
1996
1997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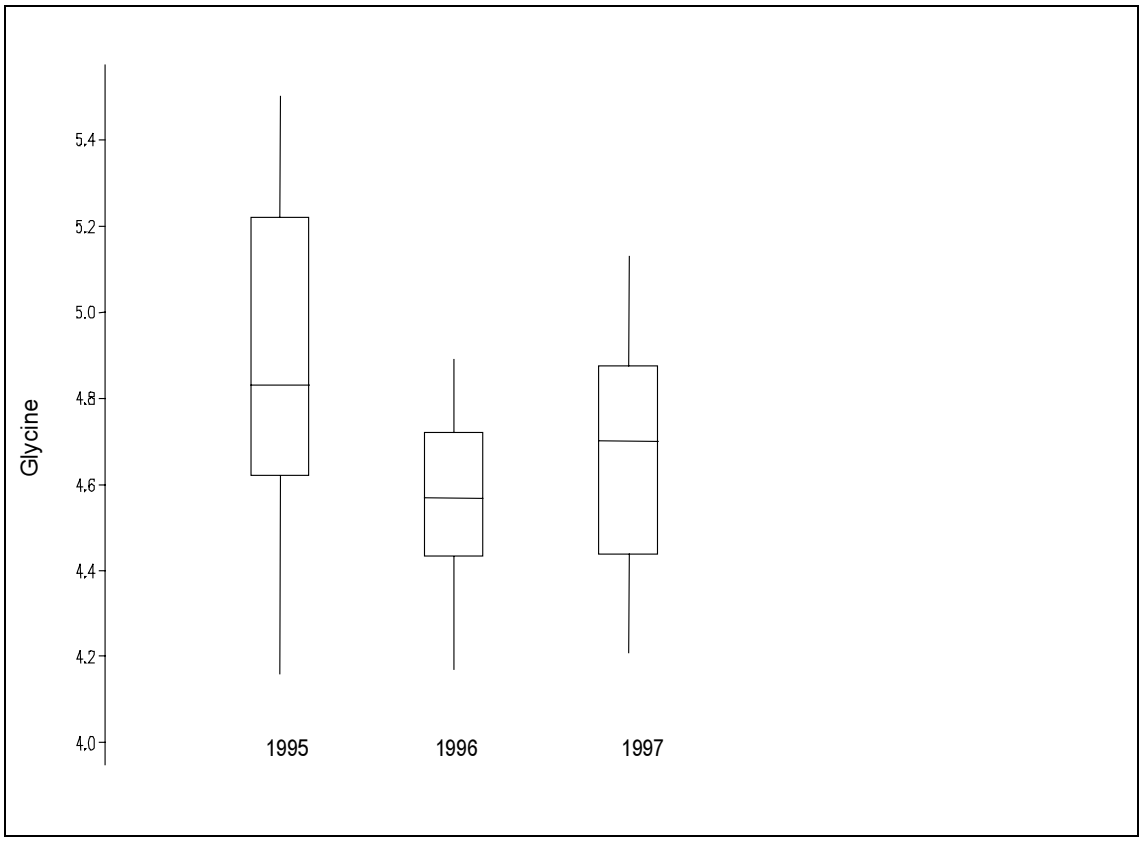
6.0
5.5
1995
1996
1997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4.4
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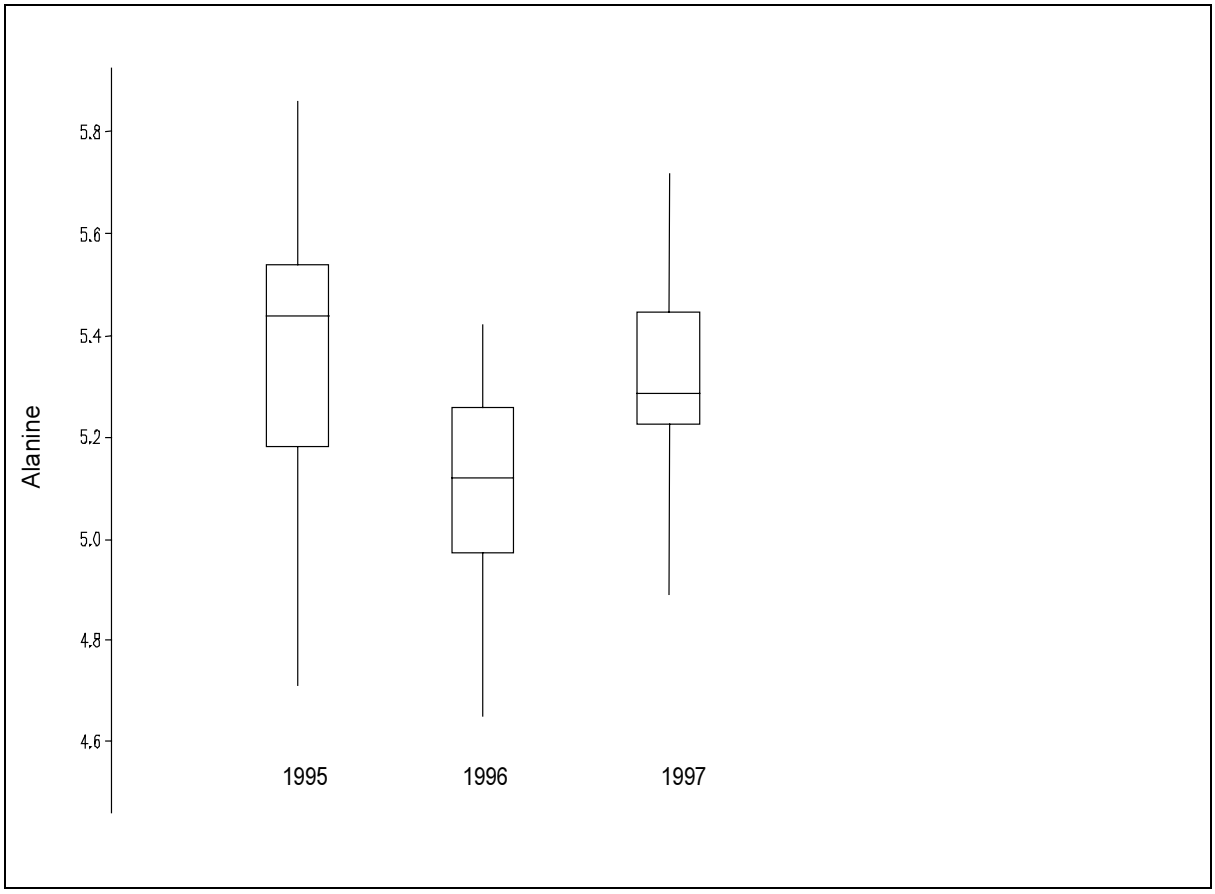
4.0
1995
1996
1997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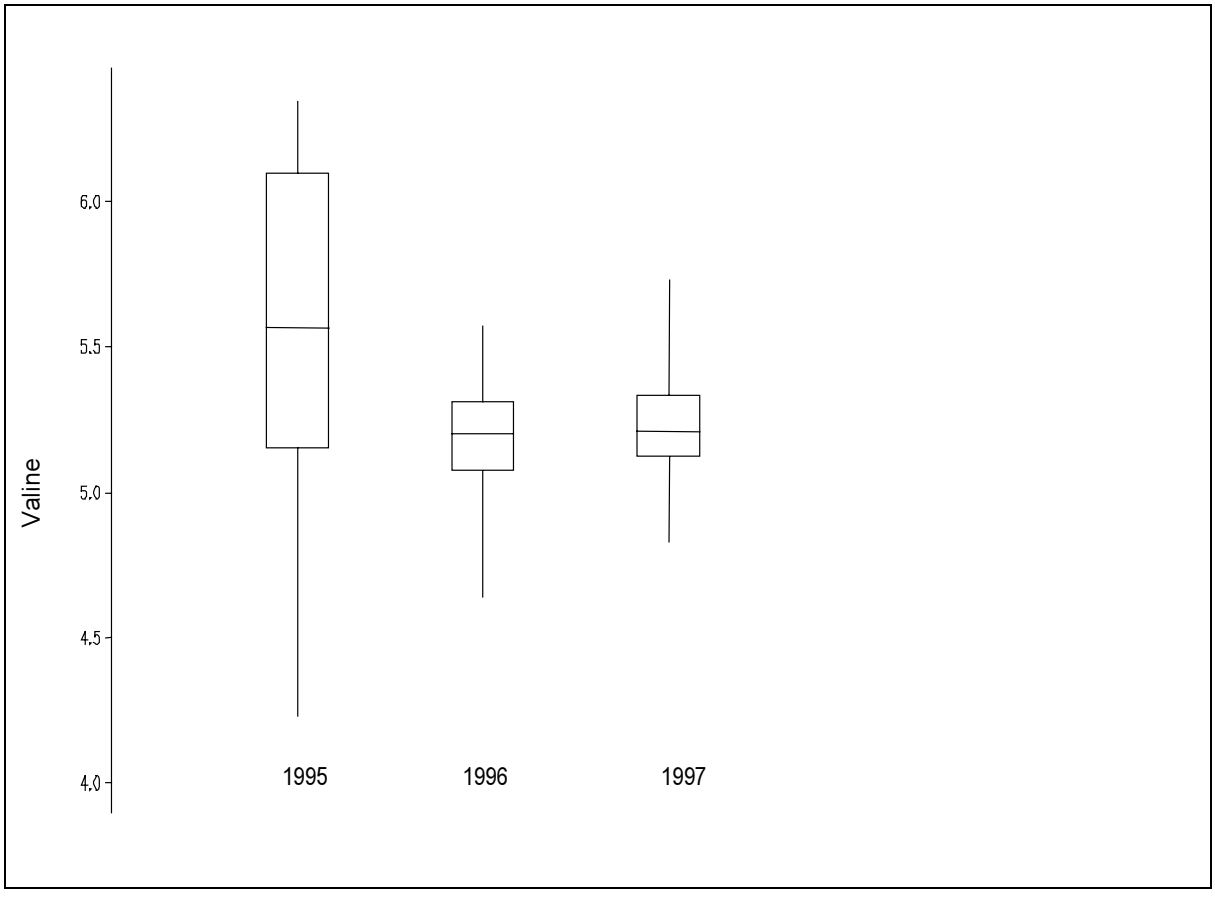
1995
1996
1997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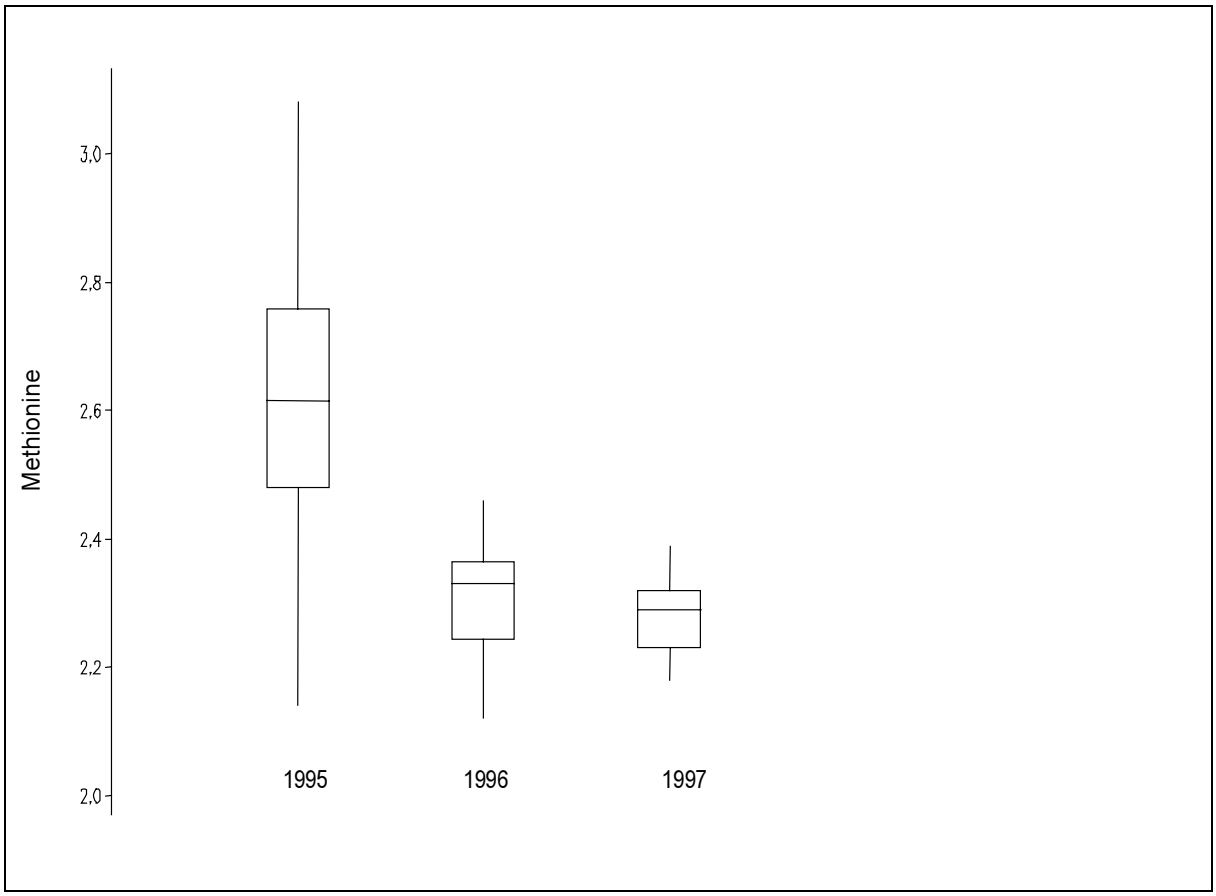
5.0
4.5
4.0
1995
1996
1997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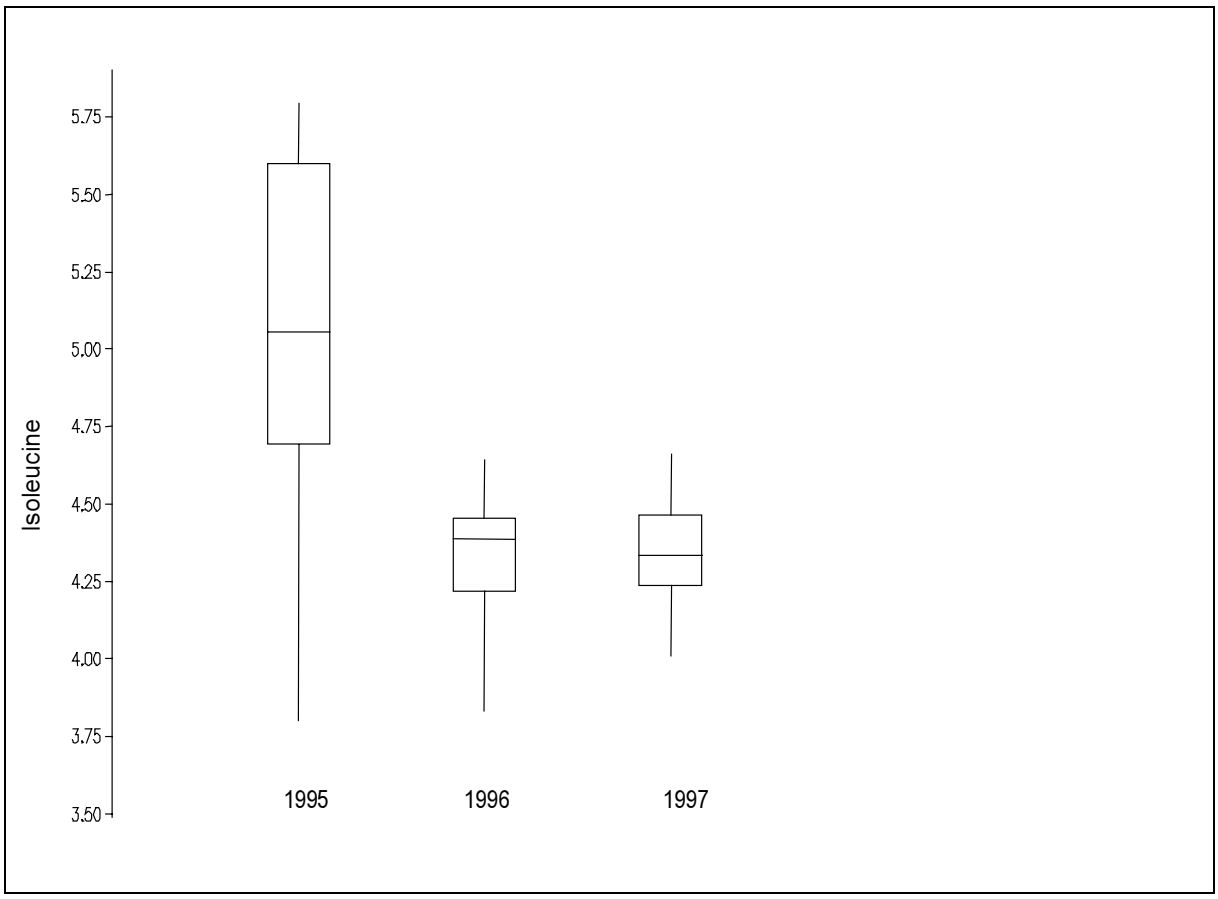
2,8
2,6
2,4
2,2
2,0
1995
1996
1997


Isoleucine
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4.50
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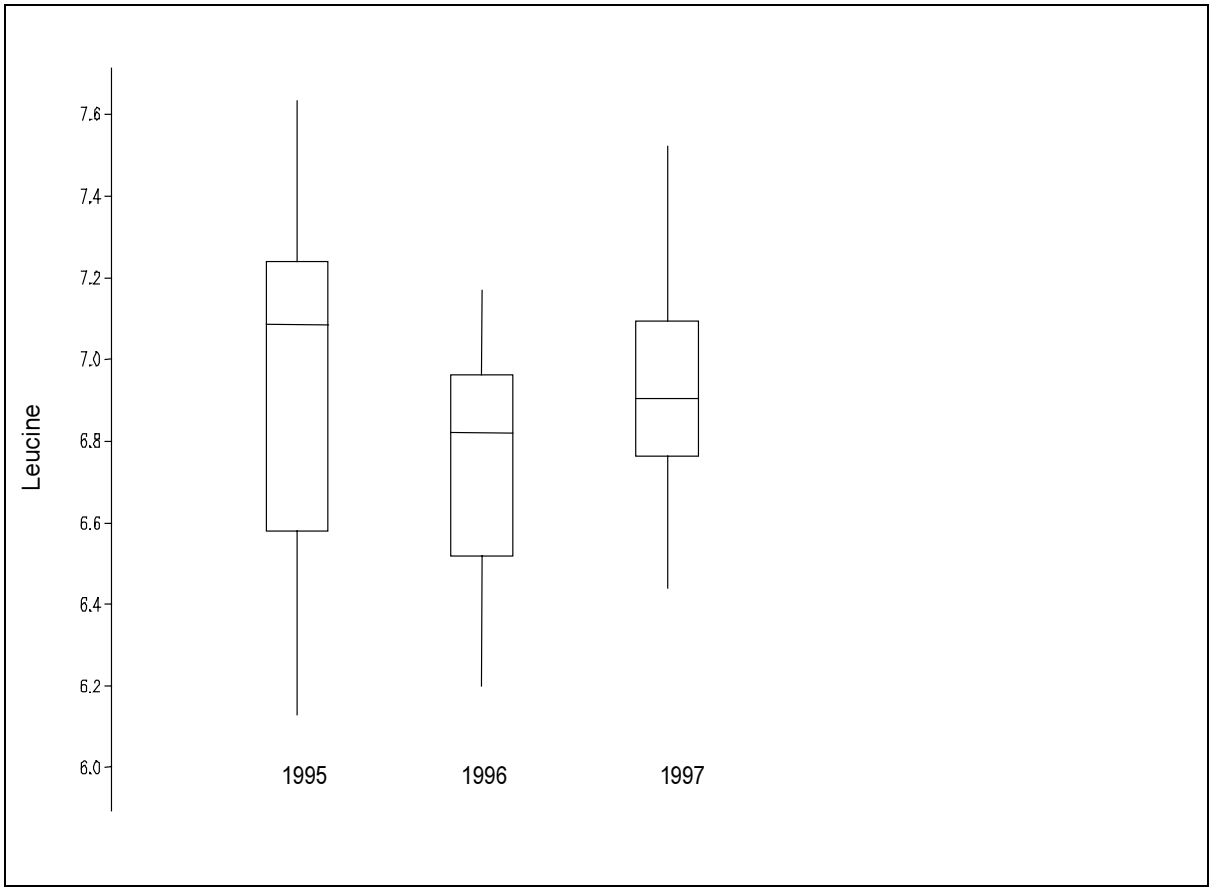
1995
1996
1997


Leucine
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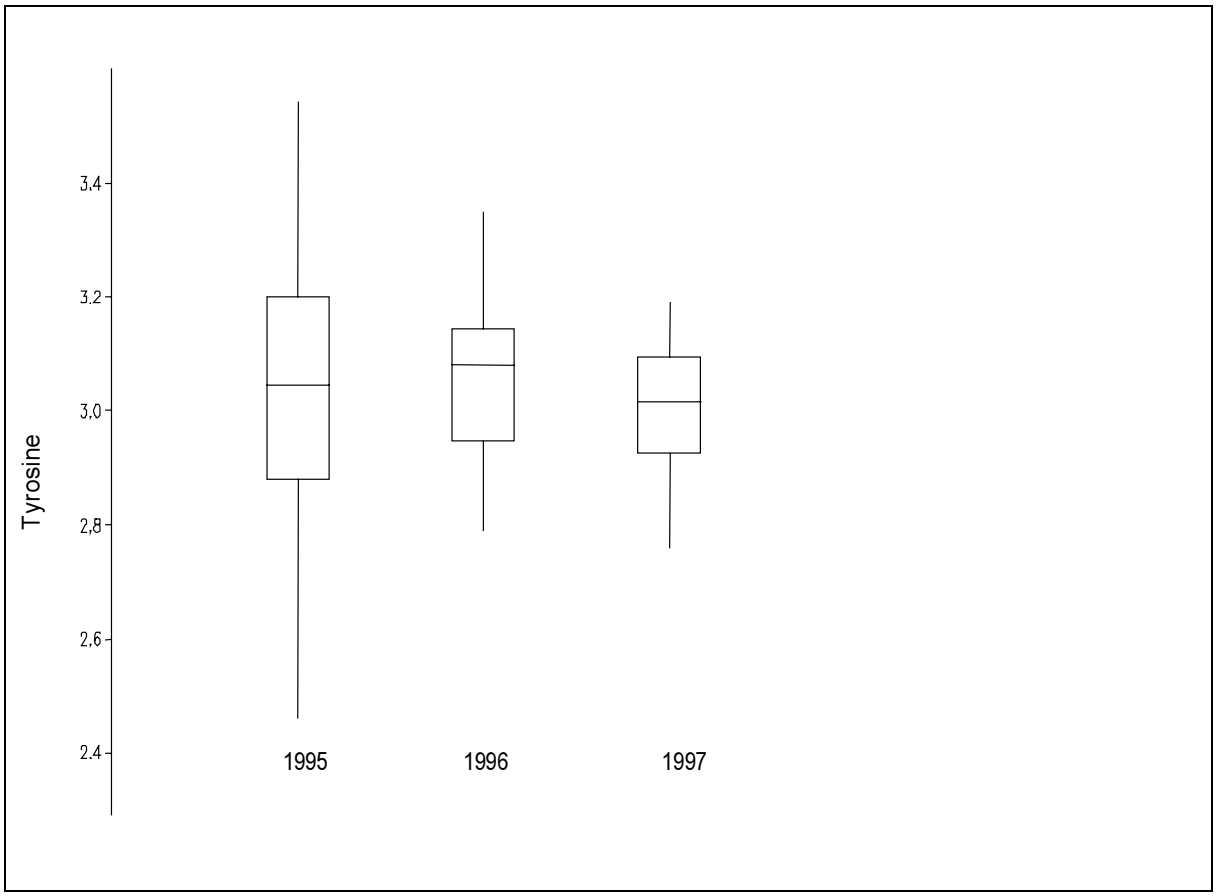
6.2
6.0
1995
1996
1997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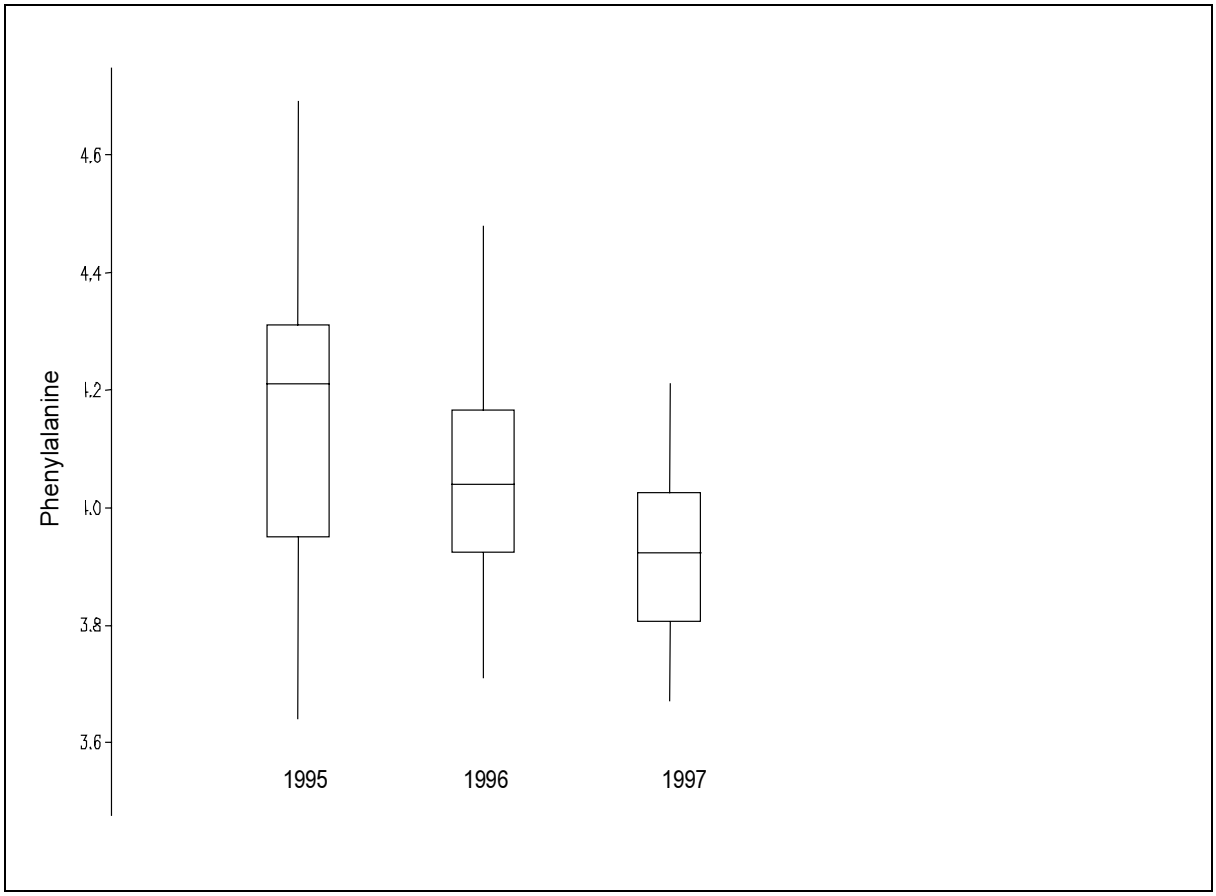
2.6
2.4
1995
1996
1997


Phenylalanine
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4.4
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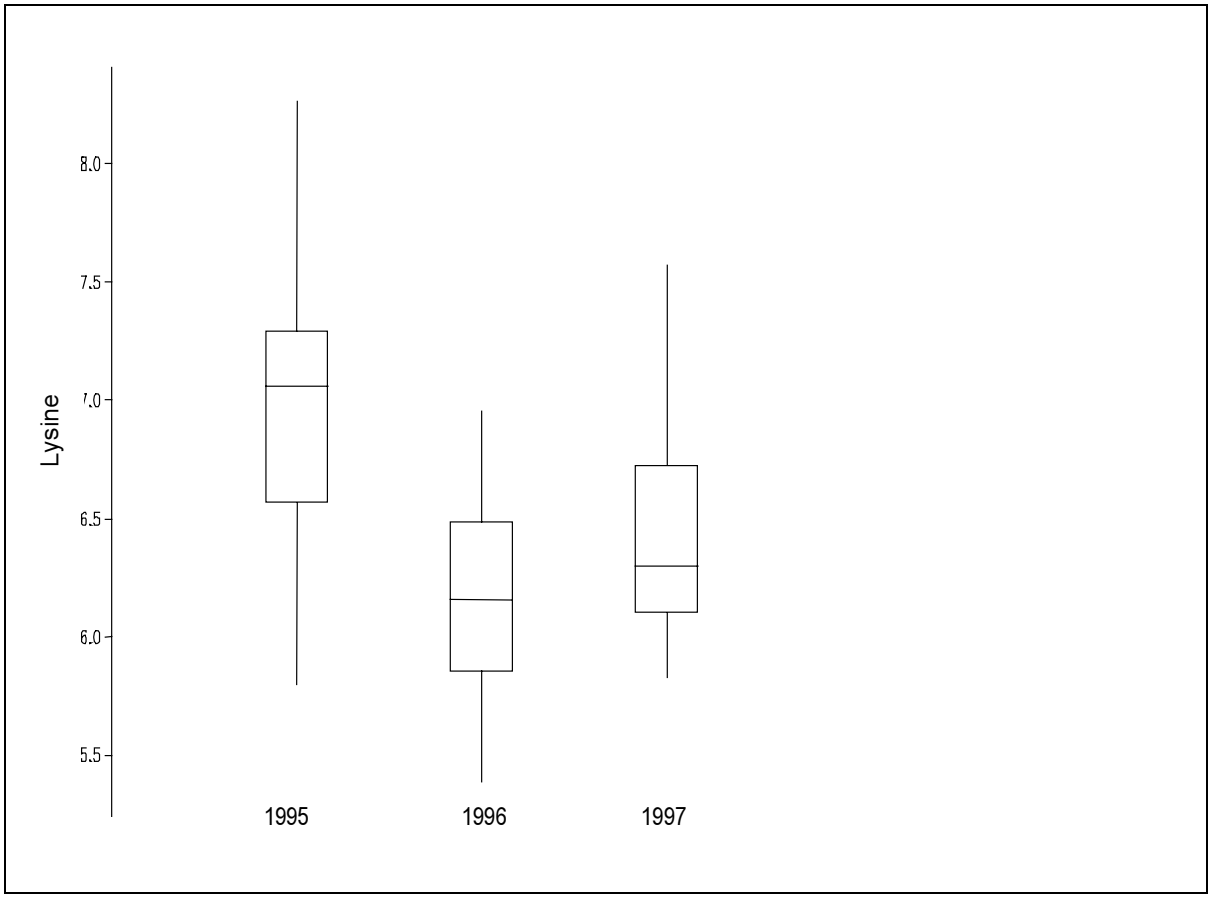
3.6
1995
1996
1997


Lysine
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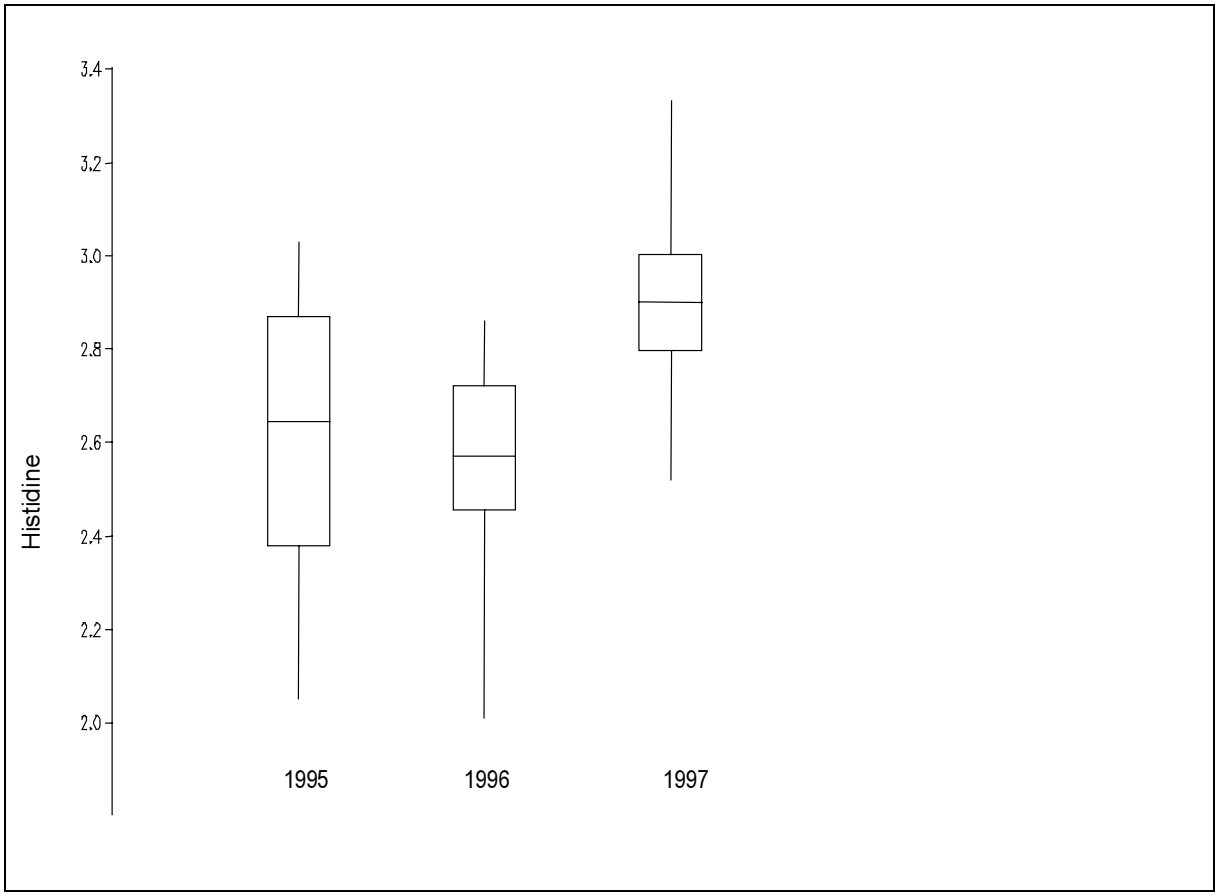
7.0
6.5
6.0
5.5
1995
1996
1997


Histidine
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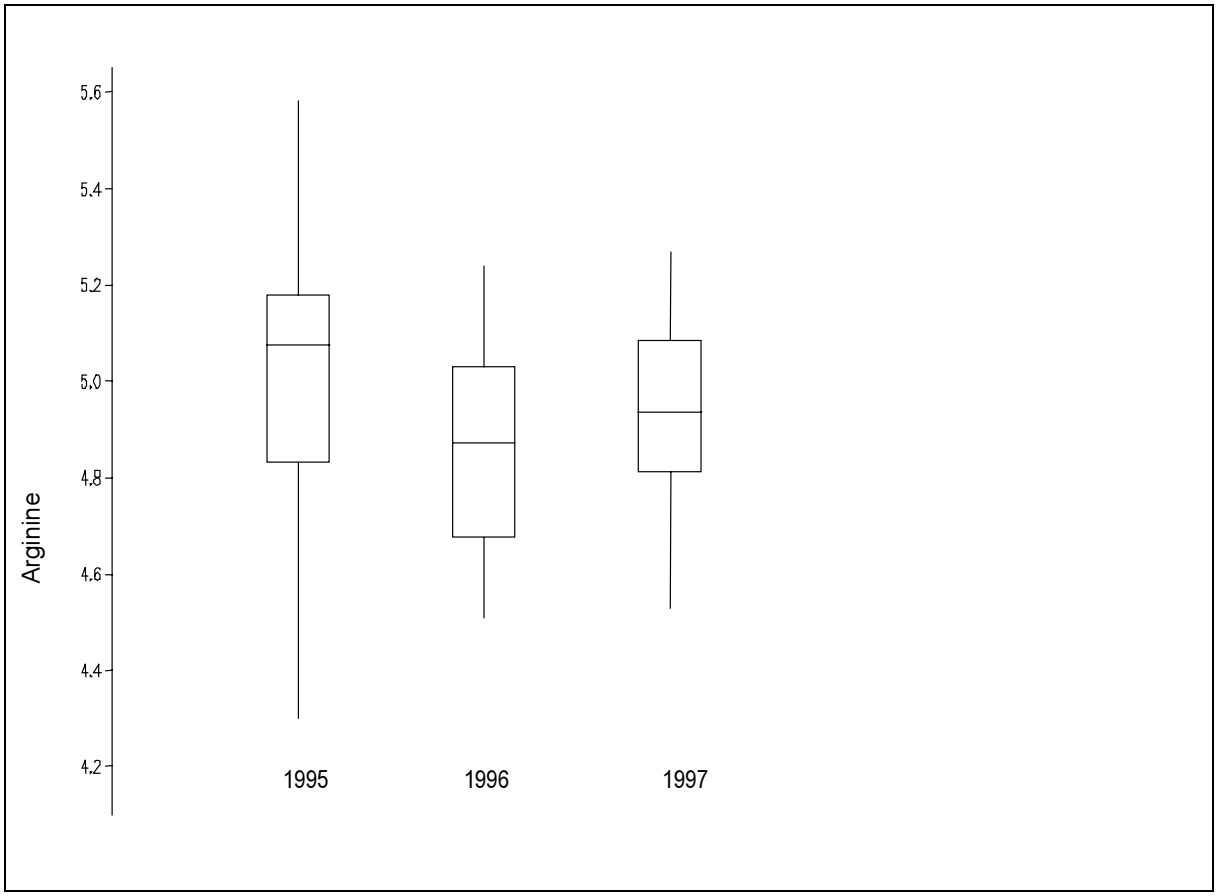
2.6
2.4
2.2
2.0
1995
1996
1997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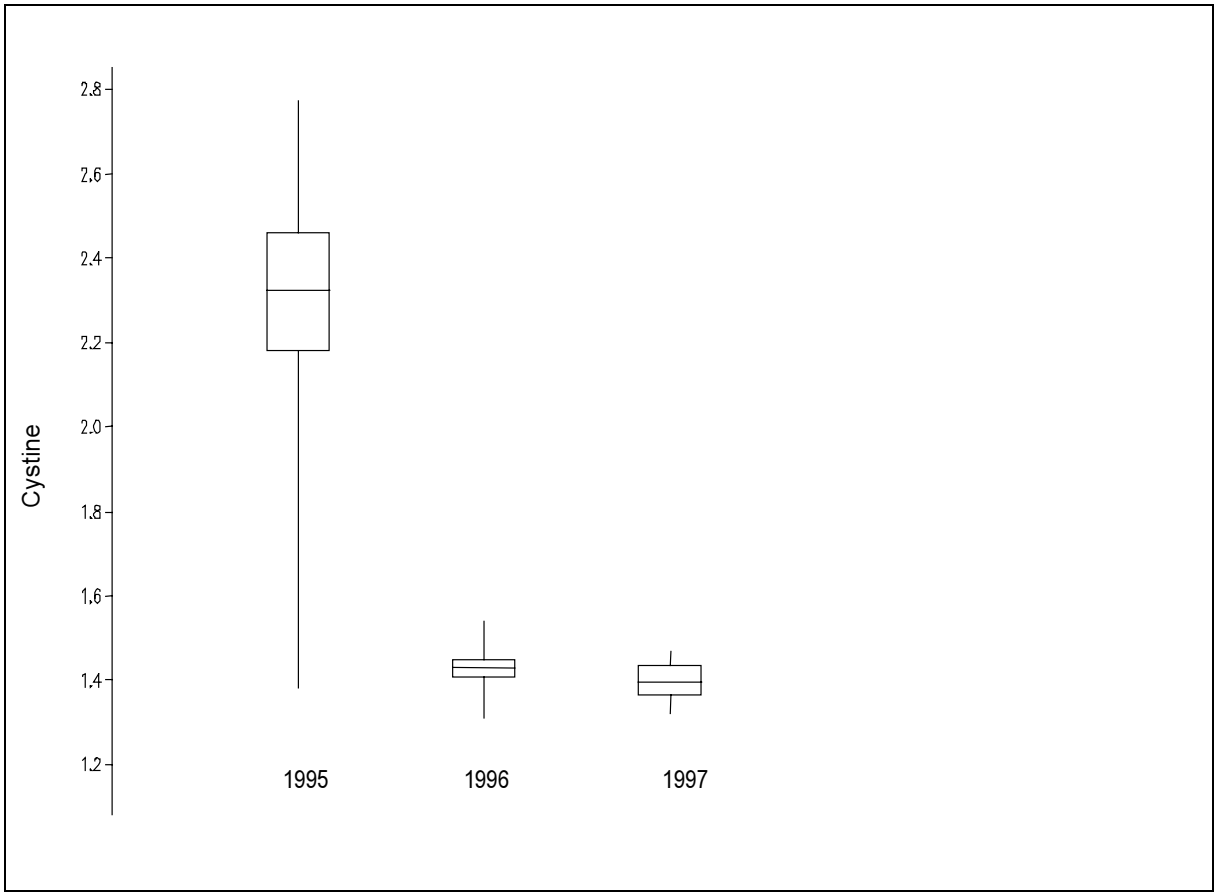
4.4
4.2
1995
1996
1997


Cystine
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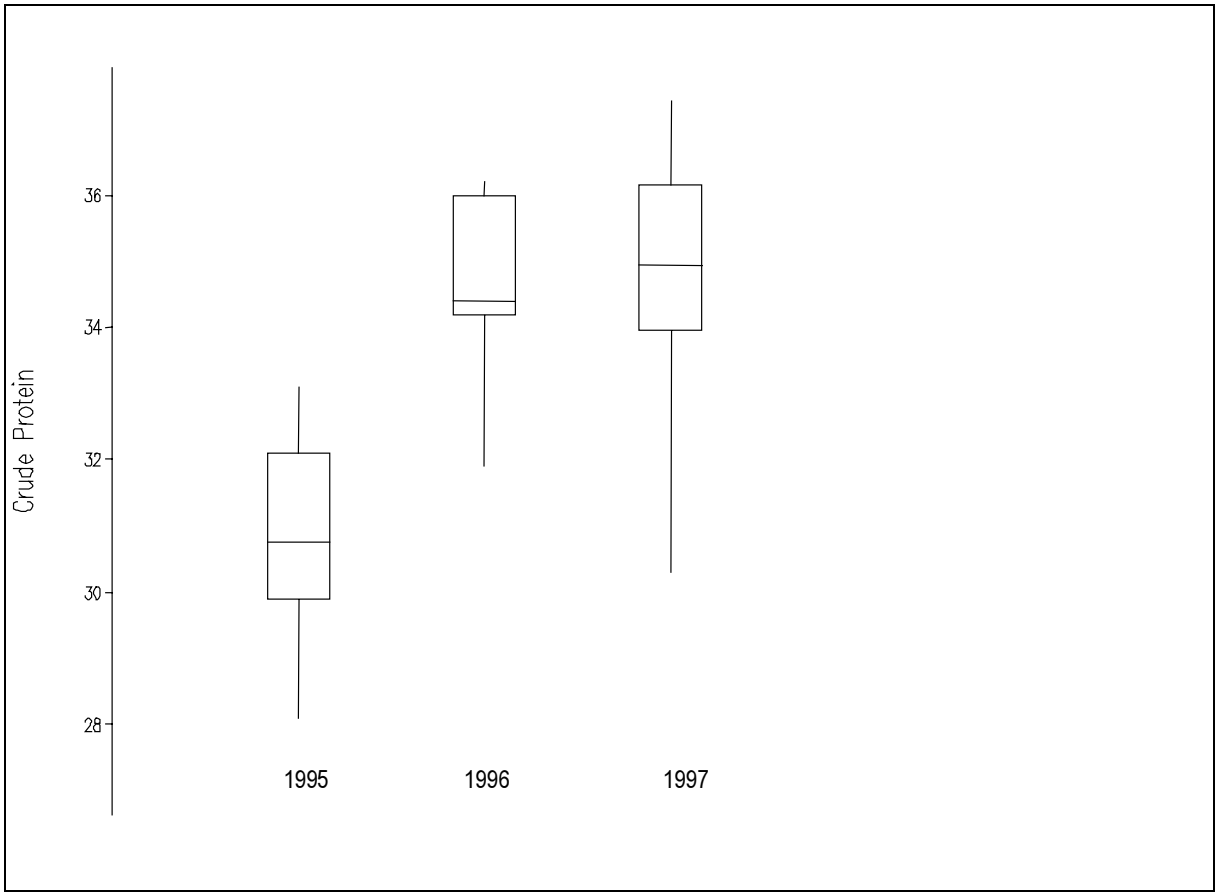
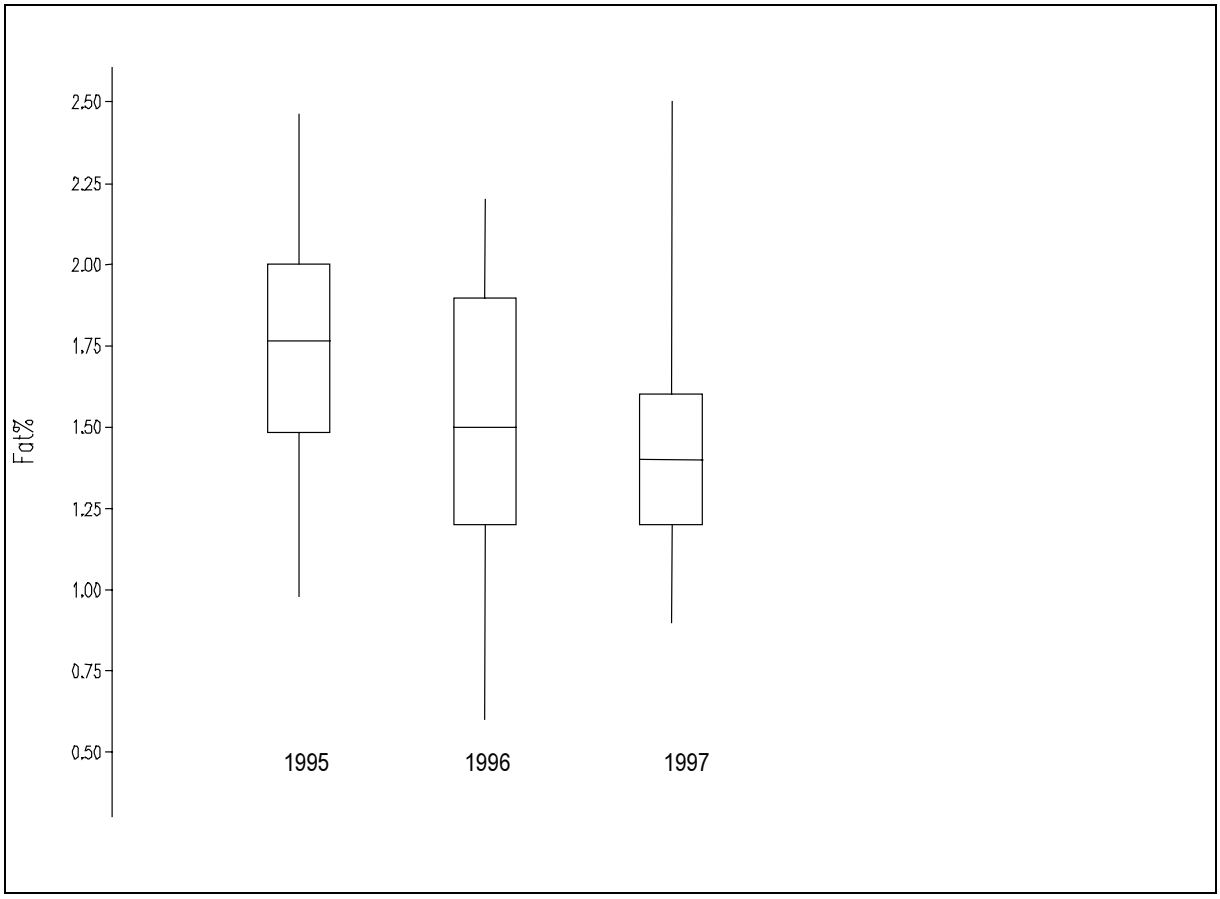
1.6
1.4
1.2
1995
1996
1997


Crude Protein
36
34
32
30
28
1995
1996
1997


Fat%
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
1995
1996
1997

4.2 Paterson's Curse *(Echium Plantagineum)* Pollen Variability from 1995 To 1997 for 9 Locations

Pollen samples were collected from a range of locations. On nine sites, pollen was collected for more than one year. The results of the amino acids, crude protein and fat % levels over the three years over the nine sites is outlined in the following table.

The sites included in this analysis include:

Site	Year
Candelo	95, 96, 97
Cowra	95, 96 (x2), 97 (x2)
Darlington Point	95, 96
Dubbo	95, 96, 97
Goulburn	95 (2x), 96, 97
Henry Lawson Way	95, 96 (x3), 97 (x4)
Jugiong	95, 97
Narrandera	95, 96, 97
Stockinbingal	95, 96

Table 6. **Difference of Paterson's curse *(Echium plantagineum)* pollen samples from nine locations from 1995 to 1997 using the Wald statistic test for Amino Acids, Crude Protein and Fat levels.**
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

Year	1995 mean	1996 mean	1997 mean	Wald Statistic	Level of Significant Difference
No. of Samples	10	11	11		
Aspartic Acid	13.15 *a*	12.40 *a*	14.11 *b*	17.5	P < 0.001
Threonine	4.24 *a*	4.40 *ab*	4.46 *b*	7.8	P < 0.01
Serine	4.46 a	5.11 *b*	5.26 *b*	19.3	P < 0.001
Glutamic Acid	11.01 *ab*	10.69 *a*	11.36 *b*	12.2	P < 0.01
Proline	6.99 *b*	6.58 *a*	6.54 *a*	6.8	P < 0.01
Glycine	4.80 *b*	4.52 *a*	4.63 *ab*	4.3	n.s.
Alanine	5.26 *ab*	5.09 *a*	5.33 *b*	7.8	P < 0.05
Valine	5.57 *b*	5.12 *a*	5.22 *a*	10.1	P <0.01
Methionine	2.54 *b*	2.31 *a*	2.26 *a*	26.5	P < 0.001
Isoleucine	5.10 *b*	4.32 *a*	4.39 *a*	53.5	P <0.001
Leucine	6.82	6.69	6.91	3.5	n.s.
Tyrosine	2.90	3.03	3.01	3.6	n.s.
Phenylalanine	4.11 *b*	4.01 *ab*	3.91 *a*	4.7	n.s.
Lysine	6.97 *b*	6.21 *a*	6.67 *a*	26.5	P < 0.001
Histidine	2.57 *a*	2.53 *a*	2.89 *b*	11.8	P < 0.01
Arginine	4.87	4.85	4.94	0.9	n.s.
Cystine	2.21 *b*	1.42 *a*	1.39 *a*	162.4	P < 0.001
Crude Protein %	30.97 *a*	34.79 *b*	34.64 *b*	30	P < 0.001
Fat %	1.74 *b*	1.56 *ab*	1.44 *a*	5.6	n.s.
Values with the same letter in the same row do not differ significantly with a probability of less than .05 (5%).					

There is no clear trend across all variants in relation to the years and locations on which pollen was collected. The amino acids, Leucine, Tyrosine and Arginine were very consistent for 1995, 1996 and 1997. Methionine, Isoleucine, Lysine, Cystine and Crude Protein demonstrated highly significant differences between years. The Crude Protein levels were generally lower for 1995 but the amino acids, Methionine , Isoleucine and Cystine were higher for 1995 than 1996 and 1997.

4.3 Variation of Amino Acids, Crude Protein and Fat % in the One Species over Four Collection Dates On Two Locations

Eight samples of Paterson's curse *(Echium plantagineum)* pollen samples were collected on four occasions in November 1997 at Henry Lawson Way and Bimby Road. The sample dates were 5, 11, 15 and 19th. The samples were tested for 17 amino acids, crude protein and fat % and compared for variations that may occur within the one species on the same geographic location over the one flowering period.

Table 7. Analysis of variance for Crude Protein, Fat and Amino Acid Percentages for two groups of four Paterson's curse pollen samples, collected on 5, 11, 15 and 19th November 1997 at Henry Lawson Way and Bimby Road.

Amino Acids	**CV %**
Aspartic Acid	4.9
Threonine	3.0
Serine	3.1
Glutamic Acid	3.4
Proline	7.8*
Glycine	6.0*
Alanine	3.8
Valine	5.2
Methionine	2.0
Isoleucine	3.9
Leucine	4.1
Tyrosine	2.9
Phenylalanine	3.7
Lysine	3.6
Histidine	6.9*
Arginine	2.7
Cystine	2.2
Crude Protein %	5.4*
Fat %	36.6**

The standard deviation for Proline, Glycine and Histidine all vary by levels greater than 5%, indicating a significant variability of these amino acids on the one site in the same season. Although this variation is also typical for amino acid determination.

Crude protein also varied by a significant amount over the eight samples from the two sites with the Bimby Road CP levels ranging from 34.5 to 36% and the Henry Lawson Way CP levels varying from 30.3 to 36.1%.

Fat levels were highly variable for the same sites with a standard deviation of 36.6%. For Bimby Road the levels ranged from 1.1 to 2.5% and Henry Lawson Way 0.9 to 1.3% fat. The 2.5% level was rather high for this group, with the next highest level at 1.4% fat.

4.4 Variability of Amino Acid, Crude Protein and Fat % in Pollen Collected from Four Species: Apple Box, Flatweed, Spotted Gum and Turnip Weed

A total of six pollen samples were collected from Apple box *(Eucalyptus bridgesiana)*. Samples were collected from Bombala, Williamsdale, Ironmungie and Burra Creek in March 1996 plus a further sample from Collector in February 1997.

Nine samples were collected from Flatweed *(Hypochoeris radicata)*. Samples were collected from Black Springs, Tarago, Molong and Amaroo in 1996, Bungonia and Weethale in 1997 and Goulburn in 1998 from November to January.

Six samples were collected from Spotted gum *(Corymbia maculata)*. Samples were collected from Moruya, Nowra, Bermagui and Narooma from May to July 1997.

Five samples of Turnip weed *(Rapistrum rugosum)* pollen were collected from Paynters Sidings in October 1995, Mildura in Victoria, Coonamble, Walgett and Dirranbandi in Queensland in August and September 1996.

Table 8. Variability of six Apple box pollen samples collected in 1996 and 1997.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient Variation
Aspartic Acid	9.05	8.97	8.16	9.75	0.6	6.67
Threonine	3.76	3.74	3.61	4.00	0.14	3.72
Serine	4.44	4.73	3.45	5.22	0.74	16.55
Glutamic Acid	10.99	11.07	10.23	11.87	0.69	6.27
Proline	14.98	15.49	12.66	15.91	1.24	8.27
Glycine	4.76	4.82	4.26	5.25	0.41	8.59
Alanine	5.34	5.37	4.92	5.8	0.35	6.5
Valine	5.34	5.01	4.84	6.26	0.64	12.06*
Methionine	2.43	2.41	2.00	2.85	0.34	13.94*
Isoleucine	4.21	4.05	3.52	5.13	0.71	16.74*
Leucine	6.93	6.91	6.16	7.58	0.49	7.15
Tyrosine	2.82	2.78	2.54	3.12	0.21	7.55
Phenylalanine	3.99	3.97	3.67	4.27	0.21	5.31
Lysine	5.86	5.76	5.15	6.56	0.53	9.03
Histidine	2.27	2.39	1.59	2.61	0.36	16.05*
Arginine	5.96	5.85	5.38	6.58	0.46	7.64
Cystine	1.81	1.91	1.18	2.27	0.46	25.2*
Crude Protein %	23.83	23.3	22.6	25.9	1.28	5.39
Fat %	1.03	1.1	0.43	1.72	0.47	45.75*

* Coefficient of variation below 10 is not considered of any great consequence in these results. Above 10 suggests a significant variability in the samples for this variant.

Table 9. Variability of nine Flatweed pollen samples collected in 1995, 1996 and 1997.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient Variation
Aspartic Acid	8.18	8.28	7.05	9.26	0.69	8.51
Threonine	3.68	3.81	3.05	4.17	0.42	11.53*
Serine	5.25	5.13	4.8	6.0	0.37	6.98
Glutamic Acid	8.06	8.15	6.76	8.88	0.66	8.24
Proline	14.06	15.08	7.01	16.92	3.09	21.99*
Glycine	4.49	4.52	3.79	4.92	0.33	7.32
Alanine	4.79	4.82	4.17	5.07	0.29	6.02
Valine	3.99	4.17	2.98	4.55	0.51	12.88*
Methionine	1.98	2.05	1.43	2.18	0.23	11.67*
Isoleucine	3.46	3.51	2.7	4.27	0.45	12.89*
Leucine	5.69	5.76	4.94	6.24	0.45	7.98
Tyrosine	2.55	2.53	2.18	2.77	0.19	7.54
Phenylalanine	3.55	3.61	3.04	4.1	0.41	11.44*
Lysine	7.9	7.8	6.61	8.88	0.69	8.75
Histidine	3.97	3.84	3.12	4.9	0.57	14.34*
Arginine	3.49	3.57	3.01	3.93	0.3	8.64
Cystine	1.77	1.48	1.4	2.55	0.47	26.38*
Crude Protein %	15.7	17	9.2	18.2	2.78	17.71*
Fat %	7.74	7.43	5.26	11.2	1.8	23.26*

* Coefficient of variation below 10 is not considered of any great consequence in these results.
Above 10 suggests a significant variability in the samples for this variant.

Table 10. Variability of six Spotted gum pollen samples collected in 1997.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

	Mean	Median	Minimum	Maximum	Standard Deviation	Coefficient Variation
Aspartic Acid	10.58	10.89	8.76	11.74	1.16	11*
Threonine	3.99	3.95	3.68	4.4	0.26	6.62
Serine	5.21	5.24	4.67	5.65	0.33	6.35
Glutamic Acid	11.75	11.99	9.68	13.54	1.31	11.12*
Proline	12.82	13.18	11.35	13.84	1.05	8.16
Glycine	5.05	5.24	4.38	5.52	0.51	10.14
Alanine	5.37	5.46	4.84	5.71	0.33	6.17
Valine	5.05	5.1	4.72	5.44	0.28	5.54
Methionine	2.2	2.22	2.03	2.29	0.09	4.23
Isoleucine	3.82	3.82	3.63	4.09	0.17	4.38
Leucine	7.25	7.41	6.31	8.06	0.64	8.88
Tyrosine	2.79	2.74	2.58	3.09	0.19	7.09
Phenylalanine	4.11	4.04	3.77	4.54	0.3	7.31
Lysine	6.15	6.11	5.5	6.94	0.51	8.24
Histidine	2.76	2.77	2.55	2.91	0.14	5.13
Arginine	7.61	7.75	6.63	8.37	0.63	8.33
Cystine	1.4	1.4	1.36	149	0.05	3.42
Crude Protein %	28.5	28.9	24.9	30.4	1.89	6.65
Fat %	1.55	1.45	1.1	2	0.37	24.05*

* Coefficient of variation below 10 is not considered of any great consequence in these results.
Above 10 suggests a significant variability in the samples for this variant.

Table 11. Variability of five Turnip weed pollen samples collected in 1995 and 1996.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

	Mean	**Median**	**Minimum**	**Maximum**	**Standard Deviation**	**Coefficient Variation**
Aspartic Acid	9.35	9.19	8.61	10.03	0.63	6.69
Threonine	4.66	4.67	4.55	4.75	0.08	1.86
Serine	5.84	5.85	5.73	5.93	0.07	1.26
Glutamic Acid	10.32	10.59	9.38	10.92	0.68	6.68
Proline	10.17	9.87	7.62	14.11	2.56	25.22*
Glycine	4.51	4.5	4.42	4.64	0.08	1.84
Alanine	5.19	5.11	5.01	5.54	0.21	3.97
Valine	4.93	4.88	4.7	5.27	0.22	4.52
Methionine	2.32	2.31	1.85	2.61	0.29	12.83*
Isoleucine	4.37	4.33	3.86	4.86	0.36	8.29
Leucine	6.86	6.97	6.51	7.05	0.21	3.12
Tyrosine	3.09	3.13	2.62	3.44	0.3	9.75
Phenylalanine	4.25	4.25	4.1	4.44	0.13	3.04
Lysine	7.05	6.8	6.46	8.47	0.82	11.55*
Histidine	2.05	2.09	1.85	2.25	0.16	7.9
Arginine	5.07	5.09	4.78	5.58	0.33	6.43
Cystine	1.87	2.01	1.14	2.19	0.42	22.25*
Crude Protein %	22.72	22.7	21.6	24.6	1.19	5.24
Fat %	6.02	5.93	5.23	7	0.73	12.26*

* Coefficient of variation below 10 is not considered of any great consequence in these results. Above 10 suggests a significant variability in the samples for this variant.

There is consistent variability for the fat % in all four species of pollen samples. Methionine and Cystine exhibited significant variability in three of the four groups of samples.

The six Spotted gum samples had the most consistent levels for all amino acids with Aspartic and Glutamic the only ones exhibiting variations just over 10.

Flat weed pollens had the most number of amino acids exhibiting variation, with 8 out of 17 with a CV over 10.

The variability of the levels of Proline in Turnip weed and Flatweed is rather high when compared to other amino acids in the same pollens, also when compared to the variability of Proline in Apple box and Spotted gum.

4.5 Repeatability of Amino Acid, Crude Protein and Fat % in Five Samples Analysed Three Times by the Same Laboratory

Five samples of pollen, Eggs and bacon *(Dillwynia species)*, Flat weed *(Hypochoeris radicata)*, Rough barked apple *(Angophora floribunda)*, and two Paterson's curse *(Echium plantagineum)* were tested three times for 17 amino acids, crude protein and fat percentage to determine the variability and precision of the analytical process used by the chemistry laboratory.

Table 12. Repeatability of results for amino acids, crude protein and fat—five pollen samples tested in the same laboratory.

Variants	**CV %**
Aspartic Acid	2.4
Threonine	4.0
Serine	3.9
Glutamic Acid	2.6
Proline	6.7
Glycine	3.2
Alanine	3.4
Valine	3.8
Methionine	2.8
Isoleucine	4.4
Leucine	3.0
Tyrosine	4.5
Phenylalanine	4.7
Lysine	6.1
Histidine	2.9
Arginine	3.8
Cystine	2.9
Crude Protein %	2.4
Fat %	11.4

The CV % needs to be below 5% to be confident of lab results. Variation is expressed as a percentage of the mean. The fat % variation at 11.4% is very high, indicating that there may be a problem accurately measuring fat levels in pollen particularly at low levels.

Lysine and Proline also significantly vary within the one sample to indicate that the test used to determine these variants may vary significantly within the one sample.

4.6 Differences Between Laboratory Analysis

It was necessary to send samples to two separate laboratories to conduct the chemical analysis of the pollen samples. The NSW Agriculture chemistry section at Wollongbar conducted the analysis for most of the samples collected in 1995 and the 1996 and 1997 samples were analysed by Agriculture Victoria, State Chemistry Laboratory at Werribee.

There is a possibility that the laboratories may differ in the results obtained for the analysis of the same pollen sample, thus confusing the ability to compare the results obtained in 1995 with those obtained in 1996 and 1997. The same five pollen samples were analysed by both laboratories.

Table 13. Differences between chemistry laboratories for five pollen samples.
(Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.)

	Apple box	Apple box	Canola	Canola	Rough-barked apple	Rough-barked apple	Paterson's curse (Bathurst)	Paterson's curse (Bathurst)	Paterson's curse (Goulburn)	Paterson's curse (Goulburn)	F.probability
Aspartic Acid	8.96	8.97	8.09	9.45	8.86	11.18	13.31	13.16	11.67	14.07	0.09
Threonine	4.00	3.74	4.92	4.82	4.17	4.79	4.56	4.18	4.29	4.51	0.92
Serine	5.22	4.82	5.66	6.36	5.25	6.03	5.19	5.23	4.9	5.57	0.19
Glutamic Acid	10.79	11.36	10.19	11.11	10.47	12.8	11.13	11.05	10.48	11.78	0.07
Proline	15.91	14.57	6.42	5.94	14.57	15.37	7.25	6.13	7.12	6.31	0.19
Glycine	4.91	4.73	4.62	4.43	4.72	5.65	4.69	4.22	4.35	4.55	0.82
Alanine	5.55	5.19	5.29	5.27	5.23	6.25	5.17	5.02	5.08	5.44	0.52
Valine	5.09	4.94	5.36	4.9	5.47	5.99	5.48	4.74	5.12	5.15	0.49
Methionine	2.85	2.00	2.64	1.94	2.34	2.06	2.65	2.18	2.63	2.18	0.005
Isoleucine	4.24	3.52	4.94	4.34	4.71	4.7	4.89	4.28	4.64	4.62	0.064
Leucine	7.02	6.79	6.95	6.98	7.19	8.67	6.83	6.58	6.49	7.09	0.566
Tyrosine	2.83	2.71	3.05	2.91	2.99	3.55	3.31	2.9	2.87	3.07	0.919
Phenylalanine	3.98	3.89	4.39	4.21	4.25	5.09	3.96	3.72	4.02	3.95	0.639
Lysine	5.6	5.92	8.38	7.94	5.57	6.62	5.86	6.57	7.05	7.07	0.133
Histidine	2.43	2.61	2.17	2.10	2.7	2.68	2.52	2.18	2.23	2.61	0.887
Arginine	6.58	5.7	5.09	5.17	6.07	7.02	5.18	4.87	4.87	5.36	0.865
Cystine	2.24	1.18	2.33	1.22	2.49	1.31	2.4	1.38	2.31	1.43	<.001
Crude Protein %	23.1	25.9	22.1	23.5	21	22.9	30.9	31.6	29	29.9	0.015
Fat %	0.43	1.1	7.31	7.3	1.55	1.1	0.98	1.9	1.73	1.9	0.35
Lab	NSW	VIC	NSW	VIC	NSW	VIC	NSW	VIC	NSW	VIC	-

When the F.probability is less than 0.05 this indicates that the laboratory results, when compared are significantly different for these variants at a 5% level.

Cystine, Methionine and Crude Protein are significantly different between laboratory providers, with Cystine levels highly significant between laboratories, although traditionally Cystine and Methionine show the worst precision of most amino acids which was reinforced by the amino acid proficiency testing program which was carried out for the Pig Research & Development Corporation (Rayner & Kerr, 1996).

5. Discussion

Although this research project focuses on the nutritional values of pollens derived from individual plant species, it is interesting and important to note that most events at trapping pollen, more often than not, include a mixture of species. From the 92 records listed on the pollen collection data sheets in appendix II, only 22 (24%) collection events were composed of one pollen as distinguishable by colour. The greatest number of species in any one collection, as distinguishable by colour, was 6. When checked with a microscope, the same species demonstrated different colours such as Paterson's curse which varied from a deep, dark purple to a blue and to a light mauve colour. Generally speaking, the colour for each species in each collection was similar, the variation occurred between locations and collection events.

The mean number of pollens as identified by colour was 2.56. Thus, if any particular pollen from a single species is deficient in one or more nutritional components necessary to satisfy honey bee requirements, then these could be neutralised by the collection of other pollens from species that do demonstrate satisfactory levels of these components.

Nutritional imbalances are far more likely in pollen collections that are derived from only one species, or where the pollen being collected by bees is largely from the one species and not a mixture of pollens from a range of species.

Kleinschmidt and Kondos (1977) found that the amino acid profiles of mixed pollen samples were not significantly different, whereas there was a wide variation in the amino acid profiles of single pollen species in southern Queensland and northern New South Wales.

The total volume of pollen available to a colony may well be the most limiting factor in the development and expansion of the hive population. Even if a colony has access to a mixture of pollens or a single high quality pollen, if there is not sufficient quantity then this will have a major impact on the available food for developing larvae and young adult bees. In this context, it is arguable that beekeepers should be first concerned about the volume of pollen the colony is collecting and storing before turning their attention to the quality, although decision making processes should consider pollen sources that provide both quantity and quality.

As the strength of a colony and the demands of a colony vary significantly according to the time of year and even between colonies on the one location, it is difficult to conclusively state what species consistently produce significant quantities of pollen. The climatic conditions prevailing at the time of collection will also impact on the amount of pollen produced and released by the target plants. Even so, in this trial, significant plant species that demonstrated their importance as a source of pollen due to volumes collected by bees were Paterson's curse, Canola, Turnip weed, Apple box, Spotted gum and Sunflower.

From these six species, Sunflower pollen is of significant concern as its crude protein levels are very poor, thus bees may breed well on the volume of pollen supplied but the adult bees are likely to be short lived. If a colony of bees working a Sunflower crop, from which bees obtain most of their pollen requirements, is moved onto a heavy honey flow the colony would be expected to collapse or seriously diminish in population due to the low body protein levels of the adult bees.

5.1 Crude Protein

Crude protein is an essential dietary component for the development and well being of a colony of bees. Herbert (1992) indicates that many factors such as air temperature and soil moisture, pH and soil fertility affect the nutritive value of pollen. Consequently, pollen from a single floral source may be different chemically from a similar pollen collected in a different area. He also states that protein levels for pollen from different plants will range from 8 to 40%.

The crude protein levels in the 194 samples analysed since collection began in 1995 for this trial ranged from 9.2% (Flat weed) to 37.4% (Paterson's curse) with a mean of 25.85%.

Contrary to the statements made by Herbert (1992), that pollens from the same species differ significantly in their nutritive values according to a range of factors, results from this trial indicate pollens do vary in their nutritive values but each species appears to have a range within which these values fall given similar conditions.

Sixty one Paterson's curse pollens were collected between 1995 and 1997. Of these samples, the crude protein varied from 28.1% to 37.4%. There is clearly a significant difference between the minimum and maximum levels , but what is important is that even the minimum CP levels are considered to be of a high quality.

Muss (1987) noted that during two consecutive drought years there was a reduction in the levels of amino acids and nitrogen. The opposite was observed from the results obtained for Paterson's curse pollen from 1995 to 1997 with the mean CP levels in 1995 at 30.97%. This year experienced generally a higher rainfall on the areas on which Patersons curse pollen was collected as compared to 1996 and 1997 when the mean CP levels were 34.79 and 34.64%. Paterson's curse pollen collected on the same site over four separate dates during November 1997 varied significantly, the CP levels ranged from 30.3 to 36.1% and 34.5 to 36%. The soil type and locations were identical for each group with collection dates for the four samples on each location, only 6, 4 and 4 days apart.

It would appear that even the pollen collected from the same species on the same location and date will vary significantly in their crude protein levels. Pollens with crude protein levels below 20% are considered to be below what is considered to be a minimum level to sustain breeding and development of a colony. Kleinschmidt *et al* (1974) found that the digestive capacity of bees limit protein intake and pollens containing less than 20% crude protein did not appear to satisfy a colony's nutritional requirements.

The higher the crude protein percentage, the less pollen is required by the bees to sustain production. For every 10 grams of protein required by a colony for net production, it is necessary for about 48 grams of pollen containing 30% crude protein to be consumed. If the protein content of pollen is reduced from 30% to 20%, then the colony is forced to increase consumption of pollen from 48 grams to 72 grams in order to maintain satisfactory levels of production (Kleinschmidt & Kondos, 1976).

Thus, when there is an average honey flow combined with average breeding levels, at least a 25% crude protein level is required to maintain body protein levels but on a heavy honey flow combined with increased breeding, then pollen at 30% crude protein could not maintain bee body protein levels (Kleinschmidt, 1986).

Based on this information we can divide the plant species into three general categories: Pollens that will not sustain the growth and development of a colony; pollens that will sustain a colony but only under light honey flow conditions; and average colony replacements and pollens that should be sought after if colonies are to be working a heavy honey flow following the breeding of a few generations of brood.

Species with mean crude protein levels below 20% include: Black she oak, Black thistle, Blueberry, Buckwheat, Capeweed, Citrus, Eggs and bacon, Flat weed, Lavender, Maize, Nodding thistle, Saffron thistle, Silky hakea, Sunflower and Willow.

If these pollens are the dominant or only species being collected, then it can be assumed that the colonies will decline in populations, particularly if they are made to work a medium to heavy honey flow following the feeding of this pollen to developing larvae and young adult bees.

Species with mean crude protein levels above 20% but below 25% include: Alpine ash, Apple box, Canola, Currawong wattle, Faba beans, Grey box, Manna gum, Hedge mustard, Onion weed, Pussy willow, Red box, Red ironbark, Red stringybark, River red gum, Rough barked apple, Skeleton weed, Swamp mahogany, Sydney golden wattle, Turnip weed, Vetch, White box, White mallee, Yellow burr and Woollybutt.

Bees will do well on these pollens if they are not exposed to high levels of intensive foraging activity, as happens on a heavy nectar flow. Bees may be able, in many circumstances, to consume higher quantities of these pollens to make up for their average nutritional worth. Thus, these pollens should be considered by beekeepers as a desirable source of pollen when there is ample quantity available.

Pollens with crude protein levels above 25% should be considered of high nutritional importance as a source of nutrition for honey bees. Species that exhibited such levels in this trial include: Paterson's curse, Almond, Balansa clover, Blakely's red gum, Bloodwood, Brittle gum, Christmas mallee, Clover, Gorse, Grey gum, Heath-leaved banksia, Lupin, Pear, Saw banksia, Scribbly gum, Spotted gum, Sydney blue gum, Vipers bugloss and White stringybark.

Of these, Patersons curse, Vipers bugloss, Spotted gum, Lupin and Saw banksia pollen are exceptional sources of crude protein, all averaging around 30% or above. Beekeepers should consider these pollens as of the highest quality and, where the aim is to build colonies for future heavy honey flows or pollination work, then these species if available should be favourably considered in a commercial beekeeping operational strategy. Lupins may be the exception to the top list as beekeepers generally do not regard this species as being of importance, possibly due to its low attractiveness to foraging honey bees.

In a survey of commercial beekeepers in NSW, conducted from 1996 to 1999 (Somerville, 1999), no response was received for this plant indicating any value for either honey or pollen based on beekeepers' experiences and observations. Despite this lack of value beekeepers place on Lupins as a significant floral resource, based on this pollen research, it may well benefit beekeepers to place loads of bees in agricultural areas where the bees can fly to both crops of Lupins and Canola. A mixture of pollens should prove very beneficial to the build up and future honey gathering potential of a colony.

5.2 Amino Acids

Ten essential amino acids necessary to meet honey bee nutritional requirements have been identified and quantified by DeGroot (1953). These essential amino acids and their minimum levels necessary to meet honey nutritional requirements are stated in the following table.

Essential Amino Acids to Satisfy Honey Bee Nutritional Requirements (DeGroot, 1953)	
Essential Amino Acids	***Bee Requirements g/16g N***
Threonine	3.0
Valine	4.0
Methionine	1.5
Isoleucine	4.0
Leucine	4.5
Phenylalanine	1.5
Histidine	1.5
Lysine	3.0
Argine	3.0
Tryptophan	1.0

DeGroot (1953) demonstrated that if a protein devoid of any one essential amino acid, but otherwise complete, was taken as the sole protein in the bees' diet, nitrogen equilibrium and bee development was impossible.

In the absence of results for the amino acid Tryptophan, in this study, Isoleucine is the most frequently limiting amino acid in the 194 samples tested. The lack of results for Tryptophan may be significant in not permitting a greater understanding of the role of amino acids in honey bee nutrition. There is less information published on the levels of Tryptophan in Australian pollens, compared to all the other nine essential amino acids. Rayner & Langridge (1985) identified 10 species out of 20 deficient in this amino acid, compared to eight species deficient for Isoleucine.

Kleinschmidt (1983), Stace (1996) and Muss (1987) do not have any published data for Tryptophan levels in pollen.

A total of 69 samples had levels of Isoleucine below the desired 4g/16g N level representing 35% of all samples in this study. Only two other amino acids were recorded below desirable levels: 11 samples (5.6%) indicated Valine below the optimal level of 4g/16g N and 2 samples (1%) indicating Methionine below the ideal level of 1.5 g/16g N.

The two samples indicating low levels of Methionine are Flatweed and Sydney blue gum. The Sydney blue gum pollen was also deficient in Isoleucine and the Flatweed sample was deficient in Valine. Of the 11 Flatweed samples, six were deficient in both Valine and Isoleucine and four Isoleucine only. All the samples deficient in Valine including Black sheoak, Flatweed, Skeleton weed, Sweet scented wattle, Willow and Mustard were also deficient in the amino acid, Isoleucine.

From the 42 samples of pollen identified as derived from Eucalyptus, or related species Corymbia and Angophora, 31 samples or 74% of this group of species indicate levels of the amino acid Isoleucine below 4g/16g N.

The amino acid Isoleucine appears to be consistently at low levels in many samples of bee collected pollen. Day *et al* (1990) found that Isoleucine in the absence of Tryptophan analysis was the most frequently limiting amino acid in pollen. Kleinschmidt (1983) found that Isoleucine and Valine in most pollens collected for his study were consistently below minimum levels by about 25%. Lysine,

Histidine and Arginine were also found to be limiting in some areas of Queensland in the same study. Tryptophan and Isoleucine were found to be limiting in all the pollens from six Eucalyptus species in a study conducted in Victoria (Rayner & Langridge, 1985).

Muss (1987) analysed pollen from 14 Eucalypt species and found five deficient in Isoleucine (36%)—this is significant. Given the 43 species tested in her study, 11 were found to be limiting in Isoleucine (26%). Of these 11 pollen sources, half were Eucalypt species.

The results of this study indicate that most essential amino acids in bee collected pollen are at levels sufficient to meet honey bee nutritional requirements. Flatweed pollen is not a desirable pollen for bees to collect based on the low amino acid and crude protein levels. If this pollen is the dominant source of protein and amino acids for a honey bee colony, it can be expected that a colony will perform well below average. The brood area and population of the colony will diminish and this decline may be rather rapid in the event of a heavy nectar source becoming available to the colony after a prolonged period on a diet of Flatweed pollen.

Pollens derived from Eucalypts may also be of concern in relation to the high proportion with deficiencies in Isoleucine. Beekeepers should be mindful of the dominant source of pollen collected by bees. If Eucalypt pollen is collected in conjunction with one or more pollens derived from other species, then it is possible that any amino acid deficiency will be compensated for from the other species. If bees are relying on one source of pollen derived from Eucalypt species for a lengthy period of time, then beekeepers should be mindful of the possible deficiency of Isoleucine. If the pollen is high in crude protein and there are significant quantities being gathered, then a problem may not arise. However, if the crude protein levels are low or the quantities of pollen being gathered or stored are low, then the lack of Isoleucine may inhibit the nutritional well being of the colony, and a reduction in the brood area and population may be expected as a consequence.

5.3 Fats/Lipids

The fat content for pollens collected in this trial ranged from 0% (Red stringybark) to 11.2% (Flatweed), with a mean of 2.52%. Although very little is known about the nutritional need for fats in honey bee diets, there is a requirement for sterols (cholesterol) in the diet of honey bees for normal growth, development and reproduction (Herbert, 1992). There is some indication that pollens with higher fat/lipid levels are more attractive to honey bees (Singh et el, 1999).

Field observations in this trial would support this view, as Canola (mean 6%), Hedge mustard (mean 5.8%), Turnip weed (mean 6%) and Flatweed (mean 7.2%) are all high in fat, as compared to other pollens and all are very attractive to bees. It is interesting to note that Muss (1987) found that in all seasons except spring, a small percentage of pollen collections will almost invariably contain some Flatweed pollen.

This is of particular interest as Flatweed is below the optimum for crude protein requirements, thus bees may well find Flatweed pollen attractive but will suffer nutritionally if this is the only pollen available to a colony.

The role of fatty acids may have a significant role in the control of bacterial diseases. Feldlaufer *et al* (1993) found that in laboratory tests, linoleic acid inhibited the growth of the two bacteria that cause European and American foulbrood disease.

The composition of the fat in the pollen samples collected in this research was not tested, thus it is not known what the actual components of the fat are for each species. This may have a bearing on the value to honey bee nutrition of the total fat content very similar to the concept of amino acid levels of pollens and their relationship to the crude protein levels. If certain amino acids are below optimum, even though the total level of crude protein is satisfactory, then the value of the pollen to honey bee nutritional requirements is diminished. Likewise if the components of the fat levels are not of the type that is of significant benefit, such as the presence of linoleic acid, then this source of fat may not be as useful as compared to another source of fat from other species.

5.4 Paterson's Curse Pollen—Variability of Nutrient Qualities Over Time and Location

Paterson's curse pollen was chosen as a preferred species to study the variability within one species over a three year period between 1995 and 1997 and the variation that occurs between geographic locations.

Paterson's curse *(Echium plantagineum)* also referred to as Salvation Jane or Riverina bluebell was identified by a survey of all commercial beekeepers registered in NSW (Somerville, 1999) as the most important single floral species in NSW, due to both its honey yields and level of importance as a pollen source. Out of a possible score of 5, Paterson's curse pollen had a mean value of 4.75. The yield of honey per hive averaged 44 kg. Most sites for this species were located on private property and flowering periods ranged from September to January, with the main flowering period October, November and December (Somerville 1999).

Results from this pollen research reinforce beekeepers' observations, with both large quantities of Paterson's curse pollen collected in pollen traps and the nutritional quality of the pollen very high. For the period 1995 to 1997, 61 Paterson's curse pollen samples were collected. The average crude protein for all the samples is 33%, with a range from 28.1 to 37.4%.

Muss (1987) tested five Paterson's curse pollens and obtained a mean crude protein of 31.38%; Rayner and Langridge (1985) tested two Paterson's curse pollens with a crude protein mean of 35.2%; and Stace (1996) tested two Paterson's curse pollens with a crude protein mean of 32%. All sets of Paterson's curse pollens from these three sources of research fall within the range of CP % established in this study. The results certainly indicate a significant variation in the levels of crude protein but, in essence, if these levels are all in the high 20's/early 30's for CP percentage then it can be universally stated that pollen from this species is deemed of high quality in meeting honey bee nutritional requirements.

Rayner and Langridge (1985) and Muss (1987) found that Paterson's curse was not deficient in any of the identified essential amino acids. Only 4 pollen samples in this study indicate a slight deficiency in the amino acid, Isoleucine. The minimum level was 3.8%, whereas 4.0% is considered the minimum essential level before problems may occur with deficiencies.

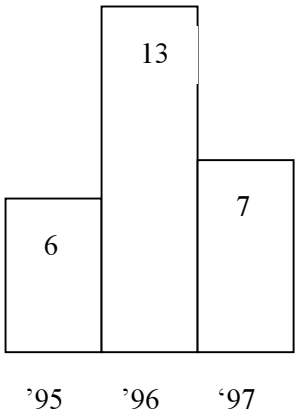
Given the high crude protein levels and amino acids generally above the levels considered essential for honey bee nutrition, Paterson's curse pollen is a high quality pollen and will meet honey bee nutritional requirements in all cases.

The results do not indicate any significant trend for differences in years according to seasonal variations. The year 1995 was considered a better year for Paterson's curse and, in part, this is the reason that 28 samples were gathered, as compared to 1996 and 1997 where only 16 and 17 samples were gathered for each year respectively. Even so, there is no clear indication to suggest a general trend up or down in the general nutrient value of Paterson's curse pollen.

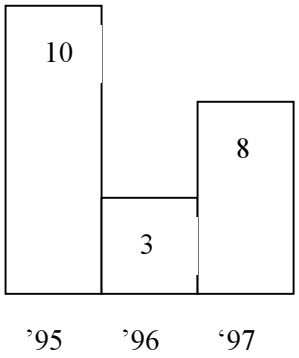
To test the variability of nutrient qualities over time and location, Paterson's curse pollen was collected from nine locations over three consecutive years. In this case the crude protein levels were higher for 1996 and 1997 than 1995. The variation in fat levels between years was not significant. As for the amino acids tested, they were slightly down in 1996 compared to 1995 and 1997. There is no significance for the three years for Glycine, Leucine, Tyrosine, Phenylalanine and Arginine. Methionine, Isoleucine, Lysine and Cystine demonstrate highly significant differences between years. Methionine, Isoleucine and Cystine in this case were higher for 1995 than the following two years. Lysine was higher for 1995 and 1997.

When the values of the amino acids do not differ significantly with a probability of less than 5% between years, the trend is for higher amino acid values in 1995 and 1997 and lower amino acid levels for 1996 (refer to Table 5). The following graphs illustrate this.

Graph 1. Groups of lowest figures for amino acids.



Graph 2. Groups of highest figures for amino acids.



Of the three amino acids with relative high levels in 1996, Threonine and Phenylalanine do not differ significantly with levels obtained in 1995 and 1997 and Serine does not significantly differ from the level obtained in 1997.

It could be argued that 1996 was a poorer year for amino acids than 1995 and 1997, even though 1996 had the highest mean crude protein level.

Three amino acids, Proline, Glycine and Histidine were found to vary considerably from pollen collected on the same sites for two locations in the same month—November 1997. This difference wasn't high but was greater than 5%, indicating significant variability for these amino acids, although this variation is also typical for amino acid determination. The soil type, climate etc. is not a significant variable under these circumstances.

From the two sets of data, i.e., the four samples of pollen collected in November 1997 on Henry Lawson Way and Bimby Rd, and from the nine geographic locations over three years, it is difficult to say how this information should be interpreted by commercial beekeepers. Ultimately, crude protein is the most important factor influencing the value of pollens to honey bee nutritional requirements and there is no clear trend indicating a significant difference according to site or year.

Ultimately though, this research supports the view by beekeepers that Paterson's curse pollen is an excellent source of nutrients satisfying honey bee dietary requirements.

5.5 Variation in Laboratory Analysis

There is a potential risk with comparing data collected by different operators, or in the case of this research, assuming that the one pollen sample will have the same results from different laboratory providers of amino acid, crude protein and fat analysis. There may also be a certain degree of potential variability in the one sample, using the same chemical analysis in the same laboratory.

Rayner and Kerr (1996) reported on an amino acid proficiency test for pig research laboratories and gave the following background information. Apparently there is a considerable body of literature on methods of amino acid analysis and there is evidence that results from analysis of the same material can differ markedly, both between methods and between different laboratories using essentially the same method. An amino acid collaborative study between five Australian laboratories who service pig research showed some major differences in amino acid results. As a result of this study funded by the Pig Research and Development Corporation, Rayner and Kerr (1996) set out to determine the accuracy of amino acid analysis in Australian laboratories.

Nineteen laboratories were involved with the study including nine from Australia and 10 from New Zealand, Norway, Thailand and Indonesia. The results for the study indicated that the testing for the amino acids, Tyrosine, Methionine, Cystine and Tryptophan were not satisfactory across the labs with CV's (Coefficients of Variation) for these amino acids above 20%, indicating a major problem when comparison of data between laboratory providers is required. Fortunately, the study indicated that the two laboratory providers used in this pollen research, State Chemistry Laboratory (VIC) and Wollongbar Agricultural Institute (NSW) had coefficients of variation in most cases, smaller than for all laboratories in the study.

Large CV's occurred for Tyrosine in all pig feed samples, particularly those which contained a high proportion of sugars. This may have significant implications for testing honey bee-collected pollen, as pollen is gathered together into a pellet adhering to the pollen baskets of the rear legs of worker bees with the aid of nectar or honey carried by the bee for such purposes when foraging for pollen.

Ultimately what the message of the study imparts is that the variability of analysis for amino acids between labs and techniques is such that comparison of data from different sources/researchers should be done with caution.

For comparison in this research, five samples of pollen were analysed by both chemistry laboratories and results were checked using an F.probability test. Two amino acids—Cystine and Methionine—and the crude protein levels are significantly different at greater than 5 % with Cystine levels consistently lower for one laboratory. The problem with obtaining consistent results for the testing of Cystine was again highlighted by Rayner and Kerr (1996) in stating that the variability of results for Cystine between all laboratories in all three proficiency programs has been unsatisfactory.

This is not such a major consideration, in relation to honey bee nutrition research, as the focus is on the 10 essential amino acids that have been identified by DeGroot (1953), of which Cystine is not one.

Five samples of pollen where also tested by the State Chemistry Laboratory (VIC) to determine the degree of CV % for the one sample. Fat % presented the greater variation with a CV % of 11.4%. Lysine and Proline also significantly vary within the one sample. Lysine is an essential amino acid necessary to meet honey bee nutritional requirements.

Personal communication with Maurice Kerr (1998) suggests that fat levels are quite dependant on the methods used. In the case of this pollen research, the observed differences in fat levels for the same pollen samples are probably due to large errors associated with the lower levels of fat being determined and possibly relatively small samples being analysed. As fat is determined gravimetrically, the error associated with the determination is due to the weights being measured. Small sample weights and small weights of fat dictate larger errors in the determination.

Given that we are not sure what benefits fats or lipids contribute to honey bee nutritional needs, it is not important to be able to accurately state the fat levels of pollens. Indicating whether the fat levels are low, medium or high is probably sufficient, particularly when associated with the apparent attractiveness of pollen with high fat content.

Original moisture levels and protein recovery figures were provided for 81 pollen samples. The range of moisture contents in bee collected pollens in these samples varies from 6.7% (Paterson's curse) to 20.6% (Sydney blue gum) with a mean of 12.14%. Protein recovery varied from 72.61% to 103.1%.

As a quality control measure for amino acid determination, the amount of nitrogen from amino acids is compared to that determined from the crude protein. This is termed the protein recovery (%). Ideally protein recoveries should fall in the range 85–110% to indicate adequate recovery of amino acids. When results are outside this range it may indicate problems with the amino acid or crude protein determinations, or that there are significant levels of non-protein nitrogen present. From previous experience with pollen samples, protein recoveries are generally low and show considerable variability, thus non-protein forms of nitrogen may well be present. It should also be noted that not all amino acids were determined (tryptophan not measured) which would normally be included in the protein recovery. Most samples do fall within the acceptable range and taking into consideration the known variability of pollen samples the recoveries are acceptable (Kerr, 1998).

Protein recoveries were only determined on amino acid samples sent to the State Chemistry Laboratory, Agriculture Victoria.

6. Appendices

6.1 Appendix I: Discussion—Pollen Qualities by Species

Articles on individual species as a pollen source suitable for meeting the needs of honey bee nutritional requirements.

Articles submitted to the:

Editor
The Australasian Beekeeper
34 Racecourse Road
Rutherford NSW 2320

for publication as a series.

LIST OF DISCUSSION ARTICLES BY COMMON & SCIENTIFIC NAME	
Common Name	**Scientific Name**
Almond	*Prunus dulcis*
Alpine ash	*Eucalyptus delegatensis*
Apple box	*Eucalyptus bridgesiana*
Balansa clover	*Trifolium balansae*
Banksias	*Banksia ericifolia* *Banksia serrata*
Black she oak	*Casuarina littoralis*
Black thistle	*Cirsium vulgare*
Blakely's red gum	*Eucalyptus blakelyi*
Blueberry	*Vaccinium species*
Brittle gum	*Eucalyptus mannifera*
Buckwheat	*Fagopyrum esculentum*
Canola	*Brassica napus*
Capeweed	*Arctotheca calendula*
Christmas mallee	*Eucalyptus socialis*
Citrus	*Citrus species*
Eggs & bacon	*Dillwynia species*
Faba bean	*Vicia faba*
Fireweed	*Senecio madagascariensis*
Flatweed	*Hypochoeris radicata*
Gorse	*Ulex europaeus*
Grey box	*Eucalyptus microcarpa*
Grey gum	*Eucalyptus punctata*
Hedge mustard	*Sisymbrium officinale*
Lavender	*Lavandula species*
Lupins	*Lupinus angustifolius*
Maize/corn	*Zea mays*
Manna gum	*Eucalyptus viminalis*
Nodding thistle	*Caduus nutans*
Onion weed	*Asphodelus fistulosus*
Pear	*Pyrus connunis*
Red bloodwood	*Corymbia gummifera*
Red box	*Eucalyptus polyanthemos*
Red ironbark	*Eucalyptus fibrosa*
Red stringybark	*Eucalyptus macrorhyncha*
River red gum	*Eucalyptus camaldulensis*
Rough barked apple	*Angophora floribunda*

LIST OF DISCUSSION ARTICLES BY COMMON & SCIENTIFIC NAME	
Common Name	**Scientific Name**
Saffron thistle	*Carthamus lanatus*
Scribbly gum	*Eucalyptus sclerophylla*
Silky hakea	*Hakea sericea*
Skeleton weed	*Chondrilla juncea*
Spotted gum	*Corymbia maculata*
Sunflower	*Helianthus annuus*
Swamp mahogany	*Eucalyptus robusta*
Sydney blue gum	*Eucalyptus saligna*
Turnip weed	*Rapistrum rugosum*
Vetch	*Vicia species*
Vipers bugloss	*Echium vulgare*
Wattle	*Acacia species*
White box	*Eucalyptus albens*
White clover	*Trifolium repens*
White mallee	*Eucalyptus dumosa*
White stringybark	*Eucalyptus globoidea*
Willows	*Salix species*
Woollybutt	*Eucalyptus longifolia*
Yellow burr	*Centaurea solstitialis*

LIST OF DISCUSSION ARTICLES BY SCIENTIFIC & COMMON NAME	
Scientific Name	**Common Name**
Acacia species	Wattle
Angophora floribunda	Rough barked apple
Arctotheca calendula	Capeweed
Asphodelus fistulosus	Onion weed
Banksia ericifolia *Banksia serrata*	Banksias
Brassica napus	Canola
Caduus nutans	Nodding thistle
Carthamus lanatus	Saffron thistle
Casuarina littoralis	Black she oak
Centaurea solstitialis	Yellow burr
Chondrilla juncea	Skeleton weed
Cirsium vulgare	Black thistle
Citrus species	Citrus
Corymbia gummifera	Red bloodwood
Corymbia maculata	Spotted gum
Dillwynia species	Eggs & bacon
Echium vulgare	Vipers bugloss
Eucalyptus albens	White box
Eucalyptus blakelyi	Blakely's red gum
Eucalyptus bridgesiana	Apple box
Eucalyptus camaldulensis	River red gum
Eucalyptus delegatensis	Alpine ash
Eucalyptus dumosa	White mallee
Eucalyptus fibrosa	Red ironbark
Eucalyptus globoidea	White stringybark
Eucalyptus longifolia	Woollybutt
Eucalyptus macrorhyncha	Red stringybark

LIST OF DISCUSSION ARTICLES BY SCIENTIFIC & COMMON NAME	
Scientific Name	**Common Name**
Eucalyptus mannifera	Brittle gum
Eucalyptus microcarpa	Grey box
Eucalyptus polyanthemos	Red box
Eucalyptus punctata	Grey gum
Eucalyptus robusta	Swamp mahogany
Eucalyptus saligna	Sydney blue gum
Eucalyptus socialis	Christmas mallee
Eucalyptus sclerophylla	Scribbly gum
Eucalyptus viminalis	Manna gum
Fagopyrum esculentum	Buckwheat
Hakea sericea	Silky hakea
Helianthus annuus	Sunflower
Hypochoeris radicata	Flatweed
Lavandula species	Lavender
Lupinus angustifolius	Lupins
Prunus dulcis	Almond
Pyrus connunis	Pear
Rapistrum rugosum	Turnip weed
Salix species	Willows
Senecio madagascariensis	Fireweed
Sisymbrium officinale	Hedge mustard
Trifolium balansae	Balansa clover
Trifolium repens	White clover
Ulex europaeus	Gorse
Vaccinium species	Blueberry
Vicia faba	Faba bean
Vicia species	Vetch
Zea mays	Maize/corn

6.1.1 POLLEN QUALITY—Almond *(Prunus dulcis)*

Doug Somerville, NSW Agriculture, Goulburn

Almonds are a major horticultural crop that benefits from the action of honey bee pollination. They flower in late winter and early spring, usually the earliest source of both pollen and nectar in many regions. The relative benefits of almond pollen to honey bee nutrition are discussed.

Amino Acid	Ideal Ratio From DeGroot (1953)	Darlington Pt–Aug '95	Mildura VIC–Sep '96	Muss (1987) *'Mission'*	Muss (1987) *'Neplus'*	*Rayner & Langridge (1985)*
Threonine	3.0	4.52	4.47	4.7	4.7	4.5
Valine	4.0	5.11	4.83	5.4	5.3	5.4
Methionine	1.5	2.57	2.38	1.2*	0.7*	2.0
Leucine	4.5	6.41	6.85	7.4	6.7	6.7
Isoleucine	4.0	4.31	4.0	4.7	4.4	4.1
Phenylalinine	2.5	3.88	4.15	2.6	2.3	4.9
Lysine	3.0	6.48	5.87	3.4	3.1	6.0
Histidine	1.5	1.94	1.82	-	-	2.1
Arginine	1.0	5.48	5.15	4.6	4.7	5.3
Tryptophan	1.0	-	-	-	-	1.1
Crude Protein %	-	25.4	24.8	23.3	25.5	30.7
Fat %	-	2.74	1.89	-	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.						

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

The two pollens collected in 1995 and 1996 meet all the amino acid and crude protein requirements of a honey bees' diet. The two samples collected by Muss (1987) indicate a deficiency in the amino acid, Methionine. This amino acid has been traditionally difficult to chemically analyse, thus these two figures may be a function of the chemical methodology used by Muss. Pollens with a CP% above 25% are considered to be of a high quality.

From the results of the pollen collected in 1995 and 1996 plus the previously published figures for CP levels in almond pollen, it can be deduced that almond blossom is an excellent source of quality pollen and will adequately meet the nutritional requirements for amino acids and crude protein for a colony's growth and development.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.2 POLLEN QUALITY—Alpine ash *(Eucalyptus delegatensis)*

Doug Somerville, NSW Agriculture, Goulburn

Alpine ash *(Eucalyptus delegatensis)* flowers in late summer/autumn and occurs in the sub-alpine areas of southern NSW and eastern Victoria, mostly between 900 m and 1450 m altitude. The tree can grow to a height of 80 m and is often dominant in montane tall open forests. Alpine ash is sometimes referred to as White top, Gum-topped stringybark, Red mountain ash or Woollybutt. *Eucalyptus delegatensis* was also formerly known as *E.gigantea*.

The flowering period may vary from December to March, with the main flowering occurring in January and February. Goodman (1973) suggests it is two years from bud initiation to flowering, whereas the results of a recent survey of beekeepers suggest one year.

It may well be that it is difficult for a casual observer to ascertain the very early stages of budding in this species. The beekeepers in the same survey suggest a two to four year period between flowering. Goodman (1973) states that a heavy flowering is usually followed by a very light crop.

Honey yields can be heavy. The honey is dark and almost has a bitter flavour, with a good density (Goodman, 1973). Responses by beekeepers indicate a medium to high value for honey production. Pollen, on the other hand, was rated as having a high level of importance for honey bees. A sample of pollen collected in February 1996 in the Tumbarumba area of NSW indicated a well balanced pollen with a crude protein level of 23%. A level of 20% is considered a minimum requirement for honey bees. All essential amino acids tested met the minimum required levels for adequate honey bee nutritional requirements.

The pollen sample tested indicates that Alpine ash could be very useful for building colonies of bees.

Amino Acid	Ideal Ratio From DeGroot (1953)	Tumbarumba Feb '96
Threonine	3.0	3.68
Valine	4.0	5.83
Methionine	1.5	2.05
Leucine	4.5	7.14
Isoleucine	4.0	4.86
Phenylaline	2.5	4.33
Lysine	3.0	6.04
Histidine	1.5	2.27
Arginine	3.0	6.5
Crude Protein %	**-**	**23**
Fat	**-**	**1.87**

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

I thank Bruce Robertson, beekeeper, Wagga Wagga for trapping pollen, and the RIRDC Honeybee Research & Development Advisory Committee for funding the project.

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6.1.3 POLLEN QUALITY—Apple box *(Eucalyptus bridgesiana)*

Doug Somerville, NSW Agriculture, Goulburn

Apple box flowers from January through to April, with the main flowering period in February and March. Flowering frequency is from two to four years, with most apiary sites in NSW located on private property. The value of the pollen as stated by beekeepers, is very high with a mean value of 4.36 out of a possible high of 5.0. The expected honey yield per hive is 30 kg on average every three years (Somerville, 1999).

This tree is widespread across the southern, central and northern tablelands, extending just over the border into Queensland and the plains of eastern Victoria (Brooker & Kleinig, 1993).

The following table lists the values for the essential amino acids and those values achieved for five pollen samples, including crude protein and fat levels.

Amino Acid	Ideal Ratio From DeGroot (1953)	Burra Ck Mar '96	Ironmungie Mar '96	Bombala Mar '96 (1)	Williamsdale Mar '96	Collector Feb '97
Threonine	3.0	3.81	3.64	3.87	3.74	3.61
Valine	4.0	4.84	4.84	5.02	6.05	6.26
Methionine	1.5	2.21	2.71	2.43	2.61	2.2
Leucine	4.5	7.58	7.31	6.91	6.73	6.16
Isoleucine	4.0	5.13	4.99	3.88*	3.86*	3.55*
Phenylalinine	2.5	4.27	4.17	3.94	3.96	3.67
Lysine	3.0	6.56	6.36	5.76	5.15	5.57
Histidine	1.5	2.35	2.47	2.52	1.59	2.18
Arginine	1.0	6.42	5.92	6.14	5.77	5.38
Crude Protein %	-	23	22.6	24.5	23.5	24.9
Fat %	-	1.26	1.72	0.77	0.57	1.1

* Below the minimum levels required to meet honey bee nutritional requirements.
(1) Mean of results received from two laboratories for the same pollen sample.

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

The five pollens indicate reasonable levels of crude protein ranging from 22.6 to 24.9%, with a mean of 23.7%.

Three pollens were deficient in the amino acid Isoleucine, although this is not a pronounced deficiency. The collection data indicates that Apple box pollen is the dominant pollen collected by field bees but is not the sole source of pollen. In these circumstances, slight deficiencies in Apple box pollen may well be made up from other sources of pollen in the mix available to the developing bees in the hive. This tree also produced ample quantities of pollen. Generally, this species is a good supplier of reasonable quality and large quantities of pollen and will adequately meet the nutritional requirements in most cases for amino acids and crude protein for a colony's growth and development.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.4 POLLEN QUALITY—Balansa clover *(Trifolium balansae)*

Doug Somerville, NSW Agriculture, Goulburn

Balansa clover is a winter growing pasture species. At first glance it looks similar to White clover, although Balansa clover can grow up to one metre high. Flowering usually begins in mid September and may continue for up to eight weeks.

The two pollen samples collected originate from the Riverina and south western slopes of NSW. This plant has a reputation for yielding extractable quantities of honey although, as yet, the pasture species is not widespread. Unfortunately Balansa's major limitation as a fodder plant for livestock is its susceptibility to red legged earth mites at the seedling stage.

The following table lists the essential amino acids, crude protein and fat levels for two Balansa clover pollens collected in 1995 and 1996.

Amino Acid	Ideal Ratio From DeGroot (1953)	Wagga Wagga Oct '95	Ariah Park Oct '96
Threonine	3.0	4.7	4.58
Valine	4.0	5.66	5.27
Methionine	1.5	2.41	2.12
Leucine	4.5	7.35	6.96
Isoleucine	4.0	5.13	4.34
Phenylalinine	2.5	4.43	4.35
Lysine	3.0	5.96	6.08
Histidine	1.5	2.41	2.48
Arginine	1.0	4.86	4.62
Crude Protein %	-	23.4	27.2
Fat %	-	2.31	1.5

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Both pollen samples exhibit all essential amino acids above the desired minimum levels, as stated by DeGroot (1953). The protein levels of 23.4 and 27.2% are also in a desirable range to satisfy honey bee nutritional requirements in most circumstances. Information from these two pollen samples would indicate that this is a very good pollen source for bees and when build conditions are desired by the beekeeper for colonies, moving bees onto Balansa clover should be very beneficial.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

References

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6.1.5 POLLEN QUALITY—Banksias
Heath-leaved banksia *(Banksia ericifolia)*
Saw banksia (Banksia serrata)

Doug Somerville, NSW Agriculture, Goulburn

There are 73 species of banksia, all occur naturally in Australia. The greatest concentration of species is in the south west and adjacent regions of Western Australia where 58 species are found. Fourteen occur in south eastern and eastern Australia (George, 1987).

Clemson (1985) lists 10 species of banksia as important in their contribution to honey bees. He also suggests that, generally, the banksias are of a relatively minor importance as a pollen source for bees. This is unfortunate, if this is the case, as the pollens analysed indicate that they are very high in protein and would be considered of high quality in relation to their contribution to honey bee dietary requirements.

Information from NSW commercial beekeepers state that the value of *Banksia ericifolia* is quite good with a mean pollen value of 3.47 out of a possible value of 5. Flowering range is said to begin in March and extend until October, with the principal flowering times from May to August. Flowering frequency is every one to two years with mean honey yields of 25 kg per hive (Somerville, 1999). *Banksia ericifolia* is by far the more important species of Banksias in NSW. *Banksia serrata* also has a coastal distribution but is only worked by beekeepers on a very occasional basis. This species normally flowers over summer.

Crude protein levels of *Banksia ericifolia* reported by Stace (1996) ranged from 30.1 to 31.8% with a mean of 30.9%. *Banksia serrata*, on the other hand, is regarded as of minor importance and flowers over the December and January period. *Banksia serrata* is not normally sourced on its own as a target honey or pollen source in NSW. All the pollen samples of banksia species demonstrate excellent crude protein levels. The two samples tested indicate low levels of Isoleucine, but this should not be a problem due to the high protein levels and that banksia pollen is rarely the only source of pollen collected by bees.

The results of the two *Banksia ornata* pollen samples are listed for comparison with the other two species to give a general overview of banksia pollen values.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Shoalhaven Jun '96 *B.ericifolia***	**Nowra SF Jan '97 *B.serrata***	**Muss (1987) *B.serrata***	**Muss (1987) *B.ornata***	**Rayner & Langridge (1985) *B.ornata***
Threonine	3.0	4.2	3.81	4.1	4.3	3.9
Valine	4.0	4.47	4.84	5.4	5.2	4.7
Methionine	1.5	2.73	2.27	2.2	2.0	2.0
Leucine	4.5	6.4	5.77	7.6	7.1	5.6
Isoleucine	4.0	3.75*	3.61*	4.5	4.1	3.5*
Phenylalanine	2.5	3.83	3.71	5.4	4.9	4.3
Lysine	3.0	6	5.49	6.5	5.6	5.1
Histidine	1.5	2.98	2.37	-	-	2.4
Arginine	3.0	6.57	7.24	7.7	6.7	8.6
Crude Protein %	-	28.6	33.3	31.19	35.31	36.9
Fat %	-	2.45	1.9	-	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.						

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system. HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgements

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.6 POLLEN QUALITY—Black she-oak *(Casuarina littoralis)*

Doug Somerville, NSW Agriculture, Goulburn

Black she-oak is a small neat tree, usually less than 12 metres high. It is commonly found on poorer soils along the NSW coast and extending into the tablelands, extending into Victoria and Queensland. Female and male flowers are carried by separate trees. The female flower very rarely produces sufficient nectar to attract foraging honey bees. Bees will regularly work the male flowers for pollen from April through to September, depending on the location.

The pollen appears to be encapsulated in a brown husk. When bees are working this pollen source, an accumulation of these brown husks is often to be seen at the entrance of a hive. The pollen is deep yellow in colour.

The following table lists the essential amino acids, crude protein and fat levels for three Black she-oak pollens collected in 1996.

Amino Acid	Ideal Ratio From DeGroot (1943)	Sussex Inlet Jun '96	Sussex Inlet Jun '96	Millingandi Jun '96
Threonine	3.0	3.19	3.67	4.16
Valine	4.0	3.3*	4.17	4.74
Methionine	1.5	2.48	2.26	2.58
Leucine	4.5	5.63	6.41	6.06
Isoleucine	4.0	2.71*	3.4*	3.91*
Phenylalinine	2.5	2.86	3.57	3.44
Lysine	3.0	3.5	4.94	4.66
Histidine	1.5	1.59	1.91	1.68
Arginine	1.0	5.82	6.4	7.09
Crude Protein %	-	11.5*	12.9*	13.1*
Fat %	-	3.25	1.38	1.15
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

The amino acids, Isoleucine are deficient in all three samples and Valine in one sample.

All three pollen samples have very low crude protein levels, ranging from 11.5 to 13.1%—well under the recognised minimum level of 20% required by bees as described by Kleinschmidt (1976), that pollen with less than 20% crude protein cannot satisfy colony requirements for optimum production.

Other published crude protein levels for she-oaks or casuarinas agree with the levels found in the above table. 13.6% CP (Kleinschmidt & Kondos, 1976); 13.9%, 17.3%, 11.3% (Stace, 1996).

The quantity of pollen was low for all three collections. This pollen is a very poor source of nutrition for bees and should not be considered as a significant pollen source for managed honey bees. If bees are made to work this species for pollen they should have access to pollen supplements to increase the total protein intake of the colony and to minimise the amino acid deficiencies.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.7 POLLEN QUALITY—Black/Spear thistle *(Cirsium vulgare)*

Doug Somerville, NSW Agriculture, Goulburn

Black thistle *(Cirsium vulgare*, also called Spear thistle) is a common weed throughout most of temperate Australia, occurring in all states except the Northern Territory. It flourishes in highly fertile soils and disturbed areas, particularly in higher rainfall areas. A native of Europe, it is a very prickly biennial plant that grows to about 1 m. Black thistle has a particularly long flowering period and has been known to yield useful quantities of nectar. The pollen is white or almost clear when bees bring it back to the hive. The flowers are purple. Black thistle pollen only represented a minor proportion, from 10 to 30%, of the total pollen collected by honey bees in the samples tested.

In the two samples tested, only one shows a deficiency in one amino acid, Methionine. The concern with this pollen source is the low crude protein levels. Both pollens are below the recommended 20% considered a minimum level for adequate honey bee nutrition. This is not a major problem, as this source of pollen in most cases is only a small portion of the total pollens collected by bee colonies.

In direct contrast, a pollen sample reported on by Kleinschmidt (1984) and collected in Gatton (Queensland) in December 1974 had a very high crude protein level and the amino acid, Lysine, was much lower than in the samples collected in central NSW. The Gatton sample was deficient in four amino acids. The sample collected at Gatton represented 19% of the total pollen collected. This is similar to the two samples collected in central NSW. The pollen was described as white to grey in colour. A pollen tested by Muss (1987) found a similar crude protein level to those in NSW, but was deficient in four of the essential amino acids. Further samples need to be collected and tested to obtain a clearer picture of this species.

Generally, this would not be regarded as a good quality pollen source. The Queensland figure confuses the story for Black thistle pollen, although to be on the cautious side of bee management, beekeepers should not consider this pollen to be of any significant value in meeting honey bee nutritional requirements.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Black Springs Feb '96**	**Taralga Feb '96**	*Kleinschmidt (1984)*	*Muss (1987)*
Threonine	3.0	4.3	3.6	3.4	1.7*
Valine	4.0	5.2	5.1	3.6*	3.4*
Methionine	1.5	1.2*	1.9	2.1	1.9
Leucine	4.5	6.7	6.2	6.4	4.6
Isoleucine	4.0	4.7	4.5	3.2*	3.5*
Phenylalinine	2.5	4.0	3.5	4.1	2.6
Lysine	3.0	6.1	6.8	1.8*	1.0*
Histidine	1.5	3.6	3.1	1.4*	-
Arginine	3.0	3.7	3.9	3.9	6.5
Crude Protein %	Min. 20%	17.6*	16.1*	31.8	18.25*
Fat %	-	2.25	2.59	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.					

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgements

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6.1.8 POLLEN QUALITY—Blakely's red gum *(Eucalyptus blakelyi)*

Doug Somerville, NSW Agriculture, Goulburn

Varies in appearance from a small tree to one of good form about 25 metres high and 1 metre in diameter, with a distribution throughout the western slopes extending slightly into the western plains in northern NSW. It also occurs in the northern and southern tablelands (Clemson, 1985).

The flowering period is mainly November and December, although blossom may appear in September and be present in February. Flowering frequency is every three to four years on average, although worthwhile honey crops have been reported up to 10 years apart. Mean honey yields of 24 kg per hive are obtained and the pollen is considered by beekeepers to be of a high value (Somerville, 1999).

The following table lists two samples of pollen obtained from Blakely's red gum; one published by Muss (1987).

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Jugiong Dec '96**	*Muss (1987)*
Threonine	3.0	3.93	3.1
Valine	4.0	5.08	4.3
Methionine	1.5	2.28	2.3
Leucine	4.5	7.16	8.1
Isoleucine	4.0	3.74*	6.6
Phenylalinine	2.5	4.22	3.4
Lysine	3.0	6.26	5.3
Histidine	1.5	2.13	2.1
Arginine	1.0	6.45	4.1
Crude Protein %	-	28.8	24.3
Fat %	-	1.5	-

* Below the minimum levels required to meet honey bee nutritional requirements.

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

The high value beekeepers place on this tree as a pollen source is justified. The amino acid, Isoleucine is deficient in one pollen sample, although it is very unlikely that this will be the only source of pollen available to the colony. Thus this deficiency should be normalised by the collection of pollens with higher Isoleucine levels.

The crude protein and amino acids are at adequate levels, in most cases, to meet honey bee nutritional requirements.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.9 POLLEN QUALITY—Blueberry *(Vaccinium species)*

Doug Somerville, NSW Agriculture, Goulburn

Blueberries are an expanding horticultural crop of increasing importance. Honey bee visitation between blueberry flowers increases cross pollination and a stocking rate of three to nine hives per hectare with a minimum of six frames of brood covered with bees is recommended to maximise yields. As the popularity of this fruit grows and export potential unfolds, increasing areas grown to blueberries can be expected.

The plant is not known to benefit honey bee colonies with any significant amounts of surplus nectar and pollen. The following pollen sample would indicate a major problem with the low crude protein level of 13.9% below the minimum level of 20% required for satisfactory colony reproduction (Kleinschmidt & Kondos, 1976).

Indications from North America are that bees do not do well on blueberries. The crude protein level in the pollen sample collected at Gunning supports this view.

Supplementary protein feeds should be considered when hives are placed on blueberries to enable colonies to come off the crop at the end of flowering in a condition suitable to work a medium honey flow. If protein supplementation is not practised, then colonies will perform poorly when they are expected to work a medium to heavy honey flow following a diet of blueberry pollen.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Gunning Sep '95**
Threonine	3.0	3.78
Valine	4.0	5.44
Methionine	1.5	2.29
Leucine	4.5	6.65
Isoleucine	4.0	4.72
Phenylalanine	2.5	3.51
Lysine	3.0	6.37
Histidine	1.5	1.98
Arginine	1.0	5.64
Crude Protein %	-	13.9*
Fat %	-	2.04
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.10 POLLEN QUALITY—Brittle gum *(Eucalyptus mannifera)*

Doug Somerville, NSW Agriculture, Goulburn

Brittle gum is also referred to by a range of common names including Red spotted gum, White brittle gum, Small spotted gum, White gum and Brittle jack. The tree is small to medium sized, ornamental in appearance, growing 9 to 18 metres with a diameter of 0.3–0.6 m. It is quite common in hilly country on poor soils where it is usually stunted and of poor form. In NSW the species occurs mainly on the southern and central tablelands and the eastern fringe of the western slopes at altitudes of 300–1000 m (Clemson, 1985).

The species is considered unreliable as a nectar source but, on occasions, heavy honey crops are obtained. Good quantities of cream coloured pollen are said to be produced. Flowering occurs mainly during February and March (Clemson, 1985).

The following table lists two samples of Brittle gum pollen collected on the southern and central tablelands.

Amino Acid	Ideal Ratio From DeGroot (1953)	Bungonia Mar '97	Oberon Apr '97
Threonine	3.0	3.91	3.57
Valine	4.0	4.96	4.78
Methionine	1.5	2.43	2.18
Leucine	4.5	6.57	6.17
Isoleucine	4.0	3.65*	3.54*
Phenylalanine	2.5	4.19	3.66
Lysine	3.0	6.09	5.61
Histidine	1.5	2.45	2.23
Arginine	1.0	5.95	5.55
Crude Protein %	-	28.1	24.3
Fat %	-	1.5	0.9
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Brittle gum pollen has a reasonably good level of crude protein—24.3% is good and 28.1% is a very good protein level. Unfortunately, both pollens are deficient in the amino acid, Isoleucine which is typical of many Eucalypts. The time of year that flowering occurs may restrict the availability of a range of other pollen sources, thus this deficiency may not be compensated for by pollen from other species. Even so, with the reasonable crude protein level, bees may be able to consume sufficient quantities of pollen to receive their dietary requirements for Isoleucine. The success of this strategy will largely depend on the colony working a light to medium honey flow during and after this pollen source and the quantity of pollen yielded by Brittle gum being sufficient to satisfy the needs of a colony.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.11 POLLEN QUALITY—Buckwheat *(Fagopyrum esculentum)*

Doug Somerville, NSW Agriculture, Goulburn

Buckwheat is a broadleaf annual crop and is not related to wheat or any other cereal. Buckwheat is very sensitive to high summer temperatures, particularly during flowering and seed formation. Flowering occurs over the summer, thus Buckwheat is more successfully grown in the cooler tableland areas.

Buckwheat benefits from cross pollination and thus the presence of bees is highly desirable. Two and a half hives/ha stocking rate is commonly recommended to achieve maximum yields. Honey crops are at times obtained but the colour is dark and the flavour strong and distinctive. Many crops in the Australian experience have not yielded extractable honey crops, thus this species is not considered of any importance for honey production.

The following table compares the results of Buckwheat pollen against the minimum requirements for amino acids necessary to satisfy honey bee nutritional demands.

Amino Acid	Ideal Ratio From DeGroot (1953)	Black Springs Jan '98
Threonine	**3.0**	**4.2**
Valine	**4.0**	**5.02**
Methionine	**1.5**	**1.98**
Leucine	**4.5**	**6.83**
Isoleucine	**4.0**	**4.46**
Phenylalinine	**2.5**	**3.85**
Lysine	**3.0**	**6.89**
Histidine	**1.5**	**2.65**
Arginine	**1.0**	**4.32**
Crude Protein %	**-**	**11.4***
Fat %	**-**	**2.2**
*** Below the minimum levels required to meet honey bee nutritional requirements.**		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Based on this Buckwheat pollen sample, the crude protein is well below the desired minimum 20% CP levels necessary to maintain body protein levels in adult bees and sustain continuous brood raising (Kleinschmidt & Kondos, 1976).

Beekeepers, when placing bees on Buckwheat for pollination purposes should monitor the pollen intake of the colony. If Buckwheat pollen is the dominant or sole pollen being gathered by the majority of the colonies, then the colonies will require a move onto better quality pollen after the Buckwheat flowering to build up body protein levels before working a medium to heavy honey flow. Alternatively, the use of protein supplements could be contemplated while the bees are still on the Buckwheat. Either way, careful management will be necessary to ensure the colonies do not decline as a result of working this pollen source.

Acknowledgements

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.12 POLLEN QUALITY—Canola *(Brassica napus)*

Doug Somerville, NSW Agriculture, Goulburn

Canola is a winter growing oilseed crop, adaptable to most cropping areas of Australia, although it is consistently grown in the better parts of the wheat belt where rainfall is adequate or irrigation is available. Canola is essentially self-pollinating although research conducted by Manning (1999) in Western Australia indicates that the yields of Canola could be improved by 15% to 16% with the foraging activity from honey bees. Canola is unusual in that beekeepers actively pursue crops of Canola to provide nectar and pollen in the spring to build colony populations and, as such, have not traditionally pursued pollination service fees. Given this, it is worthy to note that in recent years there have been increasingly greater areas of Canola grown in the traditional cropping areas to a point that the area of the Canola crop now exceeds the number of beekeepers seeking Canola to breed bees. Thus, beekeepers are now in a position to ask for a pollination service fee if a grower wishes to attract them away from their regular bee sites. Insecticide spray can be a significant drawback working this crop, thus close contact must be maintained with the grower if bees are to be placed within flying distance of flowering Canola to minimise this risk.

Beekeepers generally regard the pollen from Canola as very important with a rating of 4.34 from a possible 5. Mean honey yields of 21 kg per hive are achieved on a regular basis, usually annually depending on the rainfall. Flowering commences in some locations in July, with the main flowering range from August to October (Somerville, 1999). The quantities of pollen collected from Canola are quite substantial and the essential amino acids and crude protein levels in most samples are adequate to meet nutritional requirements. The crude protein levels of 22.8% to 26.1% are very acceptable. Rayner & Langridge (1985) found Canola pollen to have a CP level of 27.1%; Stace (1996) 23.2 and 24.9%, all very acceptable. Muss (1987) indicates a sample tested by her to have only a 10.63% CP level, well below the acceptable minimum level of 20%. This sample is not indicative of the species, but a future sample analysed from the same region may assist in clarifying whether the nutritional value of pollen varies for specific regions according to soil type, cultivar or other variables. The fat levels in Canola are very high when compared to other pollen sources. The higher fat levels appear to be associated with attractiveness of the pollen to foraging bees. Its exact contribution to honey bee nutrition is not understood. Generally Canola is a very desirable pollen source for bees in early spring.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Darlington Point Aug '95(1)**	**Woodstock Sep '97**	**Stockinbingal Nov '96**	**Ariah Park Sep '95 (Oscar)**	*Rayner & Langridge (1985)*	*Muss (1987)*
Threonine	3.0	4.87	5.11	3.93	5.03	4.8	5.6
Valine	4.0	5.13	5.57	5.15	5.49	5.2	6.8
Methionine	1.5	2.29	2.32	2.03	2.51	1.9	1.8
Leucine	4.5	6.96	7.57	6.57	7.17	6.9	8.0
Isoleucine	4.0	4.64	4.47	3.82*	5.03	4.5	6.2
Phenylalanine	2.5	4.3	4.03	3.78	4.47	4.3	5.5
Lysine	3.0	8.16	8.45	5.55	8.28	7.8	3.2
Histidine	1.5	2.13	2.72	2.52	2.19	2.2	-
Arginine	3.0	5.13	4.83	6.26	5.13	5.2	6.2
Crude Protein %	-	22.8	26.1	23.8	23.6	27.1	10.63*
Fat %	-	7.3	6.9	1.8	6.82	-	-

* Below the minimum levels required to meet honey bee nutritional requirements.
(1) Mean of results from two separate laboratory analysis for the same pollen.

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system. HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.13 POLLEN QUALITY—Capeweed *(Arctotheca calendula)*

Doug Somerville, NSW Agriculture, Goulburn

Capeweed is a native of South Africa and is considered a weed in the Australian rural scene. This species may provide an excellent stimulus for bees for brood rearing, sometimes providing a small surplus of honey (Clemson, 1985). Beekeepers rate this species as a reasonably important source of pollen with a value of 4.1 out of a possible high of 5. Flowering begins in August with the main flowering period in September/ October and finishes in November, on an annual basis. Honey yields of 17 kg per hive may be achieved under favourable conditions (Somerville, 1999).

In the early spring period all pollen sources are eagerly sought by honey bees, thus any available pollen to foraging honey bees is valuable at this time of the season to enable colonies to breed and expand in population.

The sample collected from Dubbo was only of a small quantity and other attempts to trap any volume of pollen were not successful on a few other locations. The quality of the pollen is of a low standard with the crude protein levels ranging between 16% and 17%, whereas 20% is considered the absolute minimum to maintain and meet a colony's nutritional requirements. Both pollen samples in the table are also deficient in Isoleucine which, given the low crude protein levels, will create problems in meeting the desired minimum levels for this amino acid as established by DeGroot (1953). The sample analysed by Muss (1987) also indicates a deficiency of at least two other essential amino acids.

Generally as a sole source for protein and amino acids, this species would have to be considered of poor quality. Capeweed pollen needs to be collected in conjunction with other pollens to ensure the low crude protein levels and amino acid deficiencies do not create a problem for the colony in enabling it to breed and expand during the spring period.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Dubbo Sep '96**	*Muss (1987)*
Threonine	3.0	4.16	3.6
Valine	4.0	4.34	4.2
Methionine	1.5	2.25	1.4*
Leucine	4.5	5.92	6.1
Isoleucine	4.0	3.74*	3.2*
Phenylalanine	2.5	3.89	2.1*
Lysine	3.0	7.59	7.8
Histidine	1.5	3.77	2.7
Arginine	3.0	3.75	4.2
Crude Protein %	-	17.3*	16.75*
Fat %	-	3.4	-
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.
Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.14 POLLEN QUALITY—Christmas mallee *(Eucalyptus socialis)*

Doug Somerville, NSW Agriculture, Goulburn

Christmas mallee is a typical mallee in habit, three to nine metres high with multiple stems. It occasionally occurs as a single-stemmed tree up to 15 m high and 250 mm in diameter. This species occurs in semi-arid zones and is found mainly in central New South Wales, South Australia, Victoria and Western Australia. It usually grows on sands and sand loams in association with other mallee species (Clemson, 1985).

Beekeepers in NSW regard this tree as having an average value for pollen of 3.22 out of a possible rating of 5. The main flowering period is over December and January, thus the name Christmas mallee derived from its flowering period. Flowering frequency is usually every three years, but this may range from two to five years. Honey yields of 35 kg on average may be obtained per hive (Somerville, 1999).

The one sample collected indicates a very favourable crude protein level of 26.6% but is typical of many eucalypts with a deficiency in the essential amino acid, Isoleucine. For optimal colony performance, other pollen sources need to be available to supplement Christmas mallee and ensure this deficiency is overcome

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Weethale Dec '96**
Threonine	3.0	3.49
Valine	4.0	4.5
Methionine	1.5	2
Leucine	4.5	5.97
Isoleucine	4.0	3.36*
Phenylalanine	2.5	3.57
Lysine	3.0	5.36
Histidine	1.5	2.49
Arginine	3.0	7.18
Crude Protein %	-	26.6
Fat %	-	1.8
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.15 POLLEN QUALITY—Citrus *(Citrus species)*

Doug Somerville, NSW Agriculture, Goulburn

Citrus trees are the most important fruit trees for honey production. During favourable seasons, crops of choice quality honey are obtained. Many beekeepers regularly move their hives to citrus orchards to stimulate colonies in the spring and to prepare bees for honey flows which follow elsewhere. On the central coast of NSW flowering is normally over September, extending to mid October. Citrus can yield nectar copiously when conditions are favourable, although the species and varieties can differ significantly in their pollen production and pollination requirements. For instance, Washington navels do not produce seed and thus do not produce pollen (Clemson, 1985).

Beekeepers regard this species as a valuable honey with yields of 32 kg per hive, obtainable every one to two years (Somerville, 1999). The honey produced is of a distinct citrus flavour and normally attracts a premium price for the crop.

The pollen sample tested indicated a below optimum crude protein level of 18.5%, but all the essential amino acids were above those recorded by DeGroot (1953), to meet the minimum requirements for these elements. Fortunately, citrus is rarely the only pollen source available to bees in the mid spring period, as a whole range of pollen sources are normally gathered by bees including Capeweed and Paterson's curse, thus ensuring the low protein level is not a limiting factor in a collective mix available to the colony.

Amino Acid	Ideal Ratio From DeGroot (1953)	Paynters Siding Nov '97
Threonine	3.0	4.4
Valine	4.0	5.33
Methionine	1.5	2.08
Leucine	4.5	7.21
Isoleucine	4.0	4.22
Phenylalanine	2.5	4.28
Lysine	3.0	9.53
Histidine	1.5	2.3
Arginine	3.0	5.22
Crude Protein %	-	18.5*
Fat %	-	3
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.16 POLLEN QUALITY—Eggs & bacon *(Dillwynia species)*

Doug Somerville, NSW Agriculture, Goulburn

Species in the genus *Dillwynia* are mostly erect shrubs with alternate simple narrow-linear leaves without stipules. The stems are usually covered with short soft hairs. Flowers are mostly arranged in short racemes, but may sometimes be solitary and yellow or red (Clemson, 1985).

Dillwynia is referred to as Eggs & bacon by beekeepers, also as Parrot pea. There are numerous native pea flowers that provide worthwhile quantities of pollen and at times sufficient quantities of nectar to stimulate breeding and maintain colonies. It is difficult to ascertain exactly which pea flower species bees are accessing, as often a number of plants in this group are flowering concurrently.

NSW beekeepers gave the pollen a value of 3.9 out of a possible 5, indicating a high value status. Flowering range was from July to November with the main flowering during August and September every one to two years (Somerville, 1999).

Four pollen samples were collected from pea flowers flowering in the Nowra state forests in September 1996 and 1997. Only one of these, with any confidence, could be identified as *Dillwynia* species. The sample listed in the table is only of marginal quality, with a crude protein level of 19.7%. The other three samples indicated crude protein levels of 17.1, 23.3 and 19.7%. Three of the four samples were below the desirable minimum levels of the amino acid, Isoleucine.

This pollen or group of pollens is of major benefit due to the time of year the pollen is available, but the quality is of questionable value. Other pollen from species with higher crude protein and higher Isoleucine levels needs to be collected to overcome the deficiencies in this group of plants. Bees may perform adequately on a light to medium honey flow during and after breeding on pea flower pollen but would not be expected to sustain large populations if expected to work a heavy honey flow. This information adds weight to beekeeping management strategies that involve migration onto better pollen sources.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nowra Sep '97 (1)**
Threonine	3.0	3.95
Valine	4.0	4.96
Methionine	1.5	2.36
Leucine	4.5	6.55
Isoleucine	4.0	3.77*
Phenylalanine	2.5	3.84
Lysine	3.0	5.71
Histidine	1.5	2.69
Arginine	3.0	7.11
Crude Protein %	-	19.7*
Fat %	-	1.7

* Below the minimum levels required to meet honey bee nutritional requirements.
(1) Mean results for three tests on the one pollen sample for the same lab.

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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funding for chemical analysis—rirdc honeybee research & development advisory committee.

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6.1.17 POLLEN QUALITY—Faba bean *(Vicia faba)*

Doug Somerville, NSW Agriculture, Goulburn

The faba bean is a winter legume crop. Originating from the middle east, faba beans are among the oldest crops in the world. Faba beans are grown as a rotational crop following cereal or cotton crops. In this context, faba bean crops provide a range of important benefits, including nitrogen fixation, weed control and cereal root disease management. Also, a good faba bean crop will contribute at least 50 kg nitrogen per hectare to the following crop.

Research conducted in the Riverina NSW in early spring indicates yield increases of 25% due to honey bee activity (Somerville, 1995). Unfortunately, in the same trial, faba beans did not contribute to the nectar supply of the colonies and bees had to rely on stored honey or fresh nectar from Canola crops within flying distance of the hives during suitable weather.

The levels of crude protein and the essential amino acids in the three samples listed in the following table are all at desirable levels to satisfy honey bee nutritional requirements. It has been suggested that this species produces low quantities of pollen but this was not apparent with the three samples collected in this case, where ample faba bean pollen was collected. The stocking rate of hives was one per hectare. If this level had been greater then the quantity of faba bean pollen per colony may have reduced. Even so, faba bean pollen is normally collected in conjunction with Capeweed and Canola pollen when these species are within flight distance of the hives.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Darlington Pont Aug '95**	*Somerville (1995)*	*Somerville (1995)*
Threonine	3.0	4.57	4.8	4.8
Valine	4.0	5.22	5.1	5.2
Methionine	1.5	2.24	1.8	1.8
Leucine	4.5	6.7	6.8	6.9
Isoleucine	4.0	4.83	4.6	4.8
Phenylalanine	2.5	4.15	4.3	4.0
Lysine	3.0	6.17	6.8	7.4
Histidine	1.5	2.11	2.2	2.3
Arginine	3.0	5.1	5.0	4.8
Crude Protein %	-	24.4	22.3	24.1
Fat %	-	1.72	-	-

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.18 POLLEN QUALITY—Fireweed (Senecio madagascariensis)

Doug Somerville, NSW Agriculture, Goulburn

Fireweed is a common weed of coastal pastures along the New South Wales coast and south east Queensland. Previously the plant was identified as a form of a native Australian species, *S.lautus*, but this since has proven to be incorrect (Watson *et al*, 1984). The species is a native of southern Africa.

The plant is worked regularly by field bees for pollen and occasionally stimulating supplies of nectar, but insufficient to store. Clemson (1985) suggests that this species is of major importance as a source of pollen and maintains colony strength and colony build up on the central and north coast of NSW during favourable seasons. Some flowers may be present throughout the year, theheaviest flowerings usually occurring between July and September. Rainfall can cause a flush of flowering at other times of the year.

The results of the pollen collected from Nowra on the south coast do not support this view as the crude protein level is very low at 12.4%. Given that the minimum required level is 20%, the sample of Fireweed pollen does not come close to satisfying the protein requirements of bees. Five samples collected and analysed originating from the north coast also indicate very low protein levels, ranging from 11.8% to 17.3% with a mean of 14.05% (Stace, 1996).

Bees may appear healthy and a colony populous on this pollen source, but the adult bees will be short lived and if the colony is made to work a medium or heavy honey flow following a period of breeding on Fireweed pollen, the colony will seriously reduce in strength very rapidly.

Management strategies to overcome this potential problem should include disregarding Fireweed as a source of pollen and seeking other species of higher quality or, if this is not possible, supplementing the colonies with protein based feeds to make up the shortfall in the field.

Amino Acid	Ideal Ratio From DeGroot (1953)	Nowra—Sep '96
Threonine	3.0	4.04
Valine	4.0	4.08
Methionine	1.5	2.32
Leucine	4.5	5.76
Isoleucine	4.0	3.57*
Phenylalanine	2.5	3.39
Lysine	3.0	5.44
Histidine	1.5	3.2
Arginine	3.0	4.36
Crude Protein %	-	12.4*
Fat %	-	2.41
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.19 POLLEN QUALITY—Flatweed *(Hypochoeris radicata)*

Doug Somerville, NSW Agriculture, Goulburn

Flatweed is a native of Europe and is widely distributed across temperate Australia. It is a very common plant on the coast, tablelands and easterly areas of the western plains of NSW. Flatweed is only considered of minor importance as a weed species. This plant is frequently confused with Dandelion *(Taxaxacum officinale)* which looks the same to the casual observer but grows in moister areas. They may be distinguished by the following characteristics. Dandelion bears its flowers on a single stem, while Flatweed may have up to six flower heads on a single branched stem. Flatweed leaves are more prostrate, less deeply toothed and distinctly hairy, when compared with Dandelion leaves. The leaf colour is less marked in Dandelion than in Flatweed, where the leaves are darker and more glossy on the upper surface than beneath (Clemson, 1985). Flatweed stimulates brood rearing by providing some nectar and an abundance of pollen. Occasionally small surpluses of honey are stored (Clemson, 1985).

NSW beekeepers regard the pollen from this species to be of medium importance with a rating of 3.68 out of a possible 5, with honey yields of 10 kg per hive achievable. Flowering times are from September through to March, with the main flowering period over November, December and January, on an annual basis (Somerville, 1999). The number of samples containing Flatweed pollen as a minor component of the mix was quite considerable. On a few occasions, Flatweed was the dominant pollen source. This pollen would appear to be very attractive to foraging honey bees and this could be as a consequence of the rather high fat contents in the pollen. Flatweed had a fat content ranging from 5% to 11%. When compared to other species, this is very high. Other than making this pollen very attractive to foraging honey bees, its exact nutritional contribution from the supply of fat to the colony is not known.

The crude protein levels are consistently below that required to maintain minimum honey bee nutritional requirements. Pollen levels below 20% do not meet honey bee requirements for crude protein, thus Flatweed as a sole source or dominant source of pollen will not be satisfactory in breeding long lived bees and encouraging the expansion of the brood area. Two amino acids, Valine and Isoleucine, are consistently below minimum levels required by developing bees. Fortunately, Flatweed pollen is usually a part of a mixture of pollens collected and, as such, imbalances should not be a problem.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Oberon Jan '98**	**Bungonia Nov '97 (A)**	**Goulburn Dec '98**	**Molong Nov '96**	**Tarago Jan '96**	**Black Springs Feb '96**
Threonine	3.0	3.27	3.7	4.06	4.08	3.81	3.05
Valine	4.0	3.41*	3.91*	4.27	4.27	4.17	2.98*
Methionine	1.5	2.02	1.82	2.11	2.06	1.99	2.18
Leucine	4.5	4.94	5.76	6.1	5.94	5.74	5.01
Isoleucine	4.0	3.13*	3.36*	3.63*	3.51*	3.62*	2.7*
Phenylalanine	2.5	3.06	3.59	4.1	3.9	3.76	3.05
Lysine	3.0	7.48	8.25	8.88	7.41	7.8	6.61
Histidine	1.5	3.84	4.32	4.9	4.4	4.18	3.75
Arginine	3.0	3.14	3.64	3.93	3.63	3.32	3.01
Crude Protein %	-	15.1*	17*	17.1*	18.2*	17.9*	15.6*
Fat %	-	5.9	6.6	7.4	8.5	9.2	7.43
* Below the minimum levels required to meet honey bee nutritional requirements.							

Amino Acid	Ideal Ratio From DeGroot (1953)	Amaroo Jan '98	Bathurst Jan '98	Weethale Jan '97	*Muss (1987)*	*Rayner & Langridge (1985)*
Threonine	3.0	4.17	3.85	3.17	4.1	3.7
Valine	4.0	4.55	4.46	3.84*	4.0	4.3
Methionine	1.5	2.15	2.05	1.43*	1.9	2.0
Leucine	4.5	6.24	5.97	5.59	7.0	6.1
Isoleucine	4.0	4.27	3.77*	3.15*	4.2	4.0
Phenylalanine	2.5	3.86	3.56	3.04	3.2	4.6
Lysine	3.0	7.8	8.17	8.58	6.4	6.5
Histidine	1.5	3.27	3.84	3.12	-	3.6
Arginine	3.0	3.81	3.38	3.57	6.6	3.9
Crude Protein %	-	14.1*	17.1*	9.2*	15.69*	18.4*
Fat %	-	5.26	8.2	11.2	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.						

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.

Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.

Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.20 POLLEN QUALITY—Gorse *(Ulex europaeus)*

Doug Somerville, NSW Agriculture, Goulburn

Gorse is a rather spiky, compact bush, prevalent in some areas of the southern tablelands of NSW. It is also found in other areas of NSW, Victoria, South Australia and Tasmania. It is considered a pest in most areas in Australia and originates from Europe. The shrub on the southern tablelands of NSW grows about 1½ metres high and flowers in August/September. The flowers are bright yellow and the bush is usually densely covered in the pea-like flowers. The shrub is covered in spines 2–3 cm long and is very prickly to handle.

Gorse is considered an important beekeeping floral resource in New Zealand. Although not as common in Australia, there are areas that harbour significant populations of Gorse that would make it useful for commercial numbers of honey bees.

All amino acids in the sample tested are above the minimum levels required for adequate honey bee nutrition. The crude protein is well above the 20% minimum level required. The significance of the fat levels is yet to be determined. Wherever honey bees have access to quantities of this pollen, colonies should expand and the resultant bees should be long lived. This will be largely dependent on the weather conditions at the time of foraging, as the weather on the tablelands in August and September can be quite variable and not conducive to honey bee activity.

Generally, honey bees do not fly in temperatures below 12°C and maximum flight is attained when temperatures rise above 19°C. Gorse also produces stimulating quantities of nectar that contribute to provide excellent breeding conditions. The pollen is a deep yellow colour and the sample collected was free of pollen from other species.

A sample of Gorse pollen collected in Victoria and reported by Muss (1987) indicates a significantly different story for this species. With a crude protein of 16.5% and a deficiency in at least two essential amino acids, Isoleucine and Lysine, this pollen falls very short of the required minimum quality to sustain colonies in brood expansion and rearing. Further samples of Gorse pollen need to be analysed before a generalisation for the quality of this pollen across all geographic locations can be confidently stated.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Collector Aug '96**	*Muss (1987)*
Threonine	3.0	4.51	4.3
Valine	4.0	5.14	10.7
Methionine	1.5	2.35	3.2
Leucine	4.5	7.15	14.4
Isoleucine	4.0	4.43	2.1*
Phenylalanine	2.5	4.39	11.3
Lysine	3.0	5.99	2.4*
Histidine	1.5	2.26	-
Arginine	1.0	4.73	2.6
Crude Protein %	-	28.4	16.5*
Fat %	-	2.08	-
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.21 POLLEN QUALITY—Grey box *(Eucalyptus microcarpa)*

Doug Somerville, NSW Agriculture, Goulburn

Grey box is referred to as Western grey box, Brown box and Inland grey box. This is a medium sized tree, 15–24 m high. Western grey box was thought to be two separate species: Brown box *(E.microcarpa)* and Inland grey box *(E.woollsiana)*. Brown box occurs in the north west, extending from Tamworth into Queensland, and Inland grey box occurs in the south. The two differ markedly, especially in their bark, buds and fruits, and Brown box is the heavier honey yielder. This species is common in the wheat belt where there are hot summers and an annual rainfall of about 380–630 mm. It is found mainly at altitudes of 120–300 m, usually on gentle slopes and plains. Inland grey box is moderately reliable as a honey producer and is useful in following the main summer honey flows, but because of likely bee losses that result, apiarists prefer to work alternative sources. The Brown box of the north is capable of producing very heavy crops of honey but is not a regular or reliable source.

Bees gather moderately good quantities of cream coloured pollen from this species but because it grows in country that often experiences extremely dry periods, and may be the only significant source of pollen, colony strength may seriously decline. Colony strength will decline even further if bees work pollen deficient flows, such as Mugga *(E.sideroxylon)*, after working Inland grey box. The regular losses that occur, particularly in the more eastern and elevated areas of Inland grey box country, have caused some beekeepers to call this tree 'Knockem box' (Clemson, 1985).

In a study documenting the floral resources of NSW, Grey box was regarded as having a fairly average pollen value of 2.39 out of a possible rating of 5. The main flowering period is February and March, with a range of January to May. Flowering frequency was every two to three years with five years between heavy budding events not uncommon (Somerville, 1999). The crude protein levels of the pollen collected in March 1997 and the levels reported by Muss (1987) and Rayner & Langridge (1985) all indicate reasonable protein levels. Kleinschmidt & Kondos (1976) also recorded a protein level of 25% for crude protein.

The problem with this species would appear to be the deficiency in the amino acid, Isoleucine, common to the three samples in the table. If Grey box is the only pollen collected by bees then the diets fed to developing larvae and young adults will suffer a deficiency. Adult bees will be shorter lived as a result than if the pollen had sufficient levels of all essential amino acids. Feeding protein supplements rich in Isoleucine with a protein content over 25% could improve hive performance while colonies are working a Grey box honey flow.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Flagstaff Mar '97**	*Muss (1987)*	*Rayner & Langridge (1985)*
Threonine	3.0	3.92	3.3	3.7
Valine	4.0	5.11	4.0	5.0
Methionine	1.5	2.07	1.1*	1.7
Leucine	4.5	6.5	5.3	6.5
Isoleucine	4.0	3.77*	3.1*	3.8*
Phenylalanine	2.5	3.85	3.2	3.8
Lysine	3.0	5.96	5.0	5.1
Histidine	1.5	2.38	1.6	2.2
Arginine	3.0	6.44	4.6	5.6
Crude Protein %	-	23.6	25	23.3
Fat %	-	3	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.22 POLLEN QUALITY—Grey gum *(Eucalyptus punctata)*

Doug Somerville, NSW Agriculture, Goulburn

The common name, Grey gum, can refer to small fruited grey gum—*E.propinqua* (Wyong to SE QLD), large fruited grey gum—*E.punctata* (Jervis Bay to Mudgee and into QLD for some varieties), *E.canaliculata* (Dungog/Gloucester region), *E.biturbinata* (Gloucester to Kingaroy in QLD), *E.major* (SE QLD), thus particularly from the NSW central coast to SE QLD, it is very difficult, with any degree of confidence to state that any particular Grey gum is a specific Grey gum species. Flowering periods are: *E.propinqua*—January to March, *E.punctata*—December to April, *E.canaliculata*—November to December, *E.biturbinata* and *E.major*—summer (Brooker and Kleinig, 1990). The sample of pollen collected in the Nowra State Forest is deemed to be *E.punctata*, as this is the most southerly range for Grey gum and the nearest related species is found north of Sydney.

This species may provide extractable surpluses of honey in good seasons, but it is generally more valuable as a contributory source of nectar with other species which flower in the same area and at the same time, for example Red bloodwood *(E.gummifera)* and Scribbly gum *(E.haemastoma)*. It is of minor to medium importance as a source of honey in NSW.

Grey gum produces a large quantity of cream pollen which is gathered by bees. Colonies often dwindle seriously after working Grey gum flows because of adverse weather at the time of flowering (Clemson, 1985).

The pollen collected in the Nowra State Forest in January 1997 is of reasonable quality with a crude protein level of 27.3%. Kleinschmidt & Kondos (1976) also reports Grey gum pollen with a CP level of 24%. Both these levels are satisfactory to meet normal breeding and maintenance of the colony. The amino acid, Isoleucine, is deficient in the one sample analysed which is typical of many eucalypt pollens. Care should be taken if working Grey gum to determine whether Grey gum pollen is the sole source of amino acids. If other species are also being collected then it is possible the low Isoleucine levels will not be a problem.

The dwindling population experienced by colonies after working Grey gum, as reported by Clemson (1985), could be due to this amino acid deficiency or possibly increased Nosema levels. It could also be due to adult bees with low protein levels being made to work a medium Grey gum honey flow which will speed up their death, compared to longer lived high protein bees.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nowra SF Jan '97**
Threonine	3.0	3.5
Valine	4.0	4.76
Methionine	1.5	1.68
Leucine	4.5	6.03
Isoleucine	4.0	3.45*
Phenylalanine	2.5	3.51
Lysine	3.0	5.42
Histidine	1.5	2.26
Arginine	3.0	5.57
Crude Protein %	-	27.3
Fat %	-	2
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.23 POLLEN QUALITY—Hedge mustard *(Sisymbrium officinale)*

Doug Somerville, NSW Agriculture, Goulburn

Hedge mustard is widely distributed in southern and eastern Australia. A native of Europe, it is a common weed of wasteland, cultivation and disturbed habitats in Australia. This species flowers during spring and into summer. Some plants are still in flower in early autumn. Clemson (1985) does not regard Hedge mustard as valuable when compared to *Brassica* and *Rapistrum* species, but it does provide provisions used for brood rearing.

The three samples of pollen collected in 1995 and 1996 from the southern tablelands are of average quality, although only one sample is deficient in the essential amino acids, Valine and Isoleucine. In all three samples an abundance of pollen was trapped indicating that quantity of protein should not be a problem. Bees working this species should be able to consume sufficient amounts of pollen to meet their dietary requirements for essential amino acids, although if the body protein levels are low prior to working this pollen source then it may take three or four generations for the colony to build up in strength and body protein levels suitable to work a heavy honey flow.

The high fat levels are of interest as this seems to be a factor in attracting bees to forage on this species of pollen. Generally it has been observed that pollens with high fat contents are very attractive pollen sources. What specific dietary contribution fat offers to honey bees is not known.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Goulburn Nov '95**	**Tarago Feb '96**	**Goulburn Feb '96**
Threonine	3.0	5.06	4.23	4.66
Valine	4.0	5.34	3.27*	5.7
Methionine	1.5	2.43	2.77	2.64
Leucine	4.5	7.31	5.63	7.23
Isoleucine	4.0	4.92	3.14*	5.34
Phenylalanine	2.5	4.51	3.21	4.2
Lysine	3.0	8.71	5.81	8.09
Histidine	1.5	2.25	1.79	2.67
Arginine	3.0	5.33	4.1	4.99
Crude Protein %	-	22	22.3	22.4
Fat %	-	5.68	6.39	5.4
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.24 POLLEN QUALITY—Lavender *(Lavandula species)*

Doug Somerville, NSW Agriculture, Goulburn

Lavender is a very common ornamental garden plant grown for its grey foliage, purple flowers and strong scent. Lavender is also grown commercially to produce essential oils and dried flowers. There is a growing group of specialist growers of Lavender in Australia and the areas grown will probably increase at least on a small scale.

Lavender is a significant source of nectar in its place of origin. Yields of 6 to 60 kg per hive are obtained from Lavender areas in France. Thus, if the area grown to Lavender increases in Australia, this then may become a localised floral resource of significance for a few beekeepers. The pollen collected at Goulburn in December 1998 is of poor quality and would not be suitable to maximise breeding and longevity of the adult bees. Fortunately, in most cases, Lavender pollen will most probably be only a component of the total pollen collection by a colony. Thus, depending on the qualities of the other species, the poor quality pollen derived from Lavender will be improved by the addition of higher quality pollens from other species. The pollen was collected from "Italian" Lavender and represented 43% of the pollen trapped.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Goulburn Dec '98**
Threonine	3.0	4.17
Valine	4.0	4.54
Methionine	1.5	2.21
Leucine	4.5	6.04
Isoleucine	4.0	3.59*
Phenylalanine	2.5	4.11
Lysine	3.0	6.38
Histidine	1.5	3.67
Arginine	3.0	4.31
Crude Protein %	-	19.4*
Fat %	-	2.9
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

References

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6.1.25 POLLEN QUALITY—Lupins (Lupinus angustifolius)

Doug Somerville, NSW Agriculture, Goulburn

Lupins are a winter growing grain legume used in crop rotations on acid soils. They are highly valued in livestock nutrition, and are providing an alternative source of winter cropping income for an increasing number of farm enterprises in central and southern NSW. Expansion in intensive livestock industries, both here and overseas, has stimulated an increased demand for Lupins as an alternative source of protein. In addition, Lupins are superior to all other grains as a supplement for protein deficient, dry grazing for sheep and cattle.

Narrowleaf Lupins *(Lupinus angustifolius)*, are the main species grown, while Albus Lupins *(Lupinus albus)* are of very minor, but increasing importance. Well grown Lupin plants may be over 1 m high, but modern varieties are becoming shorter with pods increasingly concentrated in the upper half or third of the plant. Lupins flower over a period of four to eight weeks, in early spring.

Langridge and Goodman (1977), in a trial conducted in Victoria, concluded that mean yields of seed from *Lupinus angustifolius* were significantly greater from plots to which bees and larger insects had access, than from plots from which these insects were excluded. They found an 18.5% increase in yield by exposing flowers to foraging honey bees. In the same trial they also found that lupin pollen was more attractive to bees than capeweed pollen.

Information on the value of Lupins as a honey plant is limited. Langridge and Goodman (1977) claimed that Lupins are good honey plants with 9–19 kg of honey surpluses per colony on *L.angustifolius*. Two samples of Lupin pollen were collected from the Riverina in September 1997 and 1998.

The following table details the results of the nutritional analysis of the three samples, as compared to the Ideal Ratios determined by DeGroot (1953). They indicate no deficiencies, whatsoever, in the listed essential amino acids, and the overall crude protein level is desirable—as any protein level above 20% is regarded as acceptable for adequate honey bee nutrition, and above 25% is considered of high quality.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Boree Ck Sep '97**	**Sandigo Sep '98**	Muss (1987) *L.albus*
Threonine	3.0	4.36	4.99	3.9
Valine	4.0	5.35	5.72	5.5
Methionine	1.5	2.07	2.13	1.7
Leucine	4.5	7.96	8.05	7.4
Isoleucine	4.0	4.44	4.91	4.6
Phenylalanine	2.5	4.24	5.06	4.1
Lysine	3.0	3.25	7.4	7.3
Histidine	1.5	2.22	2.8	-
Arginine	3.0	4.7	5.5	5.6
Crude Protein %	-	34.7	33.7	28.0
Fat %	-	3.1	2.7	-

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgements

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.26 POLLEN QUALITY—Maize/Corn *(Zea mays)*

Doug Somerville, NSW Agriculture, Goulburn

Maize is a summer growing crop that is popular throughout the world as a staple food and as a stock feed. Maize is widely grown through agricultural areas of Australia for both grain and silage. The processed grain is used in many food and non-food products, such as Cornflakes and starches. The rain and whole plant is commonly used as stock feed. Up to 23 t/ha of grain and up to 100 t/ha of silage is possible. Good management and conditions should produce 6–8 t/ha of grain or 60–75 t/ha of silage in higher rainfall areas.

Maize largely flowers in the summer in temperate Australia when the tassel fully emerges and the pollen is shed. Pollination is usually via air movement and insect activity is not usually a consideration for adequate pollination of maize. Even so, at times honey bees will gather large quantities of Maize pollen.

The results of one sample of Maize pollen collected at Darlington Point in January 1996 indicate that the pollen has questionable value. Even though significant quantities of pollen were collected, the crude protein level of 14.9% is well below the 20% level necessary to meet the basic requirements of honey bee nutrition.

Stace (1996) also found the crude protein levels to be very low from 14% to 15%, thus this pollen should be avoided where possible by beekeepers as the bees bred on this poor quality pollen will be short lived and not suitable to be worked on a medium to heavy honey flow.

Amino Acid	Ideal Ratio From DeGroot (1953)	Darlington Point Jan '96
Threonine	3.0	5.11
Valine	4.0	5.9
Methionine	1.5	1.57
Leucine	4.5	6.82
Isoleucine	4.0	4.84
Phenylalinine	2.5	3.84
Lysine	3.0	5.55
Histidine	1.5	1.86
Arginine	3.0	4.7
Crude Protein %	-	14.9*
Fat %	-	1.8
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.27 POLLEN QUALITY—Manna gum *(Eucalyptus viminalis)*

Doug Somerville, NSW Agriculture, Goulburn

Manna gum is also referred to as Ribbon gum and White gum. It is found in areas of the tablelands and coast, growing near sea level to altitudes over 1000 m. It grows best on moist, well drained, alluvial and basaltic soils in mountain valleys. Buds are carried for 15 months and flowering normally begins in February but varies with weather, altitude and latitude. The main flowering period is March and April extending into winter on some localities. The pollen is cream in colour of good quality, abundant and attractive to bees (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from Ribbon gum had a mean value of 3.86 out of a possible high of 5. The main flowering period was March and the frequency was every two to three years, normally with a mean honey yield per hive of 18 kg (Somerville, 1999).

The pollen sample collected from Nimmitabel in March 1996 was of good quality and expressed no deficiencies in any of the essential amino acids. Only one amino acid, Arginine, was deficient in a sample of pollen reported by Muss (1987).

Thus, generally, the bees reared on this pollen source should be in reasonable shape to over winter or work a light to medium honey flow in late autumn or through winter.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nimmitabel Mar '96**	*Muss (1987)*
Threonine	3.0	3.75	3.0
Valine	4.0	5.62	4.2
Methionine	1.5	2.48	2.5
Leucine	4.5	7.08	6.6
Isoleucine	4.0	4.74	6.2
Phenylalanine	2.5	3.94	6.8
Lysine	3.0	6.22	5.9
Histidine	1.5	2.47	5.2
Arginine	3.0	5.46	2.8*
Crude Protein %	-	23.7	21.31
Fat %	-	0.48	-
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.28 POLLEN QUALITY—Nodding thistle *(Caduus nutans)*

Doug Somerville, NSW Agriculture, Goulburn

Nodding thistle originated in Europe. There are extensive areas of this weed on the southern and particularly the northern tablelands of NSW. The species is proclaimed as a noxious weed in all local government areas within NSW. Plants grow up to 2 m tall and dense mature stands inhibit stock movement and reduce the accessibility of pasture to stock (Medd, 1984).

Nodding thistle flowers from January to March on the southern tablelands and can produce 20 kg of honey per colony in a favourable season.

The pollen sample collected in February 1996 has a crude protein level of 15.1%, indicating that this species, as a source of pollen, is of poor quality, as a minimum level of 20% is necessary for the maintenance and breeding of a colony. In southern NSW, bees working Nodding thistle are usually bred on Paterson's curse. As this pollen is of a high protein, the bees will be long lived and capable of collecting significant honey crops, but once the bees have worked Nodding thistle for two or more generations, the body protein of bees will have reduced to a level that will see significant reduction in adult bee longevity.

Bees bred on Nodding thistle will not be suitable to work a medium to heavy honey flow following the completion of the Nodding thistle flowering event. Other species flowering at the same time may provide a balance in protein levels if they are higher in total crude protein than that of Nodding thistle. Generally, beekeepers should factor in a brood maintenance move onto better breeding conditions if a further significant honey flow is to be worked later in autumn or early winter.

	Ideal Ratio From DeGroot (1953)	**Taralga Feb '96**
Threonine	3.0	3.78
Valine	4.0	4.78
Methionine	1.5	2.25
Leucine	4.5	5.72
Isoleucine	4.0	4.19
Phenylalanine	2.5	3.44
Lysine	3.0	6.13
Histidine	1.5	3.61
Arginine	3.0	3.69
Crude Protein %	-	15.1*
Fat %	-	2.25
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.29 POLLEN QUALITY—Onion weed *(Asphodelus fistulosus)*

Doug Somerville, NSW Agriculture, Goulburn

Onion weed is a native of the Mediterranean region. It is distributed throughout Australia and is considered a weed of pastures and crops. In NSW it is more common in the far south west of the state. Onion weed flowers mainly during August, September and October. Nectar is produced and during favourable seasons a surplus of honey may be stored. Onion weed is of minor to medium importance as a source of honey. An abundance of reddish pollen is provided so this species is considered to be of medium to major importance as a pollen source.

This weed is of major importance to apiarists who operate hives in areas where it is common as it boosts brood rearing during the early spring, thus assisting with the preparation of colonies for major honey flows which follow its flowering (Clemson, 1985).

Unfortunately, the quality of the pollen collected at Carwarp in 1996 is fairly ordinary, due to the low levels of the essential amino acid, Isoleucine. On its own, Onion weed will not produce high quality long lived bees. The sample of Onion weed pollen reported by Muss (1987) has a very low crude protein level and is also deficient in at least one essential amino acid. The amino acids, Valine and Arginine are very high in this sample which is unusual. Ideally, another one or two samples of onion weed pollen need to be analysed for amino acids and protein before a definitive value on onion weed pollen can be given with a higher degree of confidence. However, thus far, the two samples tested indicate a generally poor quality pollen.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Carwarp VIC Sep '96**	*Muss (1987)*
Threonine	3.0	3.53	3.0
Valine	4.0	4.06	18.1
Methionine	1.5	1.79	0.8*
Leucine	4.5	5.31	8.5
Isoleucine	4.0	3.22*	5.9
Phenylalanine	2.5	3.06	3.7
Lysine	3.0	3.77	-
Histidine	1.5	1.64	-
Arginine	3.0	3.4	11.4
Crude Protein %	-	22.5	14*
Fat %	-	4.5	-
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.30 POLLEN QUALITY—Pear *(Pyrus communis)*

Doug Somerville, NSW Agriculture, Goulburn

Pear blossom does not attract bees to the same extent as the blossom of other pome fruits under most conditions. This is possibly because of the nectar's lower sugar content. Bees work the blossom mainly for pollen in early spring. One or two hives per hectare are recommended where bees are used as pollinating agents (Clemson, 1985).

The sample of pollen analysed for crude protein, amino acids and fat content indicates a reasonable quality pollen that will adequately meet honey bee dietary requirements. There should not be a need to provide supplementary protein but there could be a case for sugar feeding hives to stimulate brood rearing and recruit more pollen gatherers onto pear blossom to increase fruit set.

Amino Acid	Ideal Ratio From DeGroot (1953)	Goulburn Valley VIC Oct '97
Threonine	3.0	4.42
Valine	4.0	5.4
Methionine	1.5	2.43
Leucine	4.5	6.89
Isoleucine	4.0	4.11
Phenylalanine	2.5	4.15
Lysine	3.0	6.42
Histidine	1.5	2.64
Arginine	3.0	4.77
Crude Protein %	-	26.2
Fat %	-	1.8

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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6.1.31 POLLEN QUALITY—Red bloodwood *(Corymbia gummifera)*

Doug Somerville, NSW Agriculture, Goulburn

Red bloodwood is usually a medium sized tree, 15–18 m high with a diameter of 0.3–0.6 m, although under ideal conditions it may grow to 36 m with a diameter of 1–1.3 m, with a wide distribution along the length of the NSW coast, extending into southern Queensland (Clemson, 1985).

The flowering period is mainly February and March, although blossom may start to appear in January and extend into May. Flowering frequency is every two to three years on average, although worthwhile honey crops have been up to six years apart. The mean honey yields per hive are 25 kg and the tree as a source of pollen is considered to be of average value (Somerville, 1999).

The following table lists one sample of pollen collected from Red bloodwood.

Amino Acid	Ideal Ratio From DeGroot (1953)	Nowra Mar '97
Threonine	3.0	4.35
Valine	4.0	5.36
Methionine	1.5	2.31
Leucine	4.5	7.28
Isoleucine	4.0	4.04
Phenylalanine	2.5	4.72
Lysine	3.0	6.6
Histidine	1.5	3.09
Arginine	1.0	7.74
Crude Protein %	-	26.9
Fat %	-	1.6

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

With only one pollen sample collected from this species it is difficult to say what variability exists in the species. Bees do not tend to collect much Bloodwood pollen and this is probably the major limiting factor with this species, i.e., lack of quantity, sufficient to meet the amount required by a strong to average colony of bees. Supplementing protein on this species when working it for a honey crop may be beneficial.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.32 POLLEN QUALITY—Red box (Eucalyptus polyanthemos)

Doug Somerville, NSW Agriculture, Goulburn

Red box occurs at altitudes of 120–600 m and grows where summers are warm and winters are cool to cold. In NSW it is most common on the central western and south western slopes and on the lower sections of the central and southern tablelands on slopes, plains, foothills and in valleys. It is often found growing in association with Yellow box. Flowering occurs mainly in October about nine months after buds appear. The species is not regarded as a reliable source of nectar or a good source of pollen (Clemson, 1985).

This is possibly due to the time of year it is flowering when most commercial beekeepers will be working Paterson's curse or similar more reliable and regular pollen and nectar sources. The pollen collected at Bigga is only of average quality but, as the essential amino acid, Isoleucine is deficient in this sample (typical of many Eucalyptus species), this detracts from its value to honey bees.

On its own, Red box would fringe on being a poor quality pollen unless other pollen were also being actively collected by bees on the same location to make up for the deficiency in Isoleucine. It would also benefit the bees to have a higher protein pollen available for this time of year to breed longer lived bees going into the main honey production period of the year.

Amino Acid	Ideal Ratio From DeGroot (1953)	Bigga Sep '96
Threonine	3.0	3.8
Valine	4.0	4.9
Methionine	1.5	2.24
Leucine	4.5	6.39
Isoleucine	4.0	3.61*
Phenylalanine	2.5	3.73
Lysine	3.0	5.66
Histidine	1.5	2.54
Arginine	1.0	6.23
Crude Protein %	-	22.4
Fat %	-	3.9
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.33 POLLEN QUALITY—Red ironbark *(Eucalyptus fibrosa)*

Doug Somerville, NSW Agriculture, Goulburn

Red ironbark is also referred to as Broad-leaved ironbark. This species has a wide distribution along the coastal forests and inland around the central tablelands and Pilliga regions of NSW, extending into QLD. In favourable seasons this species may provide a worthwhile honey flow, but it has specific climatic needs for good production. Adequate rain during bud development and just prior to flowering is one of the pre-requisites. Pollen is attractive and is produced in moderate quantities (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from Red ironbark was of a rather average to poor quality giving it a rating of 2.1 out of a possible rating of 5. Flowering ranged from June through to March with the main flowering period December to February. Flowering frequency was every three to four years with average honey crops of 40 kg per hive. Some beekeepers in the study indicated that it can be up to 10 years between honey flows on some locations (Somerville, 1999).

The pollen sample collected at Mogo on the south coast, probably close to the most southerly range of the species, was of average quality with a crude protein level of 20.5%. Kleinschmidt & Kondos (1976) indicated a Eucalypt species not the same as *E.fibrosa*, but with the same common name—Red ironbark—as having a crude protein level of 22.6%. There is a possibility that these two species are one and the same.

The quantity of pollen collected in the trap at Mogo was low. With a low quality and poor quantity, bees would not be able to breed and expand under these circumstances. Colonies, after working Red ironbark, would be expected to be in poor condition and not suitable for working a medium to heavy honey flow without a period of maintenance on another more favourable pollen source. Supplementary feeding protein may be beneficial when bees are working a Red ironbark honey flow to maintain sufficient flow of protein into the hive.

Amino Acid	Ideal Ratio From DeGroot (1953)	Mogo Feb '96
Threonine	3.0	3.41
Valine	4.0	5.34
Methionine	1.5	2.51
Leucine	4.5	6.63
Isoleucine	4.0	4.39
Phenylalanine	2.5	3.7
Lysine	3.0	5.58
Histidine	1.5	2.05
Arginine	1.0	6.5
Crude Protein %	-	20.5
Fat %	-	2.21

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.34 POLLEN QUALITY—Red stringybark *(Eucalyptus macrorhyncha)*

Doug Somerville, NSW Agriculture, Goulburn

Red stringybark is usually a small to medium sized tree with a straight bole, but it may grow to a height of 30 m or more under favourable conditions. The tree is found on the southern tablelands, the western part of the central tablelands and the central western slopes. Agricultural development (as well as pine forestry) has greatly reduced the areas of Red stringybark. Red stringybark is not a reliable honey producer but particularly heavy flows of varying duration occur in favourable seasons especially on the southern tablelands, the tree also produces moderate supplies of pollen (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from Red stringybark had a rating of 3.9 out of a possible top score of 5. Flowering periods ranged from December through to May with the main flowering period from January to March. Flowering frequency was mainly every three to four years producing an average of 35 kg of honey per hive (Somerville, 1999).

A considerable number of Red stringybark pollens have now been analysed, giving an indication of the range of qualities that may be expected from this species. The four samples collected in 1996, 1997 and 1998 were all reasonable to good for crude protein levels, but three samples demonstrated a deficiency in the amino acid, Isoleucine. This was also the case for two other samples of Red stringybark pollen (Muss 1987; Rayner & Langridge, 1985). Stace (1996) reported on two samples collected in March 1991 and 1992, with crude protein levels of 23.44% (origin southern tablelands) and 23.2% (origin Inverell).

The important aspect of this pollen source is that the quantity of pollen trapped was reasonable, thus beekeepers when working Red stringybark should be very conscious of the quantity of pollen being gathered by the bees and stored around the brood nest. If this is at all limiting, then supplementing an artificial protein source may be of benefit in some years if the colonies are to maintain strength to work another medium to heavy honey flow following on from Red stringybark.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nth Orange Feb '96**	**Abercrombie Caves Mar '96**	**Tumbarumba Feb '98**	**Oberon Feb '97**	*Muss (1987)*	*Rayner & Langridge (1985)*
Threonine	3.0	3.34	3.48	3.71	3.88	3.1	3.3
Valine	4.0	4.29	5.75	5.37	5.65	3.8*	4.8
Methionine	1.5	2.23	2.11	2.11	2.22	1.9	1.3*
Leucine	4.5	6.12	6.86	6.86	7.25	5.0	6.0
Isoleucine	4.0	3.4*	4.79	3.84*	3.95*	2.9*	3.6*
Phenylalanine	2.5	3.58	3.89	3.53	3.65	2.8	3.4
Lysine	3.0	5.14	6.24	6.07	6.34	4.0	5.4
Histidine	1.5	2.1	2.5	2.33	2.33	1.3*	1.9
Arginine	1.0	5.59	5.65	5.49	5.57	5.1	6.4
Crude Protein %	-	24.2	22.1	26.9	26.2	23.44	30.1
Fat %	-	2.24	2.58	1	0	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.							

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.35 POLLEN QUALITY—River red gum *(Eucalyptus camaldulensis)*

Doug Somerville, NSW Agriculture, Goulburn

River red gum is a medium to tall growing tree, reaching a height of 25 m and a 1–2 m diameter. River red gum is the most widespread Eucalypt in Australia, common along most of the inland rivers of the country and in some areas becoming a pure stand due to the regular flooding it sometimes endures. It is one of the few species that can handle being flooded for extensive periods of time without affecting the health of the tree. In fact, it's regular flooding that is said to initiate budding and ensure heavy flowering on a regular basis. Buds are carried for 11 to 12 months, with the flowering period varying with the locality. River red gum is of major importance as a source of honey, producing heavy yields of nectar in good seasons and is a major source of pollen (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from River red gum had a very high rating of 4.56 out of a possible top value of 5. The main flowering period was December and January every two to four years, although significant honey crops were even further apart in some locations up to 10 years. Average honey yields per hive are 39 kg (Somerville, 1999).

The two pollen samples collected in the Riverina region in 1995 and 1996 are of reasonable quality although the crude protein levels are average. The two samples reported by Muss (1987) and Rayner & Langridge (1985) were similar, although the essential amino acid, Isoleucine, is significantly deficient in three of the four samples listed in the table. Two factors may help bees overcome the average protein levels and deficiency in Isoleucine. The first is the large quantities of pollen normally collected from this species, thus bees may be able to consume sufficient quantities of pollen to obtain their necessary dietary requirements and secondly, other species such as Paterson's curse may be in flower at the same time, allowing bees to balance the diet with a diversity of pollens depending on availability.

It is interesting that bees find River red gum pollen very attractive and at least one of the two samples collected in 1995 and 1996 has a particularly high fat content of 4.58%. Pollens with high fat contents would appear to be very attractive to honey bees.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Narrandera Dec '95**	**Darlington Pt Dec '96**	*Muss (1987)*	*Rayner & Langridge (1985)*
Threonine	3.0	3.97	3.82	3.2	3.6
Valine	4.0	5.45	4.98	5.0	4.9
Methionine	1.5	2.99	2.52	1.1*	1.8
Leucine	4.5	6.86	6.46	5.4	6.4
Isoleucine	4.0	4.53	3.6*	3.2*	3.7*
Phenylalanine	2.5	3.82	3.75	5.9	4.0
Lysine	3.0	5.87	5.49	3.4	5.9
Histidine	1.5	2.33	2.33	1.5	2.2
Arginine	1.0	6.48	6.23	8.0	6.0
Crude Protein %	-	22.6	25.6	21.88	26.5
Fat %	-	4.58	1.3	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.					

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.36 POLLEN QUALITY—Rough-barked apple *(Angophora floribunda)*

Doug Somerville, NSW Agriculture, Goulburn

Rough-barked apple is a medium sized to a fairly large tree, 15–25 m high and 0.6–1 m in diameter, with a spreading crown and crooked branches. In NSW this species grows in patches throughout the central and northern areas of the western slopes and on the northern tablelands. It also occurs on the coast. It is most commonly found on alluvial soils and deep sandy loams along flats and watercourses but may extend to hillsides. It also grows on poor sandy soils. Budding occurs during December and January when conditions are favourable. It often happens when rains follow a severe drought, but may also occur under extremely hot and dry conditions. Flowering occurs about four weeks after budding. Rough-barked apple is the most important of the *Angophora's* for the honey industry. Although the honey is strongly flavoured and dark in colour, this species produces a particularly heavy supply of creamy pollen which is gathered by honey bees. Because it most commonly flowers during and shortly after droughts, it is especially valuable for brood rearing and the preparation of colonies for wintering or subsequent flows of better quality honey. It is of major importance as a source of pollen for bees (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from Rough-barked apple had a mean value of 4.13 out of a possible high of 5. The main flowering period is January every two to five years, depending on rainfall. It is possible for 22 kg of honey to be produced per hive from this tree in favourable seasons (Somerville, 1999).

The two pollen samples collected in Bega in 1996 and 1998 are of average quality with a slight deficiency in the amino acid, Isoleucine. Rough-barked apple is rarely the only pollen source available to bees at the time of flowering and, as such, any minor deficiency in Isoleucine should be corrected by other available pollen sources. This pollen was in abundance when trapped and, as such, should satisfy a colony's requirements for breeding and expansion of the brood area. This species should be considered a worthwhile producer of pollen for bee hive maintenance and breeding on light to medium honey flow conditions.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Bega (A) Jan '96**	**Bega (B) Jan '98**
Threonine	3.0	4.48	3.95
Valine	4.0	5.73	5.27
Methionine	1.5	2.2	2.14
Leucine	4.5	7.93	7.02
Isoleucine	4.0	4.7	3.97*
Phenylalanine	2.5	4.67	4.09
Lysine	3.0	6.1	5.7
Histidine	1.5	2.69	2.58
Arginine	1.0	7.02	6.09
Crude Protein %	-	22.9	22.3
Fat %	-	1.1	1.5

* Below the minimum levels required to meet honey bee nutritional requirements.
(A) Mean of two labs for the one sample.
(B) Mean of three tests for the one sample.

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system. HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.37 POLLEN QUALITY—Saffron thistle *(Carthamus lanatus)*

Doug Somerville, NSW Agriculture, Goulburn

Saffron thistle is a native of the Mediterranean region and has become a serious weed of crop and pasture lands in Australia. Flowering occurs during late spring to early summer. Saffron thistle may be more abundant after a period of prolonged drought which lowers the competition for pasture species (Gorham, 1986).

Clemson (1985) states that Saffron thistle flowers mainly in the summer and provides good pollen supplies, particularly following showers of rain. With favourable conditions, some nectar may also be provided.

The Saffron thistle pollen collected on the southern tablelands of NSW in February 1996 was part of a mixture of pollens, dominated by Nodding thistle pollen. The Saffron thistle pollen in this case has a low crude protein level and is, as such, considered to be of low quality. Unfortunately, so has Nodding thistle. Thus, even though Saffron thistle is of low quality, the accompanying and dominant pollen, Nodding thistle in this case, will not make up the protein levels necessary to maintain strong colonies with populations of long lived bees.

A few more samples of Saffron thistle from other geographic areas should be analysed for crude protein before any confidence can be deduced that all pollen obtained from Saffron thistle is of a poor quality.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Taralga Feb '96**
Threonine	3.0	4.05
Valine	4.0	5.69
Methionine	1.5	2.55
Leucine	4.5	6.94
Isoleucine	4.0	5.03
Phenylalanine	2.5	4.18
Lysine	3.0	6.77
Histidine	1.5	4.43
Arginine	3.0	4.48
Crude Protein %	-	18.1*
Fat %	-	3.86
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.38 POLLEN QUALITY—Scribbly gum *(Eucalyptus sclerophylla)*

Doug Somerville, NSW Agriculture, Goulburn

The common name, Scribbly gum, can refer to at least five species of Eucalypts: *E.signatta, E.rossi, E.racemosa, E.haemastoma* and *E.sclerophylla*. *E.sclerophylla* and *E.racemosa* are common along the coast. *E.sclerophylla* is found mainly between Batemans Bay and Sydney. *E.racemosa* ranges from just south of Sydney to the Newcastle area and occurs at altitudes between sea level and 300 m on the coast. *E.rossi* is found on the tablelands and western slopes. *E.signata* occurs from Port Stephens northwards along the coast to Fraser Island. *E.haemastoma* is of restricted distribution on the central coast and tablelands. These species normally grow in poor open coastal forests, sometimes in pure stands, but usually in association with any of a wide range of species growing in the forests. These species flower quite regularly but are usually of only minor value for honey production, although in good seasons satisfactory honey yields are obtained. Scribbly gums produce only light pollen supplies (Clemson, 1985).

The sample of pollen collected in the Nowra State Forest in March 1997 was identified as coming from *E.sclerophylla* and not one of the other Scribbly gum species. This particular sample of pollen is of excellent quality with a crude protein of 29.7% and no deficiencies in the essential amino acids. Bees breeding on this pollen source should be long lived and the colony should be in a good condition to work a medium to heavy honey flow after breeding on Scribbly gum pollen. Thus this species should be sought after by beekeepers for this purpose, although a degree of caution needs to be expressed as this information is based on the results of one pollen sample only. Further samples from Scribbly gum need to be analysed for crude protein and amino acids before beekeepers can comfortably say that this species is universally a producer of high quality pollen across its growing range.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nowra SF Mar '97**
Threonine	3.0	4.11
Valine	4.0	5.2
Methionine	1.5	2.52
Leucine	4.5	6.91
Isoleucine	4.0	3.88
Phenylalanine	2.5	4.13
Lysine	3.0	6.08
Histidine	1.5	2.5
Arginine	3.0	7.09
Crude Protein %	-	29.7
Fat %	-	2.3

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.39 POLLEN QUALITY—Silky hakea *(Hakea sericea)*

Doug Somerville, NSW Agriculture, Goulburn

Silky hakea develops into a shrub 1 to 3 m high and flowers during spring. It is attractive to bees but only small quantities of nectar and pollen are gathered. It is a widely spread species found south of Newcastle on the central coast and south coast of NSW (Clemson, 1985).

The pollen collected on the south coast in August 1996 was only a small component of the total pollen trapped on that occasion. Difficulty was experienced identifying the source of the pollen as it is a light mauve or purple colour, and the flowers of the Hakea are white. The association was made as hakea pollen has a very distinctive shape when viewed under a microscope.

The quality of the pollen is below average and on its own is of a low value to bees due to the low crude protein level and deficiency in the amino acid, Isoleucine. As a small component of a mixture, this pollen is essentially adding to the bulk of available pollen to the colony.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nowra Aug '96**
Threonine	3.0	4.26
Valine	4.0	4.78
Methionine	1.5	2.04
Leucine	4.5	6.59
Isoleucine	4.0	3.93*
Phenylalanine	2.5	3.81
Lysine	3.0	4.66
Histidine	1.5	2.4
Arginine	3.0	6.41
Crude Protein %	-	18.4*
Fat %	-	2.82
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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6.1.40 POLLEN QUALITY—Skeleton weed *(Chondrilla juncea)*

Doug Somerville, NSW Agriculture, Goulburn

Skeleton weed is a native of Europe and western Asia. In NSW it is widespread and common on the southern and central western slopes, particularly in cultivation areas. Beneficial nectar is produced by Skeleton weed and bees may store a small surplus of the golden honey. It is a major source of pollen and, with favourable rainfall, is very beneficial for bees (Clemson, 1985).

The two pollen samples collected at Yetholme in NSW and Leneva in VIC are of average quality with crude protein levels of 22.2 and 23.4%. One sample was significantly deficient in the essential amino acid, Isoleucine, which detracts from its food value for honey bees. This plant as a source of pollen is relatively important if no other pollen sources of higher quality are available. If bees have reduced body protein levels prior to working Skeleton weed as the main source of pollen, they will take three or four generations to build the body protein levels up to a point where the colonies could be used to work a medium to heavy honey flow.

The value of Skeleton weed pollen would be improved if other higher quality pollens were also being collected by bees, thus lifting the protein intake of the colony. Skeleton weed pollen could be described as being of average quality.

Amino Acid	Ideal Ratio From DeGroot (1953)	Yetholme Jan '96	Leneva VIC Feb '96
Threonine	3.0	4.67	3.68
Valine	4.0	7.19	3.8
Methionine	1.5	3.05	3.6
Leucine	4.5	8.2	6.02
Isoleucine	4.0	5.77	3.1*
Phenylalanine	2.5	5.17	3.41
Lysine	3.0	5.91	4.99
Histidine	1.5	2.96	2.2
Arginine	3.0	6.03	4.52
Crude Protein %	-	23.4	22.2
Fat %	-	2.59	3.43
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

References

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6.1.41 POLLEN QUALITY—Spotted gum *(Corymbia maculata)*

Doug Somerville, NSW Agriculture, Goulburn

Spotted gum is an attractive medium to large sized tree found in coastal regions from Queensland to Bega, growing from near sea level to the lower mountain ridges in the south and on higher ground, up to 600 m, on the edge of the northern tablelands of NSW. It also grows on a wide range of soils, appearing to prefer sandy shale country but avoiding Hawkesbury sandstone. It forms almost pure stands, particularly on shales and slates. Buds are carried for 1–2 years. Flowering usually occurs over an extended period, varying slightly with the season and locality; the further south Spotted gum grows, the later it flowers. Flowering may occur between February and September. On the south coast the main flowering is between April and August, and on the central coast it is usually from late January onwards. Spotted gum produces heavy supplies of pollen and, in favourable weather, bees working it breed prolifically. The abundant pollen supplies, together with the stimulation provided by continuous supplies of nectar from this species, enable colonies of bees to maintain their numerical strength even while good honey crops are being harvested during favourable seasons, in mid winter (Clemson, 1985).

Beekeepers in a NSW study indicated that the pollen from Spotted gum had a mean value of 4.37 out of a possible value of 5, which is high. The main flowering period was January through to August with blossom possible all year; this would depend on the region, as stated by Clemson. Flowering frequency is from three to five years and honey yields of 34 kg per hive can be expected (Somerville, 1999). The six pollen samples collected in 1997 are all very good quality with average to above average crude protein levels. Five samples of Spotted gum analysed by Stace (1996) originating from the north coast, also demonstrated reasonable crude protein levels ranging from 24.7 to 31.4, with an average of 27.8%.

Kleinschmidt & Kondos (1976) reported on one sample of Spotted gum pollen with a crude protein level of 33.3%. It is of concern that five out of the six pollens collected in 1997 exhibit a deficiency in the essential amino acid, Isoleucine but, given the high crude protein levels, this should not be a significant problem in meeting a colony's dietary requirements. Spotted gum was also a prolific producer of pollen with large collections in pollen traps. Generally Spotted gum is an excellent pollen both in quality and quantity provided to the colony of bees.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Moruya Jul '97**	**Moruya May '97**	**Nowra SF Jul '97**	**Bermagui Jun '97**	**Moruya Jul '97**	**Narooma Jul '97**
Threonine	3.0	3.83	3.68	4.15	4.4	3.82	4.06
Valine	4.0	4.74	4.72	5.16	5.44	5.04	5.2
Methionine	1.5	2.19	2.03	2.26	2.19	2.25	2.29
Leucine	4.5	6.69	6.31	7.59	8.06	7.26	7.57
Isoleucine	4.0	3.87*	3.63*	2.88*	4.09	3.67*	3.77*
Phenylalanine	2.5	3.89	3.77	4.4	4.54	3.97	4.11
Lysine	3.0	5.79	5.5	6.44	6.94	6.01	6.2
Histidine	1.5	2.65	2.55	2.74	2.9	2.8	2.91
Arginine	3.0	7.65	6.63	8.04	8.37	7.13	7.84
Crude Protein %	-	24.9	30.4	29.5	28.4	29.1	28.7
Fat %	-	1.5	1.4	1.1	1.3	2	2
* Below the minimum levels required to meet honey bee nutritional requirements.							

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.42 POLLEN QUALITY—Sunflower *(Helianthus annuus)*

Doug Somerville, NSW Agriculture, Goulburn

Sunflower is a major oilseed crop and originates from Arizona and New Mexico as long ago as 3000 BC. Pollination and seed set of sunflowers are strongly influenced by the environment. Weather conditions, sunlight, soil moisture, soil fertility, presence of honey bees and pests and diseases will all influence the final crop yield (Dale, 1984).

A trial on an irrigated sunflower crop in northern Victoria using honey bees, increased crop yields in excess of 60%. Also, the percentage germination and oil content of seed from plots serviced by bees were significantly greater than plots without bees (Langridge & Goodman, 1974).

Stocking rates of one strong hive per hectare are recommended for dryland crops and two hives per hectare for irrigated crops. Bees can gather nectar from sunflowers but is not considered a major crop of importance for honey production in Australia. Rich golden pollen is also gathered, but sunflowers do not rate highly as pollen producers when compared with some other field crops such as *Brassicas* (Clemson, 1985).

The pollen quality is very poor for sunflowers, with crude protein levels as low as 12.9% or up to 18.5% (Kleinschmidt & Kondos, 1976).

At these levels, the pollen cannot sustain a strong colony with a dominance of long lived bees. Given the light nectar flow and time of year (mid summer) the colony will be stimulated to breed and possibly expand but if these colonies are expected to work a medium to heavy honey flow after breeding on sunflower pollen, then they would in all probability collapse or seriously dwindle in field bees due to the low body protein levels. It is unlikely that bees would consume protein supplements while on sunflowers as plentiful quantities of fresh pollen will normally be available in most circumstances and this is more attractive to the bees.

Given the poor quality pollen and the risk of bees being sprayed while foraging on sunflowers, beekeepers should avoid this crop as a floral resource for bees and only place bees on the crop in return for a pollination fee. This fee needs to reflect the lack of a honey crop, increased risk of spray damage, and the requirement to build colonies in strength before and after the sunflowers to be able to work future honey flows.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Griffith Jan '96**	**Griffith Jan '97**	*Muss (1987)*
Threonine	3.0	3.96	4.06	3.4
Valine	4.0	4.57	4.64	4.6
Methionine	1.5	2.24	1.82	2.3
Leucine	4.5	6.61	6.41	6.8
Isoleucine	4.0	4.28	4	4.6
Phenylalanine	2.5	3.7	3.55	7.1
Lysine	3.0	5.75	6.21	3.9
Histidine	1.5	4.61	4.79	-
Arginine	3.0	3.71	3.98	5.7
Crude Protein %	-	13.8*	12.9*	15*
Fat %	-	1.41	1.1	-
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods	
Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system. HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.43 POLLEN QUALITY—Swamp mahogany *(Eucalyptus robusta)*

Doug Somerville, NSW Agriculture, Goulburn

Swamp mahogany is a small to medium sized tree usually about 15 m high and is found mainly on tidal flats or along salt water lagoons and in adjoining valleys. Most trees are close to the sea. It is distributed from Eden in the south of NSW, north into QLD. Under ideal conditions, this species may produce a surplus of about 15 kg of honey per hive.

In wet weather, however, bees may be lost through flying under adverse weather conditions, excessive condensation within hives, nosema disease, or deterioration of stores, thus supporting the belief of many beekeepers that Swamp mahogany kills bees. Swamp mahogany is a fairly reliable source of pollen and of medium importance in this respect (Clemson, 1985). Heavy flowering is common every second year normally beginning in late April or May reaching a peak in June and July.

The pollen sample collected at Jervis Bay is of reasonable quality with an average crude protein level of 22.6% and exhibiting no deficiencies in any of the essential amino acids necessary for honey bee dietary requirements. Nosema disease may be an issue with bees working a winter honey flow, as this disease will shorten the life span of adult worker bees similar to that of poor quality pollen. A higher quality pollen, under these circumstances, would be more beneficial to bees. It would be very important to place apiaries in a sunny protected site if they are to work Swamp mahogany.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Jervis Bay Sep '96**
Threonine	3.0	3.74
Valine	4.0	5.08
Methionine	1.5	2.46
Leucine	4.5	6.64
Isoleucine	4.0	4
Phenylalanine	2.5	3.97
Lysine	3.0	5.29
Histidine	1.5	1.82
Arginine	3.0	5.99
Crude Protein %	-	22.6
Fat %	-	1.43

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

References

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6.1.44 POLLEN QUALITY—Sydney blue gum *(Eucalyptus saligna)*

Doug Somerville, NSW Agriculture, Goulburn

Sydney blue gum is a tall shaft-like tree, 30 to 45 m high, which occurs throughout coastal NSW from Batemans Bay through to south east Queensland. Sydney blue gum is not regarded as a reliable honey producer, although in some seasons it may yield quite well. It is of medium importance as a source of pollen, producing large quantities of cream coloured pollen (Clemson, 1985).

Beekeepers in a NSW study of floral resources indicated that the pollen from Sydney blue gum had a value of 3.67 out of a possible value of 5 which indicates an average value by beekeepers similar to Clemson's comments. The main flowering period is February with a flowering range extending from December through to April. Flowering frequency is mainly every three years with a range of two to five years and honey yields of 32 kg per hive can be expected (Somerville, 1999).

The pollen sample collected at Termeil in 1997 is of reasonable quality. The crude protein is high but it is deficient in two essential amino acids, Isoleucine and Methionine. Given the high protein levels, it should be possible for bees to compensate for the amino acid deficiencies by consuming greater quantities of pollen. Reasonable amounts of pollen can be collected from this species so the requirement for quantity should be met in most cases with bees working Sydney blue gum.

Bees should be able to breed and expand on this pollen source with longevity. Further samples would be beneficial to ascertain whether Sydney blue gum consistently has these deficiencies in Isoleucine and Methionine and that the crude protein levels are consistently of a high level, to be absolutely confident that the results obtained from this one sample are consistent across the geographic range of the species.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Termeil Mar '97**
Threonine	3.0	4
Valine	4.0	5.19
Methionine	1.5	1*
Leucine	4.5	7.26
Isoleucine	4.0	3.72*
Phenylalanine	2.5	4.14
Lysine	3.0	5.89
Histidine	1.5	2.02
Arginine	3.0	6.65
Crude Protein %	-	27.6
Fat %	-	1.5
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.45 POLLEN QUALITY—Turnip weed *(Rapistrum rugosum)*

Doug Somerville, NSW Agriculture, Goulburn

Turnip weed is a common weed of cultivated paddocks, especially in winter cropping areas, roadsides and disturbed areas. It is widespread in western NSW, also occurring in southern QLD, VIC, SA and TAS. Turnip weed is a native of central and southern Europe and is a problem to grain farmers, contaminating cereal crops and tainting the taste of milk and meat in livestock production.

This weed is a good nectar producer and honey surpluses may be stored. While this species is rated as only a minor source of honey, it may provide extractable surpluses under the most favourable conditions. It is a prolific producer of pollen, and is of major importance to apiarists who regularly migrate hives to the north west of NSW in late winter and early spring to make use of its productivity. It is as important in its role of building up bee populations in the north west as Paterson's curse is in the south west. The stimulating nectar supplies and an abundance of good quality pollen greatly increase brood rearing and enable apiarists to strengthen their colonies for future honey flows. These supplies are also useful for general management and carrying out restocking programs (Clemson, 1985).

Beekeepers in a study conducted on the floral resources of importance to beekeepers in NSW indicated a pollen value for Turnip weed of 4.76 which is an excellent rating, given the top figure obtainable in the survey was 5. The main flowering period is August and September every one to two years. The average honey yields per hive are only relatively small at 16 kg (Somerville, 1999).

The quality of the pollen collected over 1995 and 1996 can only be described as average. The crude protein levels are all above the absolute minimum of 20% considered as a maintenance level, but only just. Only one of the five samples indicate a slight deficiency in one amino acid, Isoleucine. Kleinschmidt & Kondos (1976) records the crude protein levels of Turnip weed ranging between 25 and 29.2%, considerably higher than the figures established in 1995 and 1996. Stace (1996) analysed two samples of Turnip weed pollen from Moree—one in 1988 with a crude protein level of 25.3% and the other in 1992 with a crude protein level of 24.4%—both within the range indicated in 1995 and 1996. It is encouraging that both these researchers reported on Turnip weed pollen with crude protein levels well above 20%.

What is strongly in favour of Turnip weed as a valuable pollen source is the sheer volume of pollen collected by bees. Bees do not seem to have a lot of problems collecting any volume of Turnip weed pollen, thus ensuring that bees should not be limited in the availability of protein and amino acids while this species is flowering. The fat content of the pollen is rather high for bee collected pollens generally with a range of 5.23 to 7, this is considerably greater than most species tested to date. What nutritional benefits the fat content of pollen has for bees is not understood, but it would appear that pollens with high fat contents are generally very attractive to bees.

Amino Acid	Ideal Ratio From DeGroot (1953)	Paynters Sidings Oct '95	Mildura VIC Sep '96	Coonamble Aug '96	Dirranbandi QLD Aug '96	Walgett Aug '96
Threonine	3.0	4.67	4.75	4.73	4.59	4.55
Valine	4.0	5.27	4.88	5.02	4.79	4.7
Methionine	1.5	2.29	2.61	2.54	2.31	1.85
Leucine	4.5	7.05	6.83	6.97	6.97	6.51
Isoleucine	4.0	4.86	4.29	4.5	4.33	3.86*
Phenylalanine	2.5	4.44	4.17	4.25	4.29	4.1
Lysine	3.0	8.47	6.58	6.46	6.8	6.96
Histidine	1.5	2.13	2.09	1.85	1.92	2.25
Arginine	3.0	5.09	5.11	5.58	4.79	4.78
Crude Protein %	-	21.6	22.7	21.8	22.9	24.6
Fat %	-	6.51	5.93	5.23	5.43	7
* Below the minimum levels required to meet honey bee nutritional requirements.						

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system. HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.46 POLLEN QUALITY—Vetch *(Vicia species)*

Doug Somerville, NSW Agriculture, Goulburn

Vetches are not widely used as a grazing pasture species in Australia but, on occasions, they are incorporated into pasture mixes to improve the quality of the pasture feed. Vetches are an annual crop and generally only provide one grazing period (Whittet, 1969).

Bees are used to increase seed set and a stocking rate of one hive per hectare should achieve desirable results. Vetch is also said to be not always overly attractive to bees and at times a heavier stocking rate may be necessary (McGregor, 1976).

The pollen samples collected in 1995 in the Riverina indicate a reasonable quality pollen with no apparent deficiencies. Bees should be able to breed and expand their populations with no apparent nutritional disorders on this pollen source.

Amino Acid	Ideal Ratio From DeGroot (1953)	Boree Ck Sep '95	Sandigo Sep '95
Threonine	3.0	4.55	5
Valine	4.0	5.15	5.68
Methionine	1.5	2.39	2.36
Leucine	4.5	7.02	7.8
Isoleucine	4.0	4.66	5.13
Phenylalanine	2.5	4.36	4.8
Lysine	3.0	6.74	7.37
Histidine	1.5	1.98	2.18
Arginine	3.0	4.72	5.24
Crude Protein %	-	24.1	24
Fat %	-	1.77	1.68

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.47 POLLEN QUALITY—Vipers bugloss *(Echium vulgare)*

Doug Somerville, NSW Agriculture, Goulburn

Vipers bugloss, Blue flower or Blueweed is of European origin but is also a valuable bee plant in Canada. It is very closely related to Paterson's curse *(Echium plantagineum)*. In NSW this species is confined mainly to the central and southern tablelands with minor areas in the northern tablelands at altitudes of more than 500 m. This species flowers mainly from December to March but rarely yields nectar in quantity before the end of December. Good supplies of dark blue pollen are produced (Clemson, 1985).

Beekeepers, in a study conducted on the floral resources of importance to beekeepers in NSW, indicated that the value of the pollen from Vipers bugloss is 4.56 which is an excellent rating, given the top figure obtainable in the study was 5. The main flowering period is December to January but may start in November and go through to March. Flowering occurs on an annual basis, depending on available moisture. The average honey yields per hive are 27 kg—considerably below that of Paterson's curse of 44 kg per hive (Somerville, 1999).

The pollen sample collected at Yetholme on the central tablelands in January 1996 is as close to perfect as a quality pollen can achieve. It would appear from these figures that pollen from Vipers bugloss is similar to Paterson's curse pollen. In this case the level of crude protein may fall at times, depending on location and season, but will continue to remain in the high crude protein levels. Vipers bugloss should be considered one of the best quality pollen sources for the summer period on the central and southern tablelands.

Bees bred on this pollen source will be long lived and capable of working a medium to heavy honey flow during and after the Vipers bugloss flowering.

Amino Acid	Ideal Ratio From DeGroot (1953)	Yetholme Jan '96
Threonine	3.0	4.69
Valine	4.0	5.45
Methionine	1.5	2.28
Leucine	4.5	7.03
Isoleucine	4.0	4.6
Phenylalanine	2.5	4.32
Lysine	3.0	5.08
Histidine	1.5	2.36
Arginine	3.0	4.89
Crude Protein %	-	34.9
Fat %	-	4.1

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.48 POLLEN QUALITY—Wattle *(Acacia species)*

Doug Somerville, NSW Agriculture, Goulburn

Acacia is the largest plant genus in Australia with about 800 species included in this classification. The genus is not restricted to Australia and *Acacias* occur naturally in various other countries, especially in Africa. Many different species of *Acacia* are found in NSW. They vary from small shrubs to medium sized trees and grow in a very wide range of soils and climatic conditions. Some *Acacias* found on the coast are native to the inland or other States and have become naturalised after their introduction for ornamental uses.

Acacias, like Eucalypts, vary greatly in the value of the pollen produced. Some species can be prolific pollen producers imparting great benefit to colonies of bees, increasing brood rearing. Seasonal conditions, especially rainfall, humidity and temperature, have a considerable effect on certain species. Care should be taken to ensure that the particular species and the prevailing climatic conditions are favourable for pollen production. Lack of soil moisture is a common cause of failure, some *Acacias* are over-rated as pollen producers (Clemson, 1985).

The four pollen samples collected from 1995 to 1996 are of average to below average quality. The Sydney golden wattle pollen is the highest quality pollen as it has a reasonable crude protein level at 24.6% and no deficiencies in any of the essential amino acids. Currawong wattle is rather low in the amino acid, Isoleucine, which significantly detracts from the value of this pollen.

The scientific names for the four pollen samples are:

- Currawong wattle *(Acacia doratoxylon)*
- Sweet scented wattle *(Acacia suaveolens)*
- Sydney golden wattle *(Acacia longifolia)*
- Wattle Specific species unknown.

Other crude protein levels for *Acacia* species, as reported by prior research include:

Acacia cunninghamii	24.5 to 29%
" *implexa*	25%
" *ixiophylla*	27 to 28%
" *melanoxylon*	16.2%
" *polybotrya*	26.3%
	(Kleinschmidt & Kondos, 1976)
Acacia dealbata	21.44%
" *pycnantha*	19.88%
	(Muss, 1987)
Acacia baileyana	28.6%
	(Rayner & Langridge, 1985)

The *Acacia* pollens generally vary from average quality to reasonably good for crude protein. Unfortunately, bees do not always find *Acacia* blossom attractive and thus it is not unusual to view *Acacias* in full bloom with very little bee activity apparent. On the other hand, when *Acacia* pollen is worked by bees, it should provide a very worthwhile contribution to the dietary requirements of honey bees.

Amino Acid	Ideal Ratio From DeGroot (1953)	Currawong Wattle Dubbo Oct '96	Sweet Scented Wattle Shoalhaven Jun '96	Wattle Murrah SF Aug '95	Sydney Golden Wattle Nowra Jul '96
Threonine	3.0	3.01	3.71	4.63	4.54
Valine	4.0	4	3.95*	5.49	5.34
Methionine	1.5	2.21	2.84	2.54	2.74
Leucine	4.5	5.35	6.38	7.28	7.15
Isoleucine	4.0	2.94*	3.41*	4.56	4.64
Phenylalanine	2.5	3.21	3.51	4.08	4.24
Lysine	3.0	4.66	5	5.35	6.19
Histidine	1.5	2.36	1.73	2.12	1.97
Arginine	3.0	6.37	4.66	7.2	5.45
Crude Protein %	-	24.9	21.7	23.8	24.6
Fat %	-	0.9	2.52	1.2	1.44
* Below the minimum levels required to meet honey bee nutritional requirements.					

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.

Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.

Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.49 POLLEN QUALITY—White box *(Eucalyptus albens)*

Doug Somerville, NSW Agriculture, Goulburn

White box is a medium sized tree with a spreading habit and is found mainly on the western slopes, extending the full length of NSW into Victoria and Queensland.

White box is one of the most reliable honey producers and is a major source of honey in NSW. Heavy flowering usually occurs every two to three years but variations in rainfall and other seasonal factors may mean suitable flowerings occur during most years in one area or another. Cold nights and sunny days are necessary for good nectar flows. White box produces large quantities of pale cream pollen, which is readily collected by bees. However, despite the abundance of nectar and pollen produced by this species, bees may be adversely affected when working it. With prolonged periods of wet weather, particularly during late winter and early spring when it is either the only or the main source of pollen, bees may suffer digestive troubles including *Nosema* disease, and there may be problems with bees drifting to the stronger colonies. For best results, hives should be specially prepared; they should be stocked with bees reared on good quality food and the colonies should be of adequate strength, with a suitable age distribution. Special attention must also be paid to supering, hive placement, aspect and general apiary management (Clemson, 1985).

Beekeepers, in a NSW study of floral resources, indicated that the pollen from White box had a value of 3 out of a possible 5, indicating a fairly average quality in respect to beekeeper experience. The main flowering period was May through to September, although flowering trees could be found from February through to December. Flowering frequency is every two to three years with honey yields per hive of 44 kg considered an average (Somerville, 1999).

The four pollen samples collected in 1996 indicate a pollen of average quality with the crude protein levels consistently around 22 to 23%. Unfortunately, the amino acid, Isoleucine is significantly deficient in three of the four samples, indicating that bees would need to consume increased amounts of pollen to obtain the required quantities of this amino acid. Given the low crude protein levels, this may require bees to consume more pollen than they physically find possible.

If *Nosema* becomes an issue in a colony then this may also reduce the ability of bees to obtain sufficient nutrient intake from low to average quality pollens. The crude protein levels were reported at generally lower levels by Stace (1996) who analysed seven samples originating from the northern tablelands of NSW with crude protein levels ranging from 16.3 to 20.13%, with an average level of 18.4%.

Kleinschmidt & Kondos (1976) found that two samples collected in NSW were 20.6% and 24.3% for crude protein levels. Both these sets of data support the view that White box pollen is very average in its contribution to honey bee dietary requirements. A supply of high quality pollen prior to bees working White box would be of major benefit, lifting the body protein levels of bees and ensuring a longer lived workforce as there will be a slow decline in body crude protein levels on this pollen source. Colonies at the end of a White box flowering will require a quality pollen source before being able to work a heavy honey flow, otherwise the colony may require some time to build into a strong hive.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Blackville Jan '96**	**Carroll Jun '96**	**Carroll Aug '96**	**Bigga Aug '96**
Threonine	3.0	3.41	3.78	3.87	3.86
Valine	4.0	4.28	5.3	4.74	4.92
Methionine	1.5	2.7	2.69	2.55	2.33
Leucine	4.5	6	6.89	6.61	6.47
Isoleucine	4.0	3.38*	4.2	3.77*	3.59*
Phenylalanine	2.5	3.44	3.9	3.89	3.8
Lysine	3.0	5.16	5.37	4.78	5.6
Histidine	1.5	1.95	2.3	1.73	2.61
Arginine	3.0	5.79	6.41	5.77	6.78
Crude Protein %	-	22.1	22.4	22.5	23.1
Fat %	-	2.51	2.61	2.27	4.2
* Below the minimum levels required to meet honey bee nutritional requirements.					

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.50 POLLEN QUALITY—White clover *(Trifolium repens)*

Doug Somerville, NSW Agriculture, Goulburn

White clover *(Trifolium repens* L.) has perhaps the highest nutritive value and protein levels of any pasture species grown for livestock production worldwide. It also fixes large amounts of nitrogen to enrich soil fertility. It is best adapted to cooler climates such as the tablelands. Some varieties can be grown on the slopes, along the coast and under irrigation in western areas.

Research in Victoria indicated that honey bees comprised 88% of all insect visitors to a White clover crop and the action of insect visitors increased seed yields by 3100% when plots were caged to exclude bees. The same research also indicated that the stocking rate of 70 hives per 100 hectares was rather light and a higher stocking rate would be expected to increase the yields even further (Goodman & Williams, 1994). A stocking rate for pollination purposes should be two to three hives per hectare.

This species is regarded as the most important clover for honey production. During favourable seasons, high yields of choicest quality honey are obtained from colonies of bees which are properly managed, at optimum strength and working White clover. White clover rates medium to major as a honey source in NSW. Pollen is produced in moderate to large amounts. With the nectar provided, it is usually sufficient to provide stimulating conditions for brood rearing, particularly on the coast where it is one of the main plants for the spring build up of colonies. When White clover is flowering profusely for long periods, especially with other good pollen sources, swarming may be aggravated (Clemson, 1985).

Results from a survey conducted on commercial beekeepers in NSW indicate that the pollen value for White clover was 4.59 out of a maximum rating of 5. Flowering ranged from August through to February with the main flowering period from October to January. Frequency of beekeeper usage was every one to two years and honey crops were occasionally up to five to six years apart. Mean honey yields obtainable were 32 kg per hive (Somerville, 1999).

The one pollen sample collected in November 1996 was of a reasonably good quality with adequate amino acid levels and adequate protein. Three other samples reported by Muss (1987) and Rayner & Langridge (1985) also confer that clover pollen is of a very reasonable quality. Results published by Stace (1996) of five samples collected from the northern tablelands and north coast regions of NSW also have adequate protein levels ranging from 22.5 to 25.4%, with a mean of 23.7%. Stace (1996) also found that White clover pollen was deficient in the essential amino acids, Valine and Isoleucine, which is contrary to the sample collected from Candelo and the three samples tested by Muss (1987) and Rayner & Langridge (1985).

White clover will rarely be the sole source of pollen available to a colony, thus if these deficiencies do occur as stated by Stace (1996), then they are most probably neutralised by the collection of a mixture of species available to the colony. Generally, White clover pollen should be considered as a reasonable quality pollen for meeting the requirements of honey bee nutrition.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Candelo Nov '96**	*Muss (1987)*	*Muss (1987)*	*Rayner & Langridge (1985)*
Threonine	3.0	4.57	4.1	4.3	4.3
Valine	4.0	5.27	4.5	4.6	5.3
Methionine	1.5	2.18	1.5	1.8	2.1
Leucine	4.5	6.98	13.5	13.1	6.9
Isoleucine	4.0	4.44	5.7	5.7	4.6
Phenylalanine	2.5	4.28	5.0	4.6	4.6
Lysine	3.0	5.86	2.7*	2.8*	5.5
Histidine	1.5	2.49	-	-	2.6
Arginine	3.0	4.65	7.3	8.0	4.2
Crude Protein %	-	25.9	25.13	25.63	24.7
Fat %	-	2.5	-	-	-
* Below the minimum levels required to meet honey bee nutritional requirements.					

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.51 POLLEN QUALITY—White mallee *(Eucalyptus dumosa)*

Doug Somerville, NSW Agriculture, Goulburn

White mallee is a typical mallee, usually 1.5 to 9 m high and has a distribution across central and southern NSW, extending into SA and VIC. The main flowering period is generally in January and February.

White mallee can provide high honey yields when there have been good rainfalls just prior to and during flowering. It is considered to be of medium to major importance as a honey source in NSW. This species produces good supplies of creamy white pollen that is attractive to bees and beneficial for brood rearing. It is of medium importance as a source of pollen for bees (Clemson, 1985).

Beekeepers, in a NSW study of floral resources, indicated that the pollen value was only 2.88 out of a possible 5, indicating a fairly average quality pollen. The tree flowered on average every four to five years and produced 37 kg of honey per hive (Somerville, 1999).

The two pollens collected in February 1997 and 1998 support the view that pollen from White mallee is a rather poor quality pollen. With crude protein levels of 20.5 and 22.5% these levels are barely acceptable to maintain an average breeding rate within a hive. When a 20% crude protein is considered an absolute minimum level to maintain bees and allow breeding to continue, then this becomes a problem when one or more of the essential amino acids are also deficient. A sample of White mallee pollen was also reported by Muss (1987) with a slightly better crude protein level but this pollen was deficient in two essential amino acids.

Given the results of these three pollen samples, bees need to be bred on a high quality pollen prior to working a White mallee pollen source. The protein levels of adult bees will decline on White mallee pollen, thus it is necessary to start with bees with high body protein levels. Bees which have low body protein levels prior to working a White mallee pollen source will take much longer to recover in strength after the White mallee flowering event.

Amino Acid	Ideal Ratio From DeGroot (1953)	West Wyalong Feb '97	Dubbo Feb '98	*Muss (1987)*
Threonine	3.0	3.6	3.65	3.1
Valine	4.0	4.85	4.78	3.5*
Methionine	1.5	2.15	1.92	0.9*
Leucine	4.5	6.28	6.47	6.1
Isoleucine	4.0	3.54*	3.52*	4.1
Phenylalanine	2.5	3.64	4.08	3.1
Lysine	3.0	5.67	5.8	5.4
Histidine	1.5	2.46	2.84	1.8
Arginine	3.0	7.16	8.15	6.0
Crude Protein %	-	22.5	20.5	24.75
Fat %	-	1.9	1.4	-
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.52 POLLEN QUALITY—White stringybark *(Eucalyptus globoidea)*

Doug Somerville, NSW Agriculture, Goulburn

White stringybark can be anything from a small to tall tree and, under favourable conditions, obtain a height of 25 to 30 metres.

White stringybark grows mainly on the coast south of the Clarence River, and is most commonly found on the central and south coast. It extends to the eastern edge of the tablelands in the central and lower northern tableland areas. It is also found well into the Gippsland region of Victoria. It is a good nectar producer in favourable seasons, provides good supplies of pollen and is considered to be of medium importance as a source of pollen in NSW (Clemson, 1985).

Beekeepers, in a study of floral resources of NSW, indicated that the pollen from White stringybark had a mean value of 3.62 out of a possible high of 5. The main flowering period is September, but may commence in July and extend to November, with a flowering frequency mainly every three years. An average honey yield per hive is 19 kg (Somerville, 1999).

The pollen sample collected in Nowra in 1997 is of reasonable quality with a crude protein level of 29.4%. A deficiency in the amino acid, Isoleucine, detracts from the overall value of this pollen but, given the high protein level, it is compensated for to some degree.

It is difficult with any assurance to draw too many conclusions from this one sample of pollen, but if this is indicative of the species, then this is an average to above average quality pollen. Further samples of White stringybark pollen need to be analysed to ascertain whether the sample from Nowra is representative of the species.

Amino Acid	**Ideal Ratio From DeGroot (1953)**	**Nowra Sep '97**
Threonine	3.0	4.02
Valine	4.0	5.03
Methionine	1.5	2.25
Leucine	4.5	7.25
Isoleucine	4.0	3.68*
Phenylalanine	2.5	4.24
Lysine	3.0	6.34
Histidine	1.5	2.78
Arginine	3.0	7.1
Crude Protein %	-	29.4
Fat %	-	1.2
* Below the minimum levels required to meet honey bee nutritional requirements.		

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC with a cation exchange analytical column and post-column ninhydrin reaction.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.53 POLLEN QUALITY—Willows *(Salix species)*

Doug Somerville, NSW Agriculture, Goulburn

Salix is the Latin name for willow. There are over 300 species of Salix in the world, mainly originating in Asia, Europe and North America. There are no Australian native salix species. Willows are very common along rivers and water courses in most parts of Australia. Some species of willow are selectively grown for ornamental purposes. Many willows are now regarded as weeds in much of rural Australia, due to their rapid growth and heavy infestations along water courses, choking out native species. Willows are used as stock fodder in times of drought by some graziers. They quickly regenerate after pruning and lopping. In and around residential buildings, the roots of willow trees have a nasty habit of blocking and clogging drains due to their extensive root system. Even so, willows are one of the first plants to flower in spring. On the central and southern tablelands this is usually around late August to early September. In warmer areas, this may well be earlier. It is said that willows provide nectar, although that wasn't apparent while trapping pollen from Weeping willow in September in the Goulburn area of NSW.

The pollen in both samples, Weeping willow *(Salix babylonica)* and Pussy willow *(Salix discolor)* were very attractive to bees. Bee activity was observed to be rather intensive on both species, particularly during the warmer parts of the day when significant quantities of pollen were collected. Both trees take on a yellow look when in flower. It is not always possible for the untrained eye to readily see the male catkins of Weeping willow hanging down. The catkins or flowers come out prior to the small leaflets which rapidly grow out of the same axis of the stems or twigs. Pussy willow flowers first appear as silvery furry buds and become yellowish in colour as they flower, again appearing before the leaves.

The quality of Weeping willow pollen is poor with a deficiency in Isoleucine (one of the essential amino acids) and an overall crude protein level of 14.8% to 15.1%. A figure of 20% has been regarded as the base level of an acceptable crude protein level, as minimum for honey bee nutrition. Pussy willow, on the other hand, was well balanced nutritionally and generally attractive to honey bees. Unfortunately Pussy willows are not as extensively planted as Weeping willows. Even given that Weeping willows are poor in the nutritional value they provide to honey bees' diets, I would argue that any fresh pollen available to honey bees in early spring is of some value to honey bees. A poor supply of pollen is better than no pollen at all. The flowering of willows is quickly followed by the flowering of other species, mainly ground flora, that are also of benefit to honey bees.

Amino Acid	Ideal Ratio From DeGroot (1953)	Lithgow Pussy Willow Sep '95	Tarana Weeping Willow Sep '95	Goulburn Weeping Willow Sep '95
Threonine	3.0	4.5	3.41	3.89
Valine	4.0	5.51	3.93	4.52
Methionine	1.5	2.52	2.16	2.44
Leucine	4.5	7.49	5.62	6.18
Isoleucine	4.0	4.75	3.28*	3.9*
Phenylalinine	2.5	4.39	3.29	3.57
Lysine	3.0	7.16	5.25	5.85
Histidine	1.5	2.28	1.8	1.99
Arginine	3.0	6.29	6.57	6.82
Crude Protein %	-	21.9	14.8*	15.1*
Fat %	-	3.1	1.54	2.07
* Below the minimum levels required to meet honey bee nutritional requirements.				

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement

Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.54 POLLEN QUALITY—Woollybutt *(Eucalyptus longifolia)*

Doug Somerville, NSW Agriculture, Goulburn

Woollybutt is a medium size to tall tree, occurring throughout the coastal strip of NSW from Raymond Terrace to the Victorian border. It is most common, however, between Nowra and Bega on the south coast. It is mostly found in association with Bangalay *(E.botryoides)*, Coastal grey box *(E.bosistoana)* and Yellow stringybark *(E.muelleriana)*.

Woollybutt is an important production resource. The importance of its honey and pollen production is rated as medium. The tree's flowering period occurs between April and July and the buds are carried for three to six months. There are three to four years between flowerings although some beekeepers suggested that it could be considerably longer, with a figure of 10 to 40 years being suggested by one beekeeper.

The quantity of honey yielded is said to vary between 13 and 54 kg with an average of about 27 kg/hive (Somerville & Dodds, 1995).

During the winter of 1995, Woollybutt was well budded on the south coast but did not yield any significant honey crops. There has been some suggestion that bees dwindle when on Woollybutt and that was corroborated that year, with some producers reporting that bees did actually decline on Woollybutt sites. The coast was experiencing an extremely dry period, at the time, and this could have significantly reduced the quantity of nectar secreted.

Another production-limiting factor to be considered, given the time of year that Woollybutt flowers, is the possibility that Nosema disease may be present. Certainly, there is anecdotal evidence to suggest that apiaries located in open, sunny positions suffer less losses than those in heavily shaded locations, in the same areas. The diversity of supporting flora will also have an influence by virtue of their making additional nutrients, via pollen, available. A number of Acacia species were in flower, from June to mid spring, in some areas of the coastal forests. Woollybutt can be a good "bee" tree, but it needs to be carefully watched to obtain the best results.

Two pollen samples were collected from Woollybutt in 1995 and 1996 from forests on the south coast. The following table lists the results of the essential amino acids against DeGroot's (1953) ideal ratios to satisfy honey bee nutritional requirements.

The crude protein levels are at a desirable level for this time of the season. As long as other species such as acacias (wattle) are also being worked for pollen, then the amino acid, Isoleucine should not pose a problem meeting the requirements of honey bee nutritional requirements. On both occasions, ample quantities of pollen were collected in the pollen traps, thus quantity should also be satisfactory.

Amino Acid	Ideal Ratio From DeGroot (1953)	Murrah SF Jun '95	Millingandi Jun '96
Threonine	3.0	3.67	3.46
Valine	4.0	4.75	4.49
Methionine	1.5	2.99	2.39
Leucine	4.5	6.26	6.32
Isoleucine	4.0	3.84*	3.5*
Phenylalinine	2.5	3.72	3.54
Lysine	3.0	5.82	5.03
Histidine	1.5	1.84	1.75
Arginine	3.0	6.5	6.33
Crude Protein %	-	24.9	25.4
Fat %	-	-	2.41
* Below the minimum levels required to meet honey bee nutritional requirements.			

Chemical Analysis Methods

Nitrogen (crude protein): Macro Kjeldahl method.
Amino acids: HPLC using pre-column derivatisation using PICO•Tag® system.
Fat: Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

Acknowledgement
Funding for chemical analysis—RIRDC Honeybee Research & Development Advisory Committee.

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6.1.55 POLLEN QUALITY—Yellow burr *(Centaurea solstitialis)*

Doug Somerville, NSW Agriculture, Goulburn

Also referred to as St Barnaby's thistle, this species is a native of southern Europe. In NSW it is a common weed throughout the wheat belt, including the tablelands and slopes. Flowering commences in summer and may continue from mid December until the arrival of frosts. This weed is an excellent pollen producer and, with favourable rainfall, may produce very satisfactory honey crops. For best results, spring and early summer rainfall should be adequate and followed by good mid summer rains, then hot conditions with periodic rain. The plant is adversely affected by long periods of extremely dry conditions followed by heavy rainfall when the growth is advanced (Clemson, 1985).

Beekeepers, in a study conducted on the floral resources of importance to beekeepers in NSW, indicated that the value of the pollen from St Barnaby's thistle is 4.06 which is a reasonably good rating, given the top figure obtainable in the study was 5. The main flowering period is January and February but may start in December and extend to April. Flowering may occur every one or two years depending on rainfall. The average honey yields per hive are 24 kg (Somerville, 1999). The pollen collected at Molong in January 1996 can only be described as ordinary. Given that a crude protein level of 20% is regarded as a minimum level for bees to breed and maintain populations, this level of protein does not permit hives run down on previous poor pollen sources to rapidly recover. A higher crude protein level would be required.

What is encouraging with this sample is that there are no deficiencies in the essential amino acids necessary for honey bee dietary requirements. Three St Barnaby's thistle pollens reported on by Stace (1996) indicate a range of crude protein levels from 18.68, 22.4 to 26.4%. Under these circumstances bees should be able to breed and maintain populations on a light to medium honey flow but would not have sufficiently high body protein levels after being reared on St Barnaby's thistle pollen to work a heavy honey flow in the autumn.

It is interesting to note that Stace (1996) reported that one sample of pollen contained a fat level of 8%, compared to the 2.83% for the sample collected at Molong. This is quite a significant difference. The role of fat in a bees' diet is not understood, although pollens with high fat contents seem to be very attractive to foraging honey bees.

Amino Acid	Ideal Ratio From DeGroot (1953)	Molong Jan '96
Threonine	3.0	4.2
Valine	4.0	4.94
Methionine	1.5	2.14
Leucine	4.5	6.96
Isoleucine	4.0	4.52
Phenylalanine	2.5	3.96
Lysine	3.0	6.34
Histidine	1.5	3.74
Arginine	3.0	4.41
Crude Protein %	-	20.6
Fat %	-	2.83

Chemical Analysis Methods

Nitrogen (crude protein):	Macro Kjeldahl method.
Amino acids:	HPLC using pre-column derivatisation using PICO•Tag® system.
Fat:	Extraction with petroleum spirits.

Amino acids are expressed as free amino acids in grams/16 grams of Nitrogen.

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6.2 Appendix II: Pollen Collection Data Sheets

These sheets are not comprehensive for all samples collected. Data sheets were not recorded for all samples, particularly pollens collected in 1995. Quite a number of pollens collected were not chemically analysed for a range of reasons.

I. The sample was in very poor condition, e.g., mouldy or wet.

II. There was not sufficient amount of the desired pollen to send for crude protein, fat and amino acid analysis.

III. Some samples were very dirty, they contained a high degree of roughage and debris from the hive. It was not feasible to clean these samples.

IV. A lack of confidence that the pollen was collected from the stated species.

V. Due to the cost of analysis, the number of samples analysed had to be conservative, as funds were finite.

The information in the data sheets is a guide to the collection details of some of the pollen samples processed during this research.

In most cases only one or two traps were used on any one location to target a given species. On a few occasions more than two traps were used as was the case in Nowra in January 1997 where five traps were used to collect pollen. The traps were placed on similar strength hives. A range of 150 to 995 grams of pollen, with a mean of 495 grams per hive over a 10 day collection period, indicates the significant variations that can occur in the field between hives.

Another two samples collected at Candelo in November 1997 were 65 grams and 145 grams, again demonstrating the variability that can occur within an apiary.

To measure quantity of pollen collected and associate this with the species as typical of possible future pollen yields is difficult, due to a range of factors. These include hive strength and pollen requirements of the colonies, weather conditions as they impact on bee flight and the release of pollen, soil moisture, humidity and temperature as they affect pollen production from the plant, and pollen trap design. Thus, figures in the following sheets should be used with some reservation if determining values of pollen based on quantities trapped.

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
Goulburn (Mummel Rd)	16 Nov '97	-	29	4	Purple Yellow Orange White	78% trace 22% trace	Paterson's curse Mustard Flatweed Unknown	*
Jugiong (Futter Park)	14 Nov '97	-	460	1	Purple	100%	Paterson's curse	*
Paynters Sidings (Narrandera)	10 Nov '97	7	92	5	Purple White Orange Lt Yellow Dk Yellow	47% 34% 19%	Paterson's curse Unknown Unknown	*
Bungonia	10 Nov '97	-	410	5	Orange Dk Yellow Purple Lt Yellow Black	66% 33%	Flatweed Unknown	*
Cowra	5 Nov '97	-	300	3	Purple Yellow Orange	60% trace 40%	Paterson's curse Canola Flatweed	*
Victoria (Goulburn Valley)	Oct '97	-	32	4	Cream Green Dk Green Orange Dk Yellow	68%	Pear Unknown Unknown Unknown	*
Nowra (State Forest)	26 Sep '97	8	100	2	Lt Green Lt Orange	90% 10%	White stringybark Eggs & bacon	*
Nowra (West)	26 Sep '97	-	59	2	Dk Orange Yellow/Green	41% 59%	Eggs & bacon Spotted gum	*
Boree Ck (Narrandera)	15 Sep '97	7	130	2	Brown/Orange Yellow	76% 24%	Lupins Canola	*
Nowra (State Forest)	9 Sep '97	8	136	1	Lt Yellow	100%	Spotted gum	
Bermagui	18 June '97	-	250	1	Lt Yellow/Green	100%	Spotted gum	*
Moruya (Lynch's Creek)	22 May '97	-	100	1	Lt Yellow/Green	100%	Spotted gum	*
Oberon	16 Apr '97	-	205	1	Lt Yellow	100%	Brittle gum	*
Batemans Bay	March '97	-	25	1	Yellow	100%	Bloodwood	
Flagstaff	26 Mar '97	9	75	1	Yellow/Green	100%	Grey box	*
Nowra	24 Mar '97	10	Av 5 traps	2	Cream Yellow		Bloodwood	*

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
(State Forest)			88		Lt & Dk		Scribbly gum	
Bungonia	24 Mar '97	5	Av 2 traps 345	2	Cream/Yellow Orange	94% 6%	Scribbly gum	*
Termeil (Clyde River)	6 Mar '97	-	290			100%	Sydney blue gum	*
Yetholme	March '97	-	270	3	Purple Orange Yellow	9% 20% 71%	Blueweed Skeleton weed Apple box	
Oberon	20 Feb '97	-	66	3	Lt Cream Orange Brown	2% 1% 97%	Unknown Unknown Unknown	
West Wyalong	12 Feb '97	8	130	2	Dirty Yellow Orange	94% 6%	White mallee Skeleton weed	*
Oberon	11 Feb '97	-	67	4	Brown Clear White Orange Purple	26% 20% 44% 10%	Clover Black thistle Dandelion Unknown	
Griffith	30 Jan '97	14	420	1	Orange	100%	Sunflower	*
Weethale	14 Jan '97	7	150	2	Orange Lt Yellow	79% 21%	Skeleton weed Christmas mallee)	
Goulburn (Mummel Road)	8 Jan '97	15	102	3	Orange Yellow Purple	64% 26% 10%		
Nowra (State Forest)	28 Jan '97	10	Av 5 traps 495 Range: 150–995	3	Dk Green Lt Green/Yellow Yellow	19% 81% trace	Saw banksia Grey gum wattle	* *
Nowra (State Forest)	24 Mar '97	-	87	2	Cream Lt Green		Unknown Unknown	
Bega (Buckajo)	Jan '96	-	Av 2 traps 33	6	Brown Dk Yellow White Purple Orange Yellow	88% Residue	Rough-barked apple Unknown	*
Dubbo (70 km SW)	7 Oct '96	5	320	4	Yellow Orange Black	62% Residue	Currawong wattle Capeweed Unknown	*

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
					Deep Red		Unknown	
Dubbo	15 Oct '96	2	135	2	Purple Orange/Yellow	93% 7%	Paterson's curse Unknown	*
Dubbo	9 Oct '96	-	185	3	Orange Yellow Black	88% } Residue	Capeweed Unidentified	*
Collector	Early Feb '97	-	106	3	Yellow/Green Orange White	64% 5% 31%	Apple box Flatweed Black thistle	* *
Ariah Park	4 Oct '96	-	600	5	Dk Yellow Yellow Purple Olive Green Orange	71% } Residue	Balansa clover Canola Paterson's curse Unidentified Capeweed	*
Woodstock (6 km)	Sep '97	-	415	3	Yellow Black Orange	80% } Residue	Canola (Oscar) Unidentified Capeweed	*
Woodstock	Oct '97	-	240	3	Purple Yellow Orange	92% } Residue	Paterson's curse Unidentified Unidentified	*
Dubbo	20 Oct '97	6	60	2	Yellow Purple	60% 40%	Unidentified Paterson's curse	*
Narooma	July '97	-	150	1	Cream	100%	Spotted gum	*
Moruya	July '97	-	380	1	Cream	100%	Spotted gum	*
Henry Lawson Way	5 Nov '97	-	27	2	Purple Yellow	85% 15%	Paterson's curse Unidentified	*
	11 Nov '97	6	66	3	Purple Yellow	88% Residue: 12%	Paterson's curse	*
	15 Nov '97	4	50	1	Purple	100%	Paterson's curse	*
	19 Nov '97	4	45	2	Purple Yellow	96% 4%	Paterson's curse Unidentified	*
Bimby Rd	5 Nov '97	-	42	2	Purple Yellow	87% 13%	Paterson's curse Unidentified	*
	11 Nov '97	6	57	3	Purple -	-	Paterson's curse Unidentified	*
	15 Nov '97	4	55	2	Purple -	-	Paterson's curse Unidentified	*

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
	19 Nov '97	4	46	2	Purple -	- 	Paterson's curse Unidentified	*
Black Springs	10 Jan '98	-	65	2	Lt Yellow/Green Orange	- -	Buckwheat Flatweed	*
Oberon	3 Jan '98	-	160	2	Orange Yellow	98% trace	Flatweed Unidentified	*
Sheparton Victoria	Nov '97	-	-	5	Purple Orange Lt Green White Lt Yellow	- 59% - 25% 14%	Unidentified Flatweed Unidentified Unidentified Kiwifruit	
Narrandera (Sandigo)	9 Sept '98	-	-	4	Dull Orange Bright Orange Yellow Black	41% - - -	White lupins Capeweed Canola Unidentified	*
Walgett	21 Sept '96	-	450	1	Yellow	100%	Turnip weed	*
Mogo	31 Mar '97	-	30	2	Similar colour	-	Bloodwood	
Nowra	18 Sep '97	-	80	2	- -	98% 2%	Eggs & bacon Unidentified	*
Bathurst	Early Jan '98	-	100	1	Orange	100%	Skeleton weed	
Henry Lawson	29 Nov '96	-	60	1	Purple	100%	Paterson's curse	*
Way	8 Dec '96	-	90	1	Purple	100%	Paterson's curse	*
Candelo	18 Nov '97	-	2 traps Av 105 (65–145)	5	Purple Brown Orange Yellow White	51% - - - -	Paterson's curse Clover Flatweed Mustard Black thistle	*
Cowra (12 km SE)	25 Nov '97	-	140	1	Purple	100%	Paterson's curse	*
Oberon	20 Feb '97	-	50	1	Lt Cream	99%	Red stringybark	
	23 Feb '97	3	40	1	Lt Cream	99%	Red stringybark	*
Tumbarumba	3 Mar '98	6	320	1	Dirty Cream	100%	Red stringybark	
Jugiong (Futter Park)	5 Dec '96	3	77	2	Yellow Purple	85% 15%	Blakely's red gum Paterson's curse	*
Weethale	23 Dec	5	-	3	Yellow/Green Orange White	82% 3% 15%	Christmas mallee Skeleton weed Unidentified	*
Cowra (15 km SE)	14 Dec '96	7	160	4	Orange Purple	62% 12%	Unidentified Paterson's curse	

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
					Yellow Brown	24% 2%	Unidentified Unidentified	
Darlington Point	mid Dec '96	7	330	1	Yellow	100%	River red gum	*
Cowra (Canowindra Rd)	13 Dec '96	-	80	3	Purple Orange Yellow	83% 11% 6%	Paterson's curse Unidentified Unidentified	*
Henry Lawson Drive	13 Dec '96	-	59	4	Purple Yellow Orange Clear	79% 2% 12% 7%	Paterson's curse Unidentified Unidentified Unidentified	
Crookwell	9 Dec '96	-	130	3	Purple Green Purple	29% 71% Trace	Paterson's curse Clover Thistle	
	5 Dec '96	8	135	4	Yellow Purple Orange Brown	60% 9% 26% 5%	Hillgum Unidentified Unidentified Unidentified	
Canowindra/ Eugowra (½ way) (same site as '95)	Nov '96 (1 Dec '96)	17	280	4	Purple Orange Brown White	99%	Paterson's curse Unidentified Unidentified Unidentified	*
Mingenew Three Springs WA	Nov '96			4	Yellow Purple Orange Brown	51% 46% 2% 1%	Eucalypt species Paterson's curse Unidentified Unidentified	*
Stockinbingal	Nov '96	-	170	2	Blue Yellow	58% 42%	Paterson's curse Canola	*
Henry Lawson Way (Canowindra)	26 Nov '96	-	69	3	Purple Yellow Orange	94% 5% 1%	Paterson's curse Unidentified Unidentified	*
Molong	16 Nov '96	3	80	3	Orange Purple Green	42% 35% 23%	Flatweed Paterson's curse Clover	* *
Candelo	7 Nov '96	7	310	3	Green Yellow Purple	78% 16% 6%	Clover Mustard Paterson's curse	* *
Molong (Norah Creek)	5 Nov '96	3	200	4	Yellow Orange	80% 9%	Unidentified Unidentified	

Location	Date Pollen Collected	Collection Days	Total Weight (gms)	No. of Pollens Distinguishable by Colour	Colour of Pollen	% by Weight	Plant Name	Analysed for CP, Amino Acid, Fat %
					Purple Brown	8% 3%	Paterson's curse Unidentified	
Donnybrook WA	Oct '96	-	-	3	Yellow Orange Brown	73% 15% 12%	Unidentified Unidentified Unidentified	
Donnybrook WA	Oct '96	-	-	3	Orange Brown Yellow	44% 51% 5%	Unidentified Unidentified Unidentified	
Paynters Sidings (Narrandera)	25 Oct '96	4	155	3	Purple Yellow Orange	76% 24% trace	Paterson's curse Unidentified Unidentified	
Walgett	4 Oct '96	14	3080	3	Yellow White Purple	65% 30% 5%	Turnip weed Unidentified Unidentified	
Darlington Point	Early Oct '96	-	1200	3	Purple Yellow Brown/Green	70% 30%	Paterson's curse Unidentified Unidentified	
Carwarp	Sep '96	-	-	1	Orange	100%	Onion weed	*
Tathra	13 Sep '96	-	-	1	Yellow-Green	100%	Woollybutt	
Bigga	26 Sep '96	3	85	3	Brown Yellow Orange	62% 37% 1%	Red box Unidentified Unidentified	*
Hungerford	4 Sep '96	-	220	3	White Orange Pale Yellow	70% 17% 13%	Unidentified Unidentified Unidentified	
Dongara WA	Aug '96	-	-	3	Purple Yellow Dirty Yellow	34% 13% 53%	Unidentified Unidentified Unidentified	
Eneabba WA	Aug '96	-	-	3	Yellow Orange Dirty Yellow	68% 17% 15%	Unidentified Unidentified Unidentified	
Paynes Find WA	Mar '96	-	-	2	Yellow White	42% 58%	Unidentified Unidentified	
Yetholme	Jan '96	-	130	4	Yellow Orange Dk Orange Purple Yellow	6% 4% 72% 18%	Unidentified Flatweed Vipers bugloss Mustard	*
Dubbo	-	-	280	3	Yellow	86%	Unidentified	

Location	**Date Pollen Collected**	**Collection Days**	**Total Weight (gms)**	**No. of Pollens Distinguishable by Colour**	**Colour of Pollen**	**% by Weight**	**Plant Name**	Analysed for CP, Amino Acid, Fat %
					Green Dull Orange	7% 7%	Unidentified Unidentified	
Goulburn (Tirranaville)	24 Dec '98	-	600	3	Purple Orange Yellow	43% 57% trace	Lavender Flatweed Mustard	*
Harden	21 Nov '96	-	-	4	Dirty Yellow Purple Orange Bright Yellow	41% 52% 5% 2%	Unidentified Paterson's curse Unidentified Unidentified	*

7. Recommendations

- The value of the amino acids to honey bee nutrition is largely a function of the total crude protein (CP). Given that the cost of analysing pollen for amino acids is rather high—over $250 per sample—and CP is well under $50, it would be more cost effective to measure the CP to determine the initial value of any particular pollen to ascertain whether it will meet this basic honey bee nutritional requirements.
- Given the variability of results for any one species, it is apparent that using the data from one sample to state that this is the nutritional value of the pollen from this species for all locations and seasons is not consistent. One measurement of a particular species should only be used as a guide and not as a definitive level of nutritional elements for this species.
- The quantity of pollen collected may, in many cases, be more important to beekeepers than the individual nutrient values of single pollen species. During the course of this research some species produced abundant quantities of pollen, as compared to other species that were shy producers of pollen. This research mainly focussed on the quality and not the quantity of pollen produced. Future research should also collect data on quantity as compared to strength of hive, etc., as a low quality pollen in abundance may well be far more valuable to beekeepers than high quality pollen in short supply.
- The fat % or lipids, as measured in this research, open an interesting area for further study. Some species are clearly very high in fat % and these species are also very attractive to foraging bees even though their CP levels, in some cases, are well below the ideal levels. Fat % (lipids) could be an interesting area for research, to determine their composition. This may be of use in the formulation of artificial supplements.
- Future pollen analysis for particular regions could first identify the pollen sources beekeepers perceive to be of importance. I say perceived importance, because observations in this trial indicated that beekeepers thought pollen was being collected from one floral source and, in fact, the pollen source was another unrelated species. A survey of beekeepers would still be desirable to identify a basis on which the researcher should focus their trapping and collection of pollens.
- After reading the literature on honey bee nutrition and discussing the relative merits of various chemistry analysis with Maurice Kerr (Chemist, Agriculture Victoria), conducting work on vitamin content of pollens may be very difficult due to many of the vitamins being unstable. The role vitamins play in honey bee nutrition is also very unclear. Future work on vitamins will require careful thought as to the desired outcome of the researcher. Also, the cost of measuring vitamins is rather high, measured in the hundreds of dollars per sample.
- Research on mineral levels of pollen could be of interest to the beekeeping industry. Minerals are very stable in pollen and will not vary with length of storage. The cost of analysing samples is also reasonably affordable, depending on how many elements are to be measured per sample. A number of livestock health issues can be related back to mineral deficiencies or toxicities with livestock management in Australia. It is possible that minerals may be an issue with management of bees in some regions, due to similar circumstances as experienced by the livestock industry.
- Beekeepers, in many circumstances, have difficulty in managing their bees according to the variation and availability of pollens in their management of colonies. By monitoring the mix of pollens and total volume of pollen entering a colony, better medium term decision-making could occur with a possible increased use of pollen supplements. The use of supplements would seem to be a better proposition at present as complete substitution of pollen does not appear to be highly successful in the nutritional management of bees.
- The significance of honey bee nutrition in disease status of bee colonies may be of major importance to the beekeeping industry as well as recommendations to persons rearing queen bees to ensure optimal nutritional conditions are met to produce a well mated queen of consistent high quality. Provision of supplements in both circumstances may be of significant benefit to the industry and studies along these lines could be considered by future researchers.

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