Barley Breeding in South Africa - Past and Future

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Abstract

The malting barley industry in South Africa is fairly young and small in comparison to industries in Australia and the rest of the world. Proper malting barley production only started around 1978 in the Southern Cape area and at its height reached an acreage of 135 000 ha. It has decreased to about 70 000 ha in the Southern Cape while 10 000 ha are cultivated in the irrigation areas of the Northern Cape.

Barley breeding for malting purposes started in 1976 and was conducted by the Agricultural Research Council and by the then known Sensako, a co-operative institute. The Sensako program was later sold to Monsanto and when they terminated all their barley research the South African Barley Breeding Institute was established as part of South African Breweries.

Financing for the programs mainly came, and still comes, from the producers and SA Breweries who have to pay a statutory levy on every ton of malting barley delivered or imported.

Since the start of the industry Clipper was the main cultivar and is still cultivated. Research showed that the Australian cultivars were fairly well adapted to the environment in the Southern Cape and the developing programs made good use of material from this origin to establish well-adapted varieties with good quality. European varieties are well adapted under irrigation.

An indication of progress with specific agronomic and quality characteristics in the SABBI program is given.

The future of malting barley breeding and the industry in South Africa are very much dependent on the development and successful cultivation of a variety with acceptable quality for SA Breweries, and the future financial support of the industry.

Keywords: South Africa; barley breeding; barley varieties

Barley Industry

The South African malting barley industry really got going with the introduction of the Australian variety, Clipper, in 1978 in the Southern Cape. As a result of this South African Breweries Ltd (SAB) decided to expand there malting capacity by building a malting plant at Caledon, one of the major towns in the Overberg area of the Southern Cape. A company, Southern Associated Maltsters (SAM), was formed as a joint venture between SAB (main shareholder) and the producers of the Southern Cape (preferential shareholders). The new malting plant, with a capacity of 34 000 tons malt, delivered its first piece in 1981. The capacity of the plant was enlarged in 1999 to 182 000 tons of malt and SAM now supplies approximately 80% of SAB's malt requirements. During 2006 SAM became the South African Breweries Maltings (SABM), a whole owned subsidiary of SABMiller.

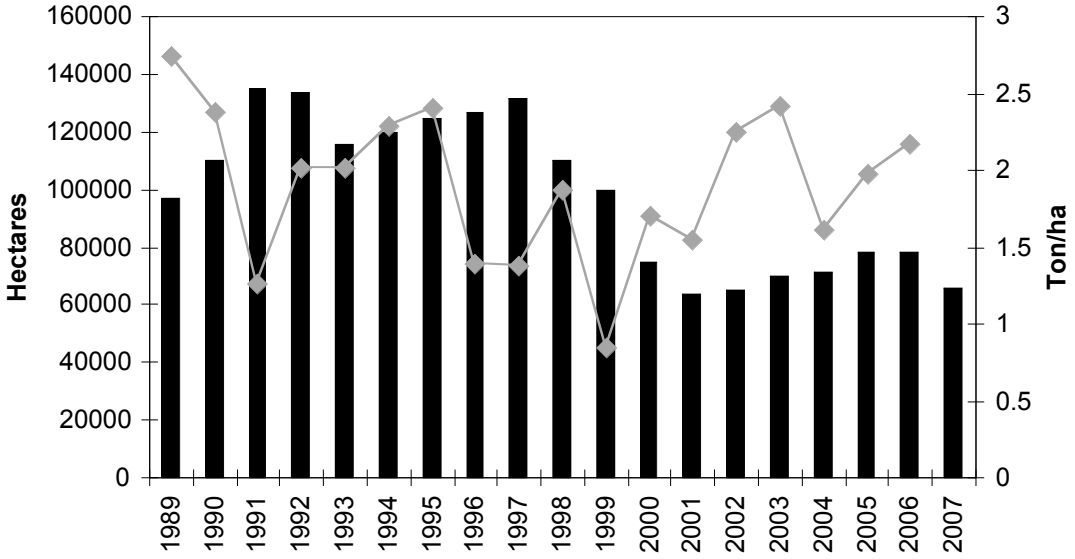
Previously there were only one malting plant in Johannesburg with a capacity of 40 000 tons malt and the production of malting barley was about 50 000 tons per year. Swanneck was the only variety and colour was the main barley quality criteria. The majority of malt had to be imported, usually of Klages or Triumph. Clipper was successfully cultivated and the hectares increased from around 30

000 hectares to a record of about 135 000 hectares in 1991. Quality evaluation also became more sophisticated.

The hectares under production plateaued from 1991 and in 1995 a record crop of 320 000 tons was realised. From 1997 production started decreasing to stabilise between 60 000 and 70 000 hectares (Figure 1). The decrease in hectares was mainly because SAB started to contract local malting barley to a maximum of 150 000 tons for this area, driven by a need for higher fermentable varieties that they had to import. The higher risk of producing barley with malting quality, in comparison to producing wheat with acceptable quality, and the non-existence of a viable feed barley market added to the decreasing popularity of barley as a crop.

The Southern Cape is a winter rainfall area with a Mediterranean type of climate and spring barley is produced under dry land conditions as a winter crop. The annual rainfall varies from 400mm to 500mm with between 45 and 70% of the precipitation during the growing season. Fairly low for the production of a crop, but the temperatures are mild and farming practices used tended more and more towards the preservation of moisture with the practice of minimum tillage increasing.

Figure 1: Hectares of malting barley planted and average yields from 1989 to 2007 in the Southern Cape region of South Africa



The long-term average yields vary from 2,2 tons/hectare in the western region to 1,7 tons/hectare in the eastern region of this area. Unfortunately the quantity and the quality of the crop produced can vary from year to year, due to the big fluctuation in weather conditions. In 1999, for example, the whole production area produced an average of only 0,85 tons/ha malting barley (mainly because of drought and rain during harvest time) in comparison to the average of 2,74 tons/ha in 1989. A bad crop can be the result of one or more of the following: low precipitation, high infestation of fungal diseases, insect damage, and strong winds or high rainfall during harvest time. In the eastern, drier areas, problems with low plumpness and high nitrogen during certain years are experienced, while the crop's quality is more stable towards the middle and western areas.

A second production area was developed in the irrigation areas of the Northern Cape after intensive evaluation on variety adaptability and production practices by SAM. Production started on a small scale in 1994 when Blenheim, a variety from the United Kingdom, was introduced. This expansion was mainly to secure a more stable supply of good malting quality barley to the malting plants. Yields are fairly stable with an average of 6,0 tons/hectare good quality barley over the last four years.

History of Breeding

The Agricultural Research Council (ARC) started a barley development program, situated at Stellenbosch, in 1976. From the start they had close links with programs in Europe, but also evaluate material from other parts of the world. The program's headquarters was later moved to Bethlehem in the Free State from where the program is still managed.

A second program was started by Sensako (a national co-operative providing seed to the grain industry) in 1978 as part of their Wheat Development program in the Southern Cape. Initially they only focused on the evaluation of local varieties and a few introductions from Australia. Introductions from all parts of the world followed, and the goal was to evaluate as many varieties as possible from abroad in order to find a variety or varieties, which could be successfully cultivated in South Africa.

Results from the two programs indicated that the majority of the introductions were agronomically not suitable for South African conditions. The Australian varieties seemed to be best adapted to our conditions, and following the success of Clipper, two other varieties, namely Stirling (released in 1987) and Schooner (released in a restricted production area in 1989), were released from the program of Sensako. The acreage of both these varieties, however, stayed low and both were discontinued after only about five years of production. Clipper is very well adapted over the whole barley producing area of the Southern Cape and is still in production.

In 1982 Sensako went into consultation with SAM and together they decided to start with a variety development program for the Southern Cape. Sensako ran the program with financial and technical support from SAM. Dr. Bart Lombard, who at that time was the head of Sensako's wheat program, made the first crosses in 1983 at the Experimental farm of the University of Stellenbosch. The material used in these crosses was Australian and European varieties as well as lines from CIMMYT.

In 1985 the program became independent when Sensako bought a 50 ha piece of land near Napier in the Southern Cape to start an experimental farm, which could serve as the centre for their malting barley development program. Facilities on the experimental farm were gradually developed and in 1995 the program was expanded with the introduction of doubled haploid breeding as a tool to shorten the development time for a new variety. A laboratory was build and came into full production in 1997.

In 1999 Sensako was taken over by Monsanto. For the barley program this dispensation only lasted two years, as at the end of 2001 Monsanto decided to end all its barley activities and they entered into talks with SAB on the transfer of the germ-plasm. An agreement was reached whereby all the germ-plasm and certain trial implements would be transferred to SAB in order for the program to continue. An Article 21 company (non-profitable company) was formed, and the program now continues under the name of the South African Barley Breeding Institute (SABBI).

Funding

From the start both development programs were supported by the industry. The Wheat Board, a statutory council, was established in the 1930's with the aim of stabilising the production and marketing of small grain in South Africa. They introduced a research levy payable by all producers of small grain. Funds collected from the barley producers were distributed by the Barley Committee of the Board to researchers on merit. Producers, the Wheat Board, the Department of Agriculture, SAB, SABM, the ARC, Sensako and Universities had representation on this committee. Producers were paid a fixed price for barley, and the levy was fairly moderate and comprised only of about 0,5 to 1% of the barley price.

Since the dismantling of the Wheat Board, and all the other statutory councils, in 1996, grain has been trading under a free market and all statutory levies were abolished. All the grain industries now had to apply to the Department of Agriculture if they wanted their statutory levy to be continued. All the role players in the small grain industry formed a Winter Cereal Trust (WCT). The WCT decided to apply for the continuation of statutory levies, which was granted, and that assured the availability of money for research.

Contributors to the programs, therefore, are:

Breeding programs: develop the research facilities and infrastructure, and supply expertise and technical support in the development and day-to-day running of the programs;

SAB Maltings: supply the expertise on quality requirements, collection of germ-plasm for quality, the infrastructure for grading and micro malting of material and financial support;

Producers: contributed to the programs through the statutory levy. Also involved in the agricultural evaluation of new varieties through the agricultural businesses and Co-ops.

SAB: pay the statutory levy on all imported barley and malt to ensure continuity of research in years of crop failure.

Classification Protocol

A national system for the final evaluation of breeding material from the two programs, called the Line Evaluation Program (LEP), exists since 1997. This program and the protocol for experimental and final classification is overseen by a committee, called the Barley Evaluation Committee. This committee consists of representatives of the Agricultural businesses and Co-ops, SABM, SAB, the producers and the breeding programs. They have drawn up a protocol for evaluation and classification by which lines are evaluated on certain agronomic and quality characteristics.

According to this protocol lines can be promoted to the LEP after they have been evaluated in the individual programs for at least two years. The committee will decide on which lines can be promoted. Lines then have to be evaluated for three years agronomically and be supported by two years' micro malting data from the specific production area, before it can be released as an experimental variety. Commercial evaluation then starts. Experimental varieties are planted by the producers and delivered to the agricultural businesses. SABM does an extensive malting evaluation and SAB evaluates the brewing potential of the experimental varieties for three successive years. For these evaluations they need 350 tons of grain in the first year, 1 000 tons in the second and 3 000 tons in the third year. During these three years the agricultural businesses and the breeders will evaluate the new varieties agronomically. If a variety is then acceptable for all the parties concerned, it will enter commercial production.

Breeding Strategy

Clipper is agronomically very well adapted to the environment of the Southern Cape, but it has certain shortcomings, namely limited malting quality (low extract, low fermentability, high beta-glucan and high viscosity) and lack of resistance to the main fungal diseases of this area. The breeding strategy in both programs, therefore, from the start focussed mainly on the improvement of fungal disease resistance and malting quality.

When the programs started the main fungal diseases in the Southern Cape were scald (*Rhynchosporium secalis*) and leaf rust (*Puccinia hordei*). Scald became insignificant as the infestation by net blotch (*Pyrenophora* complex) rocketed in the middle nineties. At the moment the spot form of net blotch (*Pyrenophora teres* f. *maculata*) as well as the net form (*Pyrenophora teres* f. *teres*) are causing major problems and the infestation levels become higher each year. Spot blotch

(*Bipolaris sorokiniana*) is also becoming an issue with some of the new experimental varieties. Thousands of rands are spent each year by producers just to secure a good quality crop. Old chemical formulations aren't very effective any more and new formulations, at much higher prices, have to be used at the moment.

Malting and brewing quality, of course, was the other major issue in the breeding programs. The required quality is decided by SAB, because they are the only buyer of malt in South Africa. The wanted quality is very much dependent on the preferences of the beer drinking population for specific brands. From 1985 to about 1997 we were striving to move closer to the European type of quality in our varieties. Because of a change in the brand preferences in South Africa, resulting in increased adjunct brewing, we now have to focus more on high fermentable varieties. This change asked for a major change in strategy and use of germ-plasm.

Since 2005 SAB divides the malt into two specific quality categories, namely Type A and Type B. Type A represents malt with high fermentability (Harrington/Metcalfe) and Type B the traditional European type of malt.

In Sensako's program the initial selection for quality was based on an index value where the major characteristics were extract, FAN/TSN, DP, alpha amylase, viscosity and homogeneity. Main emphasis, though, was on extract by doubling its index value. Later we started selecting lines looking at minimum values for specific individual characteristics and superiority in a few important ones. The more important characteristics we are currently selecting for are DP, AAL, Viscosity, beta glucan and FAN. At the moment fermentability is the key word in malting quality and our main aim is to develop a Type A variety for both production areas. The problem is how to measure it and which malting characteristics, measurable at micro malting level, would give you a good indication of fermentability.

On the agronomic side the main focus was on improvement of yield potential, improved plumpness under dry conditions, moderate nitrogen levels and resistance to lodging.

Progress with Breeding

Southern Cape

In the Southern Cape five varieties have been released to date - all of them from the program of SABBI (Table 1). SSG 525 in 1996 for the southern region, SSG 532 in 1998, SSG 564 in 2003, SSG

Table 1: Varieties released in the Southern Cape

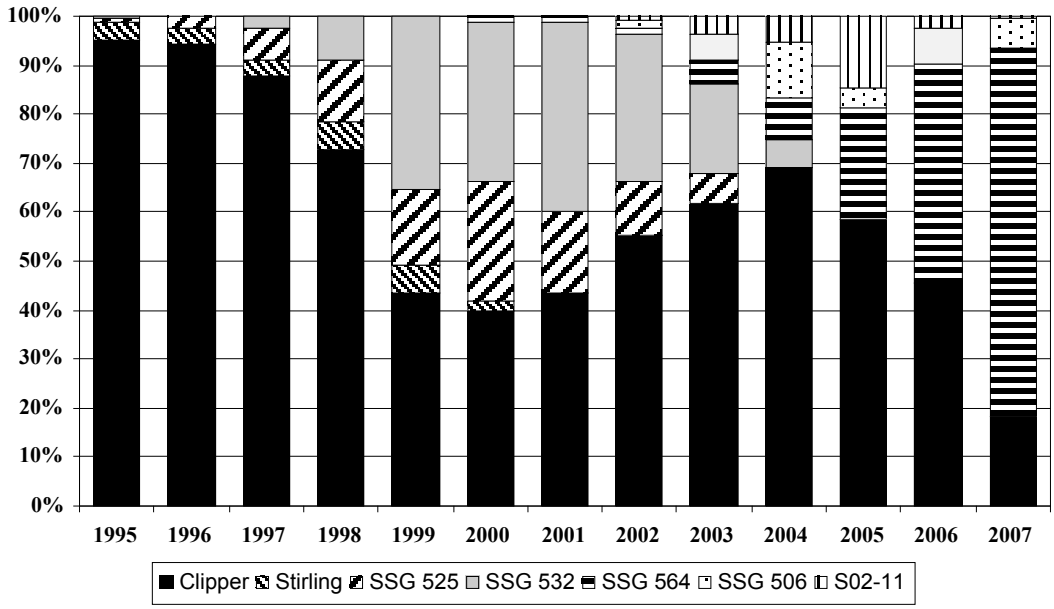
Cultivar	Year experimental release	Year of final release	History (as in 2007)
SSG 522	1992	-	Withdrawn before final release
SSG 525	1992	1996	Phased out in 2003
SSG 532	1993	1998	Phased out in 2004
SSG 564	1996	2005	In production
SSG 575	1997	-	Withdrawn before final release
SSG 585	1998	-	Withdrawn before final release
SSG 506	2000	2006	In production
S02-11	2002	2006	In production
S04-11	2004		Experimental Year 3
S04-16	2004		Experimental Year 3
S5	2005		Experimental Year 1
S6	2006		Seed multiplication
S7	2007		Seed multiplication

506 and S02-11 in 2005. SSG 525 was phased out in 2003 and SSG 532 in 2004. Five varieties from SABBI's program, S04-11, S04-16, S5, S6 and S7, are currently on the list of experimental varieties and are in different stages of agronomic and/or malting and brewing evaluation.

As mentioned, Clipper is agronomically very well adapted in this environment. Some of the new varieties have threatened to replace Clipper, but mostly as a result of changes that occurred in the composition of specific fungal pathogen populations in the area, had to be withdrawn. Figure 2 gives an indication of the percentage of hectares planted for each variety from 1995 to 2007.

The first varieties to be introduced in the Southern Cape had very good scald resistance. Once they had been introduced a major shift in the occurrence of barley diseases occurred. The result was a shift in focus, present mainly on the net and spot forms of net blotch and spot blotch.

Figure 2: Percentage of each variety planted in the Southern Cape from 1995 to 2007



Germ-plasm with good resistance against these diseases is not readily available. At present SABBI are evaluating a few lines from Australia and some lines that have already been evaluated are used as donor germ-plasm. Progress is slow and the harshness and variability of the environment just adds to the complication in this regard. In an attempt to speed up progress, a new project with the University of Southern Queensland has been initiated.

Initially we also had fairly good success with the introduction of leaf rust resistance. Most of the new experimental varieties introduced in the middle nineties reflected good resistance, but within one year most of the resistance collapsed. According to our latest information only three known resistant genes are still effective, namely Rph3, Rph7 and Rph11.

Progress with agronomic traits is visible. All the new varieties have excellent resistance to lodging, while steady progress is found in characteristics like yield potential and plumpness stability.

Performance of the new varieties in comparison to Clipper (Table 2) shows that we are making progress in certain characteristics. The following trends are visible:

- a significant increase in yield especially with the new experimental varieties;
- more stable plumpness in extreme environmental conditions evident in the new varieties;
- diastatic power (DP) showing a slight increase since the first varieties were released;

- progress made in the levels of AAL;
- Beta-glucan of all the varieties much lower than that of Clipper;
- proteolytic modification similar to Clipper.

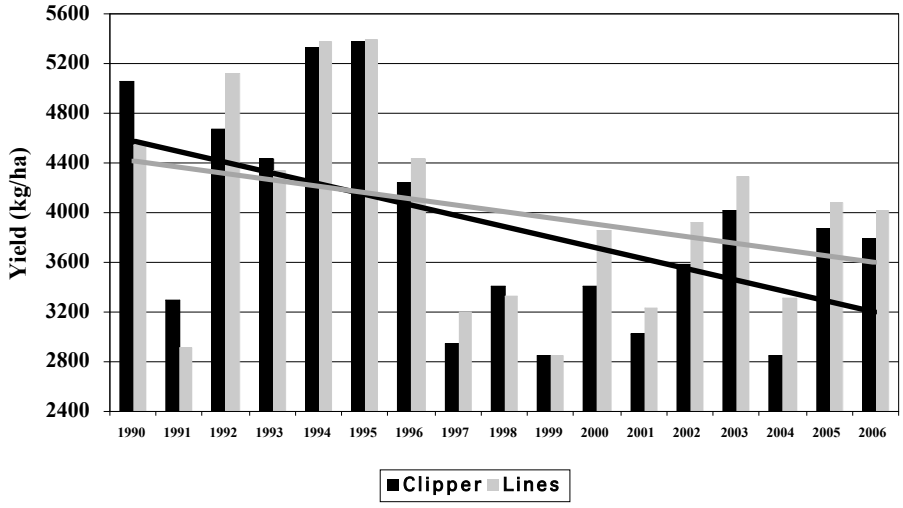
Table 2: Average performance of all the varieties in the trials for some important characteristics as a percentage deviation from Clipper.

Varieties	Yield	Plumpn	TN	Extract	KI	FAN	DP	Visc	AAL	BGluc
SSG 525	+2.3	+2.8	-0.9	+0.3	-7.3		+2.2	-0.4		
SSG 532	+10.1	+5.8	+5.1	+0.6	-1.5		+20.7	-3.5		
SSG 564	+2.8	+2.5	+0.3	+0.2	+2.8	+6.3	+35.9	-2.1	+2.6	-46.0
SSG 506	0.0	+14.8	+0.6	+1.2	+2.8	+3.6	+29.0	-1.9	+3.7	-23.3
S02-11	+9.1	+6.5	+0.4	+2.6	+7.7	+5.1	+31.5	-2.3	+3.2	-67.5
S04-11	+15.8	+5.4	-0.1	+1.6	+3.6	+3.7	+19.3	-1.2	+1.3	-43.6
S04-16	+15.1	+5.3	-1.4	+0.8	+5.4	+6.7	+36.1	-1.5	+2.9	-45.8
S5	+10.3	+7.7	-1.4	+1.2	+6.4	+15.7	+36.3	-3.2	+3.6	-60.9
S6	+11.8	+5.0	-8.2	+0.8	-12.2	-25.6	+28.8	-1.0	+0.8	-36.8
S7	+13.7	+8.2	-4.9	+2.4	-1.1	-8.2	+42.4	-0.7	+3.6	-10.6

A big step forward was taken when SSG 564 was accepted by SAB as a Type A variety. The preliminary malting and brewing results of the new experimental varieties also look promising.

To measure progress for individual traits in the SABBI program, and see if we are shifting the genetic make up of our germ-plasm in the right direction, the average of all the new breeding lines in the LEP trial for a specific trait in a specific year is plotted on a graph against the performance of Clipper in the trial (Figures 3 to 5).

Figure 3: Yield performance of Clipper vs. all new lines in the LEP trial of the Southern Cape (Regression lines: black = Clipper; grey = lines)



For the last six years the average yield of all the lines in the experimental field trials (LEP) has been significantly higher than that of Clipper (T0.05). The regression lines show that genetic progress has been made with this characteristic, as in 1995 the breeding lines' line passed Clipper's and the gap seems to get bigger.

Two quality graphs are given below as an example to show the progress in this area.

Figure 4: Diastatic power performance of Clipper vs. all new lines in the LEP trial of the Southern Cape (Regression lines: black = Clipper; grey = lines)

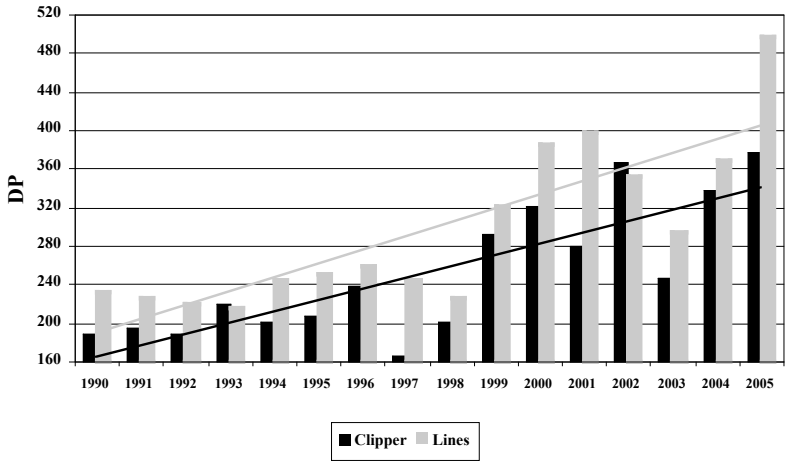
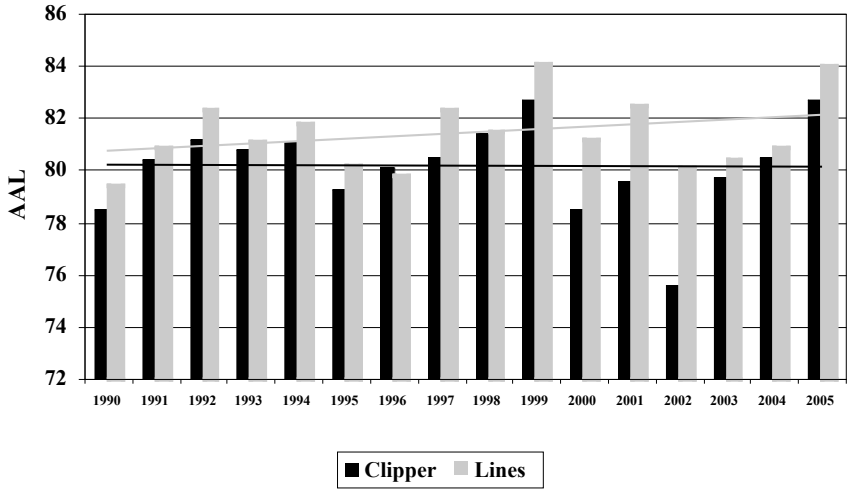


Figure 5: AAL performance of Clipper vs. all new lines in the LEP trial of the Southern Cape (Regression lines: black = Clipper; grey = lines)



Since 1997 the focus in our malting and brewing quality breeding was firstly on higher DP and AAL values and then lower beta-glucan while monitoring our FAN values. Although small progress was made with DP the average of the breeding lines was always higher than that of Clipper. Selection for DP and AAL also reflected in higher extract, slightly lower viscosity and similar FAN values to Clipper.

Northern Cape Irrigation

The European varieties seemed to be very well adapted in the irrigation area. Until now it was mainly European varieties that were cultivated, but in 2003 an introduction, introduced by the ARC, was released and is still dominating production (Table 3). A locally developed variety, SSG 585 of SABBI, was released in 2006. Evaluation of varieties from Europe is still an integral part of the program in this area and Cocktail is now in the experimental phase of evaluation.

Table 3: Varieties released under irrigation in the Northern Cape

Cultivar	Year experimental release	Year of final release	History (as in 2007)
Blenheim		1994	Phased out in1999
Chariot	1997	1999	Phased out in 2004
Puma	2000	2003	In production
SSG 585	2002	2006	In production
Cocktail	2007		Experimental Year 1

Criteria for selection here is mainly yield potential, nitrogen level, resistance to lodging and malting and brewing quality.

Acceleration in SABBI Program

From the start breeding was done and programs modelled and developed on the traditional breeding protocol. In an effort to accelerate progress and success Sensako introduced the method of doubled haploid breeding in 1995. A laboratory was built at the experimental station at Napier and it started developing doubled haploids for the wheat and barley programs of Sensako (later Monsanto). This program was very successful and most of the varieties released since the 2000's were doubled haploids.

When the breeding program was transferred from Monsanto to SAB the laboratory continued producing DH's for the new company, SABBI, under contract. This agreement, however, terminated last year and SABBI decided to proceed with the development of DH's in its own laboratory, which will be operational in 2008.

Since the pressure to develop new varieties with Type A quality is very high, SABBI also decided to investigate the probability of expanding the program to include marker assisted selection (MAS), especially for certain quality characteristics. A private laboratory was earmarked to do this. Our focus is on markers for increasing Alpha- and Beta-amylase activity, higher DP levels and increasing Beta-amylase thermostability. At the moment we are validating their use with our germ plasm. Through a joint project with the University of Southern Queensland we also hope to establish a sound pathological and host resistance basis to breed barley varieties resistant to *Pyrenophora teres* f. *teres* and *Bipolaris sorokiniana.* This will be supplemented with the identification of informative DNA markers and the implementation of MAS.

The Future

The barley industry in South Africa is very small, in fact so small that it barely justifies a breeding program. At the moment there are two.

The important role players in the industry discussed this matter and decided that, given our unique environment, we can't be dependent on introductions to keep the industry viable in future. We need at least one breeding program. Since then efforts have been made to integrate the breeding programs of the ARC and SABBI. Until now very little progress has been made, but we are still in conversation with one another to see if one national program for South Africa can be developed.

The future of barley breeding will be very much dependent on support from the industry. During the days of regulation a statutory levy was in place. Since deregulation it became the choice of the industry whether to have the same type of levy. All the role players in the barley industry came to a consensus that for the moment this will be the best way to move forward, and a statutory levy is therefore still payable by the producer as well as importers of malting barley and malt. This secured the status of the breeding programs. This levy, however, is up for reconsideration every four years. When one of the role players decides to withdraw from it, this method of income for research can fall away and leave the breeding programs with a dilemma.

The survival of the industry is very much dependent on the development of varieties with the right quality attributes. If we can supply the brewers with the type of quality required with local malt, less will be imported, and an expansion in the local industry will become a reality. This will give the breeding programs also a more viable and secure future.

Supplementary income will become a future focus for the programs and for this objective exporting seed and maybe varieties into Africa is a possibility. The African market is becoming more open and viable and focus should be on expanding in this direction.

Acknowledgment

From the start of Sensako's program we received a lot of goodwill and support from various people and institutions, especially in Australia. I specially want to thank:

- Dr. Roger Boyd for his loyal support, expertise and friendship through the years;
- Christy Grime at the UWA;
- The programs of the Dept of Agriculture WA (Dr. Reg Lance), University of Adelaide (Drs. Jason Eglington and Andy Barr) and VIDA Victoria (Dr. David Moody);
- Drs. Jerry Franckowiak and Greg Platz