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Evaluation of Guar Cultivars in Central and Southern Queensland

A report for the Rural Industries Research and Development Corporation

by C.A. Douglas

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Researcher Contact Details
C A Douglas
Department of Primary Industries and Fisheries
Locked Bag 1
BILOELA QLD 4715)

Phone:	07 4992 9112
Fax:	07 4992 3468
Email:	col.douglas@dpi.qld.gov.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

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 4819
Fax:	02 6272 5877
Email:	rirdc@rirdc.gov.au.
Website:	http://www.rirdc.gov.au

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Foreword

Guar is a dryland summer legume that is predominantly grown in India and Pakistan as a vegetable, fodder and grain crop. The grain of guar contains up to 30% of a galactomannan gum that is used widely in industrial manufacturing and food processing. India and Pakistan currently supply 90% of world demand for guar grain.

Australian research in the 1970s and 1980s determined that guar was well suited to the dryland cropping environments of northern Australia but despite promising grain yields and establishment of key agronomic guidelines there were insufficient markets to support a domestic industry at that time.

Interest in an Australian guar industry has been renewed since 1999 due to increasing world demand for the product and the presence of an international chemical company seeking to source guar from Australia. Lack of a suitable variety has been identified as one barrier to the establishment of a local industry.

This publication reports on the evaluation of 469 guar cultivars in central and southern Queensland.

This project was funded from RIRDC Core Funds provided by the Australian Government. Industry funding was provided by Lambert s.p.a. and Australian Gum Products Pty. Ltd.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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I wish to gratefully acknowledge the generous financial contributions of industry partners Lamberti s.p.a. and Australian Gum Products to this project. In addition I would like to acknowledge the contributions of Dr. Peter Lawrence, Mervyn Rettke, Julie Edwards and the farm staff at Queensland Department of Primary Industries and Fisheries' Biloela and Roma Research Stations. I would also like to thank Dr. Helen Murphy and Katherine Raymont for undertaking grain quality analyses.

Abbreviations

ATCFGRC	Australian Tropical Crops and Forages Genetic Resources Collection
AGP	Australian Gum Products Pty. Ltd.
CSIRO	Commonwealth Scientific and Industry Research Organisation
GIDA	Guar Industry Development Association
DPI&F	Queensland Department of Primary Industries and Fisheries

Contents

Executive Summary

Dryland summer cropping in Queensland is based predominantly on grain sorghum. The viability of this farming system is being questioned by farmers who are increasingly looking for alternative crops to spread their risk in the highly variable dryland cropping environments of central and southwestern Queensland. In particular there are limited summer cropping options that provide a rotation out of cereal crops such as wheat and sorghum.

Guar (*Cyamopsis tetragonoloba*) is an annual legume species grown widely in the semi-arid tropics of India and Pakistan. DPI&F and CSIRO research in the 1970s and 1980s established that guar is well suited to the hot, dry summers of northern Australia and could produce viable grain yields. Guar is deep-rooted and has long been considered as a beneficial forage or rotation crop. However the real value of guar is marketing the grain for its gum content.

Guar grain contains 25-30% of galactomannan gum. This vegetable gum is extracted from the seed and used as a stabiliser or thickener in food and has industrial applications in textile, paper, and pharmaceutical manufacture and in oil well drilling. There has been renewed interest in developing a domestic guar industry since 1999 when Italian company Lamberti s.p.a. began trying to source guar from Australia.

Low grain yields and difficulties in crop management have resulted from poor quality planting seed and a mixture of cultivars in commercial seed stocks. Identification of a new high yielding variety and ensuring varietal purity were identified by growers and industry as key factors in order to achieve sufficient production to sustain a domestic guar industry.

Four hundred and forty four lines from the Australian Tropical Crops and Pastures Genetic Resource Centre and 25 imported lines were evaluated between 2001 and 2004. Field trials at Biloela (central Queensland) and Roma (south west Queensland) identified two high yielding line cultivars with agronomically suitable plant type for commercial production in Australia. Grain yields of elite cultivars were significantly higher than CP177 the main variety in commercial planting seed. At a crop value of $300 per tonne the adoption of new cultivars could increase gross margins by $90 per hectare.

1 Introduction

Guar or clusterbean (*Cyamposis tetragonoloba* (L.) Taub) is a summer legume traditionally grown in the semi-arid regions of India and Pakistan as a vegetable, forage and grain crop. It is tolerant of hot, dry conditions and has a deep taproot.

Guar grain contains 25-30% of galactomannan gum. This vegetable gum is extracted from the seed and used as a stabiliser or thickener in food and has industrial applications in textile, paper, and pharmaceutical manufacture and in oil well drilling. Guar seedmeal contains up to 47% protein, this by-product of the gum extraction process and has great value as a stockfeed, in particular for monogastric animals.

The crop was introduced to Australia from the United States in the early 20th Century and evaluated in New South Wales, Queensland and the Northern Territory (Jackson and Doughton 1982). Subsequent research conducted in Queensland and the Northern Territory in the 1960s, 1970s and 1980s demonstrated guar was well adapted to the dryland cropping environments of northern Australia.

Lines imported from India and the United States had grain yields of up to 2 tonnes per hectare dryland and 4 tonnes per hectare irrigated in Central Queensland but were highly variable across seasons (Davey, et al 1984). Guar was recognised as a beneficial rotation crop and considered to have greatest potential on the drier margins of the cropping zone where summer crops such as sorghum and sunflower were not economically viable. DPI&F and CSIRO research on guar was concluded in 1983 due to low world oil prices and reduced demand for the gum product.

More recently world demand for guar gum has increased and continues to grow at 2% per annum, current production levels are estimated at 190 000 tonnes processed gum (500 000 tonnes grain), 90% of which is produce by India (Bryceson and Cover 2004).

Interest in growing guar in Australia was renewed in 1999 when Lamberti s.p.a. an Italian chemical company sought to purchase guar grain from Australia. But despite a willing buyer Australia has been unable to produce reliable quantities of guar grain for a number of reasons

- Unrealistic expectations of the crop
- Unsuitable commercial seed stock; mixture of lines with marked differences in plant type and maturity that have complicated crop management decisions, in particular timing of harvesting and achieving good grain quality
- Poor seed quality and seed hygiene; low germination rates and weed contamination
- No registered chemicals for weed control
- Lack of access to agronomic advice
- No domestic facility for grain processing.

This research project was undertaken to evaluate 444 guar cultivars held at the ATCFGRC and to import and evaluate new material from India and the United States. Identification of a high yielding guar cultivar with a plant type suitable for grain production and its availability to growers through a certified seed scheme will be a first step in producing consistent supply of the guar product necessary to support a domestic industry.

The Guar Industry Development Association (GIDA) was formed by growers, advisors and industry stakeholders in 2002 to advance the establishment of a domestic guar industry. GIDA commissioned a value chain and market analysis of the Australian Guar Industry that was published by RIRDC in November 2004.

2 Objective

Outcome

To identify a new cultivar of guar with a grain yield higher than the current commercial variety (CP177) that is suitable for commercial dryland production in central and southern Queensland.

Research Strategy

1) Import advanced breeding lines from USA and India
2) Evaluate guar germplasm currently in Australia and new introductions in agronomic trials over years at 2-3 locations in central and southern Queensland
3) Analyse harvested seed from trials for galactomannan content

Communication Strategy

1) Publish Croplink pamphlet about marketing and agronomic management of guar
2) Organise farmer field days to facilitate information exchange about commercial guar production
3) Identify new guar cultivar and commercialise through Plant Breeders Rights

3 Methodology

3.1 Preliminary agronomic evaluation of guar cultivars

Four hundred and forty four guar cultivars from the Australian Tropical Crops and Forages Genetic Resource Collection (TCFGRC) were evaluated in a partially replicated trial planted at DPI&F Biloela Research Station in November 2001. Cultivars were assessed for field emergence, plant height, lodging resistance and yielding ability.

Cultivars identified in the 2001-02 trial that had a plant type suitable for grain production were grown in a fully replicated trial planted at Biloela Research Station in the 2002-03 season and assessed for field establishment, date of 50% flowering, plant height, plant growth habit, grain yield and grain quality.

Twenty-five new guar accessions were added to the ATCFGRC at Biloela since June 2001. Fourteen accessions from guar breeding programs in the United States and 4 landraces from India and Pakistan were evaluated in single row plots in the 2002-03 summer season. A further five landrace varieties were evaluated in small plots in 2004. Two grower-selections made from commercial seed stocks were added to the collection in 2001 and evaluated in replicated trials.

3.2 Identifying elite guar cultivars suited to commercial grain production

Twenty-three accessions of guar were planted in replicated trials in November and December 2003 at DPI&F Biloela, Kingaroy and Roma Research Stations. The Kingaroy trial at Jo Bjelke Peterson Research Station was destroyed by summer storms in January 2004.

Plots consisted of four rows and were 8 metres long by 2 metres wide. Trials plots were assessed for plant population, days to flowering, plant height, lodging resistance and plant growth habit. Grain yields were determined using a small plot mechanical header at crop maturity.

3.2.1 Biloela trial site

The Biloela trial was planted on 2 December 2003 (trial 1) into a dark, non-cracking clay soil, pH 8.0 with a full moisture profile (170 mm plant available water content) and 40 kgha-1 Starter-Z applied at sowing. Rainfall directly after sowing resulted in soil crusting and compromised crop emergence. The trial was replanted (18th December, trial 2) into an adjacent area of the same paddock and both trials were taken to completion. Biloela received average rainfall in the 2003-04 summer season, in-crop rainfall for trial 1 was 469mm and 264mm for trial 2. Due to dry conditions one in-crop irrigation was applied on 23 January using subsurface drip tape (run for 24 hours, equivalent to 50mm rainfall). Crop duration was 118 days (trial 1) and 103 days (trial 2). Grain yields are presented for both trial 1 and trial 2 but seed quality and agronomic data relates to trial 2.

3.2.2 Roma trial site

Roma Research Station was selected because of guaranteed access to water and the ability to manufacture a planting opportunity within the optimum planting window. The trial was planted on 18 November 2003 with 38 $kgha^{-1}$ Starter-Z applied at sowing. Soil was a brown vertosol, with a full moisture profile (120 mm plant available water content). Rainfall directly after sowing resulted in soil crusting and compromised crop emergence. One in-crop irrigation was applied on 31st December using overhead sprinklers (equivalent to 50mm rainfall). Crop duration was 108 days and the trial received 479mm of in-crop rainfall, above average for Roma. Waterlogging was evident following heavy summer rain in January.

3.3 Determination of galactomannan gum yields

Grain samples (5 grams) from promising entries in 2002-03 and 2003-04 trials were submitted for laboratory analysis of galactomannan content. Galactomannan content of grain was determined by enzyme assay. Analyses in 2002-03 were undertaken at University of Queensland using a protocol developed by Megazyme Intl Ltd. (http://www.megazyme.com/booklets/KGALM.pdf). Analyses in 2003-04 were conducted using a modification to this protocol from Lamberti s.p.a.

3.4 Communication Strategy

Two field days were held in conjunction with the Western Sustainable Farming Systems Project at DPI&F Biloela and Roma Research Stations in 2003. In addition the print and broadcast media were used to disseminate information to the farming community on results of guar research and guar's potential as a new summer dryland option.

A chapter on guar (Douglas & Routely 2004) was published in RIRDC's New Crop Industry Handbook in 2004 and a poster paper (Douglas and Lawrence 2004) was presented at the 2nd Australian New Crops Conference, University of Queensland Gatton Campus in September 2004.

The proposed Croplink pamphlet on guar marketing and agronomy was not produced. The project had too many consecutive milestones for a small 3-year project. Whilst elite guar cultivars have been identified it was not also possible to collate credible information on guar agronomy. A full value chain and market analysis of the Australian guar industry was completed in RIRDC project UQ-112A (Bryceson and Cover 2004).

4 Results and Discussion

4.1 Preliminary agronomic evaluation of guar cultivars

One hundred and four cultivars from the initial trial in 2001-02 were selected for further evaluation on visual assessment of agronomic performance. No seed was harvested from this trial due to reduced quality from wet conditions at the end of the season. Original seed of the 104 selected cultivars was re-planted at Ayr Research Station in north Queensland in a winter seed increase in April 2002.

Twenty-three of 104 cultivars in the 2002-03 trial were identified with plant-types suited to grain production and mechanical harvesting. Grain yields of up to 500kgha^{-1} were recovered from hand-harvested plots, no significant differences were found between cultivars with respect to grain yield.

Seed galactomannan contents in 2002-03 had a high degree of error due to variability across the trial and the laboratory protocol used. No conclusions on the gum content of individual guar cultivars were drawn from this trial.

Twenty-three cultivars imported from India and the United States evaluated in 2002-03 had forage plant types or low grain yields and were unsuitable for commercial grain production.

4.2 Identifying elite guar cultivars for commercial grain production

4.2.1 Biloela Research Station trials

There were significant differences in grain yields of guar cultivars in trial 1 at Biloela (p<0.001), HF223 (1360 kgha-1) was significantly higher yielding than other cultivars. Mean yield for trial 1 was 717 kgha^{-1}, Table 4.1. There were also significant differences in grain yield of cultivars in trial 2 (p<0.001), S47-2 (1298 kgha^{-1}) was higher yielding than HF-223 and the current commercial cultivar CP177. Yield range for trial 2 was 664 kgha^{-1} (cultivar Pardeshi) to 1298 kgha^{-1} (cultivar S47-2) mean yield was 994 kgha^{-1}. Across both Biloela trials cultivars HF223 and S47-2 were the two highest-ranking cultivars with mean grain yields of 1181 and 1158 kgha^{-1} respectively.

Significant differences in thousand seed weights (TSW) were found between cultivars (p<0.001). TSW ranged from 27.8 g (cultivar T64002-5-1-8-17-1-B) to 36.6 g (cultivar Q19929). Of five agronomically promising varieties selected for grain quality testing there were no significant differences in galactomannan content, Table 4.1.

There were significant differences between cultivars with respect to established plant population in trial 2 at Biloela (p<0.001). In particular 'CSIRO Selection 4' (5 plants m^{-2}) and 'Pardeshi' (6 plants m^{-2}) produced poor plant stands. Sowing rates for each cultivar were adjusted for seed viability and increased by a factor of 1.5 but guar cultivars still failed to establish at the target population of 30 plants per square metre. Hard-seededness (resulting in uneven germination) and the low rates of plant establishment in cultivars across this trial, and reported by farmers (Bryceson & Cover 2004) represents a major constraint to commercial production.

All cultivars in the trial flowered between 35 and 40 days after planting. Significant differences between cultivars in time taken to reach 50% maturity, plant height and standability (Table 4.2) had no relationship to grain yield.

Table 4.1 Summary of yield and seed quality in guar trials at Biloela Research Station 2003-04

Cultivar	Grain yield Biloela 1 trial ($kgha^{-1}$)	Grain yield Biloela 2 trial ($kgha^{-1}$)	Gum content (% dry wt)	1000 seed weight (g)	Mean yield ($kgha^{-1}$)
HF223	1360	1001	23.6	32.8	1181
S47-2	1017	1298	25.9	32.7	1158
T64001-30-1-3-2-B	807	1253	-	31.3	1030
S44-2-1-2-1	928	1072	-	33.4	1000
RGC471	661	1208	-	35.7	935
CP177 (Roma seln)	838	989	-	33.2	914
T64002-5-1-8-17-1-B	662	1164	-	27.8	913
T64002-6-1-2-B	572	1205	-	31.2	889
Q20023	567	1208	26.0	31.8	888
CSIRO seln 13	772	1000	-	31.7	886
Texsel (early)	666	1080	-	34.7	873
CSIRO seln 4	967	744	-	32.0	856
CP177	650	1052	27.0	33.2	851
CSIRO seln 33	845	830	-	32.6	838
AG111	642	1007	-	29.0	825
NC-70	592	996	28.0	28.5	794
Q19929	463	1056	-	36.6	760
Okla GL-7 texsel seln	601	884	-	30.5	743
MSS-2	518	936	-	30.9	727
Okla GL-6 texsel seln	586	845	-	28.9	716
Okla GL-5 texsel seln	564	850	-	29.5	707
Q19790	480	853	-	31.6	667
Pardeshi	610	664	-	31.3	637
Grand Mean	717	994	26.1	31.8	856
p	***	***	ns	***	
lsd	317	222	n/a	1.7	
cv	31.3	15.8	12.2	3.8	

*** $p<0.001$

Table 4.2 Summary of agronomic data in guar trial 2 at Biloela Research Station 2003-04

	Plant population (m^{-2})	**50% pods (days after sowing)**	**Degree of branching (1-5, 1=single stem)**	**Plant height (cm)**	**Standability (1-9, 1=erect)**
HF223	12	101	3.8	138	6.8
S47-2	11	100	3.5	126	4.0
T64001-30-1-3-2-B	11	103	3.5	113	4.3
S44-2-1-2-1	11	103	1.8	164	8.3
RGC471	13	102	3.3	130	6.0
CP177 (Roma seln)	13	99	2.0	156	7.8
T64002-5-1-8-17-1-B	11	99	4.0	110	6.8
T64002-6-1-2-B	12	104	4.0	113	4.8
Q20023	13	97	1.0	125	7.0
CSIRO seln 13	9	101	3.8	124	4.8
Texsel (early)	12	99	2.0	125	8.0
CSIRO seln 4	5	104	3.5	140	6.0
CP177	13	104	2.0	153	7.3
CSIRO seln 33	10	101	1.8	171	7.3
AG111	11	89	1.3	120	6.0
NC-70	12	91	1.0	121	7.5
Q19929	13	90	1.3	124	8.0
Okla GL-7 texsel seln	12	91	1.0	123	4.3
MSS-2	10	94	1.0	124	4.0
Okla GL-6 texsel seln	10	94	1.0	121	4.5
Okla GL-5 texsel seln	12	95	1.3	123	3.8
Q19790	9	101	2.8	126	6.3
Pardeshi	6	101	2.8	141	6.8
Grand Mean	11	98	2.3	131	6.1
p	***	***	***	***	***
lsd	3.1	5.8	0.65	13.5	1.5
cv	21.1	4.1	19.7	7.3	17.6

*** $p<0.001$

4.2.2 Roma Research Station trial

There were significant differences in grain yield and thousand seed weights between cultivars at Roma Research Station ($p<0.001$). No differences were found in relation to gum content of cultivars submitted for laboratory testing, Table 4.3.

Table 4.3 Summary of 2003-04 guar trials at Roma Research Station

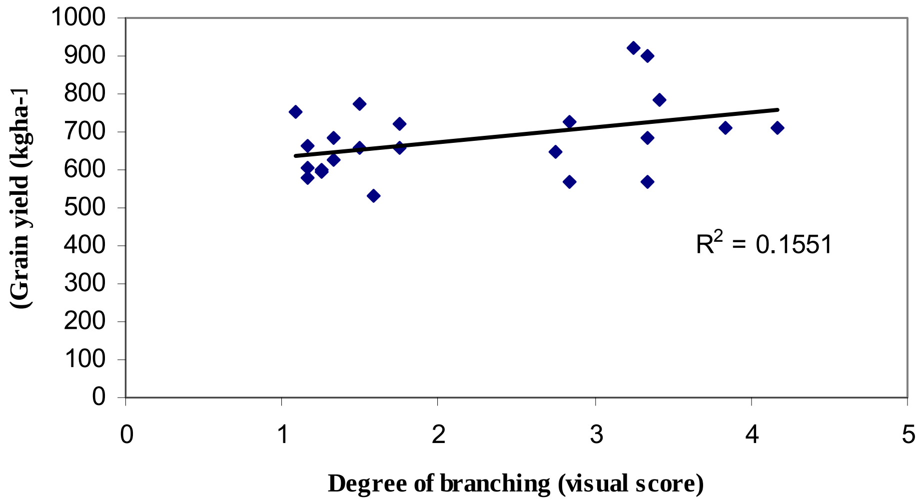
	Plant population (m^{-2})	Degree of branching (1-5)	Plant height (cm)	Standability (1-9)	1000 seed weight (g)	Grain yield ($kgha^{-1}$)	Gum content (% dry wt)
Q20023	19	1.3	79	7.0	28.5	489	23.5
NC-70	15	2.0	78	5.5	28.3	466	23.9
Okla GL-7 texsel seln	14	1.3	81	6.0	29.3	396	-
Okla GL-5 texsel seln	12	1.0	74	4.5	28.4	394	-
Okla GL-6 texsel seln	12	1.0	80	5.0	26.4	390	-
S47-2	16	3.0	81	6.5	28.5	387	22.2
Q19790	20	2.5	68	7.3	28.7	367	-
T64002-6-1-2-B	13	3.5	81	8.0	25.0	353	-
AG111	10	1.0	79	5.3	27.9	346	-
CP177 (Roma seln)	17	1.0	93	6.0	29.5	342	-
CSIRO seln 4	17	3.0	81	6.0	29.6	335	-
Pardeshi	14	1.0	71	6.3	29.1	327	-
S44-2-1-2-1	14	1.3	95	7.3	28.6	319	-
T64002-5-1-8-17-1-B	16	3.8	68	8.0	26.9	308	-
RGC471	19	2.0	89	7.3	31.5	306	-
CSIRO seln 13	16	2.5	101	7.8	28.5	303	-
T64001-30-1-3-2-B	17	3.3	79	7.5	26.2	293	-
MSS-2	11	1.0	81	5.8	30.6	291	-
CP177	16	1.3	89	6.8	29.0	279	20.1
CSIRO seln 33	14	2.8	79	7.0	26.5	274	-
Q19929	15	1.0	81	7.3	31.9	264	-
Texsel (early)	19	1.3	80	7.3	28.4	230	--
HF223	16	2.3	91	6.5	28.8	199	20.2
Grand Mean	15	2.0	82	6.6	28.5	327	22.0
p	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	ns
lsd	5.7	0.83	8.6	1.6	2.2	111.1	n/a
cv	26.3	30.4	7.5	17.5	5.4	24.1	14.1

Significant differences between cultivars for, plant height standability ($p<0.001$) and plant population ($p<0.05$) were present but did not indicate any clear ranking of cultivars for agronomic traits nor relate to grain yield. In general terms cultivars with a low degree of branching such as Q20023 and NC-70 ranked higher for grain yield at Roma than at Biloela. Cultivar S47-2, a standout at Biloela ranked 6^{th} at Roma but HF223 (highest ranking yield at Biloela) was the lowest ranking cultivar at Roma.

Plant populations in the Roma trial were compromised by pre-emergence rainfall, resulting in an uneven plant stand. Three hundred and twenty millimetres of rain fell during January and February 2004, water logging and premature leaf senescence was observed across the trial. Grain yields were severely affected and did not exceed 500 $kgha^{-1}$.

Anecdotal evidence and observations in previous trials had indicated there might be an agronomic and yield benefit to cultivars with non-branching habit. In Biloela and Roma trials branching was assessed on a visual score (1-5, where 1=single stemmed, 5=highly branching). Significant differences were found between cultivars for branching pattern ($p<0.001$) but there was no relationship between grain yield and branching pattern, Figure 4.1.

Figure 4.1 Grain yield in guar cultivars was independent of branching



5 Implications

The results from two trials at Biloela in a single season suggest that cultivars HF223 and S47-2 are high yielding lines with a strongly branching plant type and favourable agronomic characteristics. Trials at Biloela indicated a 30% yield advantage of HF223 and S47-2 over the currently available commercial guar cultivar CP177. At a crop value of \$300 t^{-1} the adoption of these newly identified cultivars would represent an increase in gross margin of \$90 ha^{-1} for guar producers. As no varietal differences were found for seed gum content the productivity of commercial crops will be determined by grain yield.

Grain yields of less than 500 $kgha^{-1}$ at Roma were well below potential, would not be considered viable in a commercial situation and underline the importance of paddock selection. Guar is known to prefer lighter, free draining soils; heavy soils where there is high a risk of waterlogging are not suitable for guar.

6 Recommendations

From the results of this research it is proposed that cultivars HF-223 and S47-2 should be recognised as replacements for the current commercial seed stock. Research trials conducted so far have used small plots and as a consequence worked on limited quantities of seed, typically less than 500 g. Original seed from the Australian Tropical Crops and Forages Genetic Resource Collection is currently being multiplied at Biloela and should yield 50 kg pure seed of each of the new cultivars by April 2005.

Further testing of HF-223 and S47-2 is planned for 2005 through the Western Sustainable Farming Systems Project (co-ordinated by Richard Routley, DPI&F Roma). On-farm testing over a wider range of environments and soil types is necessary to validate the performance of these new cultivars. In addition agronomic and farm-scale development trials are needed to investigate planting methods to improve crop emergence, determine optimum plant populations, and sowing dates for different locations in order to realise the potential of the newly identified cultivars. Herbicide tolerance studies and applications for off-label permits are also required.

Key stakeholders such as GIDA and industry partners Lamberti and AGP must develop a strategy for the multiplication, commercialisation and distribution of new cultivars. A quality assurance scheme such as seed certification will be essential in maintaining the integrity of pure seed and would need to address the concerns many previous guar growers have expressed about varietal purity and seed hygiene.

7 Appendices

Appendix 1 Guar accessions added to ATFGRC since June 2001

Name	Country	Breeding Status
Tx 76-3114	USA	cultivar
Tx 76-3285	USA	cultivar
Tx 76-2746	USA	cultivar
Tx 77-3347	USA	cultivar
Tx 78-3695	USA	cultivar
Tx 78-3337	USA	cultivar
Tx 79-2741	USA	cultivar
Lewis	USA	cultivar
Santa Cruz	USA	cultivar
Tx 78-3726	USA	breeding line
Tx 73-2731	USA	breeding line
Tx 71-3292	USA	breeding line
G-04	USA	breeding line
G-05	USA	breeding line
CP 177 (Roma seln.)	Australia	cultivar
Cedric seln.	Australia	cultivar
WKP-88-30	Pakistan	landrace
WKP-88-41	Pakistan	landrace
WKP-88-43	Pakistan	landrace
PI 542608	India	landrace
Lamberti 1		landrace
Lamberti 2		landrace
Lamberti 3		landrace
Lamberti 4		landrace
Lamberti 5		landrace

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