Milk Thistle Agronomy Trials (2003-2005)

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Background

Milk thistle is native to the Mediterranean, but is now widespread throughout the world. This stout thistle usually grows in dry, sunny areas. The stem branches at the top and reaches a height of about 1.5 to 4 m. The leaves are spiny and wide, with white blotches or veins. The flowers are red-purple. The small, hard-skinned seed is brown, spotted, and shiny. Milk thistle is an easy to grow annual plant. It has an indeterminate growth and flowering habit, resulting in uneven development and maturity of flower heads.

A group of flavenoids called “silymarins” represent the medically valuable compounds sought after in milk thistle. Silymarins have been demonstrated to both protect and alleviate problems with liver and kidney function. Silymarins are present throughout the milk thistle plant, but occur at the highest concentration in mature seed. By comparison, immature seed contains relatively little silymarin. Consequently, the timing of seed harvest is critical. However optimum harvest timing is complicated by the fact that;

a) milk thistle is a late maturing plant with an indeterminate flowering habit.
b) milk thistle is prone to shattering once the seeds are mature

At present, milk thistle is harvested by hand-cutting each seed head as it matures. This process is slow and costly, particularly as the plants sport very large and sharp thorns. Saskatchewan growers are struggling to effectively compete with other potential suppliers of milk thistle who have access to more available and affordable sources of hand labor.

Once-over mechanical harvest of milk thistle is possible but yields can be less than 50% of those achieved by hand harvesting (Wahab 2002). The quality of the resulting crop is also poor as the once over harvest combines mature and immature seeds. The practical and economic viability of mechanical harvesting milk thistle may be improved if ...;

a) lines of milk thistle with more uniform flowering habit are identified. This objective was addressed in the germplasm evaluation component of this report.

b) agronomic practices are identified that enhance uniformity of crop development and flower maturity

c) pre-harvest desiccation is used to accelerate and synchronize maturity of the flower heads.

The objectives of this project include:

i. Seeding rate and row spacing effects on yield and quality.
ii. Seeding date effects on growth characteristics and productivity.
iii. Nitrogen and phosphorus effects on productivity.
iv. Effectiveness of vinegar as a desiccant for machine harvest compared to Reglone.

Study Description

Agronomic studies were conducted 2003 through 2005 at the Canada-Saskatchewan Irrigation Diversification Center in Outlook Saskatchewan. All studies were conducted under dryland conditions, as previous experience at CSIDC showed that irrigation can prolong vegetative growth and delay maturity of milk thistle, resulting in considerable yield losses. The soil at the test site is a clay loam. The soil properties at the test locations are summarized in Table 1. Land was prepared in the traditional manner to form a firm seed bed. Milk thistle seed from Richter's Herb Co. was used in the studies. This line was selected as it has produced reasonably good yields in previous trials and has a good quality profile. Each test plot was 3.7 m x 1.2 m. Seeding was done with a double-disc press drill and seeds were placed approximately 1-2 cm deep. Rows were spaced 60 cm apart with seeding rate of 100 seeds/m2 for all studies except for the seeding rate and row spacing study.

Milk thistle initially grows relatively slow but once established it grows vigorously and competed very well against late season weed pressure. One early weeding was sufficient. The crop was desiccated when the flower heads matured, i.e. formation of pappus on the seed. During maturity, the purple petals dried and white pappus appeared; the seed turned from light brown and soft texture to dark brown and hard.

Two desiccants, Reglone (2.7 l/ha in 1000 l water/ha) and vinegar (14% acetic acid at 1000 l/ha) were sprayed for desiccation during the appropriate stages based on the trial, i.e when flower heads were 30% and 60% mature. Seeds were harvested using a Wintersteiger plot combine.

Table 1: Spring soil analyses (0-30 cm depth) at Milk Thistle test sites: 2003-2005			
	2003	2004	2005
Soil texture	Clay loam	Clay loam	Clay loam
Soil pH	8.2	8.3	8.3
E.C: 1S:2W (mS/cm)	0.4	1.1	0.3
E.C. Sat. Extract (mS/cm)	0.9	2.4	0.7
Salinity:	Non-saline	Slightly saline	Non-saline
NO3-N:	28	>144	26
P (kg/ha)	> 54	70	>108
K (kg/ha)	311	398	511
SO4-S (kg/ha)	>43	>86	>86

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2003 Studies

I. Effects of nitrogen, phosphorus and harvest stage on yield and quality of milk thistle:

Three levels of pre-plant nitrogen (0, 50, 100 kg N/ha.) and three levels of phosphorus (0, 60, 120 kg P2O5/ha) were examined in this study. Field plots were laid out as a 3 (nitrogen) x 3 (phosphorus) factorial in a Randomized Complete Block Design with four replications. Two similar trials were conducted for desiccation at two different stages (30% and 60% mature flower heads) using Reglone. Seeding was done on May 23, 2003. The first desiccation (‘Early’) was carried out when approximately 50%-60 % of the flower heads were mature (September 2, 2003) and the second desiccation (‘Late’) six days later (September 8, 2003). The ‘Early” desiccated crop was harvested on September 5, while the ‘Late’ desiccated crop was harvested September 12.

II. Seeding rate and row spacing effects on yield for milk thistle desiccated with vinegar.

Six seeding rates (25, 50, 75,100, 125, 150 seeds / m2) and two row spacing (20, 60 cm) were evaluated. Field plots were laid out as a 6 x 2 factorial in a Randomized Complete Block Design with four replications. Seeding was done on May 23, 2003. The crop was desiccated with Vinegar on September 12, 2003 (when 50%-60% of heads were mature) and harvested on September 19, 2003.

2004 Studies:

I. Effects of nitrogen, phosphorus on yield and quality of milk thistle when desiccated with vinegar and Reglone at two maturity stages:

Three levels of pre-plant nitrogen (0, 50, 100 kg N/ha.) and three levels of phosphorus (0, 60, 120 kg P_2O_5/ha) were examined in this study. Field plots were laid out as a 3 (nitrogen rate) x 3 (phosphorus rate) factorial in a Randomized Complete Block Design with four replications. Four similar trials were conducted for the combination of the two desiccants (vinegar and Reglone) and two stages of crop maturity (30% and 60% maturity). Seeding was done on May 14, 2004. The ‘Early’ desiccation (30% maturity) was carried out on September 7, 2004 for Reglone, and on September 8, 2004 for vinegar. The ‘Late’ desiccation (60% maturity) was carried out on September 15, 2004 for both vinegar and Reglone. Seed harvest was taken on September 27, 2004.

II. Seeding rate and row spacing effects on yield for milk thistle desiccated with vinegar.

Six seeding rates (25, 50, 75,100, 125, 150 seeds / m2) and two row spacings (20, 60 cm) were evaluated. Field plots were laid out as a 6 x 2 factorial in a Randomized Complete Block Design with four replications. Seeding was done on May 14, 2004. The crop was desiccated with Vinegar on September 15, 2004 (when 50%-60% of heads were mature) and harvested on September 24, 2004.

2005 Studies:

Studies conducted during the summer of 2005 were similar to those conducted in 2004. Test plots were seeded on May 13, 2005. The ‘Early’ desiccation (30% maturity) was performed on August 27, 2005 and the ‘Late’ desiccation (60% maturity) was performed on September 1, 2005. The seed crop was harvested on September 19 and 20, 2005.

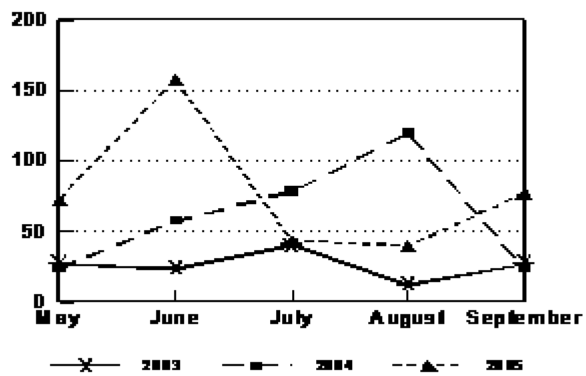
Fall Seeding Study:

Studies were also conducted in 2003 and 2004 to examine the feasibility of seeding milk thistle during the fall. The objective of fall seeding was to advancing flowering and consequently harvest period. Identical seeding rate and row spacing combinations similar to spring seeding were used for the fall seeding studies.

Results and Discussion

Cropping conditions at the site were generally suited to milk thistle production. Crop health was good is all years. The 2003 growing season was relatively warmer and dryer than 2004 or 2005 (Figures 2 and 3). The 2003 growing season received 133 mm of rain compared to 304 mm in 2004 and 391 mm in 2005.

On average, the 2004 season produced higher seed yields relative to 2003 or 2005. The 2005 crop had the potential for excellent yields but a heavy rain and wind storm on September 11 (69.2 mm) caused substantial seed loss from the mature heads. Yields in 2005 were consequently poor.



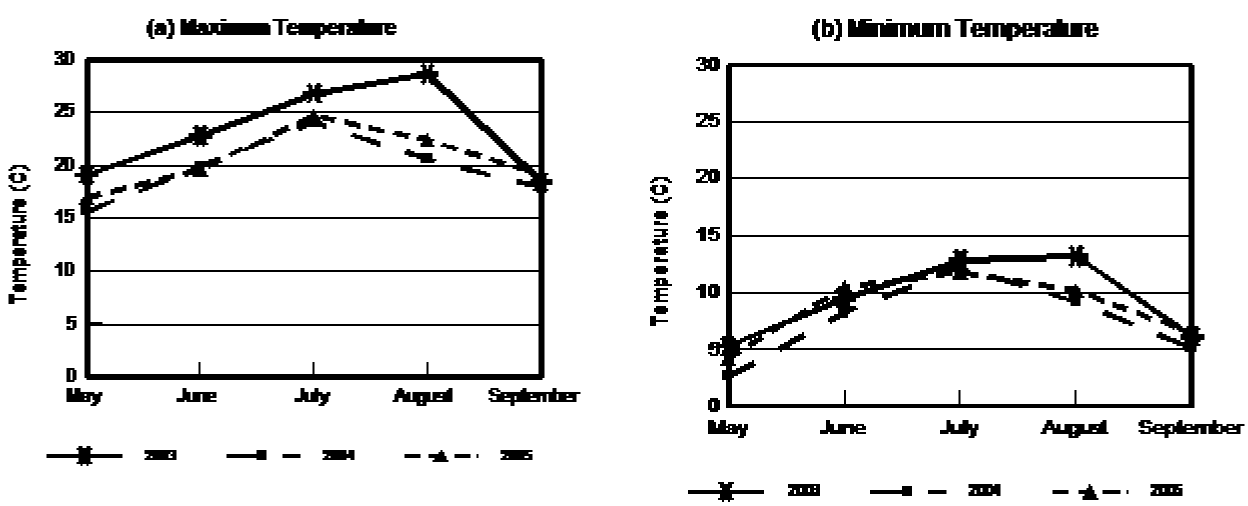


Figure 2. In-season rainfall during the 2003, 2004, and 2005 growing seasons.

Figure 3 Average maximum temperature (a) and minimum temperature (b) during the growing seasons: 2003, 2004, and 2005.

Seeding Rate and Row Spacing Effects:

Studies conducted 2003 through 2005 examined seeding rates ranging from 25 to 150 seeds per m2 and 20 cm and 60 cm row spacings. Seeding rates and row spacing had no effect on seed yield during the three years (Table 2). Between the seeding rates tested, seed yields ranged between 602 kg/ha and 710 kg/ha in 2003, 983 kg/ha and 1015 kg/ha in 2004, and 318 kg/ha and 387 kg/ha in 2005.

The two row spacings tested, i.e. 20 cm and 60 cm produced similar seed yields during the three years (Table 2). Although the effect was non-significant, the 60 cm row spacing produced higher seed yield than the 20 cm spacing in 2003, while the 20 cm spacing produced slightly higher yields than the 60 cm spacing during 2004 and 2005.

Table 2. Seeding rate and row spacing effects on seed yield for milk thistle

Treatment	Seed yield (kg/ha)		
	2003	2004	2005
Seeding rate:			
25 seeds/m2	615	1015	387
50 seeds/m2	699	998	447
75 seeds/m2	747	1070	370
100 seeds/m2	682	983	364
125 seeds/m2	602	960	417
150 seeds/m2	710	1004	318
Row spacing:			
20 cm	690	1028	416
60 cm	992	982	352
Analysis of variance			
<u>Source:</u>			
Seeding rate (R)	ns	ns	ns
Row spacing (S)	ns	ns	ns
R x S	ns	ns	ns
C.V. (%)	22.3	10.9	38.6

ns indicates non-significant treatment effects.

Nitrogen and Phosphorus Rate Effects:

The yield response to rates of nitrogen and phosphorus application in combination with the type of desiccant (vinegar, Reglone) and desiccation timing (30% and 60% maturity of flower head) during the 2003, 2004, and 2005 growing seasons are summarized in Tables 3, 4 and 5 respectively.

During 2003, application of 100 kg N/ha produced the lowest seed yields compared to 50 kg N/ha or no nitrogen control (Table 2.3). In 2004 and 2005, nitrogen application in a few instances tended to produce slightly higher yield than the no nitrogen control (Tables 4 and 5).

Phosphorus application rate had no effect on seed yield of milk thistle across the three years (Tables 3, 4, and 5).

Table.3. Nitrogen and phosphorus rate effects on milk thistle seed yield when desiccated with Reglone at two stages: 2003

Treatment	Stage of desiccation	
	30% mature	60% mature
Nitrogen (kg N/ha)		
0	808	1121
50	782	1291
100	287	683
Phosphorus (kg P2O5/ha)		
0	655	996
60	573	998
120	649	1102
Analyses of Variance		
Source:		
Nitrogen (N)	***(166)	***(230)
Phosphorus (P)	ns	ns
N x P	ns	ns
C.V. (%)	32.1	26.9

*** and ns indicate significance P<0.001 level of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of probability.

Table 4. Nitrogen and phosphorus rate effects on milk thistle seed yield when desiccated with vinegar and Reglone at two different stages: 2004

	Method of desiccation			
	Vinegar		Reglone	
Treatment	30% Mature	60% Mature	30% Mature	60% Mature
Nitrogen (kg N/ha):				
0	1017	1170	1308	1423
50	1079	1196	1342	1507
100	1104	1410	1289	1617
Phosphorus (kg P2O5/ha):				
0	1050	1202	1289	1456
60	1043	1271	1315	1575
120	1107	1303	1335	1517
Analyses of Variance				
Source:				
Nitrogen (N)	ns	***(132)	ns	ns
Phosphorus (P)	ns	ns	ns	ns
N x P	ns	ns	ns	ns
C.V. (%)	17.2	12.4	7.7	13.0

*** and ns indicate significance P<0.001 level of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of probability.

Table 5. Nitrogen and phosphorus rate effects on milk thistle seed yield when desiccated with vinegar and Reglone at two different stages: 2005

	Method of desiccation			
	Vinegar		Reglone	
Treatment	30% Mature	60% Mature	30% Mature	60% Mature
Nitrogen (kg N/ha):				
0	281	364	316	212
50	304	328	317	212
100	281	353	324	288
Phosphorus (kg P2O5/ha):				
0	294	397	358	248
60	281	350	301	237
120	291	298	297	227
Analyses of Variance				
<u>Source:</u>				
Nitrogen (N)	ns	***(132)	ns	ns
Phosphorus (P)	ns	ns	ns	ns
N x P	ns	ns	ns	ns
C.V. (%)	21.1	32.8	20.7	48.6

*** and ns indicate significance P<0.001 level of probability and not significant respectively. Values within parentheses are LSD estimates at 5.0% level of probability.

Comparison of Vinegar and Reglone as Desiccants and Timing of Desiccation:

Application of Reglone at 2.7l/ha @ 1000 l water/ha was a more effective desiccant than the commercial grade vinegar, i.e.14% acetic acid (Figure 4).

Figure 4 Desiccated milk thistle, three days after seeding: Vinegar on the left and Reglone on the right.

Despite the large plant size and crop vigor at the time of treatment, a single application of Reglone usually produced adequate dry down. The fact that relatively large volumes of water were used likely enhanced the efficacy of the Reglone treatment. It was possible to combine the Reglone treated crop within 3-7 days after spraying depending the weather conditions. Dry down was faster when the weather was warmer compared to cooler weather conditions. By contrast, vinegar was not an effective means of top-kill of milk thistle . Even after two applications, the dry-down was insufficient after two weeks for proper machine harvesting.

On average, desiccation with Reglone produced 23% higher seed yield in 2003 and 22% higher seed yield in 2004 than using the vinegar. This reflected seed loss during the extended dry down period required for the vinegar treatment. However in 2005, desiccation with vinegar resulted in 15% higher seed yield than desiccation with Reglone. This is likely due greater shattering loss in the drier Reglone desiccated crop during the rain event that occurred just prior to harvest in 2005.

Delaying desiccation, from 30% mature heads to 60% mature heads, produced higher seed yields in 2003 and 2004 for both methods of desiccation. In 2005, the early treatment increased yields in the Reglone desiccated plots - this again likely reflects differences in shattering loss during the fall storm event (Tables 3, 4 and 5).

Fall Seeding:

Fall seeding was attempted for milk thistle during two years with the objective of achieving early crop establishment - thereby potentially increasing yields and seed quality. Germination and stand establishment were extremely poor in the fall seeded crop in comparison to spring seeding (Figure 5).

Summary:

- Milk thistle shows little yield response to a wide range of in and between row seed spacings. As seed is large and costly, low seeding rates (25 seed/m2) appear sufficient.
- 20 and 60 cm row spacings produced similar seed yields. The wider row spacing allowed more room for early weed competition, but it also facilitated mechanical tillage to remove the weeds.
- Fall seeding was not successful, as stand establishment was extremely poor compared to spring seeding. The fact that volunteer milk thistles are uncommon despite the fact that the crop shatters extensively also suggests limited overwinter survival of the seed.
- Milk thistle shows little yield response to nitrogen or phosphorus fertilizer application on a site with fairly high background levels of soil fertility. Fertilizer applications did tend to increase vegetative growth of the crop - but this was often detrimental as it made harvesting more difficult. Fertility levels had no impact on levels of bio-active compounds in the seed.
- The crop has to be desiccated prior to machine harvest.
- Delaying desiccation until 60% of the flowers had begun to dry down produced higher seed yields and superior seed quality (higher silymarin content).
- Harvest timing is critical. Inclement weather when the crop is ready for harvest (rain, wind etc.) can cause severe yield losses due to seed shattering.
- Reglone is an efficient and cost-effective desiccant for milk thistle.
- Commercial grade vinegar (14% acetic acid) can be used as an organic desiccant, but it is expensive, slow acting and results in increased seed loss to shattering as compared to desiccation with Reglone.

Conclusions - Over the 3 years of this study we examined the seed yield potential and level of active ingredient (% silymarin) in a range of selections obtained from commercial suppliers, breeders and gene banks. There was very significant variability in the performance of the material available. Some the lines failed to mature within the growing season available in Saskatchewan, while others were fully mature by late August. There was also significant variation in seed quality as measured by the silymarin content. There was no real association between yield potential and seed quality. The relative performance of the lines tested was not overly consistent from year to year in terms of either their yield potential or seed quality. This made it difficult to select for clearly outstanding lines. In discussions with members of the Saskatchewan Herb and Spice Growers who are marketing Milk Thistle ... there are at present no standards being stipulated for minimum silymarin content. In that situation, lines with exceptional yield potential (ie; Austra Hort, Bolier or TMP 14068) would be best. In situations where quality is also considered in developing a market price, lines that have both yield and quality would be required. Austra Hort and Kalyx-1 have the desired combination of yield potential with seed quality.

Wanda Wolf (pers comm 2002) estimated the break-even yield for hand harvested milk thistle at 500 kg/ha. Yields of some of the better adapted lines in this trial were around 1500 kg/ha. At a market price of $ 8.00 CDN/lb, a 1500 kg/ha milk thistle crop has a theoretical net return potential of $14,200/ha.

Seeding and stand establishment are straight forward for milk thistle and the crop has no problems out-competing weeds. Fertility responses were minimal or negative (reduced stand and delayed maturity) . Yields were not affected by either in row or between row spacings. Milk thistle appears to be a very plastic crop, adapting to the growing space available. As the seed is large and costly, the data suggests that a low seeding rate and wide row spacing would be most economical without compromising yield potential of the crop. There were no significant disease problems observed and any insect pests were easily managed.

Increasing the duration of the growing season, either by early planting or delayed harvest increased yields and the concentration of active ingredients in the seed. However, shattering of over-mature seed heads appears to be the greatest production threat for milk thistle. The highly desirable early maturing, large seeded lines appeared to be particularly prone to shattering. Timing and timeliness of harvest is critical - to minimize the risk of shattering, the crop should be harvested within a few days of the seed pods reaching maturity (60% fluff) - either natural maturity or maturity triggered by frost or application of a chemical desiccant. Once the crop reaches that stage of maturity, any delay in harvesting can result in substantial seed loss. The desiccant Reglone provides a very quick die down of milk thistle - and consequently shattering losses are minimal. However, Reglone is not approved for organic production. Although application of high rates of vinegar did eventually result in desiccation of the crop, shattering losses during the extended dry down period were excessive.

Milk Thistle is traditionally hand harvested - with each seed head individually harvested as it reaches maturity. Although this may increase yields and enhance uniformity of seed maturity, it is not a practical option in Saskatchewan. Not only would hand harvesting be prohibitively expensive, it is doubtful that a labor pool could be identified that would be willing to work with the extremely sharp thorns on the seed heads. Mechanical harvest using standard small plot combines appears to be a viable alternative - providing that the crop has been desiccated (by frost or chemically) prior to combining. In two years of trials, a once over harvest with a standard small plot combine produced yields that were comparable or slightly higher than a selective hand harvest. Obtaining a yield advantage by combining was unexpected. While harvesting the individual mature seed heads, the hand harvesters may have been bumping adjacent heads causing them to shatter out. Several of the highest yielding lines identified in this project also appeared well suited to mechanical harvesting - in that they matured uniformly, were not excessively vegetative and did not shatter prior to harvest. Milk thistle was easily threshed, providing the tops were dead prior to harvest. Cleaning and sorting of the seed is readily accomplished using standard equipment. Some upgrading of quality is possible by seed sizing - but color sorting does not look to be a straight forward option.