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Evaluation of Hemp and Kenaf Varieties in Tropical and Sub-tropical Environments

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by B R Weeden

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Foreword

In recent years manufacturers throughout the world, including Australia, have shown significant interest in the old and new uses of plant bast fibres. These fibres can be used in manufacturing environmentally sustainable products and it is claimed, can be grown as a part of a more environmentally sustainable cropping system.

This publication reports on the performance of a number of hemp and kenaf varieties grown under tropical and sub-tropical environments in Queensland.

This project was funded from RIRDC Core Funds which are provided by the Australian Government. Industry funding was provided by Ecofibre Industries Limited.

This report, an addition to RIRDC's diverse range of over 1500 research publications, forms part of our New Plant Products R&D program, which aims to facilitate the development of new industries based on plant or plant products that have commercial potential for Australia.

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

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Finally I would like to thank Phil Warner and Tanya Jobling from EIL for their support for this project and their passion for the development of a bast fibre industry in Australia.

Abbreviations

CSIRO	Commonwealth Scientific and Industry Research Organisation
DAS	Days After Sowing
DPI&F	Department of Primary Industries and Fisheries
EIL	Ecofibre Industries Limited
Hemp	Industrial hemp – in Qld a species of *Cannabis sativa* with < 1.0 % THC for fibre production, with <0.5 % for seed production
MDIA	Mareeba-Dimbulah Irrigation Area
RIRDC	Rural Industries Research and Development Corporation
THC	Tetrahydrocannabinol

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Executive Summary

Background
In recent years fibre manufacturers throughout the world, including Australia, have shown significant interest in using plant bast fibres because these fibres can be used in manufacturing environmentally sustainable products. Recently three Bast Fibre Conferences in Australia have successfully brought researchers, farmer producers, processors, and manufacturers together to work together across the value chain.

Processors and manufacturers are particularly interested in using hemp and kenaf for manufacturing non-woven products. Hemp fibre has a similar tensile strength to fibre-glass, but is half the density. Kenaf has a lower tensile strength than fibre-glass but greater than pine-wood fibres. Because both hemp and kenaf are bio-degradable, these fibres are ideal for manufacturing products such as reinforced composites for use as internal mouldings in cars. Other uses of non-woven bast fibres are geo-textiles and other civil engineering applications. Hemp is also suitable for woven fabrics and the seed oil has many uses in the food and cosmetics industries. The lower quality hurd fraction of the kenaf and hemp stem is ideal for animal bedding and absorbent materials.

Previous investigations during the past 10-20 years in both Australia and USA focussed of using kenaf as a source of paper pulp. However, more recent studies conclude that kenaf and hemp both have potential uses in the higher value end of the market, eg industrial non-woven products, which are worthy of further investigation.

Availability of suitable cultivars of bast fibre crops (hemp and kenaf) is a major limitation to establishing a bast fibre industry in Australia. Ideally what is required is these bast fibre crops growing in a range of environments from temperate Tasmania to tropical north Queensland. This system would enable bast fibre crops to be harvested over an eight-month period from November to June, making the fibre harvesting process more economic. Recently, new improved cultivars of hemp from Europe have been successfully grown in the temperate environments of Victoria and Tasmania.

New germplasm and advanced breeding lines of hemp and kenaf are now available from Ecofibre Industries Limited and the Institute of Bast Fibres in Hunan province China. These new breeding lines offer a significant opportunity to Australia because they are higher yielding than previously available cultivars. Thus agronomic research on potential cultivars of hemp and kenaf for tropical and sub-tropical environments in Australia is warranted and is an essential pre-requisite to establishing a viable bast fibre industry in Australia.

Aims, Methods and Key Findings
Given this situation field trials, which studied the performance of a number of hemp and kenaf varieties, were conducted during 2002 – 2005 at a number of sites under tropical and sub-tropical environmental conditions in Queensland. The trials identified suitable hemp and kenaf varieties that could be expected to give commercial yields when grown in these areas. As well some soil type, irrigation, disease and nutrition issues were identified and recommendations are made.

Implications for Industry
Finally the strength of this project lies in the demonstrated commitment and cooperation of industry manufacturers in the agronomic development of adapted cultivars. Ecofibre Industries Limited contributed financially to the project and supplied seed of potential hemp cultivars. Bast fibre crops have the potential to provide viable and sustainable alternative cropping options for farmers, and to provide regional employment and value adding in the processing and manufacturing of bast fibres.

1 Introduction

In recent years manufacturers throughout the world, including Australia, have shown significant interest in the old and new uses of bast fibres because these fibres can be used in manufacturing environmentally sustainable products. Recently three Bast Fibre Conferences in Australia (1) at CSIRO Geelong in August 2000, (2) at Department of State Development in Brisbane in February 2001, and (3) at La Trobe University in Melbourne in August 2001, have successfully brought researchers, farmer producers, processors, and manufacturers together to work together across the value chain (Appendix 1).

Processors and manufacturers are particularly interested in using hemp (*Cannabis sativa* L.) and kenaf (*Hibiscus cannabinus* L.) for manufacturing non-woven products. Hemp fibre has a similar tensile strength to fibre-glass, but is half the density. Kenaf has a lower tensile strength than fibre-glass but greater than pine-wood fibres. Because both hemp and kenaf are bio-degradable, these fibres are ideal for manufacturing products such as reinforced composites for use as internal mouldings in cars. Other uses of non-woven bast fibres are geo-textiles and other civil engineering applications. Hemp is also suitable for woven fabrics and the seed oil has many uses in the food and cosmetics industries. The lower quality hurd fraction of the hemp and kenaf stem is ideal for animal bedding and absorbent materials (De Jong and Begg, 1999). An Australian company, Ecofibre Industries Limited will soon begin processing hemp crops to produce animal bedding from the hurd fraction and industrial grade fibre from the bast fraction.

The Asian horse racing industry is currently seeking a minimum of 3,500 tonnes of hurd fibre per year for the horse bedding from Australia because of our “clean green” status. The potential market in Asia is 80,000 tonnes annually, and the Australian market is over 35,000 tonnes annually. The Australian automotive industry have a requirement for 7,000 tonne annually of high quality hemp fibre, with a minimum requirement of 1,200 tonne per annum to make a production change in manufacturing interior panels for cars (Jobling, pers. comm.). These and other larger markets exist however the growing, processing and marketing infrastructure for bast fibre in Australia is being developed by small private companies with limited capital and so industry development has been slow and difficult, especially at the processing level. Thus, there is definitely an opportunity and a challenge for producers and processors to establish a bast fibre industry in Australia.

Concern for the environment has also led to regulations on waste disposal in Europe which favour the production and use of renewable fibres (Ditchfield, 1999). Also hemp and kenaf are ideal crops to be grown using sewage effluent from towns and cities. Disposal of effluent has become a major issue for many local councils. However, increasing public awareness and more stringent environmental discharge regulations are making water-based disposal a less viable option. In response, pro-active local authorities are interested in developing new land-based effluent reuse technologies. High yielding fibre products are of particular interest as they are a non-food product with a high nutrient accumulation potential and a strong market value. The Southern Cross University (NSW) is currently investigating the ability of four hemp and two kenaf varieties to bio-accumulate nutrients from sewage effluent, and to produce a high-value fibre product. The first season’s trials in 2001/02 were successful with the sub-tropical hemp cultivar reaching 4m by early January (Lawrence, *pers.comm.*). Success of this pilot trial will pave the way for larger scale collaborative trials involving research institutions, local councils and marketing organisations.

Previous investigations during the past 10-20 years in both Australia and USA focussed of using kenaf as a source of paper pulp. However, economic studies (De Jong and Begg, 1999) reveal that kenaf pulp is not economical in comparison with wood pulp. These studies conclude that kenaf and hemp both have potential uses in the higher value end of the market, eg industrial non-woven products, which are worthy of further investigation. Two companies (Fibrenova & Laroche) have recently developed new technologies to extract the bast fibre from the stalk at harvest time in the field. This mechanical process for separating fibre replaces the traditional 1 - 3 month retting procedure currently practiced in

Asia. A significant advantage of the mechanical separation process to Australia is that it will significantly reduce the cost of transporting fibre to a processing plant.

Availability of suitable cultivars of bast fibre crops (hemp, kenaf, and flax) is a major limitation to establishing a bast fibre industry in Australia. Ideally what is required is a variety of bast fibre crops growing in a range of environments from temperate Tasmania to tropical north Queensland. This system would enable bast fibre crops to be harvested over an eight-month period from November to June, making the fibre harvesting process economic. Recently, new improved cultivars of hemp from Europe have been successfully grown in Victoria and Tasmania. Past research by CSIRO and QDPI&F identified two cultivars of kenaf that are adapted to sub-tropical environments in Queensland (Lawrence, pers. comm.). New germplasm and advanced breeding lines of hemp and kenaf are now available from Ecofibre Industries Limited and the Institute Bast Fibres in Hunan province, China. These new breeding lines offer a significant opportunity to Australia because they are higher yielding than previously available cultivars. In 2000/01, a yield of 18 t/ha of stalk (harvested at flowering after 87 days growth) was obtained from a single trial plot of a new tropical hemp breeding line. Kenaf yielded 21 t/ha and 27 t/ha in two seasons of trials in Central Queensland (Lawrence, *pers. comm*.). In comparison, yields of hemp in temperate environments are typically around 10t/ha. Hence, economically viable yields are possible from these new tropically-adapted breeding lines of hemp and kenaf.

Most Australian States now have legislation permitting commercial production of hemp cultivars with low THC content. Significant research and product investment has been undertaken in Australia in the last four years by industry as a result of the changed legislation. Thus agronomic research on potential cultivars of hemp for tropical and sub-tropical environments in Australia is warranted.

Finally the strength of this project lies in the demonstrated commitment and cooperation of industry manufacturers in the agronomic development of adapted cultivars. Ecofibre Industries Limited contributed financially to the project and supplied seed of potential hemp varieties. Bast fibre crops have the potential to provide viable and sustainable alternative cropping options for farmers, and to provide regional employment and value adding in processing and manufacturing of bast fibres.

2 Objective

To facilitate the establishment of a bast fibre industry in Australia by identifying suitable high-yielding, low THC content cultivars of hemp and suitable high-yielding cultivars of kenaf that are adapted to tropical and sub-tropical environments in Queensland.

3 Methodology

Field trials were conducted over 3 years (2002/3, 2003/4 and 2004/5) at 3 Queensland Department of Primary Industries and Fisheries sites during the course of this study. The sites used were Southedge Research Station (tropical environment), Biloela Research Station and Gatton Research Station (sub-tropical environment sites). Site details are given in Appendix 2.

3.1 Hemp field trials

3.1.1 Southedge hemp trial 2002

Four hemp varieties (EIL 1-02, EIL 2-02, EIL 3-02 and EIL X-99) were planted on 23/10/02 using a randomised complete block design. Plots were 6 m long and consisted of either 4 (33 cm) or 6 (20 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 4 times. Seed planted was adjusted to give a plant population of about 133 plants/m^2 for each row configuration. Due to limited seed supply the EIL X-99 treatment was at 6 rows only. Seed emergence was 90% complete by 6 DAS (Days After Sowing). Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 25, 41 and 48 DAS. After sowing Dual Gold™ was applied (2L/ha) and then Fusilade™ (1L/ha) at 15 DAS for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers. Samples for THC content were taken at the onset of male flowering.

Harvest of each variety occurred when male plants reach approximately 50 % flowering – EIL 1-02 55 DAS, EIL 2-02 69 DAS, EIL X-99 109 DAS and EIL 3-02 116 DAS and consisted of taking the plants from 2 x 1m uniform sections of the inner two rows of each plot. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.1.2 Biloela hemp trial 2002

The same four hemp varieties as used at Southedge were planted on 21/10/02 using a randomised complete block design. Plots were 6.5 m long with 3 row spacings – 12.5, 25 and 50 cms and a plant population of about 130 plants/m^2. Emergence of the hemp seed was very poor (0-15 %) due to the surface crusting nature of the soil type and so collection of yield data was not possible however some flowering dates, height measurements and samples for THC levels were taken.

3.1.3 Southedge hemp trial 2003

Eight hemp varieties (EIL 2-02, EIL 3-02, EIL X-99, WS-03, NO-03, WL-03, MF-03 and AM-03) were planted on 15/10/03 using a randomised complete block design. Plots were 6 m long and consisted of 5 (25 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 6 times. Seed planted was adjusted to give a plant population of about 160 plants/m^2. Seed emergence was 90 % complete by 8 DAS. Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 25 and 36 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers.
Samples for THC content were taken at the onset of male flowering.

Harvest of each variety occurred when male plants reach approximately 50 % flowering – EIL 2-02 62 DAS, EIL X-99 104 DAS, WL-03 116 DAS, AM-03 124 DAS, EIL 3-02 126 DAS, MF-03 130 DAS, NO-03 138 DAS and WS-03 144 DAS - and consisted of taking the plants from 2 x 1m uniform sections of the inner rows of each plot. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.1.4 Gatton hemp trial 2003

The same eight hemp varieties sown at Southedge were planted on 23/10/03 using a randomised complete block design. Plots were 6 m long and consisted of 4 (33 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 6 times. Seed planted was adjusted to give a plant population of about 160 plants/m^2. Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 35 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 30 mm/week depending on rainfall) using overhead sprinklers.

Emergence of the hemp seed was very poor (5-50 %) due to the surface crusting soils and so collection of yield data was not possible however some flowering dates, height measurements and THC levels were taken. An individual plot of each variety was harvested where possible to give an indication of yield.

3.1.5 Southedge hemp trial 2004

Seven hemp varieties (RB-03, WL-03, MF 0-3, AM-03, NO-03, EIL 2-02 and EIL S-00) were planted on 4/11/04 using a randomised complete block design. Plots were 7 m long and consisted of 5 (25 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 5 times. Seed planted was adjusted to give a plant population of about 160 plants/m^2. Seed emergence was 90 % complete by 7 DAS. Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 26 and 34 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers. Samples for THC content were taken at the onset of male flowering.

Harvest of each variety occurred when male plants reach approximately 50 % flowering – EIL 2-02 76 DAS and all other lines at 116 DAS - and consisted of taking the plants from 2 x 1m uniform sections of the inner rows of each plot. Germination of the EIL S-00 was very poor and was excluded from the trial. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.1.6 Gatton hemp trial 2004

The same seven hemp varieties sown at Southedge were planted on 14/10/04 using a randomised complete block design. Plots were 6 m long and consisted of 4 (33 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 5 times. Seed planted was adjusted to give a plant population of about 160 plants/m^2. Fertiliser (Nitrophoska Blue TE™ and Dynamic Lifter™) was topdressed prior to planting at rates equivalent to 1,000 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 35 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 30 mm/week depending on rainfall) using trickle tape.

Seed emergence was greatly improved from the 2003 planting by sowing the seed into dry soil and using only a very light press-wheel. Seed emergence was 90 % complete by 12 DAS.

Harvest occurred on 16/3/05 for all varieties and consisted of taking the plants from 2 x 1m uniform sections of the middle 2 rows of each plot. Sampled plants were left to air dry then leaves and any flowers were removed to estimate dry stem yields.

3.2 Kenaf field trials

3.2.1 Southedge kenaf trial 2002

Five kenaf varieties (Gregg, Yuexuan 743, Dowling, Guatemala 4 and Everglades 71) were planted on 29/10/02 using a randomised complete block design. Plots were 6 m long and consisted of either 3 (50 cm) or 4 (33 cm) rows on a 1 m bed between 1.5 m wheel tracks. Treatments were replicated 4 times. Seed planted was adjusted to give a plant population of about 40 plants/m^2 for each row configuration. Seed emergence was 90 % complete by 10 DAS (Days After Sowing). Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 30 and 43 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers.

Harvest occurred on 10/4/03 (163 days of growth) and consisted of taking the plants from 2 x 1m uniform sections of the middle row (3 row plots) or two inner rows (4 row plots) of each plot. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.2.2 Biloela kenaf trial 2002

The same 5 kenaf varieties as at Southedge were planted on 21/10/02 using a randomised complete block design. Plots were 6.5 m long with 3 row spacings – 12.5, 25 and 50 cms, treatments were replicated 3 times. The trial was irrigated as required (about 30 mm/week depending on rainfall) using an underground trickle system.

Harvest occurred on the 7/4/03 (165 days of growth) and consisted of taking a uniform 2 m sample from an internal row. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.2.3 Southedge kenaf trial 2003

The same 5 kenaf varieties from 2002 were planted on 26/9/03 using the same trial design as for 2002. Seed emergence was 90 % complete by 11 DAS. Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 33, 44 and 55 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers.

Harvest occurred on 5/4/04 (191 days of growth) and consisted of taking the plants from 2 x 1 m uniform sections of the middle row (3 row plots) or two inner rows (4 row plots) of each plot. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.2.4 Gatton kenaf trial 2003

The kenaf trial design here was a duplicate of that at Southedge. The trial was planted on 23/10/03. Fertiliser (Nitrophoska Blue TE™) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 35 and 55 DAS. After sowing Dual Gold™ was applied (2L/ha) for weed control. The trial was irrigated as required (about 30 mm/week depending on rainfall) using overhead sprinklers.

Harvest occurred on 28/4/04 (186 days of growth) and consisted of taking the plants from 2 x 1 m uniform sections of the middle row (3 row plots) or two inner rows (4 row plots) of each plot. Sampled plants were left to air dry then leaves and any flowers were removed to estimate dry stem yields.

3.2.5 Southedge kenaf trial 2004

The same 5 kenaf varieties from 2002/3 were planted on 29/9/04 using the same design as the previous 2 years. Seed emergence was 90 % complete by 11 DAS. Fertiliser (Nitrophoska Blue TE^{TM}) was topdressed prior to planting at a rate equivalent to 500 kg/ha with further Nitrogen applied (urea at 100 kg/ha equivalent) at 42 and 51 DAS. After sowing Dual $Gold^{TM}$ was applied (2L/ha) for weed control. The trial was irrigated as required (about 25 mm/week depending on rainfall) using overhead sprinklers.

Harvest occurred on 13/4/05 (194 days of growth) and consisted of taking the plants from 2 x 1 m uniform sections of the middle row (3 row plots) or two inner rows (4 row plots) of each plot. Sampled plants had leaves and any flowers removed and the stems oven dried (60 C for 3 days) to estimate dry stem yields.

3.2.6 Gatton kenaf trial 2004

The kenaf trial design here was a duplicate of that at Southedge. The trial was planted on 14/10/04. Fertiliser (Nitrophoska Blue TE^{TM}) was topdressed prior to planting at a rate equivalent to 1,000 kg/ha. After sowing Dual $Gold^{TM}$ was applied (2L/ha) for weed control. The trial was irrigated as required (about 30 mm/week depending on rainfall) using trickle tape.

Harvest occurred on 27/4/05 (194 days of growth) and consisted of taking the plants from 2 x 1 m uniform sections of the middle row (3 row plots) or two inner rows (4 row plots) of each plot. Sampled plants were left to air dry then leaves and any flowers were removed to estimate dry stem yields.

3.3 Yield data

For fibre production the valuable portion of both hemp and kenaf plants is the stem. Yield results from these trials are presented as a dry stem weight yield per metre of row harvested (kg/m/row) to enable comparison between trials where different row spacings and cultural practices have been used.

For a yield per area comparison (t/ha) the row spacing (number of rows per hectare) needs to be considered. A lower kg/m/row yield at a closer row spacing may in fact give a higher t/ha yield than a higher kg/m/row yield at a wider row space (Appendix 5). Stem samples were taken from internal row(s) in a plot to allow for any edge effects and to get a better estimate of what might be expected under broad acre planting however caution should be applied when using small plot yield data to extrapolate a per hectare yield given a particular row spacing.

Stem yields from trials at Southedge and Biloela are oven-dry weights while those from Gatton are air-dry weights.

3.4 Statistical analyses

All data were analysed by the General Analysis of Variance (ANOVA) function of GenStat (8^{th} edition, 2005) software. Following ANOVA, the least significant difference (l.s.d) test at $P = 0.05$ and 0.01 was used to separate treatment means.

4 Results and Discussion

4.1 Hemp trials

4.1.1 Southedge hemp trial 2002

Table 1. Days to male flowering and harvest and % THC for each hemp variety.

Variety	Days to male flowering	Days to harvest	% THC
EIL 1-02	21	55	0.10
EIL 2-02	21	69	0.37
EIL X-99	62	109	1.20
EIL 3-02	87	118	0.10

The varieties EIL 1-02 and EIL 2-02 flowered earlier than the other two which effected stem yield (Table 2) while the variety EIL X-99 had a THC level above what is considered acceptable for industrial hemp. Under current Queensland Government legislation < 1% THC is acceptable for fibre production and < 0.5% THC for seed production however EIL is really only interested in developing varieties with < 0.5% THC (Jobling, *pers. comm*.).

There were disease issues with this first planting of hemp. Basal stem rot (*Sclerotium rolfsii*), Septoria (*Septoria cannabis*) which was a new record for Australia and Cercospora (*Cercospora sp*) were all identified. There were some plant deaths due to the basal stem rot while the Septoria and Cercospora caused some leaf damage however none of the diseases were at a level which required treatment. Under large scale commercial plantings however these diseases may be of concern, especially in tropical areas.

Table 2. Harvest height (m) and stem dry weight yields (kg/m/row) for each hemp variety.

Variety	Row spacing cms	Harvest height m	Stem dry weight kg/m/row
EIL 1-02	33	1.013 c	0.092 d
EIL 2-02	33	1.625 b	0.164 c
EIL 3-02	33	2.050 a	0.622 a
EIL 1-02	20	0.985 c	0.103 cd
EIL 2-02	20	1.550 b	0.159 c
EIL X-99	20	2.100 a	0.498 b
EIL 3-02	20	1.990 a	0.616 a
s.e.d.		0.068	0.027
l.s.d (P=0.01)		0.196	0.065

Means followed by the same letter are not significantly different at (P=0.01)

Row spacing had no significant affect on harvest height or stem dry weight yields. The varieties EIL 3-02 and EIL X-99 were significantly (P<0.01) taller plants at harvest due to their longer growth period before flowering and harvest. The variety EIL 3-02 produced significantly greater (P<0.01) stem dry weight yield compared to the others.

4.1.2 Biloela hemp trial 2002

Table 3. Days to male flowering and seed set and % THC for each hemp variety.

Variety	Days to male flowering	Days to seed set	% THC
EIL 1-02	20	40	0.10
EIL 2-02	25	50	0.35
EIL X-99	70	95	1.02
EIL 3-02	75	110	0.10

Due to the surface crusting nature of the soils at this site germination and emergence was poor and so meaningful yield data could not be collected. However from the days to male flowering it can be assumed that EIL X-99 and EIL 3-02 would have given greater dry stem yields than the EIL 1-02 and EIL 2-02. Again the variety EIL X-99 had a THC level that is above that for acceptance.

4.1.3 Southedge hemp trial 2003

Table 4. Days to male flowering and harvest and % THC for each hemp variety.

Variety	Days to male flowering	Days to harvest	% THC
EIL 2-02	30	62	0.71
EIL X-99	64	104	1.03
WL-03	80	116	0.70
AM-03	85	124	0.52
MF-03	85	126	1.03
EIL 3-02	90	130	0.17
NO-03	94	138	0.84
WS-03	100	144	0.95

The variety EIL 2-02 flowered 9 days later at Southedge in 2003 (30 days) c.f 2002 (21 days). This variety was used in each of the trials as the ‘check’ for comparison of flowering dates with other varieties. The variety EIL X-99 flowered and was harvested at a similar stage in both years.

Apart from EIL X-99 and 3-02 all other varieties had acceptable THC levels.

Table 5. Harvest height (m), stem dry weight yields (kg/m/row) and % fibre for each hemp variety.

Variety	Plant height m	Stem dry weight kg/m/row	% Fibre
EIL 2-02	1.808 d	0.112 d	15.6
EIL X-99	2.625 c	0.369 c	16.2
WL-03	3.325 b	0.468 bc	16.1
NO-03	3.333 b	0.505 bc	16.0
AM-03	3.400 a	0.469 bc	16.5
EIL 3-02	3.567 a	0.591 b	17.3
MF-03	3.708 a	0.634 b	15.9
WS-03	3.958 a	1.019 a	15.3
s.e.d.	0.219	0.079	0.68
l.s.d (P=0.01)	0.596	0.218	n.s.

Means followed by the same letter are not significantly different at (P=0.01) n.s. not significant

The variety WS-03 produced a significantly greater dry stem yield compared to the others. At just over a kilogram of dry stem yield per metre of row this was the highest stem yield recorded in any of the hemp trials and at just under 4 m was the tallest. This variety had thicker stems (10 – 20 mm average diameter) compared to others studied and was heavily branched which added to the yield obtained. Even at 0.8 kg/m/row and at 33 cm row spacing this would equate to a per hectare yield of about 24 t/ha (Appendix 5) which is about two and a half times the usually quoted commercial yield of 10 t/ha. Struik *et al.* (2000) reported experimental stem dry matter yields of 18 t/ha in Italy. The yields of EIL 2-02 and EIL 3-02 were similar to those obtained in 2002 at Southedge.

The percentage fibre levels of each of the varieties were not significantly different. At an average of 16.1 % these levels are lower than those reported for similar varieties at around 20 % (Jobling, *pers. comm*.) however the later result was from samples taken from freshly cut stems which may explain the difference. The methodology for calculating fibre percentage is given in Appendix 3.

4.1.4 Gatton hemp trial 2003

Emergence of the hemp varieties at Gatton was poor and uneven due to soil structure problems, planter issues and saline irrigation water. The black alluvial clay loam soil at Gatton tends to crust when wet and there was a severe storm with hail 2 days after planting. Also the use of press wheels at planting compacted the soil making emergence difficult. Also germinated plants that did emerge were subjected to poor quality saline (106 mg/L sodium, 1,011 mg/L chloride) irrigation bore water due to drought conditions at the time. Hemp does not tolerate salty conditions and irrigation water with a chloride content > 900 mg/L is suitable only for high salt tolerant crops. The yield figures given (Table 6) are single plot harvests selected for uniformity for each of the varieties and are shown as guide to relative yield only. The plants were 125 days old and about 3.5 m in height.

The variety EIL 2-02, although flowering early (Table 6), still produced a relatively high stem yield and was much higher than the yield achieved at Southedge, however the yield of WS-03 was only about 40 % of that achieved at Southedge which is further indication of the suitability of this variety to a more tropical environment. Apart from EIL 2-02 and WS-03 yields were similar for the varieties at both sites even though they flowered at Southedge 10 to 30 days earlier.

Cooper (2002) reported that in a trial at Trangie NSW (32° S, 148° E) the variety EIL 2-02 flowered at between 80 to 100 days depending on sowing date which is about twice the number of days found for EIL 2-02 in these trials. EIL 2-02 gave a dry stem yield of 0.090 kg/m/row which was about half that achieved at Southedge in 2002 (but similar to the results in 2003 and 2004 – Tables 5 and 8). The trial at Trangie used comparatively much narrower row spacings (15.4 cm).

Table 6. Days to male flowering and stem dry weight yield estimate.

Variety	Days to male flowering	Estimated stem dry weight kg/m/row
EIL 2-02	53	0.608
EIL X-99	91	0.642
WL-03	112	0.562
AM-03	95	0.441
EIL 3-02	105	0.494
MF-03	111	0.258
NO-03	116	0.557
WS-03	142*	0.410

* taken from plots not harvested for yield estimate

4.1.5 Southedge hemp trial 2004

Table 7. Days to male flowering and harvest and % THC for each hemp variety.

Variety	Days to male flowering	Days to harvest	% THC
EIL 2-02	25	66	0.2
EIL S-00	25	ns*	0.1
AM-03	37	75	0.2
RB-03	57	115	0.2
WL-03	57	115	0.7
NO-03	59	115	0.6
MF-03	64	115	0.7
EIL 2-02	29	-	0.2
YS-04	64	-	0.5
LS-04	67	-	0.9
LB-04	84	-	0.9
LP-04	84	-	1.0
DL-04	92**	-	ns

* no sample - insufficient plants for harvest ** single plant

The first 7 varieties in Table 7 were part of the main trial, the other 6 were single plot observations for days to male flowering and THC levels. Germination and emergence of the variety EIL S-00 was poor and so harvest for yield was not possible.

Except for EIL 2-02, similar varieties from the 2003 trial flowered between 20 to 35 days earlier (AM-03 at 48 days) in 2004. This large difference is difficult to explain. Although planted 20 days later in 2004 compared to 2003 (15/10/03 and 4/11/04) daylength exposure would not have been much different during growth. Also temperatures during growth to flowering were similar in both years as was the amount and timing of fertiliser and irrigation.

THC levels were lower in 2004 for similar varieties from 2003 which is probably related to the different ages of the plants at sampling where the older plants in 2003 had more time for the accumulation of THC within the leaves. All the varieties (except for LP-04) had THC levels at a level acceptable for commercial fibre production.

Table 8. Harvest height (m), stem dry weight yields (kg/m/row) and % fibre for each hemp variety.

Variety	Plant height m	Stem dry weight kg/m/row	% Fibre
EIL 2-02	0.990 a	0.091 a	16.2
WL-03	2.000 b	0.355 b	17.1
MF-03	2.100 b	0.409 b	18.5
NO-03	2.160 b	0.378 b	18.5
AM-03	2.230 b	0.364 b	18.5
RB-03	2.350 b	0.447 b	18.6
s.e.d.	0.213	0.057	0.96
l.s.d (*P*=0.01)	0.606	0.164	n.s.

Means followed by the same letter are not significantly different at (*P*=0.01) n.s. not significant

Plants were shorter and yields lower (about 25 %) in 2004 compared to those from 2003 however the order of ranking of the varieties was the same in both years with MF-03 giving the highest and WL-03 the lowest yields. Percentage fibre levels were not significantly different between the varieties and were about 2 % higher than those in 2003.

4.1.6 Gatton hemp trial 2004

Table 9. Days to male flowering and harvest and % THC for each hemp variety.

Variety	Days to male flowering	Days to harvest	% THC
EIL 2-02	53	153	0.4
EIL S-00	53	153	0.7
AM-03	118	153	0.3
RB-03	118	153	0.3
WL-03	118	153	0.4
NO-03	118	153	0.9
MF-03	118	153	0.4
EIL 2-02	69	-	0.3
YS-04	103	-	0.6
LS-04	108	-	1.1
LB-04	108	-	1.7
LP-04	108	-	1.4
DL-04	*	-	2.2*
LQ-04	104	-	0.7

* 2 female plants only

The first 7 varieties in Table 9 were part of the main trial, the next 7 were single plot observations for days to male flowering and THC levels.

All the varieties took about twice as long to flower at Gatton compared to Southedge and apart from EIL 2-02 and S-00, the varieties all flowered at a similar time. Due to time constraints all varieties were harvested at the same time. The THC levels were higher at Gatton compared to Southedge (again this was probably due to the older plants sampled at Gatton) and most were below the acceptable limit.

Table 10. Harvest height (m) and stem dry weight yields (kg/m/row) for each hemp variety.

Variety	Plant height m	Stem dry weight kg/m/row
EIL S-00	2.680 a	0.597
EIL 2-02	3.000 b	0.620
WL-03	3.500 c	0.770
MF-03	3.620 c	0.873
NO-03	3.700 c	0.903
AM-03	3.560 c	0.765
RB-03	3.500 c	0.778
s.e.d.	0.112	0.109
l.s.d (*P*=0.01)	0.314	*P*=0.07

Means followed by the same letter are not significantly different at (*P*=0.01)

The EIL S-00 and 2-02 varieties were significantly shorter plants than the others and gave lower yields. Stem yields were close to being significantly different between varieties (*P*=0.07) and were about double those at Southedge for similar varieties although weights at Gatton were on an air-dry basis. The harvesting of all varieties at the same time may have masked any yield differences. The yields of MF-03 and NO-03 were high and warrant further study in this environment although the THC level of NO-03 (0.9%) may be an issue.

The planting problems from 2003 were overcome by planting into dry soil and using very light presswheels. Also better quality irrigation water was used and applied through a trickle irrigation system which minimised soil crusting and so germination and emergence was very good.

There were no obvious pest or disease issues with the hemp trials at Gatton.

4.2 Kenaf trials

4.2.1 Southedge kenaf trial 2002

Table 11. Harvest height (m) and stem dry weight yields (kg/m/row) for each kenaf variety.

Variety	Harvest height m		Stem dry weight kg/m/row	
	50 cm rows	33 cm rows	50 cm rows	33 cm rows
Dowling	3.062	3.100	1.248	1.387
E – 71	2.838	3.038	1.212	1.279
G – 4	2.925	2.938	1.141	1.207
Gregg	3.100	3.100	1.321	1.548
Yuexuan 743	3.000	3.025	1.316	1.326
Mean	2.985	3.040	1.248	1.350

Harvest height was not significantly different between varieties or affected by row spacing (Table 11). Row spacing had a significant ($P<0.05$, l.s.d. 0.0915) effect on stem dry weight yield with 33 cm rows giving a greater average yield c.f with 50 cm rows. There was also a significant ($P<0.05$) difference between varieties for stem dry weight yield (Table 12) with Gregg giving the greatest yield at 1.435 kg/m/row. The variety G - 4 gave the lowest yield and has been the variety used for many years in trials (and commercially) in northern Australia (Vawdrey and Peterson, 1990). A 1 kg/m/row yield of dry stem equates to about 30 t/ha yield (at 33 cm row spacing, Appendix 5) which is higher than what is considered a good commercial stem yield of 20-25 t/ha.

Table 12. Stem dry weight yields (kg/m/row) for each kenaf variety.

Variety	Stem dry weight kg/m/row
Dowling	1.317 abc
E – 71	1.246 bc
G – 4	1.174 c
Gregg	1.435 a
Yuexuan 743	1.321 ab
s.e.d.	0.070
l.s.d (P=0.05)	0.145

Means followed by the same letter are not significantly different at (P=0.05)

4.2.2 Biloela kenaf trial 2002

The different row spacings (25, 50 and 75 cms) and varieties had a significant effect on stem dry weight yields (kg/m/row) (Tables 13 and 14). There was an almost linear increase in stem yield of 0.5 kg/m/row as row width was increased from 25 to 75 cms. This is opposite to what occurred at Southedge where the narrower row space (33 cm) gave the higher stem yield. This was likely due to the competition between plants where plants grew taller (Table 11) giving a greater stem yield. Also the more suitable environmental/cultural conditions for kenaf at Southedge was such that this extra growth was possible. On a yield per hectare basis (t/ha) however, the yields from Table 13 would show the 25 cm spacing to give the highest yield (20.44 t/ha), with 50 cm giving 20.10 t/ha and 75 cm at 18.67 t/ha.

Table 13. Stem dry weight yields (kg/m/row) for each row spacing.

Row spacing cms	Stem dry weight kg/m/row
25	0.511 a
50	1.005 b
75	1.406 c
s.e.d.	0.075
l.s.d (*P*=0.01)	0.206

Means followed by the same letter are not significantly different at (*P*=0.01)

The variety Yuexuan 743 gave a significantly higher stem yield compared to the others (Table 14) and was comparable to that achieved at Southedge although overall yields were about 25 % lower here than those achieved at Southedge. At both sites Yuexuan 743 and Gregg gave the highest yields while once again G - 4 was one of the lower yielding varieties.

Table 14. Stem dry weight yields (kg/m/row) for each kenaf variety.

Variety	Stem dry weight kg/m/row
Dowling	0.844 b
E – 71	0.930 b
G – 4	0.921 b
Gregg	0.943 b
Yuexuan 743	1.231 a
s.e.d.	0.096
l.s.d (*P*=0.01)	0.266

Means followed by the same letter are not significantly different at (*P*=0.01)

4.2.3 Southedge kenaf trial 2003

Row spacing had a significant ($P<0.05$) effect on stem dry weight yield with the 50 cm row spacing giving a greater yield (1.273 kg/m/row) compared to the 33 cm spacing (1.082 kg/m/row, l.s.d 0.155). This was opposite to what occurred in 2002 and was due to a much lower yield from the 33 cm row plots as the yield from the 50 cm row plots were similar in both years. Less plants were harvested per meter of row in 2003 (lower germination) and so plants had thicker stems and grew taller (about 1 m). There was a significant ($P<0.01$) variety effect on plant height at harvest (Table 15) and although this did not translate into significant yield differences the taller varieties gave the higher yields with yields slightly less than what was achieved in 2002.

Table 15. Harvest height (m), stem dry weight yields (kg/m/row) and % fibre for each kenaf variety.

Variety	Harvest height m	Stem dry weight kg/m/row	% Fibre
Dowling	3.940 ab	1.237	34.9 b
E – 71	3.750 b	1.019	36.7 ab
G – 4	3.744 b	1.098	37.8 a
Gregg	4.014 a	1.318	36.0 ab
Yuexuan 743	3.981 ab	1.217	35.6 b
s.e.d.	0.087	0.119	0.68
l.s.d (*P*=0.01)	0.241	n.s.	1.9

Means followed by the same letter are not significantly different at (*P*=0.01) n.s. not significant

As was the case in 2002 the variety Gregg gave the highest stem yield with Yuexuan 743 and Dowling also performing well with G - 4 and E - 71 giving the lowest yields.
Ayerza and Coates (1996) reported the variety E - 71 producing around 10 t/ha dry stem yield in Argentina (24° S) which is relatively low although no fertiliser or irrigation was used along with 80 cm row spacing. They also reported a fibre percentage of 37.2 (ave.) for this variety which is close to what was found for this variety in this series of trials.

4.2.4 Gatton kenaf trial 2003

Row spacing had a significant (*P*<0.01) effect on plant height at harvest with 50 cm rows producing taller plants at harvest compared to 33 cm rows while variety had a significant (*P*<0.05) effect on dry stem yield (Table 16).

Table 16. Harvest height (m) and stem dry weight yields (kg/m/row) for each kenaf variety.

Variety	Harvest height m		Stem dry weight kg/m/row
	50 cm	33 cm	
Dowling	3.550	3.425	0.684 bc
E – 71	3.475	3.375	0.662 c
G – 4	3.275	3.450	0.644 c
Gregg	3.725	3.400	0.791 ab
Yuexuan 743	3.700	3.350	0.806 a
s.e.d.			0.055
l.s.d (*P*=0.01) 0.138	3.545 a	3.400 b	l.s.d (*P*=0.05) 0.113

Means followed by the same letter are not significantly different at (*P*=0.05 or *P*=0.01)

Plants grew significantly taller with the wider row spacing and although not significant (*P*=0.07) the wider row spacing produced higher yields. There was also a significant variety x row interaction (*P*=0.02, l.s.d. 0.309) for plant height where the varieties Gregg and Yuexuan 743 grew much taller at 50 cm rows than 33 cms and all other varieties at either row spacing. Yuexuan 743 and Gregg gave significantly higher stem yields (as was the case for the 2002 trials) with yields lower than those obtained at both Southedge and Biloela however the ranking of varieties tended to be similar.

The kenaf trial at Gatton did not suffer with the planting and salinity problems as was the case for the hemp trial (trials were side by side) demonstrating the more robust nature of kenaf seed and its salt tolerance as a species.

4.2.5 Southedge kenaf trial 2004

Row spacing had a significant (*P*<0.05) effect on plant height at harvest with 50 cm row spacing producing taller plants (4.110 m) c.f to 25 cm spacing (3.960 m, l.s.d 0.117). Variety also had a significant effect on plant height at harvest (Table 17).

Table 17. Harvest height (m), stem dry weight yields (kg/m/row) and % fibre for each kenaf variety.

Variety	Harvest height m	Stem dry weight kg/m/row	% Fibre
Dowling	4.131 ab	1.587	34.8
E – 71	3.912 a	1.575	35.5
G – 4	3.894 a	1.556	35.5
Gregg	4.000 ab	1.519	35.4
Yuexuan 743	4.238 b	1.628	35.0
s.e.d.	0.090	0.136	0.72
l.s.d (*P*=0.01)	0.250	n.s.	n.s.

Means followed by the same letter are not significantly different at (*P*=0.01) n.s. not significant

Yields from this trial were 4-500 gms/m/row higher than those obtained the previous 2 years at Southedge and about double those obtained at Gatton in 2003. The plants were taller (about 0.5 m) and some lodging occurred with the variety G – 4 the most susceptible. Conditions at Southedge during later growth (February and March) were hotter and much wetter than those in 2002 and 2003 and were obviously ideal for growth to produce such high yields. As was the case in 2003 the taller growing varieties (Yuexuan 743 and Dowling) gave the higher yields.

Fibre percentages for each variety were very similar (n.s.) and slightly lower than those from 2003.

4.2.6 Gatton kenaf trial 2004

Row spacing had a significant (*P*<0.05) effect on stem yields with the 50 cm row spacing producing higher yields (1.051 kg/m/row) c.f to 25 cm spacing (0.943 kg/m/row, l.s.d 0.097). Variety also had a significant effect (*P*=0.05) on stem yield at harvest (Table 18).

Stem yields were higher at Gatton in 2004 compared to 2003 and more in line with what was achieved at Southedge in 2002 and 2003. In 2003 the trial was watered with overhead sprays and water quality was poor while in 2004 trickle tape was used to irrigate, water quality was improved and extra fertiliser was applied. Again Gregg and Yuexuan 743 gave the highest yields.

Table 18. Harvest height (m) and stem dry weight yields (kg/m/row) for each kenaf variety.

Variety	Harvest height m	Stem dry weight kg/m/row
Dowling	3.375	1.023 ab
E – 71	3.250	0.922 a
G – 4	3.200	0.900 a
Gregg	3.419	1.113 b
Yuexuan 743	3.412	1.028 ab
s.e.d.	0.112	0.074
l.s.d (*P*=0.05)	n.s.	0.153

Means followed by the same letter are not significantly different at (*P*=0.05) n.s. not significant

There was pest problem with this trial where a heavy infestation of red shoulder leaf beetles (*Monolepta australis*) caused some damage to the younger leaves. They were not sprayed and the crop recovered well without any apparent effect on yield.

5 Implications

5.1 Hemp

The very high stem yield of the variety WS – 03 under the tropical environment conditions at Southedge is an important milestone in the development of a commercial industrial hemp fibre industry in tropical Australia. It has the potential to be the starting variety for commercial production given that any investment in processing facilities in this region would be dependent on a reliable supply and growers being confident of achieving reliable sustainable yields.

Commercial production (growing and processing) of hemp has commenced near Dalby in southern Queensland by EIL. The stem yields of the varieties NO – 03 and MF – 03 at Gatton were higher than those they use currently for commercial production (EIL 3 –02 or RB-03) in this area and so the potential is there to increase yields (about 10-15 %) quickly by changing to these varieties.

5.2 Kenaf

For many years most kenaf trials, and more recently commercial production in north Queensland, has used the variety Guatemala 4 (G – 4). Results from this project indicate that the newer varieties Yuexuan 743 and Gregg will increase yields by about 10 % in tropical regions and by about 20 % if kenaf production was to occur in sub-tropical regions. Also results from this project indicate there is potential for yield increases by planting rows closer together than what is currently practiced commercially.

6 Recommendations

6.1 Hemp

1. The yield of WS – 03 is based on 1 trial and further larger scale plantings should be undertaken to confirm this high yield before any release for commercial production in tropical regions. Also the THC level of this variety (0.95 %) was close to the acceptable limit for fibre production (1 %) which may be a problem.

2. Further field studies should be undertaken in temperate environments to study the performance of these new varieties developed by EIL.

3. For fibre production in the tropics hemp crops are grown over the summer months to capture the longer daylengths. It is recommended that trials be undertaken to study seed production during the winter cropping months in north Queensland.

4. The fibre content of stems increases with plant density as does the quality of the fibre produced. Further research is recommended to identify row spacings and plant populations that maximise yield and fibre quality under tropical/sub-tropical conditions.

5. Most of the hemp varieties studied had THC levels below the acceptable limit of 1 % for commercial fibre production although for breeding and seed production purposes some were above the 0.5 % limit. It will be necessary to acquire a better understanding of the impact different cultural practices (time of planting, plant population, fertiliser, irrigation etc) have on THC levels in the plant to avoid those that may increase levels.

6.2 Kenaf

1. It is recommended that seed of the newer varieties Gregg and Yuexuan 743 be made available for commercial kenaf production in north Queensland and that the Australian Tropical Crops and Pastures Genetic Resource Centre play a lead role in this development.

2. Currently commercial kenaf crops grown in north Queensland are planted with 2 rows between 1.5 m wheel tracks. These rows can be from 45 to 75 cm apart but is determined so that crops can be harvested by a sugarcane harvester. It is recommended that under tropical conditions kenaf be planted at 40 cm row spacings to maximise yield, especially if the variety Gregg is planted. This will require different planting and harvesting equipment than is currently used.

3. Further studies into the amounts and timing of irrigation and nitrogen to maximise yield is recommended.

The introduction of new crops such as hemp and kenaf into a region should be done within the framework of a ‘farming system’ approach. Such a framework exists for tropical farming systems in north Queensland (Holden *et al*, 2005) and specifically for the MDIA (Holden *et al*, 2003) and should be used as guides for the successful introduction and commercial production of these crops.

7 Appendices

1. Bast Fibre Conferences

August 2000, CSIRO Geelong, Victoria.
February 2001, Queensland Department of State Development, Brisbane.
August 2001, La Trobe University, Melbourne.

2. Field trial sites

Southedge Research Station

Southedge Research Station (16°58’S, 145°20’E; elevation 450 m) is approximately 10 km north west of Mareeba in north Queensland. Southedge is a Queensland Department of Primary Industries and Fisheries research facility within the Mareeba-Dimbulah Irrigation Area (MDIA) which is part of the north-western end of the Atherton Tableland. Southedge has an average annual rainfall of 1,110 mm, predominantly in the November-March period with the climate described as dry tropical. The soil is a red earth of granitic origin and known locally as a Morganbury sandy loam and described by Isbell (1996) as a Red Kandosol.

Biloela Research Station

Biloela Research Station (24°23’S, 150°30’E; elevation 173 m) is located on the northern edge of the township of Biloela in the Callide Valley. Biloela is a Queensland Department of Primary Industries and Fisheries research facility sited on alluvial flats adjacent to Callide creek. The climate is sub tropical with erratic annual rainfall averaging 700 mm. Light frosts are common in July and August but only a few days in summer are likely to reach the 40 C mark. The soils are principally heavy sandy clay loams that are suited to irrigated agriculture although they have a tendency to surface crust following heavy rain.

Gatton Research Station

Gatton Research Station (27°32’S, 152°19’E; elevation 93 m) is situated in the Lockyer Valley approximately 90 km west of Brisbane in Queensland. Gatton is a Queensland Department of Primary Industries and Fisheries research facility which focuses on vegetable crop research. Irrigation water is available from both underground and surface supplies. Gatton has an average annual rainfall of 778 mm, predominantly in the October-March period with the climate described as sub-humid and subtropical. The soil is a black alluvial clay loam and consists predominantly of montmorillonite clay.

3. Calculation of stem fibre percentage

About 30 gms of dry stems were taken mid-plant from each plot sample - typically 9 - 11 stem pieces, 5 - 15 mm in diameter and 15 cms long. Stem pieces were then soaked in jars of tap water for 3 days. Stem pieces removed and shaken lightly to remove excess water.
Fibre was then stripped off the hurd by thumbnail. Separated fibre and hurd samples were then oven dried (60 C) for 3 days to constant weight then weighed and then fibre % calculated.

4. Site Comparison Matrix

4.1 Hemp – Days to male flowering

Variety	Days to male flowering					
	Biloela	Southedge			Gatton	
	2002	2002	2003	2004	2003	2004
EIL 2-02	25	21	30	25	53	53
EIL X-99	70	62	64		91	
AM 03			85	37	95	118
RB 03				57		118
WL 03			80	57	112	118
MF 03			85	64	111	118
NO 03			94	59	116	118
WS 03			100		142	

4.2 Hemp – % THC

Variety	% THC					
	Biloela	Southedge			Gatton	
	2002	2002	2003	2004	2003	2004
EIL 2-02	0.35	0.37	0.71	0.2		0.4
EIL X-99	1.02	1.20	1.03			
AM 03			0.52	0.2		0.3
RB 03				0.2		0.3
WL 03			0.70	0.7		0.4
MF 03			1.03	0.7		0.4
NO 03			0.84	0.6		0.9
WS 03			0.95			

4.3 Hemp – Stem dry weight yields kg/m/row

Variety	**SRS 2002**		**SRS 2003**	**GRS 2003**	**SRS 2004**	**GRS 2004**
	20 cm	**33 cm**	**25 cm**	**25 cm***	**25 cm**	**25 cm**
EIL 1-02	0.103	0.092				
EIL 2-02	0.159	0.164	0.122	0.608	0.091	0.620
EIL 3-02	0.616	0.622	0.591	0.494		
EIL X-99	0.498		0.369			
AM 03			0.469	0.441	0.364	0.765
RB 03					0.447	0.778
WL 03			0.468	0.562	0.355	0.770
MF 03			0.634	0.258	0.409	0.873
NO 03			0.505	0.557		0.903
WS 03			1.019	0.410		
EIL S-00						0.597

* single plot estimates

4.4 Kenaf – Southedge - Stem dry weight yields kg/m/row

Variety	2002		2003		2004	
	33 cm	50 cm	33 cm	50 cm	33 cm	50 cm
Dowling	1.387	1.248	1.178	1.269	1.441	1.734
E – 71	1.279	1.212	0.878	1.161	1.655	1.600
G – 4	1.207	1.141	1.001	1.194	1.555	1.762
Gregg	1.548	1.321	1.269	1.367	1.478	1.559
Yuexuan 743	1.326	1.316	1.086	1.349	1.527	1.729

4.5 Kenaf – Biloela/Gatton - Stem dry weight yields kg/m/row

Variety	Biloela 2002			Gatton 2003		Gatton 2004	
	25 cm	50 cm	75 cm	33 cm	50 cm	33 cm	50 cm
Dowling	0.395	0.982	1.153	0.656	0.712	1.014	1.031
E – 71	0.581	0.896	1.315	0.594	0.731	0.815	1.029
G – 4	0.515	0.876	1.373	0.638	0.650	0.838	0.963
Gregg	0.401	1.049	1.380	0.750	0.831	1.048	1.179
Yuexuan	0.664	1.221	1.809	0.788	0.825	1.002	1.054

5. Row Spacing and Yield/Area Matrix

Dry stem yield kg/m/row	Dry stem yield t/ha Row spacing cms					
	10	20	25	33	50	75
0.2	20	10	8	6.06	4	2.66
0.4	40	20	16	12.12	8	5.32
0.6	60	30	24	18.18	12	7.98
0.8	80	40	32	24.24	16	10.64
1.0	100	50	40	30.30	20	13.30
1.5	150	75	60	45.45	30	19.95

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