USING AGRONOMIC PRACTICES TO INCREASE THE PER HECTEARE YIELD OF FLAX FIBRE

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ABSTRACT

This paper summarizes the results of recent work that has been done in Saskatchewan and Manitoba to find agronomic practices that can be used to increase the per ha production of flax fibre. Such practices include changes in varieties grown, rates of seeding, dates of seeding and methods of harvest. Finding cost-effective ways to increase per ha fibre yields will increase the profits going to farmers and processors and hence make flax straw and fibre production, collection, and processing more financially viable.

INTRODUCTION

About 800,000 ha of oilseed flax are grown annually in western Canada but the majority of the flax straw is produced as a by-product of seed production and is presently not utilized. The fibre in oilseed flax straw is suitable for plastic composites, building insulation, filtration products, textiles etc. if the straw is managed properly.

In the last six years, Biolin Research Inc. has been involved in a number of flax related agronomic studies. Much of the funding for these studies has come from the Saskatchewan Flax Development Commission and the Agriculture Development Fund of Saskatchewan Agriculture Food and Rural Revitalization. In some cases, Biolin had little control over the collection of the straw or seed, and hence does not always have a complete set of all possible data for each trial.

Per ha fibre yield is a function of both straw yield per ha and straw fibre content. Straw yields and fibre contents are both variable. Oilseed straw fibre contents have been known to vary from 2% to 30%, however, the normal range is 13% to 18%. Straw yields are also quite variable, ranging from 0 to 2.5 t/ha, however, a normal salvageable straw yield, using traditional harvest and salvage methods would be about 1.2 to 1.5 t/ha.

Simply trying to increase the per ha fibre yield of flax straw may result in reduced profits unless it considers the economics of field production and flax straw processing. For example, consider the introduction of a possible new variety. Suppose the old flax variety had an average of 15% fibre and an average yield of 1,500 kg/ha straw. This would result in 225 kg/ha of fibre being produced. Now assume a new flax variety yields 260 kg/ha of fibre from 2,000 kg/ha of straw with a fibre content of 13 %. Obviously the new variety has a higher fibre yield/ha and, all else being equal, should have a lower straw cost of production per kg. However, we must also consider this new variety from a processor's point of view. The new variety will be less profitable to process because it has a lower fibre content (i.e., 13% instead of 15%) since more raw product is needed to produce the same amount of fibre. For example, if it costs $30/tonne to process any variety of straw, then the processing cost per kg of fibre from the old variety would be $0.20/kg and from the new variety would be $0.23/kg.

Thus, when it comes to using agronomic practices to increase the per ha fibre yield, the objective is to increase the fibre yield in ways that are attractive to both the farmer and the processor. Ideally this would be accomplished with increases in seed yield, fibre content and per ha straw yield. However, this does not always happen and there are often tradeoffs that must be made among seed yield, fibre content and straw yield.

Potential fibre production is influenced by the interaction of several factors including the geographical location the flax is planted in, the variety sown, the seeding rate, the seeding date, seeding method, soil fertility, and weather. It is also important to look at the amount of fibre that can actually be harvested and methods available to harvest the straw and make the fibre more easily extractable. This paper will discuss some of the recent agronomic research that has been done in Saskatchewan and Manitoba with respect to flax straw fibre content, flax straw yield and flax straw fibre yield. It is important to note that biological systems are complex and the interactions of uncontrollable factors like growing season weather can make massive impacts on expected results in a given year. The results contained in this paper are from only a couple years and the growing season weather during these years, was, at many sites, much drier than the 30-year normal, however, in the interests of advancing the industry, it is useful to consider some of the results we have obtained to date.

GROWING FLAX IN GENERAL

In order to use agronomic practices to increase the per ha yield of flax fibre it its important to know what agronomic practices are now commonly used. At present, the majority of flax in western Canada is grown for seed. The straw is seen as a waste or nuisance and seldom as a bi-product or co-product. Previous oilseed flax breeding programs have worked towards reducing the height of straw and the amount of straw that is put through harvesting equipment. Recommended seeding rates are 30 to 45 kg/ha. Flax should be sown about 2.5 to 4.0 cm deep into a moist firm seedbed to ensure quick emergence. Early seeding of flax often results in much higher seed yields compared to late seeding flax. However, flax is one of the crops more tolerant to fall frosts and is often sown later in the spring by farmers who choose to seed their other crops before they seed their flax. There is an increasing trend towards minimum and zero tillage seeding systems in western Canada (these practices tend to reduce soil erosion and retain soil moisture better than conventional tillage systems). Flax thrives in areas that have:

relatively few hot summer days (i.e., it does not thrive if the temperature is >28° Celsius), moderate rainfall (250 to 750 mm), soils which have neither a high percentage of sand or clay and a growing season of 100 to 120 days.

SEEDING DATE AND FIBRE CONTENT

While not conclusive, it seems that, in general, seeding later results in higher straw fibre content and higher salvageable straw yields. The effect of seeding date on fibre content is presented in Table 1. A study in 2001 found that at two of three sites seeding later resulted in a statistically significant higher straw fibre content than seeding earlier. At the third site seeding earlier produced statistically significant higher straw fibre contents. In a further study in 2003, at three "Agri-Arm" sites, seeding flax later resulted in higher fibre contents, straw yields and fibre yields compared to early seeding.

TABLE 1 THE EFFECT OF SEEDING DATE ON FIBRE CONTENT, STRAW YIELD AND FIBRE YIELD

Site, Year	Seeding Date	Fibre Content %	Straw Yield kg	Fibre Yield kg/ha
Mel-01	Early	12.8	n/a	n/a
	Late	14.9	n/a	n/a
Mor-01	Early	17.0	n/a	n/a
	Late	12.7	n/a	n/a
IH-01	Early	8.3	n/a	n/a
	Late	10.8	n/a	n/a
Can-03	Early	15.7	2,120	331
	Late	18.2	2,780	519
IH-03	Early	13.6	680	93
	Late	14.8	960	142
Red-03	Early	15.8	1,030	163
	Late	17.4	1,550	214

Notes:

n/a = not available
Mel-01 = Melfort, SK 2001
Mor-01 = Morden, MB 2001
IH-01 = Indian Head, SK 2001
Can-03 = Canora, SK 2003
IH-03 = Indian Head, SK 2003
Red-03 = Redvers, SK 2003

SEEDING METHOD

Seeding method refers to several things like seedbed preparation, seed delivery mechanism, seeding tool and seeding implement. Selection of the seeding tool and seeding implement (i.e., seed delivery mechanism) impact seedbed utilization. Seedbed utilization refers to the amount of area that seed is spread over and is measured as a percentage of the total area of the field. Increasing seedbed utilization tends to increase straw production. Hence the use of a modern well designed sweep type seeding tool results in the opportunity to increase plant populations and consequently the amount of straw that is produced. This is likely because the plants do not face as much competition from one another when they are spread out in a wider band (i.e., when seedbed utilization is increased). However, high seed bed utilization results in high soil disturbance.

The effect of seeding method on fibre content, salvaged straw yield and fibre yield from the Agri-Arm 2003 study is shown in Table 2. The seed spread pattern had little effect on fibre content but did have a significant positive effect on salvaged straw yield and fibre yield. This is likely because seeding systems using sweeps have higher seed bed utilization compared to seeding systems that use hoes. It should be noted that these results are from one year and this year was extremely dry (i.e., it is suspected that in wetter years, the advantage of using sweeps will be even greater than that indicated in Table 2).

In addition, it should be pointed out that stem diameters tend to be reduced with sweeps. Smaller diameter stems normally "ret" (i.e., biologically break down or "rot") faster than larger diameter stems and produce finer fibre which is more valuable (at least if it is for textile use). Retting is a very important method of adding value to flax fibre since it reduces the amount of mechanical energy needed to extract the fibre from the stems and allows cleaner and finer fibres to be extracted. If straw rets faster in the field because of smaller diameter stems, it can be removed from the field sooner and hence reduces the inconvenience and cost to the farmer of having flax straw lying in the field when the farmer wants to do other things in the field. The economic value of faster retting due to smaller diameter stems has not yet been measured but faster retting is desirable from both a farmer and processor's point of view.

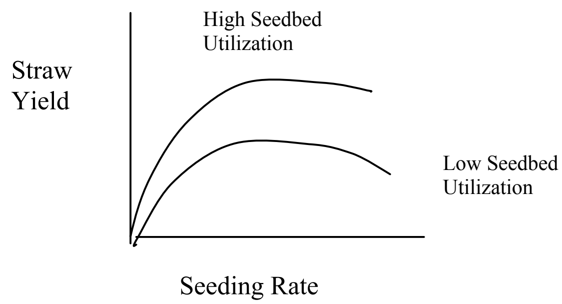
TABLE 2 THE EFFECT OF SEEDING METHOD ON FIBRE CONTENT, SALVAGED STRAW YIELD AND FIBRE YIELD

Seeding Method	Fibre Content %	Salvaged Straw Yield kg/ha	Fibre Yield kg/ha	Stem Diam. mm
Sweep	17.3	998	310	1.36
Hoe	17.2	864	276	1.49

SEEDING RATE

The seeding rate refers to the amount of seed sown per ha. As the seeding rate increases, the plant population should also increase (this can help with weed competition and may actually increase yields). As the plant population increases, the straw yield increases. However, increasing the seeding rate beyond a certain level does not necessarily increase straw yields (see Figure 1). This is because there are physical limitations to the amount of seed that can be placed in a given length of seed row. However, if we can make the seed row wider (i.e., increase seedbed utilization), we can, in theory, reach a higher level of per ha straw production before we reach the stage of too much plant competition and decreased per ha straw production levels. For this reason, to maximize the benefits of increased seeding rates, seeding methods with high seedbed utilization should be used.

Figure 1 The Theoretical Effect of Seeding Rate on Straw Yield



The results for a seeding rate trial performed in 2003 are presented in Table 3. In this trial, the results show that increasing the seeding rate beyond 80 kg/ha did not produce more straw or fibre. However, stem diameter decreased which can lead to quicker retting and removal of straw from the field.

TABLE 3 THE EFFECT OF SEEDING RATE ON FIBRE CONTENT, SALVAGED STRAW YIELD AND FIBRE CONTENT

Seeding Rate kg/ha	Fibre Content %	Salvaged Straw Yield kg/ha	Fibre Yield kg/ha	Stem Diameter mm
40	17.2	1,581	286	1.50
80	17.3	1,740	319	1.32
120	17.2	1,724	316	1.24

VARIETY SELECTION

Not all oilseed varieties have the same fibre content nor do they perform consistently year after year. This is because some varieties have different sensitivity levels to different aspects of their physical environment. For instance, some may do poorly if the spring is cold and wet; others may do poorly if there is even a short period of hot weather. Since growing season weather on the Prairies can vary dramatically from year to year, it takes years to isolate varieties that have superior traits (e.g., higher than average fibre content) in most types of growing season conditions. The Prairie region is vast and hence there are also significant physical differences in soil characteristics, altitude, length of daylight, average daily heat units, average night time temperatures, etc. Since this is the case, it also takes years of trials to pinpoint flax varieties that give superior performance at a given location or agronomic zone. With these caveats in mind, the fibre contents of different oilseed varieties grown in replicated plots at several Saskatchewan locations and years are shown in Table 4.

In these trials, fibre contents ranged from a high of 19.3% to a low of 2.1% among locations, varieties and years. Within locations and among years, the difference in fibre contents can be quite significant as well. For example, at the Kernen site (near Saskatoon), in 2001, the average fibre content was 3.6% but in 2003 the average fibre content at Kernen had risen to 11.1% (i.e., an increase of over 300% in fibre content between two years, but at the same location)!

While most of the flax grown in Western Canada is oilseed flax, European and Asian fibre flax varieties can also be grown under Western Canadian growing conditions. Fibre flax varieties have higher fibre contents, higher straw yields and higher fibre yields but lower seed yields than do conventional Canadian oilseed varieties. . Fibre contents for fibre flax varieties are generally 20-30% but can be as high as 40%. Fibre flax variety straw yields in Saskatchewan have ranged from 1.5 to 10.0t/ha depending upon the variety, agronomic practices and growing season weather. Fibre flax seed yields have generally been one third of that produced by oilseed varieties although there have been some exceptions.

FERTILITY

It seems that flax straw fibre contents tend to be higher as nitrogen application rates decrease. Results from a 2001 study in Saskatchewan found that applying 67% of the recommended rate of Nitrogen resulted in higher fibre contents at 3 of 4 sites and applying nitrogen at 133% of recommended rates resulted in decreased fibre contents at 3 of 4 sites.

Further research is required to look at the effect of nitrogen and other nutrients like K and the use of arbuscular mycorrhizae on fibre content, straw, fibre and seed yield.

HARVEST MANAGEMENT

The ideal harvest system to grow flax for oilseed and fibre is one that harvests the seed and leaves the straw in as long of pieces as possible. Limiting the amount of straw that is put through a combine and the cutting or breaking of the straw as close to the ground as possible increases recoverable straw yields. This can be done by using a stripper header or a straight cut header and cutting high to harvest the seed limiting the amount of straw that goes through the combine. While there are several options for retting flax straw the most likely way to ret flax straw in western Canada is by field retting. To field ret flax straw the straw must be placed in contact with the soil. This can be accomplished several ways including a land roller or disc bine mower.

AGRONOMIC AND ECONOMIC IMPLICATONS

It clear that with such a wide range of straw yields and fibre contents and the subsequent fibre yields, that there is need for further research to help us understand what management practices we have to put in place to increase the chances of achieving higher and more profitable fibre yields under a wide range of agronomic and growing season conditions. The potential to improve fibre yields is certainly there but we need further research and development to increase the long-term development of profitable flax fibre based industries for both the farmer and the processor.

For an example, consider results from a 2003 three-replicate plot trial done at Canora, Saskatchewan. In this trial, two oilseed flax varieties were treated to a variety of agronomic practices. These included early and late seeding dates, three different seeding rates (i.e., 40, 80 and 120 kg of seed/ha), and two different seeding methods (i.e., a narrow "hoe" seeding pattern and a wide "sweep" seeding pattern). The results indicated that fibre yield per ha can more than double by carrying out relatively simple changes to agronomic practices. . The lowest three-plot average fibre yield of any of the treatments was obtained by early seeding Taurus at 40kg/ha with hoes. This produced an average fibre yield of 264 kg/ha. In contrast, the highest average fibre yield of 657 kg/ha was achieved by seeding the variety Flanders at 80 kg/ha late in the spring using sweeps. This produced 657 kg/ha, or almost 2.5 times as much fibre as the lowest fibre yield treatment.

Taurus is now one of the most popular varieties of flax grown in Saskatchewan and seeding rates used by farmers are commonly 30 to 40 kg/ha. Many farmers are aiming to have minimum soil disturbance and hence often use hoe type seeding systems. Some farmers seed their flax early, many seed flax after all their other crops are seeded and hence flax is often sown late. In other words, the lowest fibre yield treatment corresponds to what often takes place at the present time in Saskatchewan.

Consider the highest fibre yield treatment. Flanders is an older variety, that, by chance, generally has a higher fibre content than many other Canadian oilseed flax varieties. Flanders was a very popular variety ten to fifteen years ago but newer varieties (e.g., Taurus) came along with marginally higher seed yields and few farmers now plant Flanders. Many farmers already seed flax late and more would do so if the financial incentive existed to do so. Many farmers still use sweep type seeding systems and more farmers would switch to sweeps if they saw a financial benefit from it. Seeding 80 kg/ha instead of 40/kg per ha means seed costs will double. Farmers would not hesitate to double seeding rates if it is profitable to do so (e.g. seed yields increase as seeding rates increase at a marginal rate >1, and or the value of the additional straw produced must be worth more than the additional seed cost).

In the above example, if we compare the returns between the low fibre yield treatment and the high fibre yield treatment just described, the type of fibre produced would be worth $0.50 to 0.80/kg (to a non-woven manufacturer), and hence the value of the extra fibre produced, AFTER PROCESSING, would be $148 to $237/ha. Even at the low end of the value range, the value of the extra fibre is more than sufficient to cover the cost of processing and the cost of compensating the farmer for extra costs, slightly lower seed yields (from using an older variety) and giving an additional financial incentive to the farmer to take the time and effort to produce a higher fibre yield per ha (i.e., to copy the agronomic practices of used in the high fibre yield treatment instead of those used in the low fibre yield treatment).

In the above example, all of the required agronomic changes are relatively simple to do and are inexpensive to carry out. In addition, the returns are sufficient to more than compensate all the stakeholders for the extra cost and effort that is needed to produce and process the increase in the fibre produced. More research is needed but it is obvious we are well on our way to unlocking the secrets of how to build flax fibre production and processing into an array of profitable value added business ventures.

CONCLUSIONS AND ADDITIONAL AGRONMIC RESEARCH NEEDS

Agronomic practices can influence per ha fibre yield of flax. Adjusting agronomic techniques like seeding dates, seeding rates and seeding methods are low cost ways to increase per ha fibre yield and increase the profitability of managing flax straw and of processing it. However, research into the effect of fertilizer practices (i.e., rates, methods and timing of fertilizer applications), and seeding dates, seeding rates, etc. for different areas of the Prairies is necessary to increase per ha flax fibre yields and reduce the cost of producing flax fibre for wider areas of the Prairies.

Weather is very influential for flax straw fibre content. straw yield and fibre yield. It would be beneficial to have a improved understanding of plant physiology to better explain what triggers a flax plant to change the amount and or percent of fibre, seed and straw that is produced. The development of a flax fibre production model that incorporates weather as a variable would be useful in predicting the availability of flax fibre on an annual basis.

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TABLE 4 SASKATCHEWAN FLAX VARIETY TRIAL FIBRE CONTENT (%) FOR VARIOUS LOCATIONS AND YEARS

	Assiniboia		Carlyle		Kernen			Luseland		Regina	Scott	Watrous	Battleford	
Fiber Content (%)														
Raw Data	**2001**	**2002**	**2001**	**2002**	**2001**	**2002**	**2003**	**2001**	**2002**	**2003**	**2003**	**2003**	**2001**	**2002**
AC Carnduff	18.3	8.8	15.0	10.1	4.5	10.8	12.2	10.0	11.4	7.0	14.6	16.7	17.7	10.8
AC Emerson (check)	18.0		14.4		4.3			14.2					16.0	
AC Hanley (FP 1094)	17.4	8.4	14.6	14.2	2.9	12.2	12.3	14.5	12.2	8.5	15.2	16.7	15.0	12.0
AC Lightning (FP 1069)	16.4	9.5	12.6	9.5	3.2	9.6	9.7	14.1	10.1	6.4	13.5	14.8	13.7	11.4
AC Watson	17.6	9.8	15.2	15.7	3.7	10.8	11.8	12.5	13.4	8.4	15.6	17.1	15.2	11.3
CDC Arras	16.7	8.7	13.4	11.4	3.3	9.2	9.3	10.1	12.1	9.0	12.9	17.1	15.7	11.4
CDC Bethune	16.0	9.1	13.5	12.5	3.4	9.9	10.0	12.6	10.6	-	12.9	16.8	15.5	12.3
CDC Mons (FP2044)		9.4		10.8		11.2	10.6		10.1	7.5	11.8	16.1		9.9
CDC Normandy	16.1	9.6	14.6	8.8	3.7	9.9	10.4	13.5	11.4	9.0	13.6	15.5	14.1	12.0
CDC Valour	14.3	10.4	15.5	12.5	4.7	10.7	10.7	13.5	11.4	9.3	14.3	16.3	15.2	11.6
Flanders	18.5		14.9		3.3			12.7					15.6	
FP1082	17.9		16.0		3.8			6.6					18.2	
AC MacBeth (FP1096)	16.2	9.4	13.1	9.0	2.1	10.5	9.6	8.1	10.8	7.6	14.2	15.8	13.8	11.5
Norlin														
Prairie Blue (FP2024)		10.4		11.4		10.9	11.9		12.3	10.4	14.0	16.4		10.3
Serenade														
Taurus	17.7	8.8	16.2	9.3	4.1	7.9	10.2	9.8	11.0	8.4	14.3	16.9	17.7	9.8
Vimy	17.8	10.5	14.6	7.4	3.8	10.0	11.4	9.0	11.1	8.6	14.4	16.7	17.1	12.6
Solin														
Linola™ 989	16.5	7.6	13.6	9.1	2.5	10.0		13.0	11.6				14.3	11.7
Linola™ 1084	19.3	9.4	14.5	11.4	4.1	10.5	14.0	8.8	12.5	11.2	16.5	19.1	19.1	12.6
Linola 2047 (SP2047)		8.1		12.1		9.8	10.2		9.5	8.2	14.6	16.6		9.0
SP2099		9.6		11.3		10.9	11.7		11.8	8.1	15.2	17.5		12.0
SP2100		10.4		16.6		11.2	12.6		13.3	10.3	16.3	19.0		12.6
Field Average (%)	***17.2***	***9.3***	***14.5***	***11.3***	***3.6***	***10.3***	***11.1***	***11.4***	***11.5***	***8.6***	***14.3***	***16.8***	***15.9***	***11.4***

TABLE 4 CONTINUED SASKATCHEWAN FLAX VARIETY TRIAL FIBRE CONTENT (%)
FOR VARIOUS LOCATIONS AND YEARS

	Canora	Indian Head	Melfort	Rosthern		Wynyard	Kelvington		Nipawin	Shellbrook
Fiber Content (%)										
Raw Data	**2003**	**2003**	**2002**	**2001**	**2002**	**2001**	**2001**	**2003**	**2001**	**2001**
AC Carnduff	17.6	12.2	7.6	10.9	9.3	14.4	10.3	12.8	18.5	11.3
AC Emerson (check)				13.2		14.6	7.4		17.3	14.7
AC Hanley (FP 1094)	17.6	13.4	9.9	8.9	8.1	13.8	7.0	11.6	15.7	10.6
AC Lightning (FP 1069)	15.3	11.0	7.7	9.1	7.3	11.5	6.7	8.9	16.8	9.0
AC Watson	17.0	13.9	9.1	10.8	7.8	14.3	8.2	11.4	17.8	11.0
CDC Arras	16.2	11.9	7.2	11.7	7.5	12.1	6.5	12.4	15.3	10.0
CDC Bethune	16.2	11.7	6.5	11.7	8.1	11.6	5.8	12.4	13.1	8.2
CDC Mons (FP2044)	14.9	12.2	8.8		8.9			6.8		
CDC Normandy	15.1	11.1	7.8	10.3	8.4	12.6	7.4	13.0	17.3	10.6
CDC Valour	15.5	11.5	6.8	11.5	8.2	13.2	6.2	12.4	17.1	9.2
Flanders				11.5		13.9	8.5		15.3	11.0
FP1082				10.6		14.1	8.5		15.7	10.9
AC MacBeth (FP1096)	13.8	10.9	8.7	8.4	7.0	10.8	5.6	11.0	15.9	10.3
Norlin			7.3							
Prairie Blue (FP2024)	17.3	13.4	6.5		10.3			12.0		
Serenade										
Taurus	16.6	13.2	6.9	13.3	7.6	14.3	9.2	10.8	16.1	12.5
Vimy	16.0	12.7	7.1	12.6	9.6	14.3	8.0	12.3	18.8	9.3
Solin										
Linola™ 989			8.0	10.7	8.7	15.1	8.9	-	17.6	11.4
Linola™ 1084	19.2	14.7	9.9	12.0	8.9	15.1	10.2	12.1	19.6	14.0
Linola 2047 (SP2047)	16.3	11.8	7.5		8.4			11.5		
SP2099	17.4	13.7	7.8		9.1			11.7		
SP2100	18.8	12.8	11.0		8.5			12.1		
Field Average (%)	***16.5***	***12.5***	***8.0***	***11.1***	***8.4***	***13.5***	***7.8***	***11.5***	***16.7***	***10.9***