RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Hemp and Other Natural Fibres

Today and Tomorrow

A report for the Rural Industries Research and Development Corporation

by Carolyn Ditchfield
Australian Hemp Resource and Manufacture

November 1999

RIRDC Publication No 99/119
RIRDC Project No TA989-04

ISBN 0 642 57977 6
ISSN 1440-6845

Hemp and Other Natural Fibres – Today and Tomorrow
Publication no. 99/119
Project no. TA989-04

Researcher Contact Details
Carolyn Ditchfield
Australian Hemp Resource and Manufacture

Phone: 07 3369 5925
Fax: 07 3368 1255
Email: pwalmsley@agric.wa.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

Published in November 1999
Printed on environmentally friendly paper by Canprint

TRAVEL REPORT

PRESENTED TO THE
RURAL INDUSTRIES RESEARCH AND DEVELOPMENT CORPORATION

This report covers a trip taken by Carolyn Ditchfield, of Australian Hemp Resource and Manufacture, to the Bast Fibrous Plants Today and Tomorrow – Breeding, Molecular Biology and Biotechnology Beyond 21st Century Symposium, St Petersburg between 28-30 September 1998. The intention of the trip was to present a paper with preliminary results of the world's first tropical/sub-tropical hemp breeding program, and to gain further insight into new developments occurring in the bast fibre industry in general.

Carolyn Ditchfield
Australian Hemp Resource and Manufacture
Brisbane, January 1999

TRAVEL REPORT

Primary Purpose
To present a paper at the Bast Fibrous Plants Today and Tomorrow – Breeding, Molecular Biology and Biotechnology Beyond 21st Century Symposium in St Petersburg, and to discuss new directions being taken in the bast fibre industry worldwide.

Report Summary
The paper "Discovering the Characteristics of Tropical/Sub-Tropical Hemp Cultivars", presented by Carolyn Ditchfield, outlined the progress being made in the world's first tropical/sub-tropical hemp breeding program. Interest generated by this paper resulted in offers of future collaboration with other breeding institutions around the world, and/or access to hemp germplasm that could enhance the existing program. Interestingly, some members of the audience had come specifically for information on tropical bast fibre crop production for use in their respective countries.

Twenty two countries were represented ranging from Finland to Egypt and China. Although papers directly related to flax breeding in Europe tended to dominate the symposium, interesting trends emerged about the direction and technology being employed to improve fibre crops in general that could be applied to the development of industrial hemp varieties. For example:

1) interest in fibre crops is increasing due to the impact of new environmental legislation being enforced throughout most of Europe. The market for recyclable, biodegradable and organic raw material for an expanding range of end-products continues to grow. In response, many countries are either expanding or re establishing their fibre crop industries to meet this demand;

2) fibre quality is an important crop parameter. New techniques for identifying, measuring and selecting a range of crop characteristics are continually being sought and implemented;

3) exploration of wild types and landraces suited to specific geographical conditions continues to dominate most fibre breeding programs. One fibre variety will perform very differently in different locations, therefore most countries are dedicating substantial resources to developing their own breeding programs, rather than simply importing established varieties;

4) in a few instances some breeding programs have felt that there is justification for investing substantial resources into exploring the use of biotechnical tools to enhance their fibre crop performances.

All the countries represented at this symposium view the future of fibre crops optimistically. In each case, their domestic fibre industry is backed up by breeding programs designed to improve crop performance for their particular geographical conditions. Australia has its own unique climatic conditions, and for a fibre crop industry to flourish it will also need to develop its own breeding program to develop fibre varieties that can compete on the international market.

Major Findings

Although this symposium tended to focus more on flax production, it should be noted that many of the issues raised during the symposium can also be applied to hemp production as both crops can be grown for fibre and/or oil for use in similar markets, and both have similar production and quality problems to overcome.

Expanding Natural Fibre Markets

Global trends

Many of the presentations highlighted emerging global and national trends that are expected to positively influence the bast fibre industry into the future.

The largest influence on all global markets is the predicted growth in world population from 5.6 billion currently to 11.5 billion by 2050, and it has been predicted that there will be a corresponding increase in the demand for fibre (cellulosic, cotton, wool, man-made, others) from approx. 50 million tonnes per year to 130 million tonnes per year by 2050. At present cotton dominates the fibre industry, but it has been suggested that cotton production cannot be doubled to meet this future demand due to water and pesticide consumption, and climactic limitations. A similar scenario is with in the pulp industry where regrowth of trees is unlikely to match future demand. Natural fibres may well help fill this large future short gap in supply.

There is also a strong trend in the marketplace towards natural fibres for some of the following reasons: social safety; urgent need for economic growth in rural areas; future fibre demands; the role of renewable, sustainable materials as sources for recycled polymers; environmental safety of air, water, soil and forests, pollution abatement; and greenhouse gas concerns.

Concern for the environment has also lead to a number of national initiatives that favour the use of natural fibres. Regulations on waste disposal and land fill taxes sweeping Europe are making indestructible and highly persistent packaging and materials very undesirable, and in Germany taxes have been placed on plastic products to balance their cost of disposal.

In response to such initiatives, the German Federal and State ministries have injected 100 million DM into many research institutes and industrial sector groups to determine the potential of using renewable resources as substitutes for non-renewable materials. These projects have resulted in the development of a wide range of innovative new natural fibre-based products that range from aerospace materials to a wide range of building materials.

France has recently dropped its tax on rape/canola oil to make these products competitive in price with petrol. This may lead to the opening up of markets for other natural oils for use as fuels, including hempseed and flaxseed oil.

China is seriously considering substituting the use of trees with bast fibre crops as part of their National Policy, especially in light of their recent floods that have been partly blamed on the loss of trees upstream.

Others are also viewing bast fibre crops as a means towards improving the living standards in developing countries by providing fibre for clothing and building, as well as food in the case of flax and hemp. In contrast, developed countries are viewing bast fibre crops as an economic solution to the overproduction of food on their land, rather than continuing to deploy unproductive “set aside” land.

Why It's Good Business

Bast fibres can contribute to a wide range of industries including agriculture, processing (fibre treatment, oil), machinery, manufacturing (auto, ship, air, building, textiles, paper, food), fuel, wholesale and retail.

One of the biggest markets for raw material is cellulose, which is expected to grow from 270 million tonnes per year now, to more than 480 million tonnes per year by 2010. Bast fibres are a rich source of cellulose with a great potential for future expansion.

It was pointed out that bast fibres used as mere substitutions for other fibres will be susceptible to price squeezes unless some unique characteristic gave it additional benefits. Therefore new products or high-valued products have the most potential of taking advantage of the burgeoning bast fibre industry. Some of these markets could include renewable building materials, geotextiles, biodegradable fibres as opposed to fibreglass fibres, packaging, algal decontaminants in water, amenity mulches, dental fillers, as filters or carriers of other active molecules, for absorption or adsorption. But most importantly, all the co-products of the plant need to be considered e.g. fibre, core, seed, and oil.

Some of these emerging markets are being found in the car industry:

> *"Mercedes and Volvo are planning to produce cars that are completely recyclable. Ford has announced plans to phase out the use of fiberglass by the year 2000……… Chrysler…….their policy is to build cars with completely recyclable interiors by the year 2000".*
>
> Lloyd, E. & Bowden, M. (1997) Integrated commercial production and processing of kenaf in Arizona. Proc. Flax & other bast fibres plants symposium pp.35-40.

There is also a flax/resin-based material being developed at the Aviation Research Centre, Braunschweig, Germany that is being viewed as the future for biodegradable material in airspace vehicles.

Geotexiles is one market that is experiencing a growth rate of 18% per annum (the highest growth category) in Eastern Europe, Africa and Asia where bast fibres are making a large impact.

Both flax and hemp produce nutritious seed oil especially high in essential fatty acids that are vital for good human health. The market for hempseed oil is expanding rapidly due to its exceptional fatty acid ratio, which includes rare fatty acids (GLA and SDA), and has high levels of globular proteins that contain all the essential amino acids needed for optimal health and its taste is more palatable than flax.

Identification and Measurement of Plant and Fibre Characteristics

Natural bast fibres tend to be relatively non uniform in consistency due to individual plant variations, geographical differences in climate, soil, disease etc., as well as differences in processing batches within and between mills. To access established efficient fibre-based markets, fibre needs to be as homogeneous and pure, and often, as fine as possible. Therefore a quality control or standardisation process must support the production and breeding of bast fibre.

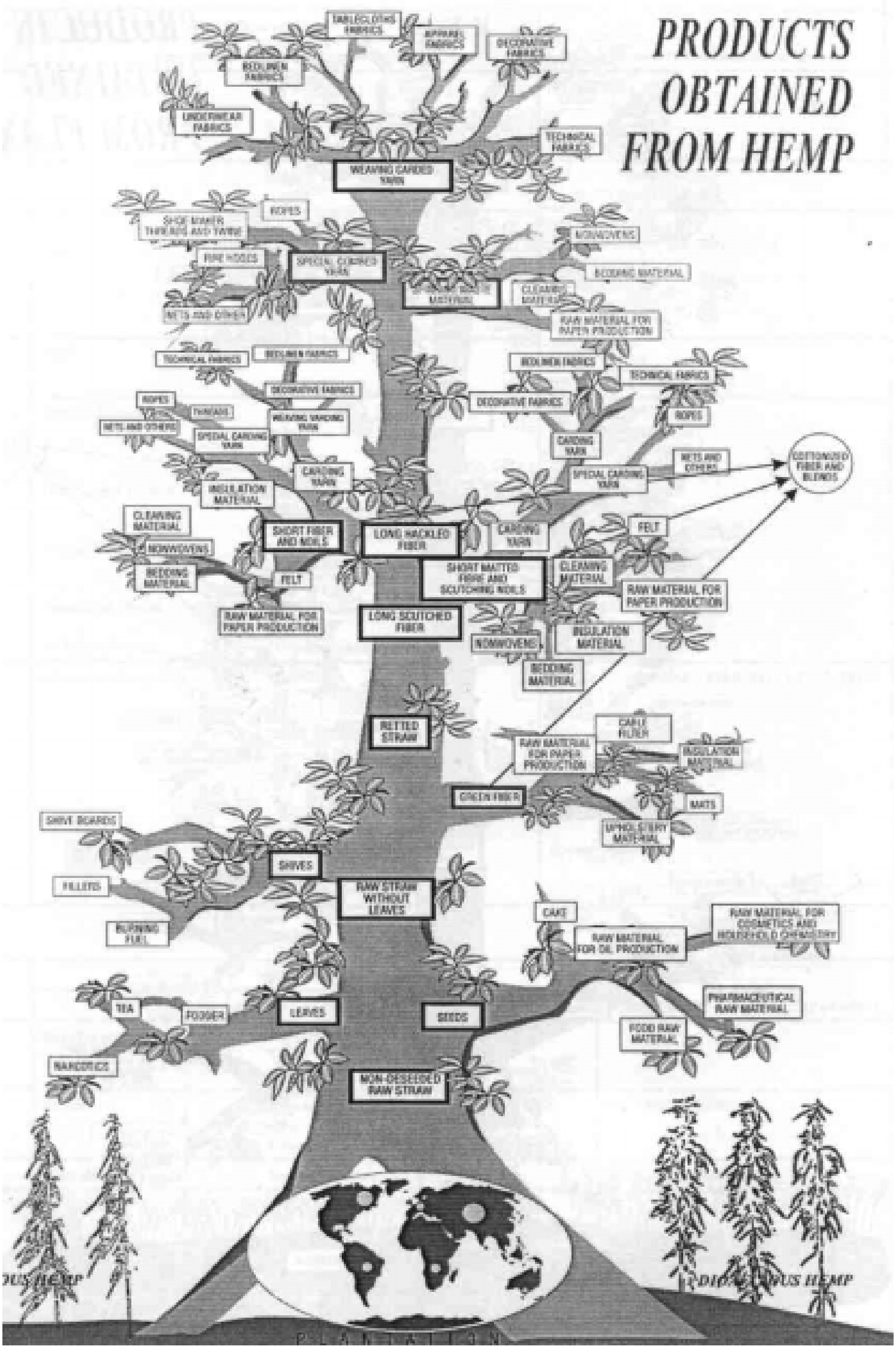
To be effective across the whole industry, this quality or standardisation process must be universally accessible and acceptable. It needs to take account of all the critical stages of production and processing where plant and fibre quality can be improved, as well as being able to accurately characterise and classify each fibre lot in relation to its end-use.

One such system has been devised in Poland (e.g. hemp below by Wasko et al)

Classification of hemp products obtained in technological processes

Name of Process	Product Name *Raw Material*	*Derivative Products*	Standard No.
Breeding Cultivation	Seeds	For sowing Technical Foodstuffs, pharmaceutical, household Chemicals	PN-R-65023:1978
Retting	Straw	Raw Retted	BN-76/7511-08 BN-76/7511-09
Breaking Scutching Hackling Carding	Fibre	Long hackled Long scutched Long teamed Short, matted scutched waste fibre Noils Green	BN-76/7522-03 BN-76/7522-03 BN-76/7522-05 BN-76/7522-04 BN-76/7522-04 BN-70/7511-12
Spinning	Yarn	Raw Carding	BN-85/7521-01 BN-86/7521-09
Wearing Improvement	Apparel fabrics Tablecloth fabrics Household fabrics Decorative fabrics Technical fabrics	Apparel Shirt Skirt Tablecloth Dishcloth Towel Sheet Curtain and other Deck chair and other	PN-P-82450.05:1986 PN-P-82450.02:1986 PN-P-82450.06:1986 PN-P-82450-9:1996 PN-P-82450.10:1986 PN-P-82450.03:1986 PN-P-82450-4:1996 PN-P-82450-7:1996 PN-P-82450.08:1986
Twisting, Knitting	Other technical Products	Threads Ropes Twines Fire hoses Binder string Nets and others	PN-P-81101/01:1990 PN-P-85013:1990 PN-P-85019:1988 PN-M-51151:1987 BN-64/7596-05 PN-ISO 1805:1994
By-Products			
De-seeding	Panicles & Leaves	Narcotics Tea Fodder	
Breaking	Shives	Raw material for particleboards Fuel Fillers	PN-P-80102:1996
Cottonisation	Short fibres	Cottonised fibre	ZN-67/MPL-05-032

This system requires knowledge of the possible products that can be derived from the hemp (or flax) plant. A diagrammatic “tree” has been devised by researchers in Poland to help understand the correlation between the plant and eventual end-products (see below).


PRODUCTS OBTAINED FROM HEMP
TABLECLOTHS FABRICS
APPAREL FABRICS
DECORATIVE FABRICS
BEDLINEN FABRICS
UNDERWEAR FABRICS
TECHNICAL FABRICS
WEAVING CARDED YARN
ROPES
SHOE MAKER THREADS AND TWINE
NONWOVENS
FIRE HOSES
SPECIAL COMBED YARN
BEDDING MATERIAL
CLEANING MATERIAL
NETS AND OTHERS
RAW MATERIAL FOR PAPER PRODUCTION
TECHNICAL FABRICS
BEDLINEN FABRICS
BEDLINEN FABRICS
TECHNICAL FABRICS
DECORATIVE FABRICS
DECORATIVE FABRICS
ROPES
THREADS
WEAVING CARDING YARN
ROPES
NETS AND OTHERS
SPECIAL CARDING YARN
CARDING YARN
NETS AND OTHERS
COTTONIZED FIBER AND BLENDS
CARDING YARN
SPECIAL CARDING YARN
INSULATION MATERIAL
CLEANING MATERIAL
SHORT FIBER AND NOILS
LONG HACKLED FIBER
CARDING YARN
FELT
NONWOVENS
SHORT MATTED FIBRE AND SCUTCHING NOILS
CLEANING MATERIAL
BEDDING MATERIAL
FELT
RAW MATERIAL FOR PAPER PRODUCTION
RAW MATERIAL FOR PAPER PRODUCTION
LONG SCUTCHED FIBER
NONWOVENS
INSULATION MATERIAL
BEDDING MATERIAL
RETTED STRAW
CABLE FILTER
RAW MATERIAL FOR PAPER PRODUCTION
INSULATION MATERIAL
GREEN FIBER
MATS
UPHOLSTERY MATERIAL
SHIVE BOARDS
SHIVES
FILLERS
RAW STRAW WITHOUT LEAVES
BURNING FUEL
CAKE
RAW MATERIAL FOR COSMETICS AND HOUSEHOLD CHEMISTRY
RAW MATERIAL FOR OIL PRODUCTION
TEA
FODDER
LEAVES
SEEDS
PHARMACEUTICAL RAW MATERIAL
FOOD RAW MATERIAL
NARCOTICS
NON-DESEEDED RAW STRAW
PLANTATION

For such a system to be effective though, the fibre needs to be measured accurately using standard testing procedures. Tubach & Kessler, Germany suggested the following methods:

Straw		Refined Short Fibres	
Variable	***Method***	***Variable***	***Method***
Maturity	Image analysis	Impurities	Trash Analyser, NIR
Retting Degree	Image analysis, spectroscopy	Strength diff. grip distances	Instron
Lignin, Pectin	Chemical test, spectroscopy	Length (-distribution)	Almeter, image analysis
Decortication resistance	Laboratory decortication unit	Fineness (CV)	Image anal., AVIS, Airflow
Homogeneity	Image analysis	Chemical composition	Spectroscopy
Straw/ha, fibre yield/ha	weight		

In Lithuania, after the fibre has been soaked, broken and hackled, its flexibility is measured using a G-2 machine, and its strength and fineness measured by a dynamometer DKV-60. In Russia, they use light analysis equipment to compare fibre colour, giving what they claim to be an objective correlation for fibre quality.

It became clear towards the end of the symposium that a comprehensive uniform quality system remains disparate, though efforts are being made to coordinate the protocols between countries.

Important Characteristics/Quality Parameters

The following is a summation of the characteristics that are being measured and quantified in breeding programs across Europe.

Important Plant Characteristics for Flax

Height	Flowering date	Stamen filament colour	Rust resistance
Stem length	Flower size	Boll type	Resistance to fusariose
Fibre ratio	Petal colour	Boll size	Resistance to scorch
Fibre yield	Petal longitud. folding	Boll cilliation of septa	Resistance to lodging
Vegetation period	Anther colour	Weight per 1000 seeds	
Seed yield	Style colour	Seed colour	
Oil yield	Sepal dotting	Linolenic acid content	

Important Fibre Characteristics for Flax

Strength	Flexibility
Fineness	Spinnability
Durability	Elementary fibre structure
Phloem fascicle structure	Coefficient of fibre diameter to stem cross section
Number of bundles per section	Number of fibres per bundle
Length and width of elementary fibre cells	

Generally speaking the longer and thinner the filaments the higher its quality for use in textiles. Often these measures are compared with a standard filament.

Some quality relationships that were observed in flax include:

- Long storage of seed leads to a downgrading of fibre quality;
- Light weight, black coloured flax seed produces inferior plants;
- Combinations of morphological characteristics have been found to correlate or act as markers for high quality flax fibre, e.g. low leafed and long internode plants, or dark-yellow coloured seed.

Some quality issues observed for hemp include:

- THC appears to be determined mainly by genetic factors
- Data suggests a monogenic inheritence of THC and CBD content in hemp
- The seed yield of hybrid hemp is increased by 70% as compared to dioecious parental forms

Methods or Techniques Being Employed

Breeding, the traditional method for improving fibre quality, is being enhanced by using genetic analysis to find inheritance patterns and gene linkages. Some countries have also committed research monies into other methods of improving bast fibre quality as well.

A joint research effort between the Netherlands and Russia have found that the developmental dynamics of cell wall metabolism, especially bast fibre cell formation, is providing a model that may help select fibre quality.

In Germany, steam explosion of fibre appears to maximise fibre quality in terms of stiffness, low elongation, high strength, non-abrasive properties, low density as well as heat and humidity transmission. This technology is now being refined and commercialised and is expected to become an integral step in the bast fibre industry of the future.

Geographically Specific Breeding Programs

The symposium was dominated by papers outlining efforts by most individual countries to find improved varieties (both hemp and flax). In many cases this has included relocating old landraces adapted to local conditions, then breeding them for commercial use. This method is supported by a study that found that of a wide range of flax varieties collected over a wide geographical area, some characteristics were better adapted to specific areas than others. Studies also found that edaphic conditions can induce many genetic variations, without the use of biotechnology, therefore the influence of regional conditions on any breeding program should be a major consideration.

The preservation of seed germplasm banks is ongoing, and the FAO European Research Network on Flax and Other Bast Plants is in the process of unifying the passport descriptors for those flaxseed germplasm banks held in Czech Republic, Russia, Ukraine, Romania, Bulgaria, France, The Netherlands, Germany, Northern Ireland, Poland, and USA. These descriptors take into account morphological traits, as well as biological and yielding characters. Efforts are also underway to maintain the world’s largest hemp germplasm bank in St Petersburg.

Some of the parameters that have been identified for determining the adaptability of a plant to a particular area include: cultivar, sowing dates, sowing rates, sowing density, fertiliser input, light, moisture and carbon requirements.

Summaries of papers given by the following countries (in alphabetical order) highlight their involvement with programs that are either aimed at improving bast crop performance in their particular region, or are preserving existing germplasm for use in future breeding programs.

Bulgaria

Bulgaria has found that introduced flax varieties are not always well adapted. The area is rich in wild species and landraces so they are now collecting seed for identification and measurement of suitable characteristics before storing them in a germplasm bank in preparation for future breeding programs.

China

In China, hemp is mainly grown on generally non-fertile fields and tends to be based on landraces with little or no effort at an improved breeding program.

Egypt

Egyptian flax varieties perform better in Egypt than European varieties that mature too early in Egypt's winter. Egypt currently has a federal program to release new varieties using both breeding and biotechnical methods of improvement.

Finland

Finland has developed a new variety of hemp ideally adapted to their conditions and for seed production. It is early maturing, which suits their high latitude, it is unbranched so plants can be sown densely, and produces a large seed head for easy harvesting and high yields (1-2 tonnes/ha). The nutritional composition is exceptionally good as well.

Latvia

Lativia had a successful flax industry before WWII using locally bred varieties. After the war they recommenced their program using commercial Russian varieties, but it was unsuccessful and closed in 1970. In 1992 Lativia began collecting remnant wild-types and will be crossing them with commercial varieties to improve characteristics such as lodging and susceptibility to disease.

Lithuania

Lithuania's selective breeding program is focussed on finding well adapted varieties of flax for their conditions, and have found that in doing this they have increased their yields by 10-30%.

Netherlands

The Netherlands flax germination collection is maintained and regenerated with the cooperation of a number of commercial breeding companies and the Centre for Plant Breeding and Reproduction Research. The focus of the program is to preserve all the available germplasm whether they have direct commercial or non-commercial applications.

Poland

Poland analysed the performance of different flax varieties using data from over 30 years of trialing under different agro-climatic conditions. These results are providing a good base for regional strategies and determining the best-adapted varieties for specific purposes and locations.

Initial hemp breeding material were derived from local landraces, and current varieties now compete well with international varieties in fibre content and THC levels. One local variety was so successful it eliminated the use of imported French varieties. They have also developed monoecious varieties aimed at getting more uniform harvests.

Romania

A number of new flax varieties have been developed over 60 years specifically adapted to Romanian conditions using local and imported varieties, and this continues to remain a priority.

Russia

Russia has commenced a specific characterisation program for the central non-chernozem zone in Russia which requires early maturing varieties. They have found cold-resistant, early maturing hemp landraces in north Russia (66^{o} latitude) that will ensure high seed yields and avoid harvest problems with autumn wet weather. Sowing seed in winter and letting it remain in a semi-germinated state until spring has also been successful, and may aid in earlier germination for maximum growth.

Ukraine

Ukraine has developed new hemp ecotypes using remote geographical forms of hemp and increasing their fibre content from 13-15% up to 25-30%, as well as lowering THC levels. The location of breeding institutions in different climatic zones allows the creation of varieties of different ecotypes.

It was interesting noting that most countries with active breeding programs continue to concentrate of finding varieties that suit their particular conditions, and this is being achieved through reevaluating local cultivars and varieties, or else incorporating characteristics extracted from germplasm banks. Rarely has a country's flax (or hemp) industry relied solely on imported varieties alone.

Enhanced Breeding Techniques and Biotechnology

There is a surprising amount of effort being put into crop improvement using either improved breeding techniques or biotechnology, given that such programs involve large amounts of capital investment. This tends to suggest that there is genuine optimism for this industry.

Romania's more conventional breeding program is using yield and genotype stability analysis according to Piepho's method[1]. Other countries are combining conventional breeding techniques with mutagenesis and biotechnology to enhance their programs. Belarus and the Ukraine are using diallele analysis to estimate genetic control of specific characters, and give special emphasis to additive gene effects. In Belarus they are also studying the differences in chloroplast structure and functions for inheritable traits that could improve crop assimilation performance. They did find metabolic reaction differences between cultivars, which may be used to detect productivity in flax cultivars.

[1] Piepho, H.P. (1995) A simple procedure for yield component analysis. **Euphytica 84:43-48**

Poland is particularly active in hemp breeding where they believe that today's cultivars yielding up to 10 tonnes/hectare have the potential to yield up to 25-35 tonnes/hectare with improved breeding techniques. In an effort to reach these levels they have created haploid and dihaploid homozygotic lines of hemp from callus regenerants in vitro and experimented with developing monoecious hemp varieties by artificially obtaining tetraploid plants using colchicine.

The use of polyploidy is proving to be a useful tool, and has tended to elongate the periods between main development stages in hemp, which translates to an extension of the whole growing season and hence yield.

A number of other methods are also being employed to generate variation or novel traits in bast fibre plants. Somaclonal and gametoclonal variations are being investigated in a joint venture between Russia and Poland, as well as the use of explants derived from anther cultures. Some of these explants have also been found to have increased ploidy.

A lot of attention has been given to optimising anther cultures to enhance the breeding of flax using haploids and dihaploids. The Czech Republic has found that flax regenerates produced by this method have often surpassed initial genotypes in many desirable agricultural characteristics.

Another popular biotechnique is the use of agrobacterium for gene transformation, but both Egyptian and Canadian researchers are looking for improvements because the method is not equally efficient across diverse cultivars. The Canadians are now investigating the use of particle bombardment or "gene gun" techniques and are exploring the possibility of including genes for salt tolerance, herbicide resistance, modifiers of fatty acid compositions and tolerance to environmental stress.

The Italians have dedicated a lot of time to identifying genetic markers and believe they have found a marker that is tightly linked to the male phenotype of hemp using 400 bp RAPD methodology. This is expected to assist the differentiation of the sexes for breeding purposes as well as monoecious individuals from males in a population.

One paper pointed out a new trend for contracting specialised biotechnical services, as opposed to traditional in-house programs. It is theorised that this is due to pressure in the agricultural industry to become more competitive. This is expected to become transglobal with a market size of $1 billion shortly after 2000.

Significance to AHRM

The symposium provided a unique opportunity for Australian Hemp Resource and Manufacture to participate in and contribute to an international gathering of like-minded researchers. Although AHRM were already members of the FAO Network on Flax and Other Bast Plants, they were able to meet other members in person for the first time to discuss global issues and trends.

AHRM also used this opportunity to advertise their breeding program to the public for the first time. It was felt that this was an appropriate forum as it involved presenting a paper to an audience of industry peers, and having it published alongside presentations from other reputable international breeding organisations.

The paper was well received and managed to attract interest from a number of European breeding organisations, which has resulted in the formation of some international agreements. One of these agreements gives AHRM access to the world's largest hemp germplasm bank, and another involves a collaborative arrangement for breeding and climatising varieties using our sub-tropical/tropical facilities.

Members of the audience also included representatives from other sub-tropical/tropical countries looking for solutions to growing hemp in their regions. Discussions with these representatives indicated that AHRM's breeding program would solve many of their more pressing problems, and AHRM continues to have on-going communications with these members.

Benefits to Rural Industry

For many years AHRM have highlighted the need for finding or developing varieties of industrial hemp specifically suited to Australia. Without such varieties it is extremely difficult for the industry to prove is economic viability. AHRM have consistently pointed out that current commercial varieties are daylength sensitive and respond to our summers by maturing too early.

AHRM's breeding program has identified varieties that are daylength insensitive, which are promising to at least double the yields of current commercial varieties. This is obviously a valuable trait for use in low latitude countries, but interestingly it is highly desired by stalk growers in high latitude countries such as Europe. Because the plant does not respond to decreasing daylength, it will continue to grow into winter until it is physiologically ready to mature, thereby maximising stalk yields.

The desire for initiating a bast fibre industry in Australia is gaining momentum year-by-year. Inquiries into growing hemp continue to increase, and authorities have responded by allowing limited hemp trials. Unfortunately these trials have only made use of unsuitable European varieties and are therefore not providing valid agronomic information from which to judge the benefits of this crop.

The introduction of suitable varieties will benefit the rural industry by allowing it to judge its <u>true</u> potential for being incorporated into current crop systems. The enhancement of AHRM's hemp breeding program through access to additional germplasm and collaborative agreements with other established breeding programs can only help the Australia's rural industry as a whole.

Recommendations

1. **Australia must keep abreast of world trends in fibre use and demand.** Fibre is used in an enormous range of end-products: from clothes, to buildings and paper. International demand for alternative fibre-based products are likely to have a large impact on export oriented countries such as Australia. Trends for more environmentally friendly fibre sources may be seen as an emerging opportunity for Australia's rural industry to take advantage of.

2. **Development of varieties specifically suited to Australia is absolutely essential.** All the countries represented at the symposium, except China, that had burgeoning bast fibre industries, each had their own breeding programs directed at developing varieties suited to their conditions. This need is more imperative for Australia with its unique climatic conditions.

3. **Australian hemp trials should not be judged before suitable hemp varieties have been trialed.** Trials to date have been compelled to use unsuitable commercial varieties from Europe. Instead of maturing within 120 days, they have been maturing with 40 days with subsequent low yields. This is producing a lot of unwarranted negative publicity. Varieties do exist that complete their full growth period in low latitude and are capable of doubling current biomass yields but need to be developed for commercial use.

4. **The development of a bast fibre industry must be supported by quality assessment protocols that correspond to international standards.** Natural fibres need to be as homogeneous and as pure as possible if they are to be used successfully in modern processing equipment. They also need to have a unified classification system so that product can be traded internationally with confidence. To enter the international market, these issues must be addressed as the industry develops.

Other Comments

It is interesting to note that so many countries around the world are viewing the bast fibre industry with optimism in terms of future potential and market demand. This is in stark contrast with Australia where bast fibre trials have been conducted in relatively ad hoc circumstances, with very little support from various governmental bodies. This is surprising given that it is set to become an import replacement and/or export oriented rural-based industry in a country with many distinct production advantages over other countries. It has also attracted the attention of a wide range of value-adding manufacturers both nationally and internationally.

In relation to hemp, each State has drawn up its own legislation in isolation to deal with this crop, which is unfortunately set to impinge on the constitutional rights of free trade of the product between States. Requests for a national contact point for the fibre industry to help coordinate the efforts of individual States has thus far proved fruitless.

Discovering the Characteristics of Tropical/Sub-Tropical Hemp Cultivars

C.G. Ditchfield (B.Ag.Sc.), T.E. Friend (B.Sc.Agr.), P. S. Warner
Australian Hemp Resource and Manufacture
Brisbane, Australia

ABSTRACT

Australian Hemp Resource and Manufacture, and its subsidiary seed company, have commenced a selection program for the investigation of tropical/sub-tropical cultivars of industrial hemp. Due to the lack of commercial quantities of certified industrial hemp seed suited to lower latitudes, this program has had to embark on an extensive search for remnant cultivars from past breeding programs. This selection program will include cultivars derived from the Sub-Continent and the Far East, as well as a range of cultivars sourced from various germplasm banks around the world. It is hoped that more cultivars will continue to be found for on-going selections. Enthusiasm for such a program has been expressed by those anxious to conserve the dwindling genetic stock of Cannabis sativa, as well as those who wish to develop a hemp fibre industry in the highly productive low latitude regions of the world. This paper will outline the reasoning and steps taken to establish this hemp selection program and present the preliminary results.

RATIONALE

Australia has commenced trialing industrial hemp to ascertain its potential as an alternative broad-acre crop. Trials to date have been limited to commercially available varieties from Europe that are proving to be unsuited to Australian conditions. Trials in Australia continue to report disappointing stalk yields of below 9tonne/hectare (Potter & Hannay, 1997, Bluett, C., 1997, Beetson & Smart 1997, Spurway & Trounce 1998). These results are not surprising given that all these European varieties are specifically bred and adapted to higher latitudes where long daylight hours are experienced during summer. Australia has shorter daylengths in summer that correspond to increasingly lower latitudes moving north. European industrial hemp is daylength sensitive, and responds to short summer days by maturing early, thereby reducing its potential growing season, and lowering its total yield (Lisson, 1998). In some cases crops in Australia have matured within 40 days (Doug Rowe pers.com.).

All trials to date have been conducted in the more temperate regions of Australia, but these regions unfortunately also experience a winter rainfall and a dry summer regime (see Figure 1). This is not an ideal situation for any summer crop unless expensive irrigation is considered. It has been identified that the northern regions of Australia hold the most potential for producing viable crops of industrial hemp on a commercial scale if suitable varieties can be found (Ditchfield, 1997, Shaun Lisson pers. com., Doug Rowe pers. com.).

Although remnant tropical/sub-tropical cultivars of industrial hemp exist in some regions of the world, no such seed is commercially available in quantity, or certified. Legislative requirements in most countries, including Australia, request that seed stock be certified before being imported. This requirement is even more imperative in the case of industrial hemp where additional fears of mistakenly importing marijuana is of concern. Therefore tropical/sub-tropical hemp remains unexplored for commercial use.

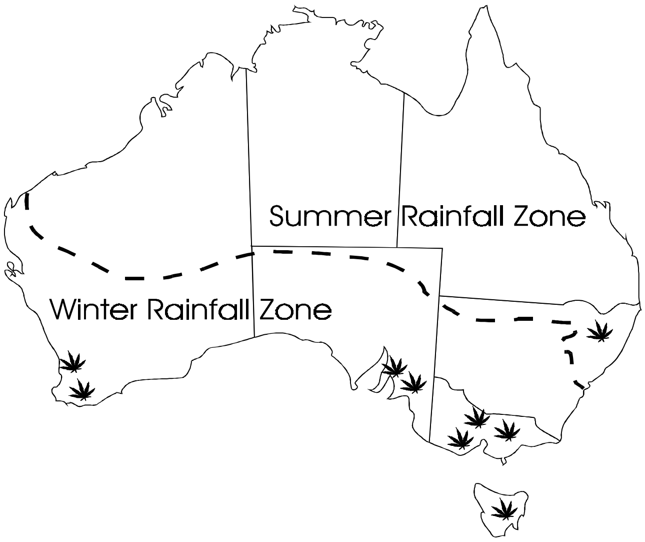


Figure 1. Map of Australia showing industrial hemp trials sites as well as regions of prevailing winter and summer rainfall (Ditchfield, 1997)

Australian Hemp Resource and Manufacture identified these problems six years ago, and after many years of research and negotiation have commenced a breeding program this year which has introduced tropical/sub-tropical cultivars to characterise and develop them into commercial varieties for lower latitude regions. Because tropical/sub-tropical cultivars of industrial hemp are not as sensitive to shortening daylengths as temperate varieties, they continue to full maturity. This may prove to be extremely attractive to stalk producers in low latitude countries as well, as they continue their search for later flowering varieties with higher stalk yields.

BREEDING LOCATION

The breeding location for this program is commercially sensitive at present, but it has the following attributes:

1. It is located between 25-30^{o} latitude (sub-tropical)
2. Under strict guidelines the government has permitted the conditional introduction of small quantities hemp seed with apparent low THC levels. These conditions include:
    - Importation of seed be exclusively for research and breeding of hemp for industrial purposes
    - Less than 200 seeds
    - Thorough quarantine procedures to remove all possible contamination, including hypochlorite dipping of seeds
    - One full generation in a totally enclosed growing environment
    - THC testing when plants mature
    - Only 1st generation or higher seed of mature plants with 1% THC and under is permitted to leave the facility (all other soil and vegetable matter is to be destroyed)
3. Outdoor plantings of seed with less than 1% THC is permissible

We believe we are the first group in the world to have commenced a tropical/sub-tropical industrial hemp breeding program within the latitudes best suited to their growth. This obviates the need to simulate tropical/sub-tropical conditions in glasshouses, and will give more accurate indications of each cultivars potential performance, especially in a commercial broad-acre situation.

BREEDING PROGRAM

Objectives of the breeding program are:
1. Source as many tropical/sub-tropical cultivars as possible
2. Characterise the attributes of each cultivar
3. Compare performance indicators with commercial temperate varieties
4. Begin crossing (breeding) to develop varieties suited to different geographical areas and/or end-uses
5. Negotiate the use of varieties in the breeding program with those holding relevant Plant Breeder Rights (PBR) on each variety

This program includes a broad-acre production component to ensure that all the attributes expressed remain true under commercial conditions. Some of the broad-acre sites will be located throughout Queensland and Western Australia and possibly northern NSW. Demand for this seed has been received from South Africa, South America, Ghana, Guyana, Thailand, Burma, Pacific region, as well as stalk producers in Europe and Canada.

FIRST SEASON RESULTS

Cultivars

Our collection of cultivars is ongoing and will continue into the future. Thus far we have introduced 5 cultivars that are expected to perform reasonably well in our latitude, and 3 commercial varieties from which comparisons can be made. We have also included FIN-314, derived from Jace Callaway, University of Kuopio, Finland, as part of a collaborative agreement to record this cultivar’s performance in low latitudes.

We received two promising cultivars of less than 200 seeds with suspected poor viability due to prolonged storage. One was a late-flowering cultivar derived from the N.I. Vavilov Institute of Plant Industry, Russia (henceforth denoted VAV1), the other was derived from the Sub-Continent (henceforth denoted SCON) and obtained through the Australian Federal Police, Canberra. These two cultivars were sown as soon as possible in an effort to generate fresh seed stocks and to commence each cultivar’s characterisation. Preliminary observations in the first season of growing for both VAV1 and SCON are presented below. Some observations on FIN-314 are used to provide a comparison for germination rates and flowering dates.

Facilities

Both cultivars were sown out of season so a lighting regime was set up, and temperature controlled. It should be noted that these facilities are still being set up, therefore breeding protocols and measurement regimes are still being established. Despite the lack of consistent thorough recordings of all growth parameters, significant differences have been recorded and identified between VAV1 and SCON that can be formally documented and presented.

Germination Room

All care was taken to ensure maximum germination rates. The following structure was used to germinate seed.

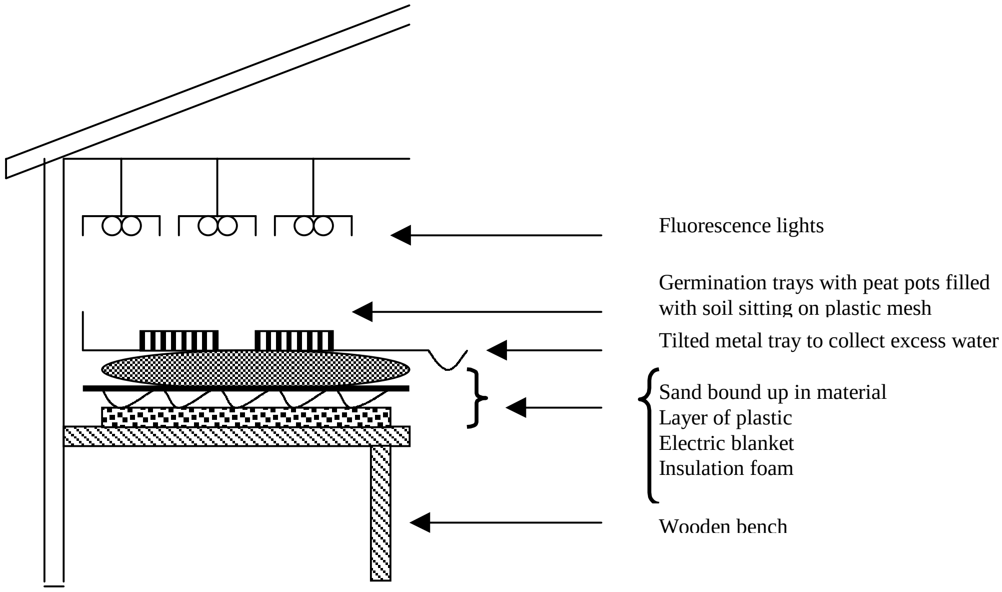


Figure 2. Cross Section of the Germination Room

Glasshouse

All germinated seedlings were removed from the germination trays and transplanted into 51/4" pots. After one month they were then transplanted into the glasshouse where natural light was supplemented with overhead lights to reflect summer daylength in the sub-tropics.

Photo 1. Glasshouse with extended night lighting

METHOD

Germination

The seeding mix consisted of 4 parts sterilised soil and 1 part vermiculite that was sieved for lumps. The clay-loam basalt based soil (5YR 4/5 under the Munsell Soil Colour Chart system) was sourced from a local greenhouse, and contained residue tomato nutrients. The soil had a pH of 5.6, which is within the ideal range for germinating industrial hemp seed (Clarke 1981, Sea of Green, 1997). The seeds were sown on 14 June 1998 at a depth of 8mm and regularly watered with tank water (pH 5.16).

Soil temperature was kept between 19-22^{o}C except for two days where it rose to 26^{o}C, and humidity remained between 75-80%.

Plant Growth

Seedlings were first transplanted into 51/4" pots after first leaf expansion with the same soil mix as used for germination. The plants were then transplanted on 14 July 1998 (1 month after sowing) into the glasshouse clay loam soil with a pH of 6.8. The plants were spaced 30.5cm apart in the glasshouse and regularly watered with bore water (pH 4.6). Quantities of water applied were recorded.

Soil temperature remained between 18-24^{o}C with air temperature fluctuating between a minimum of 13^{o}C and maximum of 33^{o}C.

Regulation of daylength was programmed to approximately represent a typical sub-tropical summer, starting with 12hrs after germination and working up to 14.5 hours of daylight after 54 days.

Liquid fertiliser (Aquasol with N:P:K ratio of 23:4:18) was applied weekly at half the recommended fortnightly rate (e.g. 4 grams per 5 litres of water per week); and the recommended rate of insecticide (Yates "Target", active ingredient permethrin) was applied as required. All applications and quantities were recorded.

RESULTS

Germination

The VAV1 seeds looked plump and were an olive green to green grey in colour. Many of the SCON seed were split, appeared smaller with a smoother surface. Their colour varied from grey green to blonde, and in some even yellow.

Of the 181 VAV1 seeds sown only 8 germinated (4%). This low germination rate is thought to be a result of long storage at the Vavilov Institute. All seeds had germinated within 4-6 days.

Of the 80 SCON seeds sown 45 germinated (56%). This relatively low germination rate is again thought to be the result of extended storage both in Australia and overseas. All seeds had germinated within 3-14 days.

In contrast fresh FIN-314 seed under the same germination conditions had a 92.2% germination rate.

It was observed that well established rooting occurred within 20-25 days after sowing of both cultivars (VAV1 & SCON).

One unusual observation was the unexpected germination of seeds upside down. Many of these seedlings failed to survive, although some did manage to extend their radicle right around the seed and back down into the soil. Drake

(1970) briefly describes this potential problem and relates it to seed positioning in the soil (Figure 3). Experiments are currently being set up to discover whether seed positioning is the cause of the problem, by germinating upside down, sideways and rightway up seeds.

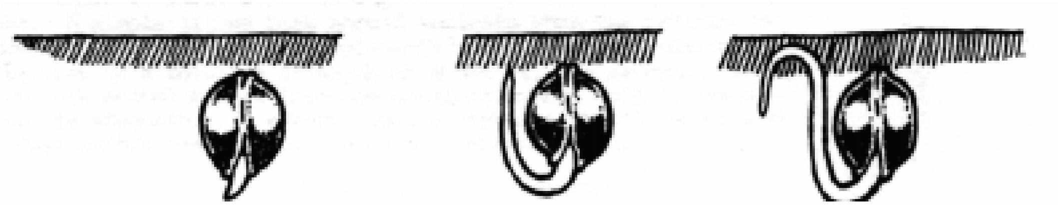
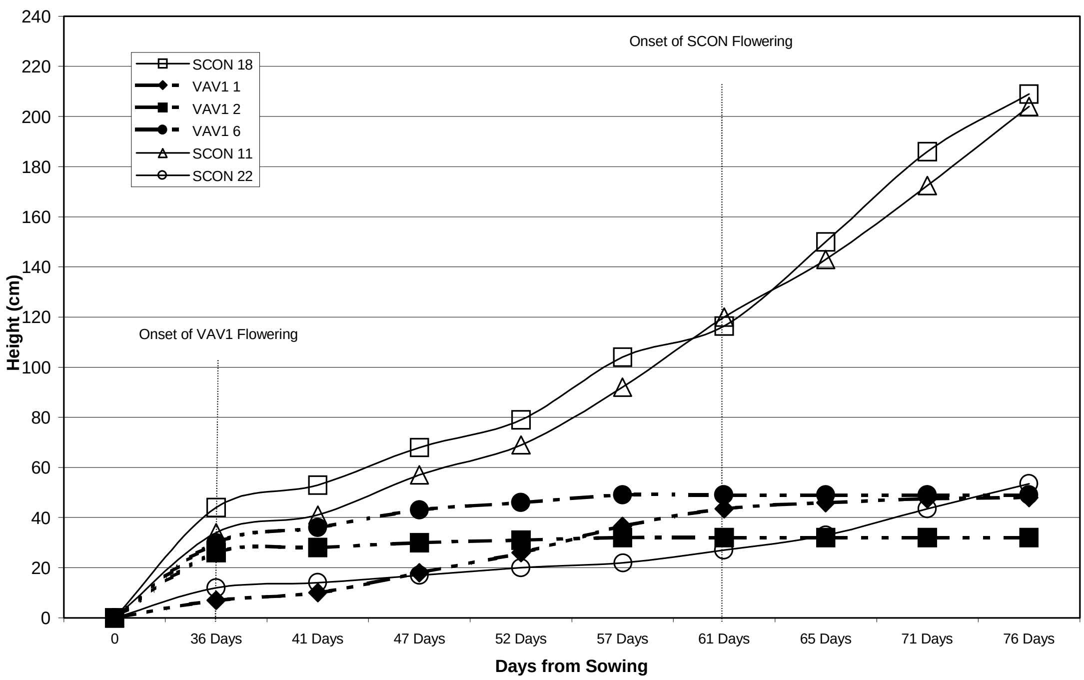


Figure 3. A seed planted pointed end down results in the radicle having to reverse its direction (Drake, 1970)

Plant Growth

It should be emphasised at this point that VAV1 and SCON continue to grow at the time of writing, therefore these results are incomplete. Although measuring protocols are being refined as the plants mature, significant differences in height and stalk diameter measurements, and flowering dates between the cultivars have been recorded. The following results are derived from six surviving VAV1 plants and 26 SCON plants.

Graph 1 shows height over time of two top performing SCON varieties (SCON 18 & SCON 11) as well as a poor SCON performer (SCON 22); and three of the six VAV1 survivors (VAV1 1, VAV1 2, VAV1 6).



Graph1. Height of VAV1 & SCON plants over time

The poor performance of SCON 22 seems to be related to poor root establishment due to a failure of the germination peat pots to break down in the soil. The maximum gain in height per day for VAV1 was 1.4cm (between 36 days and 41 days after sowing), whereas the maximum gain in height per day for SCON was 8.75cm (between 57 days and 61 dyas after sowing).

VAV1 commenced flowering after 36 days, SCON commenced flowering after 61 days (Graph 1), with some individual SCON plants still to express their sex after 65 days. It was noted that as soon as flowering commenced in VAV1, gain in stalk height eventually ceased. In contrast, SCON continues to gain in height. It is interesting to note that FIN-314 first showed signs of flowering after only 16 days.

The stalk diameter of the VAV1 plants reached a maximum of 5mm, while SCON recorded diameters of up to 10mm. The VAV1 stalk remains smooth and round while the SCON stalk has developed deep vertical ridges (corrugations) around the stalk diameter.

Five of the surviving six VAV1 plants have ceased stalk elongation and expressed strong female features. A remaining VAV1 plant continues to increase in height with relatively 'open' flowers, which is more reminiscent of a male plant. Both types of plants though are showing abnormal flower formations, which are a blend of both male and female flowers (Figure 3). It is suspected that this may have resulted from stress either from prolonged storage, or from an enforced short daylength regime on temperate adapted plants.

Figure 4. Examples of Some Sex Abnormalities (Drake, 1970).

CONCLUSIONS

The above observations have identified problems that will be corrected in future plantings. Peat pots will not be used to germinate seedlings because of their failure to breakdown and allow expansion of the root system. Placement of seeds into soil may need to be revised to ensure all seedlings germinate the right way up to improve seedling survival rates.

The outward appearance of seed does not necessarily help identify healthy seed. Contrary to expectations, the plumb VAV1 seed had very poor germination rates compared to the leaner SCON seed. As suspected, seeds that have experienced prolonged storage (more than 5 years) had lowered germination rates. This conclusion is bolstered by the high germination rate of fresh FIN-314 seed when compared to both VAV1 and SCON.

Research undertaken by Lisson (1998) supports our findings to date of a positive relationship between days to flowering and stem production in industrial hemp. It has also been reasoned through the use of growth curves, that extending the flowering date of European industrial hemp varieties by as little as an extra 10 days could increase stalk yields by up to 40% (Doug Rowe pers. com.). The SCON cultivar shows a lot of promise for prolonging this flowering date, and already appears to have good stalk yields in terms of height and diameter in sub-tropical conditions. The ridged stalk feature of SCON is also expected to increase the total surface area (hence quantity) of bast fibre, the most valued fraction of the hemp stalk, which may also contribute to its potential commercial viability.

FUTURE

Analysis of fibre quality and quantity, and THC levels are yet to be performed on both cultivars to allow for a final determination of each cultivars overall attributes and suitability. SCON is showing the most promise to date of becoming a successful commercial crop for sub-tropical regions, but it is yet to be commercialised and will require stabilisation of its characteristics and possible inclusion of other desirable traits through an extensive breeding program.

Characterisation of other cultivars continues. When a range of desirable traits have been identified, a breeding program will commence in earnest to develop varieties best suited to different geographical areas and end-uses. Expressions of interest in this breeding program are welcomed.

REFERENCES

Bluett, C. (1997) Hemp Trials in Victoria 1995-1997 – An Overview. Presented at an RIRDC national workshop on industrial hemp, 19th August, Sydney.

Beetson, B.R. & Smart, W.L. (1997) Industrial Hemp Agronomic Trials in Western Australia - A Research Report. New Industries Program, Agriculture Western Australia.

Clarke, R.C. (1981) Marijuana Botany. An Advanced Study: The Propagation and Breeding of Distinctive Cannabis. Ronin Publishing, Berkeley, California.

Ditchfield, C. (1997) The Hemp Industry in Europe and Its Future in Australia. RIRDC Research Paper Series No 97/51. DPIE Copyshop, Australia.

Drake, W D. (1970) The Cultivator's Handbook of Marijuana. Augur Publishing Co., Oregon.

'Hans' (1998) Sea of Green: The Perpetual Harvest. Trans-High Corporation, New York.

Lisson, S. (1998) Hemp & Flax as Sources of Fibre for Newsprint Production. PhD Thesis, University of Tasmania, Australia.

Lolicato, S., Bluett, C. & Blackstock, J. (1996) Low-THC Indian Hemp (*Cannabis sativa* L.) Trials in Victoria. Proceedings of the First Australian New Crops Conference, University of Queensland, Gatton College, 8-11 July, Rural Industries Research and Development Corporation.

Potter, T. & Hannay, J. (1995) Industrial Hemp. Presented at an RIRDC national workshop on industrial hemp, 19th August, Sydney.

Spurway, R. & Trounce, B. (1998) Low THC Hemp in New South Wales. Agnote DPI/202, 2nd Edition. NSW Agriculture.

Personal Communication

Doug Rowe, Mt Barker Research Station manager, AgWest Hemp Projects manager, Agriculture Western Australia

Shaun Lisson,, PhD Student, University of Tasmania, Australia

APPENDIX 1

BAST FIBROUS PLANTS TODAY AND TOMORROW – BREEDING MOLECULAR BIOLOGY AND BIOTECHNOLOGY BEYOND 21ST CENTURY

Opening Ceremony

Kozlowski, R. Baraniecki, P. & Dragavtsev, V.A. (Institute of Natural Fibres, Poland and N.I. Vavilov Research Institute of Plant Industry, Russia) – New Trends in Hemp Breeding.

Kozlowski, R. (Institute of Natural Fibres, Poland) – Present Situation and Future Prospects in the Field of Flax and Hemp Production/Processing.

Session I – Plant Genetic Resources, Breeding and Cultivation

Rowland, G.G. & Wilen, R. (University of Saskatchewan, Canada) **–** New Trends in Linseed Breeding.

Pavelek, M. (Agritec, Research, Breeding and Services Ltd, The Czech Republic) – Analysis of Current State of International Flax Database.

Brutch, N.B., Kutuzova, S.N. & Porohovinova, E.A. (N.I. Vavilov Research Institute of Plant Industry, Russia) – Genetic Collection of Flax in VIR Department of Industrial Crops.

Rozhmina, T.A. & Zhuchenko, A.A. (All Russian Flax Research Institute, Russia) – Study of National Russian Flax Collections of VNIL.

Rashal, I. & Stramkale, V. (Institute of Biology of University of Lativia, Latvia) – Conservation and Use of the Latvian Flax Genetic Resources.

Jankauskiene, Z. & Mikelionis, S. (The Upyte Research Station of the Lithuanian Institute of Agriculture, Lithuania) – *Linum usitatissimum* in Lithuania: Nowadays Situation.

Balabanova, A. (Potatoes and Flax Experimental Station, Bulgaria) – Flax Genetic Resources in Bulgaria.

Van Soest, L.J.M. & Bas N. (Centre for Genetic Resources, The Netherlands) – Genetic Resources of *Linum* in The Netherlands.

El-Hariri, D.M., Hassanen, M.S.E. & Ahmed, M.A. (National Research Centre, Egypt) – Evaluation of Different Flax Genotypes Under Egyptian Conditions.

El-Hariri, D.M. (National Research Centre, Egypt) – Varietal Development of Flax and Other Bast Fibrous Plants in Egypt.

Rolski, S. & Heller, K. (Institute of Natural Fibres, Poland) – Yielding Capacity of Different Flax Cultivars in Varied Environmental Conditions.

Popescu, F., Marinescu, I. & Vasile, I. (Research Institute for Cereals and Industrial Crops, Romania) – Fibre Yield Stability Study of the Romanian Flax Varieties of the Basis of Yield Component Analysis.

Doronin, S.V., Dudina, A.N. & Tikhivinsky, S.F. (Vyatka State Agricultural Academy, Russia) – Fiber Flax Breeding for Fibre Quality.

Karpets, I.P., Karpunina, I.I. & Ganganov, V.N. (Ganganov, Ukraine) – The Character of Inheritance of Agricultural Valuable Traits and Efficiency of Fibre-Flax Hybrids Selection by Them.

Kurt, O. (University of Ondokuz Mayis, Turkey) – Influence of Flowering Date on Seed-Setting and Seed Yield in Linseed.

Goloborod'ko, P., Virovets, V., Sytnik, V. & Orlov, N. (Institute of Bast Crops, Ukraine) – Selection of Hemp (*Cannabis sativa* L.) as a Prospective Crop of the XXI-st Century.

Grigoryev, S. (N.I. Vavilov Research Institute of Plant Industry, Russia) – Cold-Resistance of Hemp (*Cannabis sativa* L.).

Grabowska, L, Jaranowska, B., Baraniecki, P. & Tymkow, J. (Institute of Natural Fibres, Poland) – Breeding of Monoacious Hemp with Low Cannabinoids Content in Poland.

Wei, W. (Liaoning Tongxin Industrial Company, China) – Status of Chinese Hemp Growing and Production.

Ditchfield, C., Friend, E. & Warner, P. (Australian Hemp Resource and Manufacture) - Discovering the Characteristics of Tropical/Sub-Tropical Hemp Cultivars.

<u>Relevant Posters</u>

Pavelek, M. & Tejklova, E. (Agritec, Research, Breeding and Services Ltd, Czech Republic) – Objectives, Methods and Results of Flax and Linseed Breeding.

Heller, K. (Institute of Natural Fibres, Poland) – Influence of Environmental Factors on Herbicide Efficacy in Flax Cultivation.

Andruszewska, A., Rolski, S., Bloch, J., Rutkowska, E. & Byczynska, M. (Institute of Natural Fibres, Poland) – Contribution of Flax Genetic Resources from VIR Collection in the Programme of Breeding for Resistence to *Fusarium* Wilt in Poland.

Andruszewska, A. & Byczynska, M. (Institute of Natural Fibres, Poland) – Resistence of Flax and Linseed Varieties from VIR Collection to *Fusarium* Wilt in Conditions of Poland.

Silska, G. & Kozak, J. (Institute of Natural Fibres, Poland) – Agricultural Features of *Linum usitatissimum* Breeding Material Obtained from VIR in Polish Conditions.

Kondic, J. & Nozinic, M. (Poljoprivredni Institut Banja Luka, Republic of Srpska) – Hemp Production Possibility in Republika Srpska.

Bert, F., Brochard, M., Cariou, E., Morin, P. & Savina, A., (Institut Technique du Lin, France) – *Fusarium* Wilt and Scorch: A Specific Test to Identify the Pathogenicity Potential Risk of Flax Strains.

Polonetskaya, L.A., Sakovich, V.I. & Trus, N.K. (Institute of Genetics and Cytology, Belarus) – Genotypical Structure of Quantitative Characters and Selection Effect in Fiber Flax Cultivars.

Polonetskaya, L.A., Portyankin, D.E. & Sakovich, V.I. (Institute of Genetics and Cytology, Belarus) – Genetic Control of Productivity Components and Resistence to *Fusarium* Wilt in Fiber Flax in the Diallel Crossing System.

Dylenok, L.A., Yatsevich, A.P. & Kudelko, L.I. (Institute of Genetics and Cytology, Belarus) – Genetic Analysis of Anatomomorphological Stem Parameters in Fiber Flax.

Marinescu, I. & Popescu, F. (Research Institute for Cereals and Industrial Crops, Romania) – Flax Breeding to Research Institute for Cereals and Industrial Crops – Fundulea, Romania.

Becu, D.M.S., Mastebroek, H.D. & Marvin, H.J.P. (Centre for Plant Breeding and Reproduction Research, The Netherlands) – Breeding for Root Knot Nematode Resistance in Hemp.

Lassaga, S.L., Milisich, H.J. & Sanchez, A.A. (EEA Parana INTA-FCA UNER, Argentina) – Linseed (*Linum usitatissimum* L.) Anther Culture. Response at Different Pollen Development Stages. Correlation with Morphological Bud Characters.

Ponazhev, V.P. & Pavlov, A.I. (All Russian Flax Research Insitute, Russia) – Role of the Biological and Physiological Factors in Formation of Seed Quality Flax.

Pavlov, E.I. & Ponazev, V.P. (All Russian Flax Research Institute, Russia) – Methodology Aspects of Primary Flax Seed Production.

Aleksandrova, T.A. & Pavlova, L.N. (All Russian Flax Research Institute, Russia) – Efficiency of Initial Material Use in Flax Breeding.

Zhuchenko, A., Rozhmina, T., Pavelek, M., Ondrej, M., Truve, J.P., Boguk, A., Khotyljova, L. & Polonetscaja, L. (VNIIL, Russia; Agritec Ltd, Czech Republic; Fontaine-Cany, France; Institute of Genetics and Cytology, Belarus) – The Testing of Cultivars and Perspective Flax Forms in Main Flax Producing Zones.

Janyshina, A.A. (All Russian Flax Research Institute) – State of Genetic Uniformity of Flax in Primary Seed Production.

Mukhin, V.V., Romanov, V.A. & Kudrjashova, T.A. (All Russian Flax Research Institute, Russia) – New Approaches to Determination of Fibre Quality of Breeding Varieties and Collection Samples.

Bachelis, K. (Upyte Research Station of Lithuanian Institute of Agriculture, Lithuania) – A Study of the Fiber Flax Collection as Initial Material for Breeding in Conditions of the Lithuania.

Krzymanski, J. & Piotrowska, A. (Plant Breeding and Acclimatisation Institute, Poland) – Current Status of Linseed Breeding in Poland.

<u>Session II – Seed Management and Diseases Protection</u>

Kutuzova, S.N. (N.I. Vavilov Research Institute of Plant Industry, Russia) – Strategy of Developing Long-Standing Resistence to Rust in Flax Varieties.

Loshakova, N.I. & Kudriavtseva, L.P. (All Russian Flax Research Institute, Russia) – Bank of Strains of Pathogens – Activators of Flax Diseases and Its Use in Breeding on Immunity.

Pavlova, L.N., Aleksandrova, T.A., Marchenkov, A.N., Krylova, T.V. & Loshakova, N.I. (All Russian Flax Research Institute, Russia) – Bases of Flax Breeding for Productivity and Resistence to Diseases.

<u>Relevant Posters</u>

Rios de Saluso, M.L.A., Brizuela, A. & Saluso, J.H. (Estacion Experimental Agropecuaria EEA, INTA, Argentina) – Thrips Association and Climate Elements.

Kurchakova, L.N., Loshakova, N.I., Krilova, T.V., Kudriavtseva, L.P. & Karpunin, B.F. (All Russian Flax Research Institute, Russia) – Resistence of Samples of National Russian Flax Collection to the Fungous Diseases.

Kudrjavtseva, L.P. (All Russian Flax Research Institute, Russia) – Racial Composition of *Colletotrichum* Lini Pathogene.

Krylova, T.V. (All Russian Flax Research Institute, Russia) – *Rhizotonia solani* on Flax.

Loshakova, N.I. (All Russian Flax Research Institute, Russia) – Bank of Strains of Pathogens – Activators of Flax Diseases and Its Use in Breeding on Immunity.

Session III – Genetics, Biology, Biotechnology, Biochemistry

McHughen, A., Wijayanto, T. & Koronfel, M. (University of Saskatchewan, Canada) – Advancement in New Methods of Genetic Engineering in Linseed Breeding.

Salnikov, V.V., van Dam, J.E.G. & Lozovaya, V.V., (Russian Academy of Sciences, Russia; Agrotechnological Research Institute, The Netherlands) – Microscopy of Cell Wall Formation in Flax Bast Fibre.

Koronfel, M. & McHughen, A. (Cairo University, Egypt; University of Saskatchewan, Canada) – An Efficient Regeneration Procedure for Flax (*Linum usitatissimum* L.).

Koronfel, M. (Cairo University, Egypt) – Sensitivity of Flax (*Linum usitatissimum* L.) Hypocotyls and Shoots to Kanamycin, Cefotaxime and Carbencillin.

Mandolino, G., Carboni, A., Forapani, S. & Ranalli, P. (Istituto Sperimentale per le Colture Industriali, Italy) - DNA Markers Associated with Sex Phenotypes in Hemp (*Cannabis sativa* L.).

Tejklova, E. (Agritec, Czech Republic) – Study of Anther Culture in Flax (*Linum usitatissimum* L.)

Poliakov, A.V., Pavlova, L.N., Alexandrova, T.A., Loshakova, N.I., Marchenkov, A.N. & Rutkowska-Krause, I. (All Russian Flax Research Institute, Russia) – Anther Culture as a Tool For Production of New Flax Genotypes.

Rutkowska-Krause, I., Mankowska, G. & Poliakov, A., (Institute of Natural Fibres, Poland; All Russian Flax Research Institute, Russia) – Somaclonal and Gametoclonal Variation of Flax (*Linum usitatissimum* L.) in Relation to Breeding Purposes.

Schneider, Z. (University of Agriculture, Poland) – The Importance of Unsaturated Fatty Acids in Prevention of Aging and Arteriosclerosis.

Callaway, J. (University of Kuopio, Finland) – Hemp Seed as a Nutritional Food Resource.

Askew, M.F. (Alternative Crops and Biotech Group, United Kingdom) – Potential for Plant Derived Fibres in Traditional and Non-Traditional Markets: A World Review.

Tubach, M. & Kessler, R.W. (Institut fur Angewandte Forschung, Germany) – Sustainable Use of Bast Fibres in Germany – From Vision to Reality.

Kolodziejczyk, P.P. (POS Pilot Plant Corporation, Canada) – How Biotechnology Changes the Research and Development Organisations.

Relevant Posters

Chikrizova, O.F. & Poliakov, A.V. (All Russian Flax Research Institute, Russia) – Transformation of Flax by *Agrobacterium tumefaciens* on the Basis of Gene NPT-Ii Introduction.

Khotyleva, L.V., Ilchenko, V.P., Trukhanovets, N.L., Ruban, V.V. & Lemesh, V.A. (Institute of Genetics and Cytology, Belarus) – Genetic Analysis of Structural and Functional Organization of Leaf Chloroplasts in Fibre Flax.

Khotyleva, L.V. & Lemesh, V.A. (Institute of Genetics and Cytology, Belarus) – The Possibility of Molecular Market Application for Studying Genetic Diversity of Flax.

Titok, V.V. & Yurenkova, S.I. (Institute of Genetics and Cytology, Belarus) – Dynamics of Energy Metabolism Parameters in Fiber Flax Ontogenesis.

Rakousky, S., Tejklova, E., Wiesner, I., Wiesnerova, D., Kocabek, T. & Ondrej, M. (Institute of Plant Molecular Biology, Czech Republic; Agrictec, Czech Republic) – T-DNA Induced Mutations and Somaclonal Variants of Flax**.**

Miscellaneous Posters

Capaletto, P., Mongardini, F., Sannibale, M., Brizzi, M. & Passini, P. (Centro Tecnico Industriale, Italy) – Oilseed Flax Pulp in Wastepaper Furnish.

Wasko, J., Walentowska, J. & Piechowiak, K. (Institute of Natural Fibres, Poland) – Flax and Hemp Raw Materials and Products and Their Standardization.

Shamolina, L.I., Ansis, L.M., Gavrilova, V.P. & Belova, N.V. (State University of Technology and Design, Russia; Komarov Botanical Institute, Russia) – Enzymatic Potential Basidiomycetes for Flax Treatment.