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ANNUAL REPORT

"INCREASING FLAX YIELDS: A CLOSER LOOK AT FERTILIZER UTILIZATION AND WEED MANAGEMENT."

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SECTION A

FLAX AGRONOMY - A WESTERN CANADIAN REVIEW

This review will draw together results and conclusions from relevant current research in flax agronomy, including plant nutrition, seeding management, crop rotation, competitiveness with weeds, and harvest management. With each section, an outline of research which requires additional attention is provided.

1. Plant Nutrition and Fertilization

Flax has traditionally been considered a low yielding crop, with a corresponding low nutrient requirement. Unfortunately, the concept of the low yielding flax crop partly reflects poor agronomic practices in the early years of flax production. In particular, early flax crops were chronically infested with weeds before the advent of broadleaf weed herbicides. Flax is a poor competitor with weeds and often had yields less than 500 kg ha^{-1} (8 bushels $acre^{-1}$). Flax is also sensitive to fertilizer placement, and early fertilizer studies often damaged the seedlings with excessive fertilizer placed in the seedrow. With these constrictions on high yields, yield responses to added nutrients were very difficult to document, and low recommendations for flax were standard. For example, fertilizer calibration studies in South Dakota as recent as the early 1980's did not recognize flax yields over 1500 kg ha^{-1} (Fixen et al, 1982). Reviews of soil fertility research in Saskatchewan have also suggested a low nutrient requirement for flax, based on low flax yields (Bailey, 1975; Ukrainetz et al, 1975).

Provincial statistics suggest that flax continues to average lower grain yields than other crops (Table 1). In Saskatchewan and Manitoba, recent flax yields have been 56% of wheat, 43% of barley and 93% of canola yields. Improved nutrient management is a first step in achieving the yield potential of flax.

smaller grain yield response than wheat or canola (Fig. 2). The lesser amount of nitrogen removed by flax reflects the lower yield of flax relative to wheat and canola in the experiment. Flax seed yield was only 45% of canola and 55% of wheat yields. In contrast, flax seed nitrogen concentration was 140% of wheat and 120% of canola seed nitrogen concentration.

A similar pattern of nitrogen response was found in comparison of flax to spring wheat, barley and several canola varieties in Saskatchewan (Nuttall and Mahli, 1991). Flax yields were lower than yields of the other crops, but had a higher seed nitrogen concentration (Table 3).

Table 3. Comparison of several crops with added nitrogen fertilizer (67 kg ha^{-1} applied in spring). (From Nuttall and Mahli, 1991).

Crop	Grain Yield	Grain N Uptake	Grain N Concentration
	(kg/ha)	(kg/ha)	(%)
Flax	1420	50	3.5
Wheat	2490	65	2.6
Barley	3120	70	2.2
Canola	1580	51	3.2

review, Bailey (1975, 1979) predicted flax would respond economically to applications of 90 kg N ha^{-1} in moist areas of the prairies and 60 kg N ha in drier areas. Several examples of flax yield responses to high rates of fertilizer were cited, but predictions based on soil tests and environmental conditions were not provided.

It is difficult to summarize the recommendations from the various private and public soil testing laboratories on the prairies. It is also difficult to ascertain if current recommendations are based on accurate benchmark research trials, or if they are largely based on assumptions of yields and nitrogen content of grain relative to other crops. Experiments to provide a complete understanding of flax response to nitrogen under a range of environmental conditions have not been published. Certainly, standard fertilizer recommendations appear to vary in nitrogen requirements and yield predictions. For example, recent recommendations for nitrogen fertilization of irrigated flax in Alberta predict potential yields and yield increases comparable to canola (Fig. 3). Data for dryland crops are not provided, but in an earlier publication, nitrogen fertilizer recommendations for dryland flax do not exceed 45 kg ha^{-1}, while recommendations for canola reach 100 kg ha^{-1} (Alberta Agriculture, 1989). A summary of fertilizer practices for flax in North Dakota provides nitrogen recommendations for producers with flax seed yield goals from 625 to 3125 kg ha^{-1} (Dahnke et al, 1981).

overlooked in studies of nitrogen fertilization of oilseed flax varieties, in addition to the value of the meal..

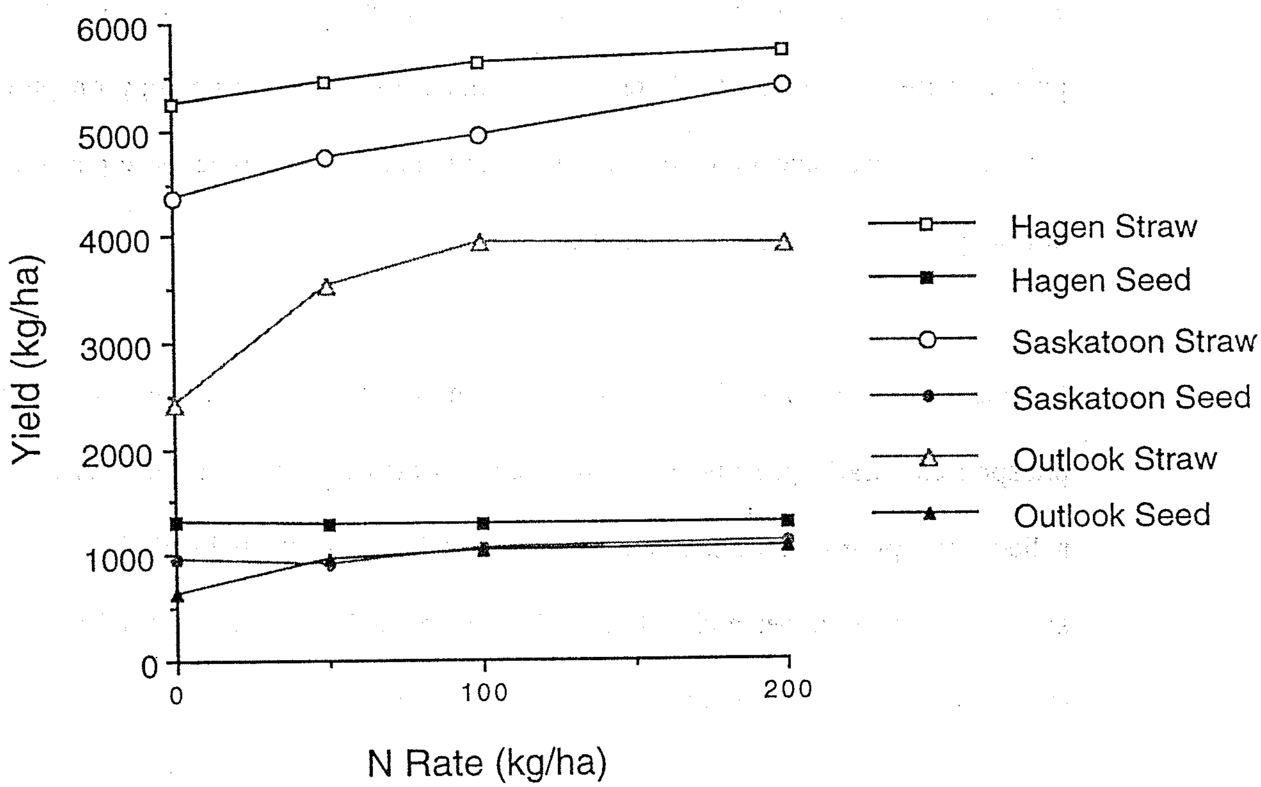

Figure 4. Response of flax straw and seed to added N fertilizer at 3 Saskatchewan sites (from Rowland, 1980).

1.2 Phosphorus

Flax contains 6.5 kg P $tonne^{-1}$ of seed, which is relatively high compared to other crops (Table 2). Despite this apparent demand for available phosphorus, flax is notorious for poor response to phosphorus fertilizer in a broad range of experiments.

conditions. For example, flax shoots and roots weighed less than 20% of the weight of buckwheat, which was deemed most efficient in phosphorus utilization. Despite the weakness of these experiments, they have had considerable bearing on fertilization management of flax.

An early study with phosphorus fertilization of various crops in field conditions found flax had a phosphorus content similar to canola, but a much lower biomass yield (Racz et al, 1965). Overall phosphorus utilization was much lower than canola, and the seed yield of flax was decreased with phosphorus placement. All of the phosphorus fertilizer (52 kg P_2O_5 ha^{-1}) was placed in the narrow seedrow, which damaged the flax.

The poor response of flax to fertilizer placed in a narrow seedrow has been measured in several other experiments (Ridley and Tayakepisuthe, 1974; Racz, 1980; Bailey and Grant, 1989). This reflects the low tolerance of flax to the salt effect of fertilizers, as discussed in section 1.5. For this reason, current guidelines do not recommend more than 20 kg P_2O_5 ha^{-1} be placed in a narrow seedrow.

In an effort to overcome the salt effect of fertilizers directly in the seed row, trials have examined phosphorus fertilizer bands to the side or directly below the seed. A classic field experiment conducted at several sites in northern Alberta measured the benefit of separate fertilizer bands from the seedrow (Nyborg and Hennig, 1969). Overall, a fertilizer band 2.5 cm directly below the seedrow gave the highest yield response (Table 5).

Field research has also found a benefit to banded phosphorus fertilizer over seedrow placements or broadcast applications (Ukrainetz, 1976; Bailey and Grant, 1989; Grant and Bailey, 1993a,b). Bands below the seedrow were slightly more effective than sidebands.

Dual bands of nitrogen and phosphorus are commonplace in prairie agriculture. Root proliferation in the dual band due to root response to available nitrogen may improve phosphorus uptake. Only one growth chamber study has examined dual bands with flax (Beever and Racz, 1987). A dual band of monoammonium phosphate with ammonium sulphate was slightly more effective than dual bands with urea, and all dual bands performed better than separate bands of phosphorus and nitrogen. This study did not provide a direct comparison to seedrow fertilizers or broadcast fertilizers.

Despite the benefit of separate fertilizer bands, not all seeding equipment is capable of this placement. Alternatives include broadcasting the fertilizer just before seeding, broadcasting high rates of fertilizer a year or more before seeding, or slowly building the soil phosphorus reserves by increasing rates of phosphorus fertilizer for crops other than flax.

Broadcast and incorporation of phosphorus just before seeding is not effective (Ridley and Tayakepisuthe, 1974; Grant and Bailey, 1993a). Response to residual phosphorus fertilizer was measured in a trial in Manitoba, where 0, 100, 200 or 400 kg P fertilizer ha[1] was applied in 1965, then continuously cropped to a wheat-flax rotation for eight years (Bailey et al, 1977; Spratt and Smid, 1978). There were no comparisons to other fertilizer

1.3 Potassium and Sulphur

Flax seed contains a high concentration of potassium and a moderate level of sulphur (Table 2). Unfortunately, there has been very little survey or study of flax potassium or sulphur nutrition on the prairies. Only a few incidental responses to potassium have been reported (Rogalsky and Ridley, 1983; Bailey and Soper, 1985). This dearth of information has been repeatedly recognized in nutrient reviews (Bailey 1975, 1979; Ukrainetz et al, 1975; Bailey and Soper, 1985), but there continues to be little data to predict nutrient requirements Recently, the Saskatchewan Soil Fertility Sub-Council has recommended that 16 kg/ha of P_2O_5 equals 16 kg/ha of K_2O in terms of the salt index, implying that the high salt index of potassium fertilizer may be no different than P fertilizer (Les Henry, pers. comm.)..

Despite the high requirement of flax for potassium , the common practice of seeding flax on clay textured soil with ample native soil potassium has probably limited fertilizer potassium requirements. The high salt index of potassium fertilizers would also prevent response of flax to potassium fertilizer in the seedrow.

Flax requires a moderate amount of sulphur, which may be deficient in certain soils in the flax growing region. Certainly, Luvisolic and coarse textured Chernozemic soils should be surveyed for probable sulphur requirements for flax.

to zinc fertilizer has been reported in more recent studies (Fixen and Farber, 1988; Grant and Bailey, 1989a,b; 1993a,b).

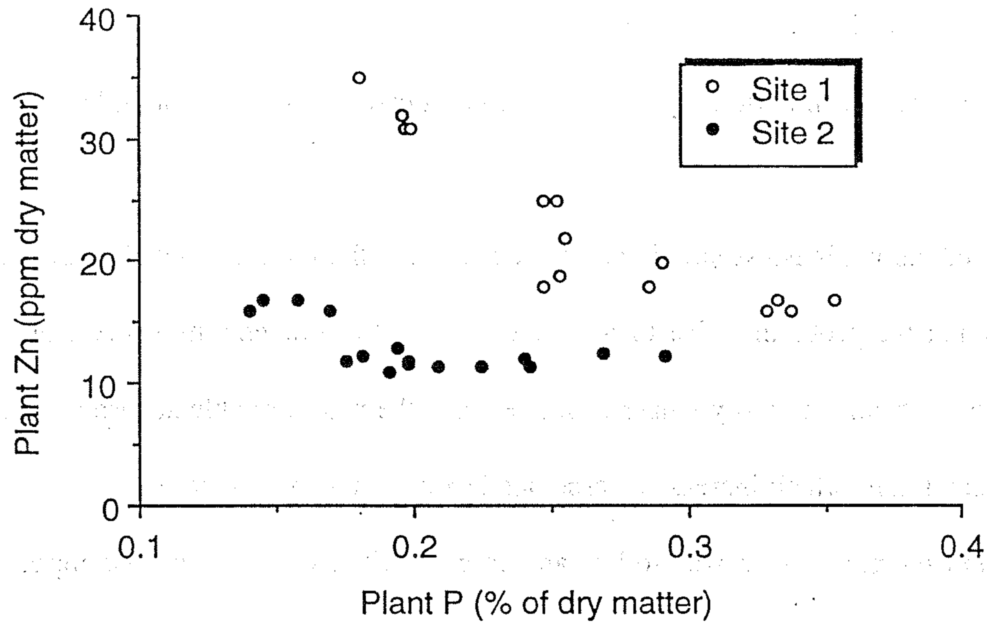

Figure. 6. Relationship of plant Zn to plant P at two sites with high levels of residual P fertilizer in Manitoba (From Spratt and Smid, 1978).

Despite selecting soil for potential zinc deficiency, and with very high rates of added phosphorus fertilizer, most studies have not found a yield response to zinc fertilizer. Furthermore, a thorough survey of selected soils in Saskatchewan found no yield increases due to zinc application, and it was concluded that crops grown on mineral soils in Saskatchewan were not likely to respond to zinc fertilizers (Singh et al, 1987). While zinc deficiencies may occur in certain soils and conditions, it appears these can be remedied as identified, without additional research.

1.4.3 Copper

Copper nutrition has not been well defined for flax, but research has indicated flax may respond to copper fertilizers. A growth chamber study with severely copper deficient organic soil collected in Manitoba found flax to be more sensitive to copper deficiency than wheat, oats, barley and canola (McAndrew et al, 1984). If this holds true in field conditions, flax deficiencies may be expected in very sandy copper deficient soils within the flax growing region. In two fields experiments in Saskatchewan, a critical soil level of 0.35 ppm DTPA extracted copper was required for flax (Karamanos et al, 1986). Recent work in northern Saskatchewan showed a 6-8 bus/ac yield increase with 3 lbs Cu/ac broadcast or 11 lbs/ac in the seedrow on soils that tested 0.4-0.6 ppm of Cu.

1.4.4 Other Micronutrients

A single study considered the effect of chloride on flax, with the premise the chloride (from potassium chloride) would reduce disease infection (Grady et al, 1988). Flax yields were increased, but there was no control to determine if the response was to potassium or chloride, and disease incidence was very low.

Other micronutrients have not been studied in flax research. While other micronutrients deficiencies may occur in the flax growing region, research must focus on the more current and efficient requirements for deficient macronutrients.

In general, phosphorus nutrition of flax has been well documented in research. Flax does not respond as well to phosphorus fertilizer as other common prairie crops, but this trend has been exaggerated by studies where phosphorus fertilizer in the seedrow damaged the seed, and by growth chamber studies which did not provide reasonable conditions for flax growth and nutrient uptake. Phosphorus fertilizer placed in sidebands and bands below the seedrow at seeding have proven to be most efficient. Additional research could examine dual bands of nitrogen and phosphorus fertilizer, or strategies to increase phosphorus supply by adding extra fertilizer to other crops in rotation. This method may benefit from phosphate solubilizing fungi.

There has been essentially no significant research to examine potassium and sulphur nutrition of flax. This research should receive priority in the future, with careful consideration to fertilizer placement. A nutritional survey of flax fields on the prairies would be a first step to estimate the benefit of sulphur and potassium fertilizers.

Micronutrient research has focussed on zinc, with very little documented response to zinc fertilizer application. While micronutrient nutrition must be recognized, research priorities should focus on nitrogen, potassium and sulphur requirements.

Fertilizer application in a narrow seedrow cannot be recommended for flax crops. Even low rates of phosphorus fertilizers provide negligible benefit, though it is recognized that no research reviewed attempted to measure the potential effect of seedrow phosphorus on crop maturity. Need to consider seed-placed fertilizer at various seedbed utilizations and

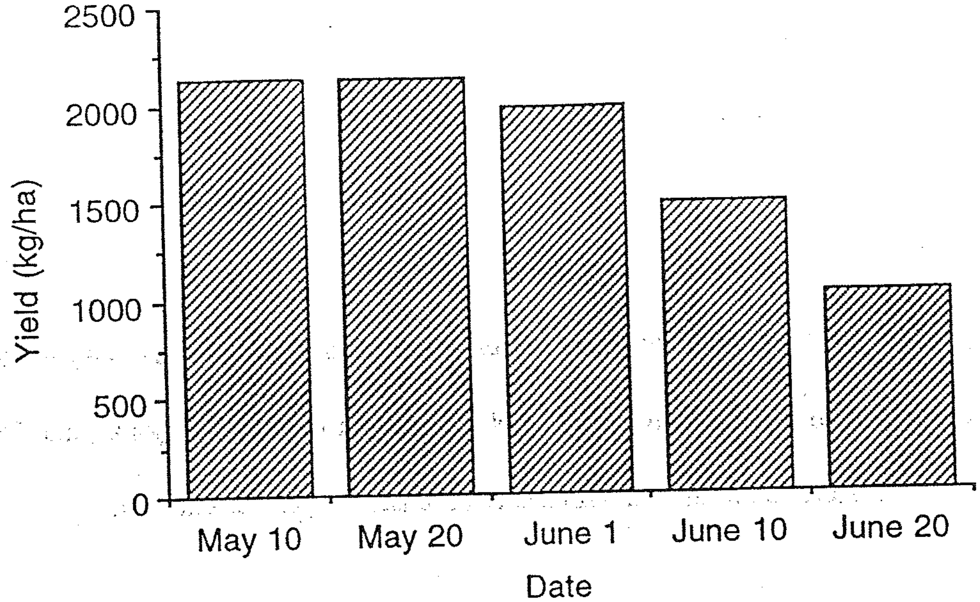

Figure 7. Average seed yield of seven flax varieties at two sites in Manitoba, as affected by seeding date (From Growing Flax in Canada (Author unknown), 1988).

In addition to a lower yield, Irvine (1994) found late seeding may also increase plant height and lodging (Figure 8). Combined with late maturity, this would add considerable difficulty to flax harvest. In this same study, no effect on flax seed size or oil content was measured with late seeding.

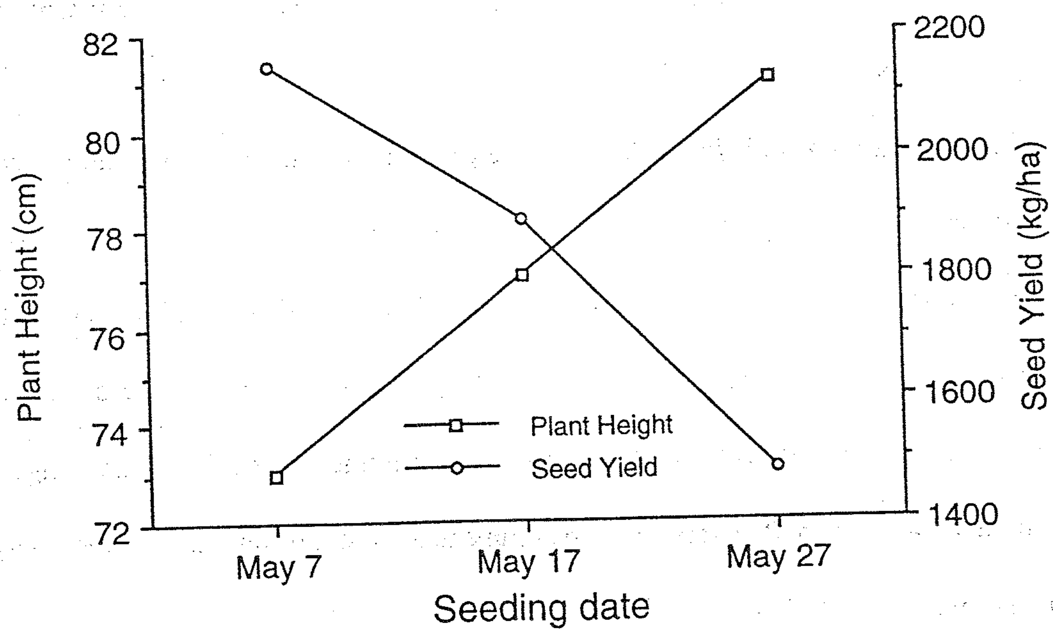

Figure 8. Flax seed yield and plant height response to seeding date, averaged for four varieties and three years at Outlook, Saskatchewan. (from Irvine, 1994).

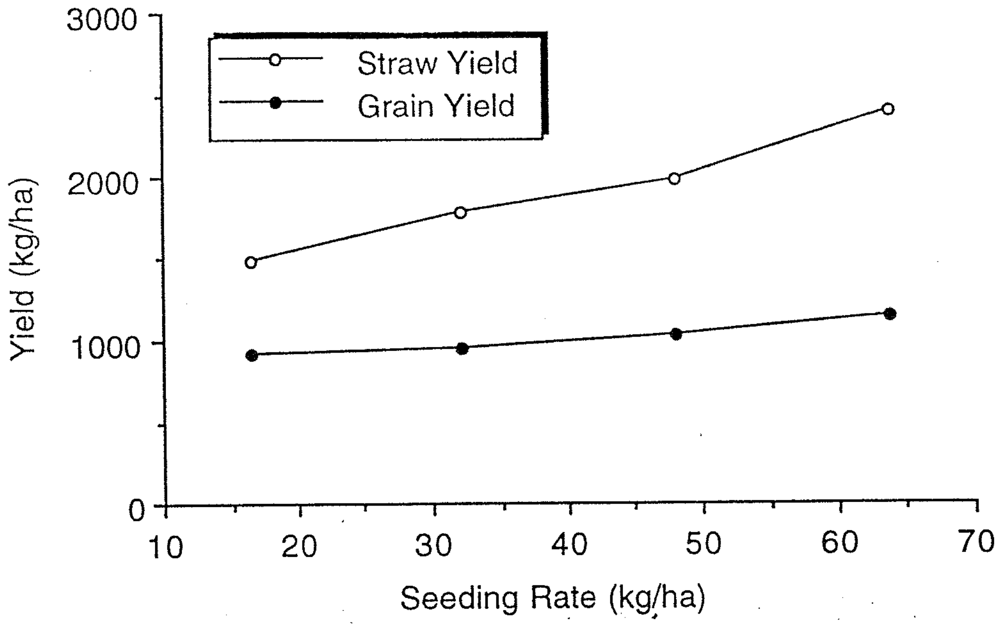

Figure 9. Flax straw and seed yield relationship to seeding rate (From Robinson, 1949).

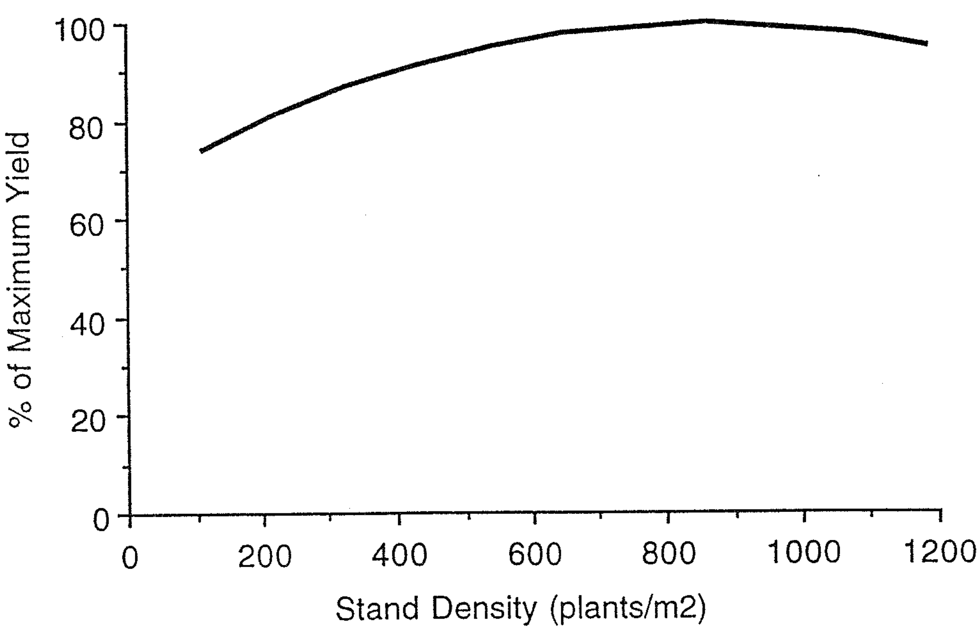

Figure 10. Effect of flax stand density on flax yield (from Hanson and Lukach, 1990).

Flax yields may be reduced by lodging when flax is seeded at high rates in nutrient rich and moist soil conditions (Irvine, 1994). Poor seed filling and increased harvest loss may then reduce yields. Irvine (1994) found that irrigated flax yielded 2201 kg ha^{-1} when seeded at 30 kg ha^{-1}, and 1792 kg ha^{-1} when seeded at 70 kg ha^{-1}. In a dryland study in North Dakota, higher seeding rates increased yield if the flax did not lodge, but decreased if the crop lodged (Table 7). Lodging has also increased with high seeding rates in dryland plots in southern Manitoba, when heavy rains and high winds occurred after seed set (Gubbels, 1978; Gubbels and Kenaschuk, 1989b).

Table 7. Seeding rate effect on flax yield in lodged and non-lodged conditions. (From Hanson and Lukach, 1990).

Seeding Rate	Grain Yield (kg ha^{-1})	
(kg ha^{-1})	Lodged	Non-lodged
22	1700	1444
33	1719	1569
45	1475	1600
56	1562	1669
67	1438	1694

Lodging at high seeding rates reflects changes in plant growth. As plant density increases, flax plants have fewer basal branches (Klages, 1932; Dillman and Brinsmade, 1938; Albrechtsen and Dybing, 1973; Gubbels, 1978). However, the choice of flax cultivar probably has a larger influence on potential lodging (Gubbels and Kenaschuk, 1989b).

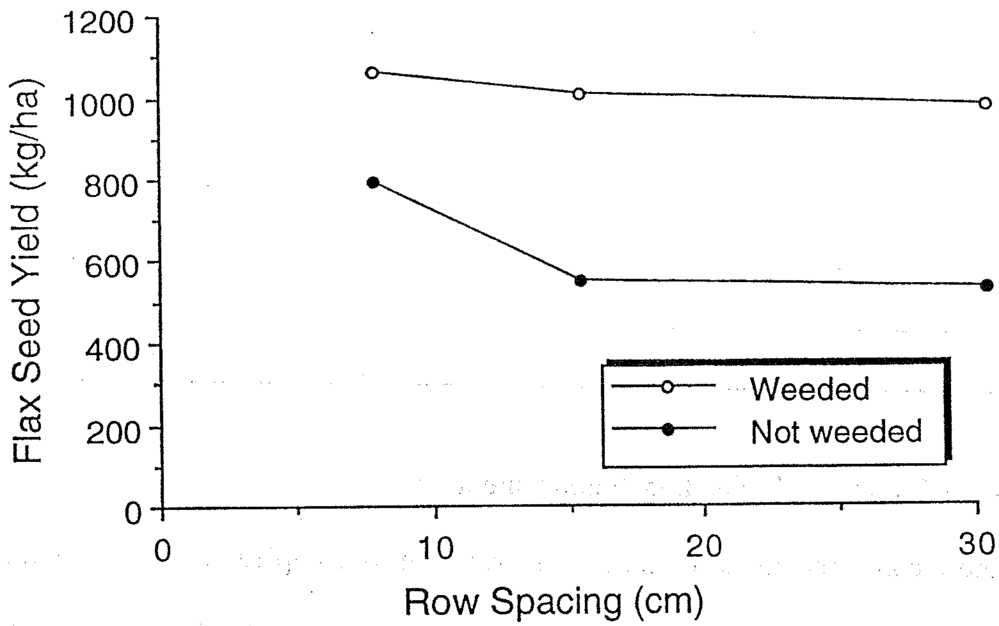

Figure 11. Weed competition may reduce yields with wide row spacings in flax (from Alessi and Power, 1970).

2.4 Seeding Depth

One of the main problems in flax agronomy is poor seedling emergence. Shallow seeding into a firm seedbed is essential for good flax germination. General recommendations call for a seeding depth of 1.5 to 4 cm (Comstock, year unknown; Author unknown, 1992). The seedbed should be packed, though excessive packing will lead to soil crusting and reduced emergence (Domier et al, 1992).

The combination of low temperature and deep seeding will sharply reduce rate of emergence (Table 8). Slow emergence will increase the potential for seedling diseases, and for crusting of the soil surface before seedling emergence. Soil temperature rapidly declines with depth in spring, so this effect cannot be underestimated.

Early seeding implicitly increases average flax yields; flax may be a candidate for fall seeding in fields where crusting of the soil surface in spring is not a problem.

Need to investigate more closely emergence problems and determine if seed vigour is the major contributing factor.

3. Crop Rotation

Flax has not played a prominent role in rotational trials on the prairies, despite its long-term place in many farm rotations. Other crops in rotational trials have overshadowed flax, and little conclusive data on this topic has been collected. Few crop rotation studies have used ideal agronomic practices; many studies have dismissed the value of flax in rotation, based on rotational studies with inadequate weed control (Campbell et al, 1990). Currently available herbicides for flax crops have reduced this problem.

3.1 Crops Preceding Flax

There has been few comparisons of flax yields after different crops. Recommendations suggest flax should not be grown after legumes or potato's due to increased infection by *Rhizoctonia* bacteria which cause seedling blight of flax (Author unknown, 1992). Data has not been published from research to support this recommendation.

Most studies of flax response to preceding crops have focussed on canola. Tilling young canola plants into the soil just before seeding flax may reduce yield, possibly due to the phytotoxic properties of the canola plants (Vera et al, 1987; Gubbels and Kenaschuk, little published data concerning flax water use, but the shallow root system of flax probably does not extract an excessive amount of soil water. There is also insufficient data to determine the effect of flax on soil structural quality. Problems with soil erosion or poor snow capture could conceivably occur due to the small amount of residue which remains after a flax crop, especially after the threshed residue is burned or removed from the field.

Unless appropriate control measures are taken, weed populations in a field will increase with a flax rotation. This problem also occurs with other crops, depending on the weed spectrum and control methods, and should not be regarded as a rotational problem specific to flax. Unfortunately, rotational research has often been plagued with weed competition in flax rotations, which has resulted in low rotation yields and unfounded conclusions (Austenson et al, 1970; Austenson, 1975; Campbell et al, 1983). A unique problem to flax is volunteer flax in other crops, magnified by the poor control of volunteer flax with most herbicides. This is an important factor in crop rotations that has not been addressed in research; a combination of herbicides and tillage systems may be the key to solving this problem.

Several experiments have measured an increased yield of cereal crops grown after flax (Gerrie et al, 1958; Gubbels and Kenaschuk, 1989a; Zentner et al, 1987). There is certainly a benefit of flax and other broadleaf crops in a rotation to reduce disease and increase yield in cereals (Sturz and Bernier, 1987). Other benefits of flax as a crop in rotation may include lower water use and nutrient removal, though these have not been adequately examined in published research.

Flax seems to be a good candidate for reduced or zero tillage. This characteristic could be further measured in relevant research. Emphasis should be placed on water use efficiency.

4. Weed Research

Flax is a weak competitor to weeds, so has been the subject to many related studies. A broad range of herbicides have been registered for the control of weeds in flax crops. Although a few studies with specific herbicides have been published, most current work is proprietary to the herbicide industry. For this reason, research with specific herbicides will not be reviewed.

4.1 Competitiveness of Flax

Flax is a poor competitor to weeds. Comparisons to other prairie crops indicate flax is less than one-half as competitive as wheat, barley or canola (O'Donovan and Sharma, 1983; de St. Remy and O'Sullivan, 1986; Friesen et al, 1992). Weed competition reduces production of basal branches and may reduce seed weight, with a consequent loss of yield (Alex, 1968; Burrows and Olson, 1955). Seed and oil quality is otherwise not affected (Burrows and Olson, 1955; Chow and Dorrell, 1977; Friesen, 1986).

Field experiments have focussed on several common weeds in competition with flax. Most published reports provide data for flax yields with increasing weed densities. Table 10 provides only a few data points from each study.

Table 11. Control of weeds with post-emergent harrowing or herbicides in flax (from Carr et al, 1994).

Treatment	Seedling Stand (plants m^2)	Weed Biomass (kg ha^{-1})	Flax seed Yield (kg ha^{-1})
No control	96	4557	343
Tine harrow	125	4497	473
Rotary harrow	186	3464	758
Herbicides	180	3278	812

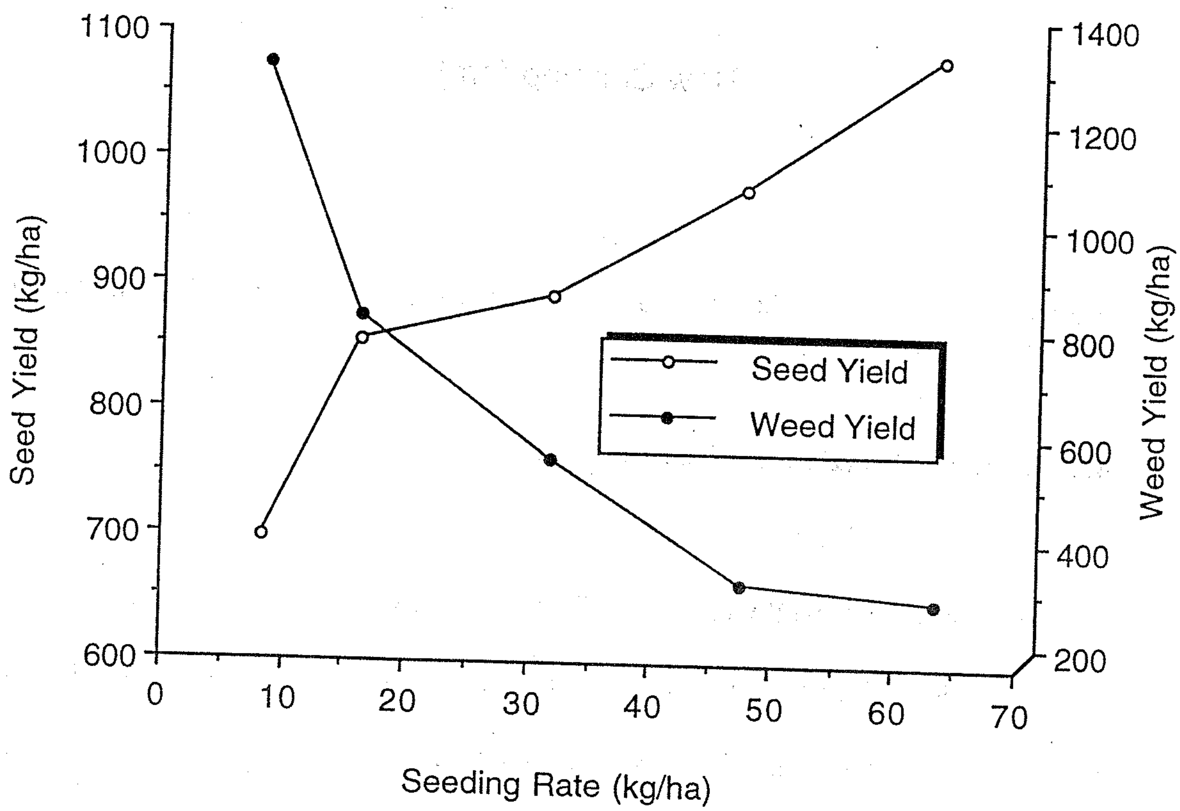

Figure 12. Flax yield response to seeding rate in weedy conditions (from Robinson, 1949).

5. Harvest Management for Flax

Flax producers are often faced with a crop that is later to mature, subject to frost damage, and difficult to cut. Research has attempted to determine guidelines and methods to improve flax harvest.

Immature flax seeds are damaged by frost before the effect is noticed on leaves, pedicels or stems. Substantial seed damage may occur when immature seeds are exposed to temperatures less than -3° C (Figure 13).

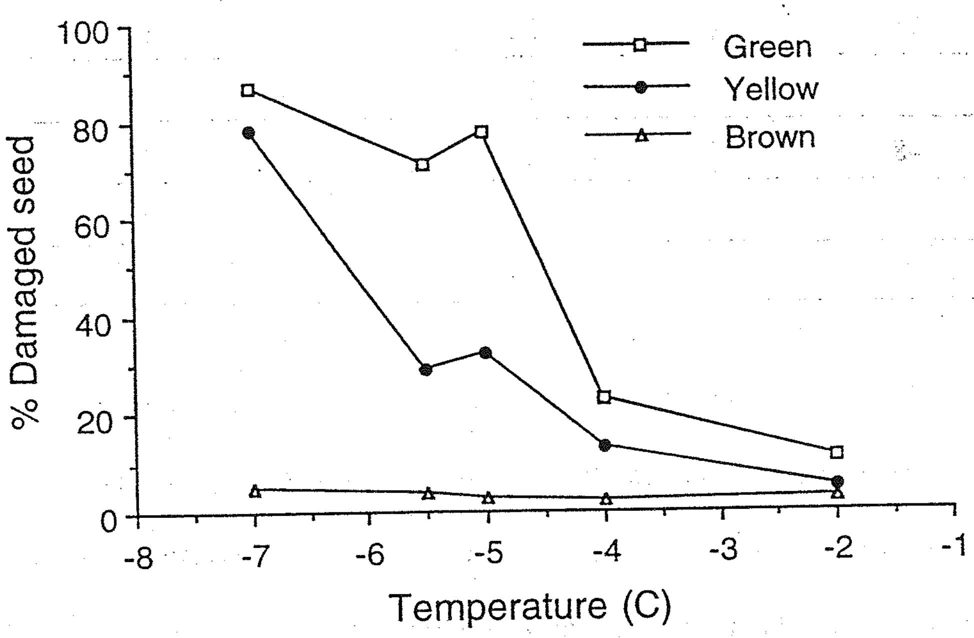

Figure 14. Flax seed injury by freezing temperatures at various stages of boll maturity (Bonner et al, 1993).

damage.(Hammond, 1972; Dorrell, 1973; Dorrell and Daun, 1980; Author unknown, 1992; Gubbels and Kenaschuk, 1993; Daun and DeClerq, 1994).

Desiccation with various herbicides is a valuable tool in speeding harvest of flax, thereby reducing frost damage and seed weathering. Depending on the herbicide used, weed control can also be achieved with desiccation. The chemicals diquat, glufosinate and glyphosate were examined for desiccation of flax in a series of field experiments in southern Manitoba (Gubbels and Kenaschuk, 1981; Gubbels et al, 1993a,b; Gubbels et al, 1994b). When used within the product label guidelines all of the products were effective. Diquat and glufosinate desiccated flax bolls within one week of application, while glyphosate required two weeks. Stem desiccation required more time for all desiccants, and cutting the crop may be difficult until the stems are dry.

Seed damage may occur if desiccants are not applied at the proper time. If applied too early, glyphosate will reduce seed germination and diquat or glufosinate will reduce seed weight and lead to seed discolouration. In some conditions, flax bolls will dry very quickly, and seed weathering may occur before the stems are dry enough to cut. Despite these potential problems, careful application within the registered guidelines for the desiccant will improve flax harvest management.

One of the greatest problems to flax producers has been management of flax straw after harvest. The straw is very slow to decay, and easily forms bunches in the field. Straw which remains in the field may make subsequent tillage and seeding operations very

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SECTION B

SUMMARY OF FLAX RESEARCH AT SCOTT AND SASKATOON

EXECUTIVE SUMMARY

The overall goal of this current flax project is to improve th potential of flax production while at the same time take into consideration not only the needs of the producer, but as well the needs of the end-user and the consumer. One objective was to review the work of Harry Ukrainetz (retired), formerly at the Saskatoon station on fertility aspects of flax production. Two series of studies were identified and summarized: the first study examined raate and placement of phosphorus fertilizer for flax on fallow and the second study examined the effects of phosphorus, seeding rate and row spacing for flax on fallow.

PART A: RATE AND PLACEMENT OF PHOSPHORUS FOR FLAX ON FALLOW.

The objective was to determine the effect of phosphorus rates and placements on plant numbers and grain yield in flax over 4 locations spanning the years 1975-1979 for a total of 16 station-years.

Plant Populations: Although flax is very good at yield compensation because of the branching habit of the crop, it is also well known that flax is very sensitive to fertilizer, especially when it is in close proximity to the seed. One always has to be concerned, not only to reduced plant stands, but of sub-lethal injury to the root as a result of the fertilizer. In five of the 10 station years, where plant counts were measured, placing the fertilizer with the seed resulted in a significant reduction in plant stand. In the other station years, although not significant, the trend was always for lower plant stands when compared to the check. If the fertilizer is placed away from the seed, in this case, 1" below or 1" below and 1" to the side, reductions in plant stands relative to the check were not observed. On occasion, placing the fertilizer away from the seed resulted in lower plant stands than the check. In those situations, it can be argued that the soil conditions were such that improper separation of seed and fertilizer occurred emphasizing once again the importance of keeping the fertilizer away from the seed. When fertilizer rate is examined relative to placement, increasing the rate of P tended to decrease plant stands. Very few interactions between row spacing and placement were observed. It should be noted that plant populations, overall, tended to be low and future studies on flax fertility should use higher seeding rates to ensure that plant populations in the range of 250-500 plants/m^2, considered to be optimum.

Grain Yields: A total of 17 station-years were reported for the effects of placement and rate of phosphorus on flax grain yields. Of those 17 station-years, 7 showed a significant effect due to placement and in all seven station-years, the yields were always better when the fertilizer was placed away from the seed, in this case, banded below or banded below and to the side. A response to phosphorus, where adding P gave a greater yield than the check was reproted in 9 of 17 station years, or 53% of the time. The yield increases were small in absolute terms meaning that large amounts of P are not required. It is more important, as has been reported, to increase soil P levels over time through continuous cropping and moderate applications of P fertilization since flax tends to use soil P more readily than fertilizer P.

PART A: Rate & Placement of Phosporous for Flax on Fallow

A1. Objectives To determine the effect of various P2O5 rates and placements on the quantity and quality of flax seed when grown on fallow for different locations and years.

A2. Materials & Methods

Location:
Kindersley (1975, 1976, 1977, 1978, 1979)
Lashburn (1975, 1976, 1977, 1978)
Scott (1975, 1976, 1977, 1978)
Rosetown (1975, 1976, 1977, 1978)

Flax variety: unknown in 1975, Noralta for others.

Treatments:

-Rate
0 kg/ha
11 kg/ha
22 kg/ha
34 kg/ha
45 kg/ha
67 kg/ha
90 kg/ha
112 kg/ha

- Phosphorus placement
- with seed
- 1" below * 1" beside seed
- 1" below seed

Variables Reported
Seed yield (kg/ha)
Plant counts (plants/m^2)

A3. Results

Kindersley

Phosphorus (P) rate but not placement had a significant effect on plant density (Table 1&2). As P rate increased, plant density decreased with the largest difference observed when the phosphorus was placed with the seed. At the lowest rate of P, plant density was greatest where the P was placed with the seed but similar in the range of 22-90 kg/ha. It is interesting to note that the check plot which received no phosphorus tended to be low relative to the values reported in the table. This could be a reflection of the inadequate seeding technology for this type of work i.e. improper separation or poor seed-bed quality.

Table 2. The effect of phosphorus rate per meter square in flax at Kindersley.

P2O5 (kg/ha)	1975	1976	1977	1978	1979
11	162	188	-	-	-
22	144	159	-	-	-
34	-	185	-	-	-
45	149	169	-	-	-
67	141	176	-	-	-
90	140	127	-	-	-
112	121	171	-	-	-
Check	137	200	-	-	-
cv%	13.5	20.1	-	-	-
s.e.	8.3	14.4	-	-	-
Rate effect	*	ns	-	-	-

Table 3. The effect of phosphorus placement on grain yield (kg/ha) in flax at Kindersley.

P2O5 Placement (kg/ha)	1975	1976	1977	1978	1979
With the seed	1071	1337	465	671	968
1" below and 1" beside	1078	1374	418	726	1006
1" below	1054	1308	455	601	977
Check	1021	1286	633	466	1015
CV%	15.1	9.1	32.0	18.7	10.8
s.e.	33	23	27	24	20.1
Rate effect	ns	ns	ns	**	ns

Table 5. The effect of phosphorus placement on plants per meter square in flax at Rosetown.

P2O5 Placement (kg/ha)	1975	1976	1977	1978	1979
With the seed	125	98	-	-	-
1" below and 1" beside	142	140	-	-	-
1" below	127	223	-	-	-
Check	136	189	-	-	-
CV%	15.8	20.4	-	-	-
s.e.	6.0	8.4	-	-	-
Rate effect	ns	**	-	-	-

Table 6. The effect of phosphorus rate on plants per meter square in flax at Rosetown.

P2O5 (kg/ha)	1975	1976	1977	1978	1979
11	148	188	-	-	-
22	147	148	-	-	-
34	-	154	-	-	-
45	137	140	-	-	-
67	121	154	-	-	-
90	119	145	-	-	-
112	116	147	-	-	-
Check	136	189	-	-	-
CV%	15.8	20.4	-	-	-
s.e.	8.5	12.9	-	-	-
Rate effect	ns	ns	-	-	-

Scott

P placement had a significant effect on plant populations in one of three years in which case all the treatments were lower than the check with the seed-placed P treatment having the lowest numbers (Table 9). The rate of P had no effect on plant populations which means that placement is the critical factor (Table 10).

P placement resulted in a significant improvement on grain yield relative to the check in three of five years (Table 11). In the reamining two years, there was no yield difference between the check. In terms of placement, when yield differences were observed, the seed-placed option was always inferior. With regards to the other two placements, in one year there was no difference, in another below the seed was better than below and to the side, and in the other, the reverse was observed. In terms of the response to P, a significant effect on yield was observed in 4of five years. In aboslute terms, the responses tended to be small (Table 13).

Table 9 . The effect of phosphorus placement on plants per meter square in flax at Scott .

P2O5 Placement (kg/ha)	1975	1976	1977	1978	1979
With the seed	84	74	229	-	-
1" below and 1" beside	106	109	278	-	-
1" below	106	79	260	-	-
Check	127	122	176	-	-
CV%	43.0	38.8	33.9	-	-
s.e.	12.3	9.1	23.2	-	-
Rate effect	ns	*	ns	-	-

Table 12. The effect of phosphorus rate on grain yield (kg/ha) in flax at Scott.

P2O5 (kg/ha)	1975	1976	1977	1978	1979
11	445	1211	226	686	1436
22	445	1401	254	688	1573
34	-	1358	250	692	1408
45	438	1427	218	790	1470
67	543	1211	256	863	1619
90	525	1051	199	831	1570
112	477	1269	259	923	1568
Check	431	1081	191	617	1535
CV%	26.1	16.5	34.8	15.4	6.7
s.e.	36.1	60.8	23.9	34.9	29.5
Rate effect	**	**	ns	**	**

Lashburn

P placement had a significant effect on plant populations in two of the three years (Table 13). Although placing P away from the seed resulted in higher plant counts than when P was placed with the seed, in those years, the plant numbers were still lower than the check in two of the three years (Table 14). These results emphasize the sensitivity of flax to fertilizer, even phosphate fertilizer.

In terms of grain yield, there was a significant effetc in two of the four years where placing the fertilizer away from the seed resulted in yield improvements (Table 15). In terms of P rate, a significant effect was observed in 2 of the four years. As with the other sitres, the response to P tends to always be samll in absolute terms.

Table 15. The effect of phosphorus placement on grain yield (kg/ha) in flax at Lashburn .

P2O5 Placement (kg/ha)	1975	1976	1977	1978	1979
With the seed	1052	1816	372	1446	-
"below and 1" beside	1109	1994	353	1541	-
1" below	854	1600	329	1441	-
Check	481	1818	492	1350	-
CV%	24.3	14.6	20.9	12.6	-
s.e.	50.1	49.8	13.9	35.4	-
Rate effect	**	**	ns	ns	-

Table 16. The effect of phosphorus rate on grain yield (kg/ha) in flax at Lashburn.

P2O5 (kg/ha)	1975	1976	1977	1978	1979
11	892	1743	321	1421	-
22	1048	1789	408	1495	-
34	-	1895	489	1458	-
45	943	1864	362	1540	-
67	1002	1804	325	1542	-
90	1087	1896	313	1479	-
112	1056	1633	239	1396	-
Check	481	1818	492	1350	-
CV%	24.3	14.6	20.9	12.6	-
s.e.	70.9	76.0	21.3	54.0	-
Rate effect	*	ns	**	ns	-

Table 1. P-values for each variable and station years measured. Values with the designation ns means that it was non significant i.e values were greater that 0.05.

	Plants / m^2		Grain N %	Grain P %	Grain Yield (kg/ha)		
Source	**Scott-90**	**Scott-92**	**S'toon - 90**	**S'toon - 90**	**S'toon - 90**	**Scott - 90**	**Scott - 92**
SR	0.025	0.0001	ns	0.04	ns	0.0001	ns
RS	0.0001	0.0001	ns	0.05	0.0001	0.0001	0.004
SR x RS	0.007	0.047	ns	ns	0.0001	ns	ns
P	0.0001	0.0001	0.056	0.054	0.002	ns	ns
SR x P	ns	0.007	ns	ns	ns	ns	0.02
RS x P	0.014	ns	ns	0.004	ns	0.02	0.03
SR x Rs x P	ns	ns	ns	ns	ns	ns	ns
cv	34.5	16.6	2.3	4.3	5.2	9.9	10.5

Plant Establishment:

The main effects, seeding rate (SR), row spacing (RS) and seed-placed-P were all significant (Table 2.). As SR increased, plant populations increased and as RS and P increased, plant populations decreased. There was an SR x RS interaction observed in both years (Table 3). As seeding rate increased, the increase in plant population was less at the wide than the narrow row spacings. A significant SR x P interaction was also observed (Table 4). The % reduction in plant populations due to P was greatest at the highest than the lowest seeding rate. There was also a RS x P interaction (Table 5) the nature of which is that the % decrease in plant populations due to P was greatest at the wide than the narrow row spacings.

Based on the results presented, it is important to remember that in order to evaluate the true effects of P as a function of RS, it is important that the P be placed away from the seed in order to alleviate the confounding effects of RS and P.

Table 3. The effects of row spacing and seeding rate on the number of plants per meter square in flax at Scott in 1990 and 1992.

1990			
	Seeding Rate (kg/ha)		
Row Spacing (cm)	**15**	**30**	**45**
10	73	117	167
20	38	60	81
30	24	45	50
s.e. =9 (p<0.01)			
1992			
	Seeding Rate (kg/ha)		
Row Spacing (cm)	**15**	**30**	**45**
10	192	319	411
20	158	253	341
30	129	181	235
s.e. =9 (p<0.05)			

Table 4. The effects of seeding rate and seed-placed P on the number of plants per square meter at Scott in 1992.

	Seed-Placed P_2O_5 (kg/ha)		
Seeding Rate (kg/ha)	**0**	**25**	**50**
15	187	147	137
30	292	252	210
45	390	341	255
s.e. = 0.12			

Table 10. The effects of row spacing and seed -palced P on grain yield of flax on fallow at Scott in 1990 and 1992.

	Seed-Placed P_2O_5 (kg/ha)		
Row Spacing (cm)	**0**	**25**	**50**
10	1747	1877	1884
20	1464	1591	1585
30	1416	1389	1272
s.e. = 109 (p<0.02)			
	Seed-Placed P_2O_5 (kg/ha)		
Row Spacing (cm)	**0**	**25**	**50**
10	1091	1141	1185
20	988	1030	1073
30	882	920	812
s.e. = 55 (p<0.03)			

SECTION C

FLAX TOLERANCE TO BUCTRIL M: ECW DATABASE STUDY

Flax Tolerance to Buctril M: ECW Database study

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Several postemergence herbicides are registered in western Canada to control broadleaf weeds in flax, including Basagran, Buctril M, Hoe-grass II, Lontrel, MCPA/MCPA K, and Stampede CM. Buctril M is the most widely used of these herbicides. This is likely due to a combination of factors, including cost, crop safety, and weed spectrums controlled. Bromoxynil, an active ingredient in both Buctril M and Hoe-grass II, controls many annual broadleaf weeds such as tartary buckwheat that do not respond to phenoxy herbicides. Other weeds controlled by this herbicide include kochia, lamb's quarters, smartweeds, stinkweed, wild mustard and wild buckwheat. Buctril M[1] is a formulated mixture of bromoxynil octanoate ester and MCPA ester. The addition of MCPA ester not only improves the control of weeds already controlled by bromoxynil, but also provides activity on flixweed, shepherd's purse, perennial sow thistle, Canada thistle, and volunteer canola and sunflower.

Flax producers often report injury (stem epinasty, stunting and leaf burn) to flax following application of Buctril M. To reduce the chance of injury, Buctril M should not be applied to flax if daytime temperatures exceed 27 C within 48 hrs before or after application, and evening spraying may also reduce the risk of injury[2]. Anecdotal reports suggest, however, that crop injury can occur even when these recommendations are followed. We do not know it whether the crop injury reported by producers have reduced crop yields. Buctril M is a useful herbicide for broadleaf weed control in flax and producer confidence in and continued use of this product is desirable from a user perspective.

Buctril M has been registered for use in flax since early to mid-1970's, and many studies have been published in the Research Reports of the Expert Committee on Weeds (ECW) on its efficacy and selectivity in flax (Appendix A, Table 1). Rather than initiate new trials to identify application

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[1]Buctril M is a registered trademark of Rhône-Poulenc, authorized user Rhône-Poulenc Canada Inc., 2000 Argentia Road, Plaza 3, Suite 400, Mississauga, Ontario, L5N 1V9.

[2]Anonymous, 1996. Buctril M. Pages 65-66 *in* Guide to Crop Protection 1996: Weeds, Plant Diseases, Insects. Manitoba Agriculture, Carman, Mantitoba.

Search Results: A summary of search results is presented in Table 1 of Appendix A. From 1976 to 1994, 519 abstracts (studies) were published in ECW research reports that included at least one treatment of Buctril M EC at the label rate (560 g ai/ha). Of these, only 183 studies provided data on both visual estimates of crop injury and seed yield. Most experiments included in the search results were conducted with the primary objective of determining Buctril M efficacy on weeds. These experiments contained a weedy or weed-free check or both. Only 80 experiments were conducted where crop tolerance was stated as the main objective, and of these, only 49 were suitable for exploring specific factors affecting flax tolerance to Buctril M. Abstracts of these experiments contained information on both yield and tolerance and most included a weed-free check (Appendix B).

Although many studies were conducted specifically to test for crop tolerance, the majority were not done under weed-free conditions. This is an important point, since it is often impossible to separate the effects of herbicide injury and weed control on yield where tests were conducted under weedy growing conditions. Only those trials conducted under weed-free conditions were considered sufficiently reliable (complete) for studying effects of growth stages, timing of application, etc. on flax tolerance to Buctril M.

Often the minimum data set needed to answer specific research questions were either not collected or not reported and reliable conclusions could not be drawn. For example, visual estimates of crop tolerance (injury) were reported in the abstract but not flax yields. Without corresponding yield data, it was not possible to determine whether observed injury reduced yields. Generally, the most reliable (complete) data were submitted by universities or provincial or federal weed specialists. Submission of incomplete data sets was both disturbing and unacceptable since valid conclusions on tolerance cannot be drawn without measuring the treatment effects on yield. To be fair, yield data may have been collected for many of these experiments, and the lack of yield data may reflect the deadlines imposed by ECW for submitting research results. Until 1996 the deadline for submitting abstracts for publication was usually the second week in October. It is possible that many trials were simply not harvested in time to meet ECW deadlines. Regardless, the lack of yield data limited the usefulness of the ECW database.

Using the general and specific purpose databases, we attempted to answer the following questions:

1. Does the addition of graminicides affect Buctril M phytotoxicity in flax?
2. Do adjuvants affect Buctril M phytotoxicity?
3. Do flax cultivars differ in tolerance to Buctril M?
4. How do flax yields compare between flax treated with Buctril M (under weed-free conditions) and a hand-weeded (weed-free) check? Does Buctril M itself reduce flax yields?
5. What effect does water volume have on flax tolerance to Buctril M?
6. What effect do application rates have on flax tolerance to Buctril M?
7. Does growth stage at application affect flax tolerance to Buctril M?
8. Does time of day at application affect flax tolerance to Buctril M?

Based on information contained in the general purpose and specific databases, there was insufficient good data to provide definitive answers to questions #1, 2, 5, 6, 7 and 8. This was due primarily to lack of testing under weed-free conditions and secondly, the limited number of tests conducted with these objectives in mind. The results of the database search, however, suggested the

Conclusions. Before initiating this review, we believed that much of the information needed to develop recommendations for improving crop safety when apply broadleaf herbicides would be found in the ECW database. This review showed that this is clearly not so, at least not for this example. What is clear, however, is that many studies conducted, lacked a scientifically sound approach. Many studies failed to include the appropriate checks, eg. weed-free checks, or experimental conditions were not maintained to meet stated objectives. Too often experiments were conducted that had multiple objectives, probably to save money and time. Lack of resources, primarily labor, may be a significant factor dictating the approach selected for conducting weed research. Establishing and maintaining weed-free check plots or an entire test under weed-free conditions is very labor intensive and timely weeding is essential. Most often, experiments conducted under weed-free conditions or that included weed-free check plots were done at universities or Agriculture & Agri-Food Canada. The findings of this review show the limitations of the ECW database, and presents a strong case for properly conducted independent research where the experiments are truly designed to meet the objective for which the data is to be used and to answer pertinent questions.

The analysis of the ECW database has shown that although the database has been useful for herbicide registration it is not useful for answering specific questions such as the relationship between crop injury from herbicide application and crop yield loss, or specific issues relating to reducing crop injury. To answer these and other questions, specific research projects need to be conducted. To date, there is inadequate information available to advise flax growers on issues relating to flax tolerance to herbicides. Given the interest in increasing flax yields, new focused research on flax tolerance to herbicides, weed control within flax, and weed management strategies for flax production are required.

Recommendations. Based on this review, several areas of research need to be conducted (preferably at more than one site per year), these include:

- New research needs to be initiated to determine the relationship between flax tolerance to herbicides and yield and factors that affect flax tolerance. This research should be conducted under weed-free conditions at three or more locations (Brandon, Morden, and Roblin, Manitoba and Saskatoon and Scott, Saskatchewan). This research should commence in 1997 and address the following issues:
    1. Time of day, growth stage and application rates of Buctril M and Stampede CM. This is identical to research conducted at Morden in 1996.
    2. Tolerance of flax varieties to Buctril M and Stampede CM. Since current flax varieties are genetically very similar testing many varieties may not be warranted. Initial testing of five genetically distinct varieties (AC Emerson, Andro, Culbert, Flanders, and NorLin) is planned for 1997.
    3. Effect of formulation on flax tolerance to Buctril M.
    4. Effect of graminicide and adjuvants on flax tolerance to Buctril M.
- Effect of environmental factors on flax tolerance to Buctril M and Stampede CM. This would include an examination of humidity, temperature, and duration of the light (or dark) period following herbicide application on crop injury. This research would be conducted in greenhouse growth room studies to explain and support field observations from the above experiments.

but only when the herbicide was applied at twice the label rate (1120 g/ha).

This preliminary study suggests that under weed-free conditions, the time of day at application will affect flax tolerance to Buctril M; particularly when it is applied before the 5 to 10-cm growth stage currently recommended in Manitoba. However, when applied at the recommended rate yield losses may not occur. This study will be repeated in 1997 at Morden and Brandon, Manitoba.

Table 1. Effect of time and rate of Buctril M application on crop injury to flax at 2, 4 and 6 weeks after treatment (WAT).

Application time	Buctril M (g ai/ha)	Crop injury (0 to 100%)		
		2 WAT	4 WAT	6 WAT
a.m.	0	0	0	0
a.m.	140	1	0	0
a.m.	280	3	1	0
a.m.	560	13	6	3
a.m.	1120	51	33	13
p.m.	0	0	0	0
p.m.	140	2	1	0
p.m.	280	3	1	0
p.m.	560	5	2	0
p.m.	1120	17	6	4

APPENDIX "A"

SUMMARY OF VARIOUS FACTORS AFFECTING FLAX TOLERANCE TO BUCTRIL M (ECW 1976-1994)

Appendix Table 2. Flax tolerance to Buctril M tank-mixtures with graminicides.

Experiment #	Treatment	Yield (% of best yield)	Crop injury (%)
94-49650 (Weed-free)	Buctril M	83	9
	Buctril M + Poast + Merge	100	9
	Buctril M + Select + Amigo	98	9
	Buctril M + Assure + Canplus	98	9
91-44239 (Weedy)	Buctril M + Poast + Merge	100	0
	Buctril M + Select + Amigo	100	0
	Buctril M + Assure + Canplus	86	0
90-43089 (Weedy)	Buctril M + Poast + Assist	100	5
	Buctril M + Select + Amigo	91	4
	Buctril M + Assure + Canplus	72	4
	Buctril M + Fusion + SOC	88	4
87-34950 (Weedy)	Buctril M	26	5
	Buctril M + Poast + Assist + AS	30	5
	Buctril M + Select + Amigo + AS	33	5
86-32808 (Weedy)	Buctril M + Poast + Assist	97	6
	Buctril M + Assure + Canplus	89	7

Conclusions: There was insufficient data in the ECW database to draw a clear conclusion on the effects of various graminicides on Buctril M phytotoxicity in flax. Of the 5 trials conducted to examine effects of graminicides on Buctril M, only 1 was conducted under weed-free conditions. In 3 trials, Buctril M tank-mixtures with Assure + Canplus tended to have lower yields than Buctril M alone or mixed with other graminicides. Crop injury was commercially acceptable. Based on visual evaluations, it appears that flax responds similarly to Buctril M tank-mixed with various graminicides.

Appendix Table 3. Tolerance of flax cultivars to Buctril M.

Experiment #	Cultivar	Yield (% of best yield)	Crop injury (%)
94-49567 (Weedy)	NorLin	78	6
	Trifid (FP 967)	76	9
76-1966 (Weed-free)	Norland	79	15
	Linott	65	33
	Noralta	97	15
	Redwood 65	75	15
	Raja	68	25
	Dufferin	71	10
76-1956 (Weed-free)	Norland	100	15
	Linott	97	20
	Noralta	115	15
	Redwood 65	100	10
	Raja	103	20
	Dufferin		15

Conclusions: Few trials were conducted on varietal differences in tolerance to Buctril M. Information on newly released cultivars is very limited. There is no difference in tolerance between NorLin and Trifid (FP 967) flax, likely due to Trifid being derived from NorLin. There appeared to be some variation in the 1976 trials, but growth stages were not the same for all cultivars at the time of application, and this may have confounded the interpetation of the results.

Appendix Table 5. Effect of water volume on Buctril M phytotoxicity in flax.

Experiment #	Water vol. (L/ha)	Yield (% of best treatment)		Tolerance (0 to 100%)	
		Buctril M	Buctril M + adjuvant	Buctril M	Buctril M + adjuvant
86-33738 Weedy	45	91	-	5	-
	110	100	12	10	12
	200	98	-	1	-
85-31857 Weedy	40	84	-	5	-
	100	87	92	6	6
	200	99	-	3	-
85-31800 Weed-free	20	N/A	-	5	-
	50	N/A	-	3	-
	100	N/A	N/A	3	3
	200	N/A	-	3	-

Conclusions: There was insufficient data to draw clear conlusions regarding the effect of water volume, but based on limited data that water volume did not have a marked effect on flax tolerance to Buctril M.

Appendix Table 7. Comparison of flax tolerance to Buctril M applied at different crop growth stages.

Experiment #	Growth stage (cm)	Yield (% of best treatment)		Crop injury (0 to 100%)		Other herbicide
		Buctril M	Buctril M + other	Buctril M	Buctril M + other	
93-48210 Weed-free	3	74	84	N/A	N/A	Poast + Merge
	6	84	100	N/A	N/A	
	12	70	83	N/A	N/A	
	22	82	74	N/A	N/A	
	32	73	78	N/A	N/A	
92-47070 Weedy	7	--	94	N/A	N/A	Select + Amigo + Fluazifop + SOC
	8	--	97	N/A	N/A	
	10	--	98	N/A	N/A	
90-43031 Weedy	2	--	100	--	6	Fluazifop + SOC
	4	--	100	--	6	
	5	--	96	--	11	
	8	--	94	--	8	
	15	--	93	--	11	
90-43030 Weedy	2	--	96	--	11	Poast + fluazifop + SOC
	4	--	97	--	19	
	5	--	100	--	14	
	8	--	97	--	18	
	11	--	97	--	18	
	15	--	99	--	11	
89-40223 Weedy	2	--	86	--	11	Poast + Assist
	3	--	94	--	11	
	5	--	97	--	14	
	8	--	100	--	16	
	11	--	87	--	10	
89-40236 Weedy	2	--	93	--	10	Fluazifop + SOC
	3	--	98	--	7	
	5	--	99	--	7	
	8	--	97	--	15	
	11	--	84	--	19	

Appendix Table 8. Effect of time of day at application on flax tolerance to Buctril M.

Expt. #	Time of applic. (h)	Yield (% of best trt.)	Crop injury (%)	Expt. #	Time of applic. (h)	Yield (% of best trt.)	Crop injury (%)
90-43028 Weedy	0500	83	18	90-43029 (Weedy)	0500	93	15
	0700	85	17		0700	87	14
	0900	83	11		0900	85	13
	1100	93	8		1100	82	11
	1300	92	17		1300	86	14
	1500	90	21		1500	88	18
	1700	91	22		1700	67	17
	1900	88	21		1900	92	22
	2100	92	22		2100	89	22
	2300	95	21		2300	91	21
89-40221 Weedy	0500	93	34	89-40222 Weedy	0500	86	50
	0700	94	37		0700	90	40
	0900	93	34		0900	86	40
	1100	93	31		1100	90	38
	1300	93	25		1300	89	27
	1500	93	21		1500	86	21
	1700	97	15		1700	87	19
	1900	96	16		1900	85	16
	2100	93	9		2100	85	11
	2300	98	9		2300	88	23
88-36560 Weedy	0500	92	15	88-36561 Weedy	0500	94	15
	0700	85	25		0700	98	25
	0900	89	40		0900	92	15
	1100	81	15		1100	100	15
	1300	81	5		1300	100	5
	1500	80	5		1500	93	5
	1700	78	5		1700	90	5
	1900	90	5		1900	92	5
	2100	95	5		2100	92	15
	2300	95	15		2300	99	15

APPENDIX "B"

ECW ABSTRACTS USED IN SPECIFIC PURPOSE DATABASE

(Available upon request)

Figure Captions

Figure 1. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M.

Figure 2. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M.

Figure 3. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M + Poast + Merge.

Figure 4. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M + Poast + Merge.

Figure 5. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M + Poast + Assist.

Figure 6. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M + Poast + Assist.

Figure 7. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M + Select + Amigo.

Figure 8. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M + Select + Amigo.

Figure 9. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M + Assure + Canplus.

Figure 10. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M + Assure + Canplus.

Figure 11. Linear regression of flaxseed yield (g/m^2) on growth stage (cm). Effect of growth stage on flaxseed yield following application of Buctril M + other graminicides.

Figure 12. Linear regression of crop injury (%) on growth stage (cm). Effect of growth stage on tolerance of flaxseed to Buctril M + other graminicides.

Figure 13. Linear regression of flaxseed yield (g/m^2) on crop injury (%). Effect of degree of crop injury on flaxseed yield following application of Buctril M.

Figure 14. Linear regression of flaxseed yield (g/m^2) on crop injury (%). Effect of degree of crop injury on flaxseed yield following application of Buctril M + Poast + Merge.

Figure 27. Linear regression of crop injury (%) on temperature (C) at application. Effect of temperature at application on the degree of crop injury following application of Buctril M + Poast + Assist.

Figure 28. Linear regression of crop injury (%) on temperature (C) at application. Effect of temperature at application on the degree of crop injury following application of Buctril M + Select + Amigo.

Figure 29. Linear regression of crop injury (%) on temperature (C) at application. Effect of temperature at application on the degree of crop injury following application of Buctril M + Assure + Canplus.

Figure 30. Linear regression of crop injury (%) on temperature (C) at application. Effect of temperature at application on the degree of crop injury following application of Buctril M + other graminicides.

Effect of growth stage on tolerance with Buctril M

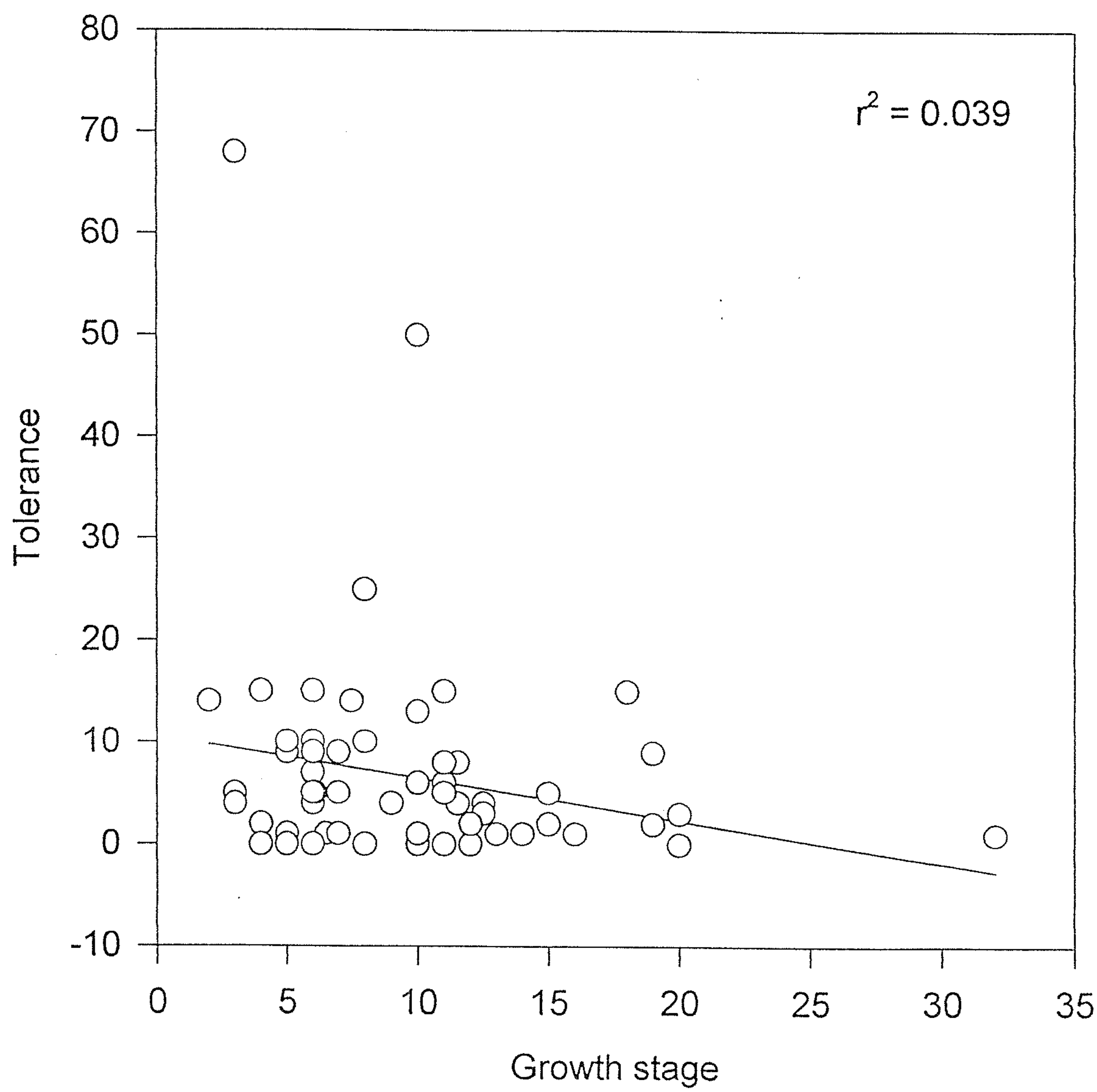
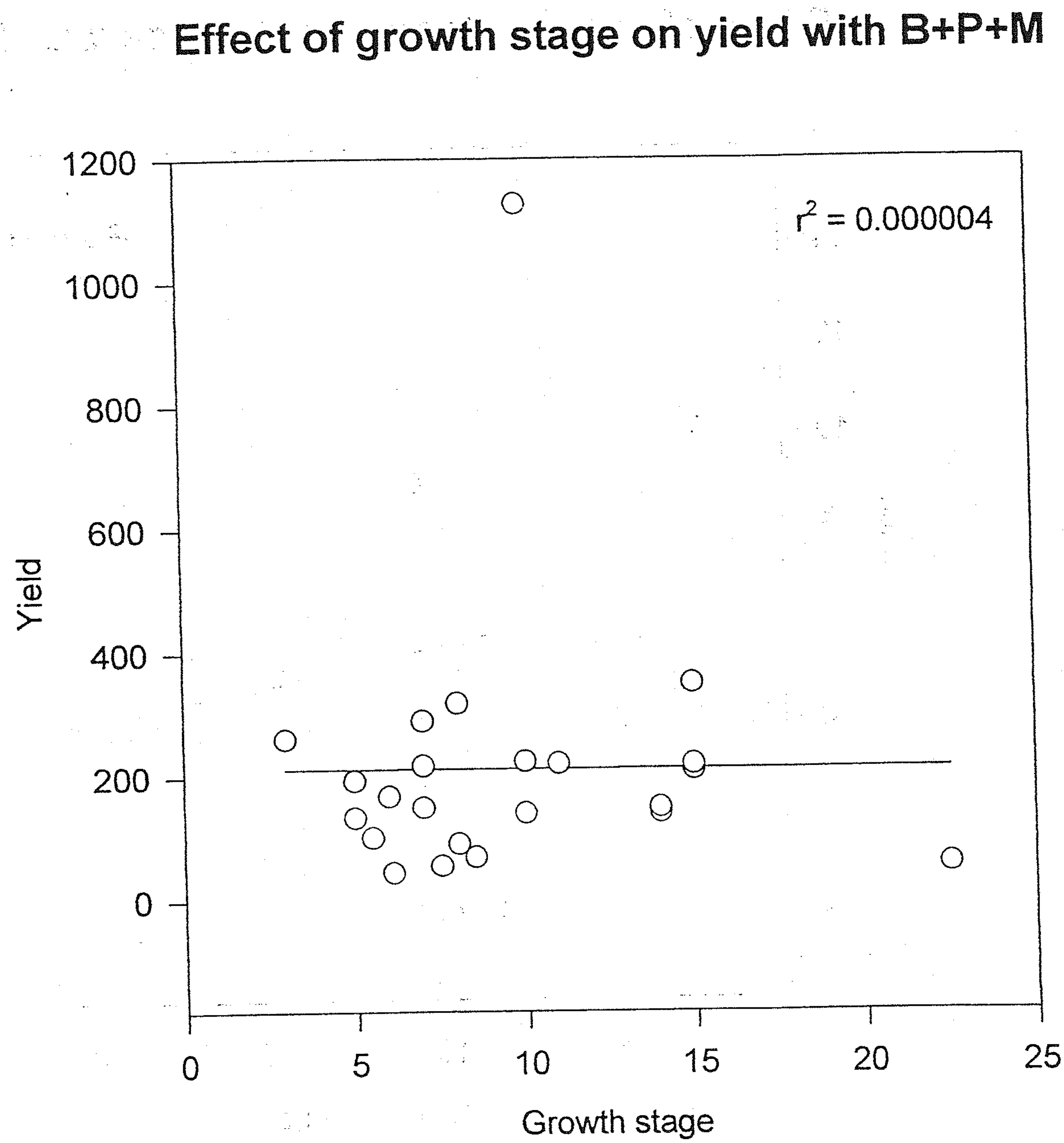


Fig #2



Effect of growth stage on yield with B+P+M
r^2 = 0.000004
1200
1000
800
600
400
200
0
Yield
0
5
10
15
20
25
Growth stage

Fig #3

Effect of growth stage on yield with B+P+A

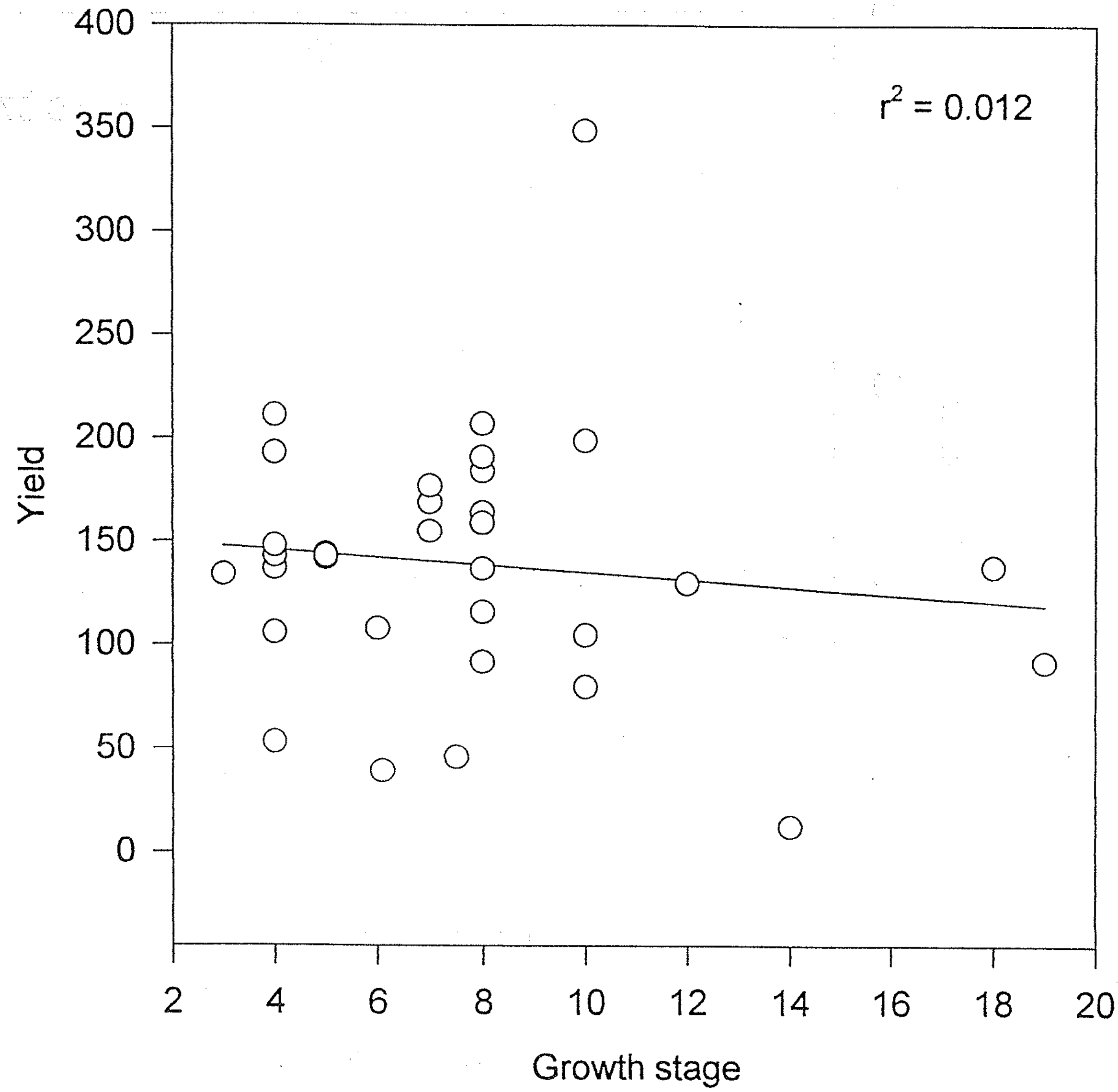


Fig #5

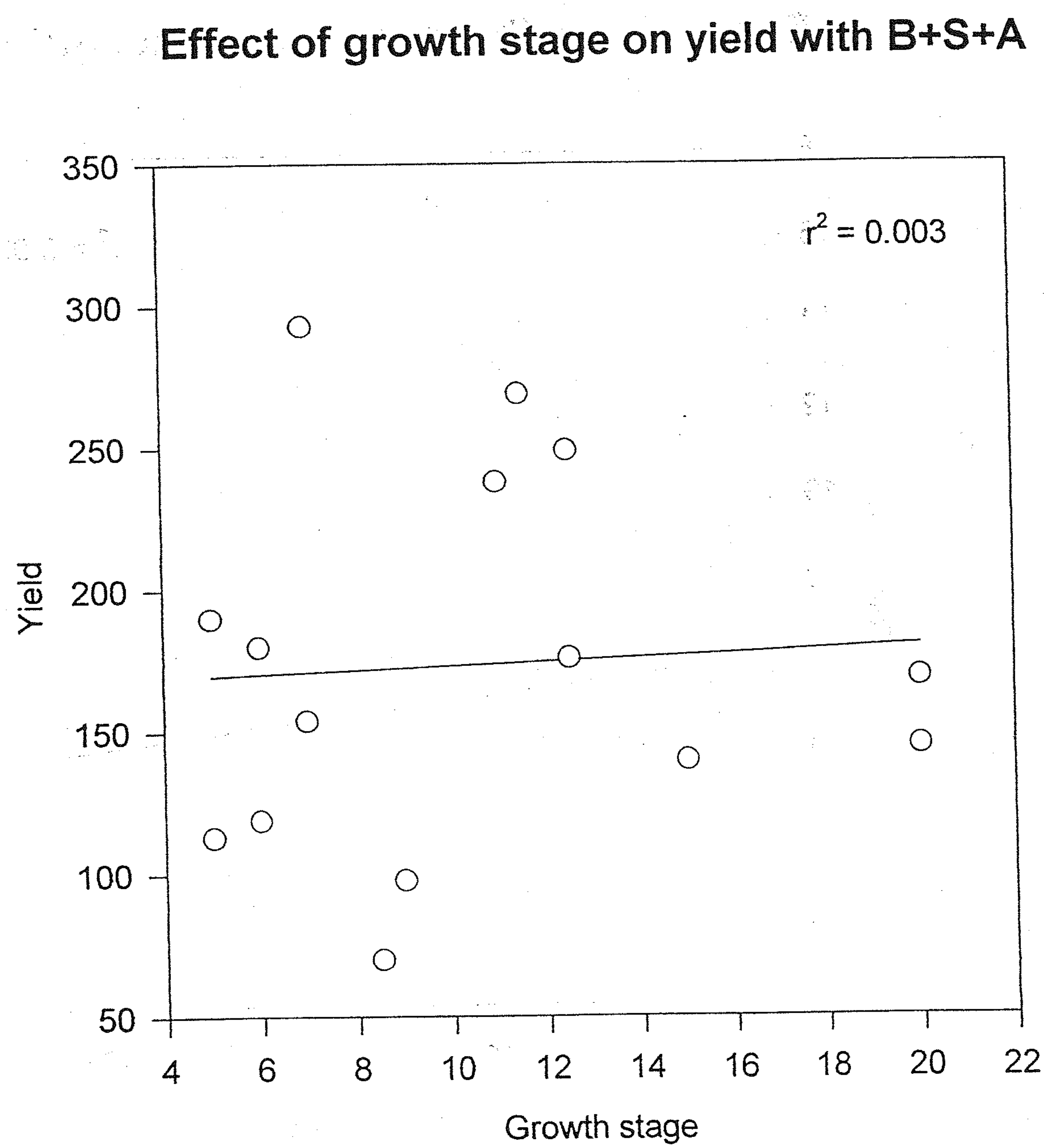

Effect of growth stage on yield with B+S+A
r^2 = 0.003
Yield
350
300
250
200
150
100
50
4
6
8
10
12
14
16
18
20
22
Growth stage

Fig. # 7

Effect of growth stage on yield with B+A+C

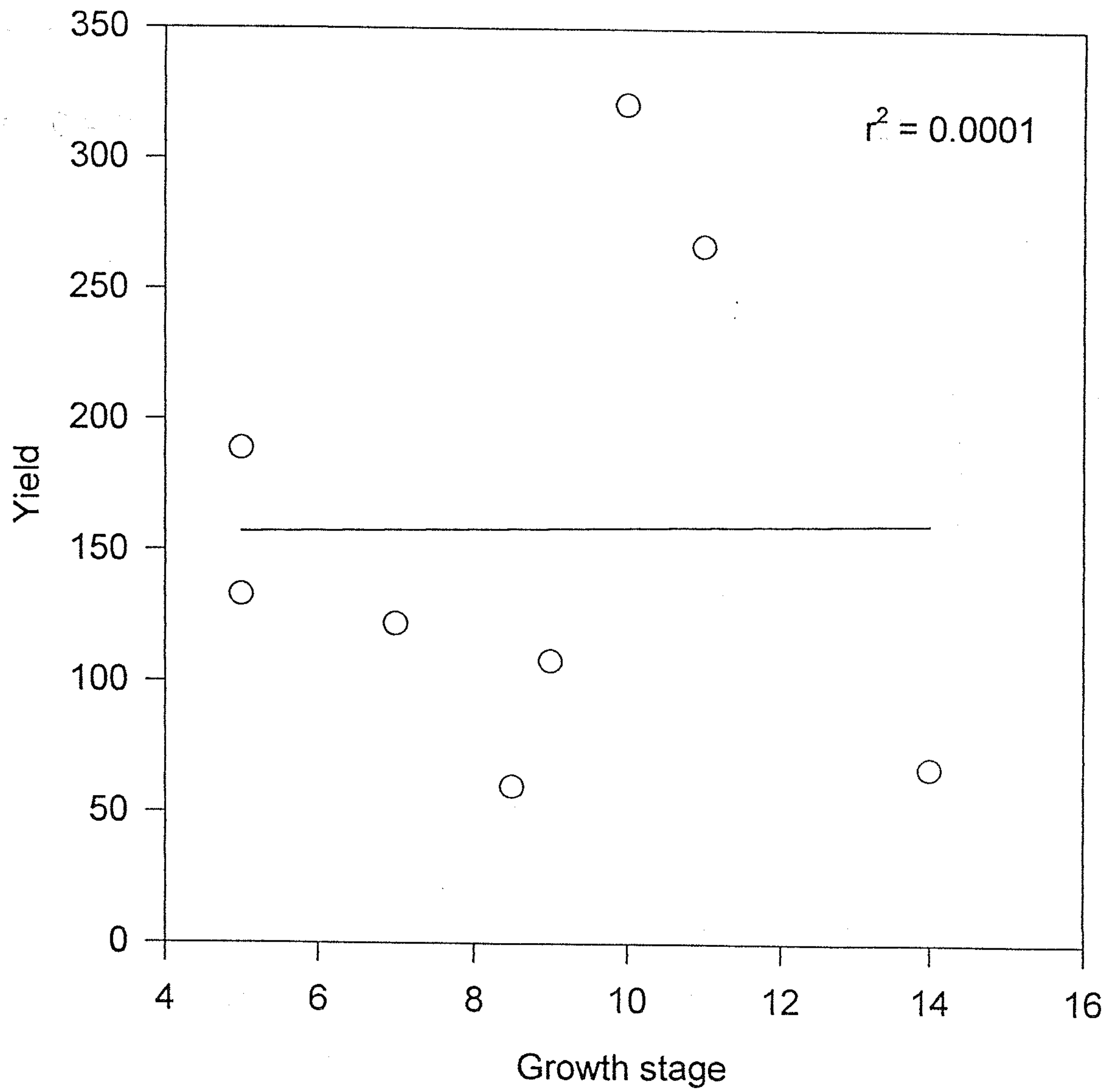


Fig #9

Effect of growth stage on yield with B+OTH

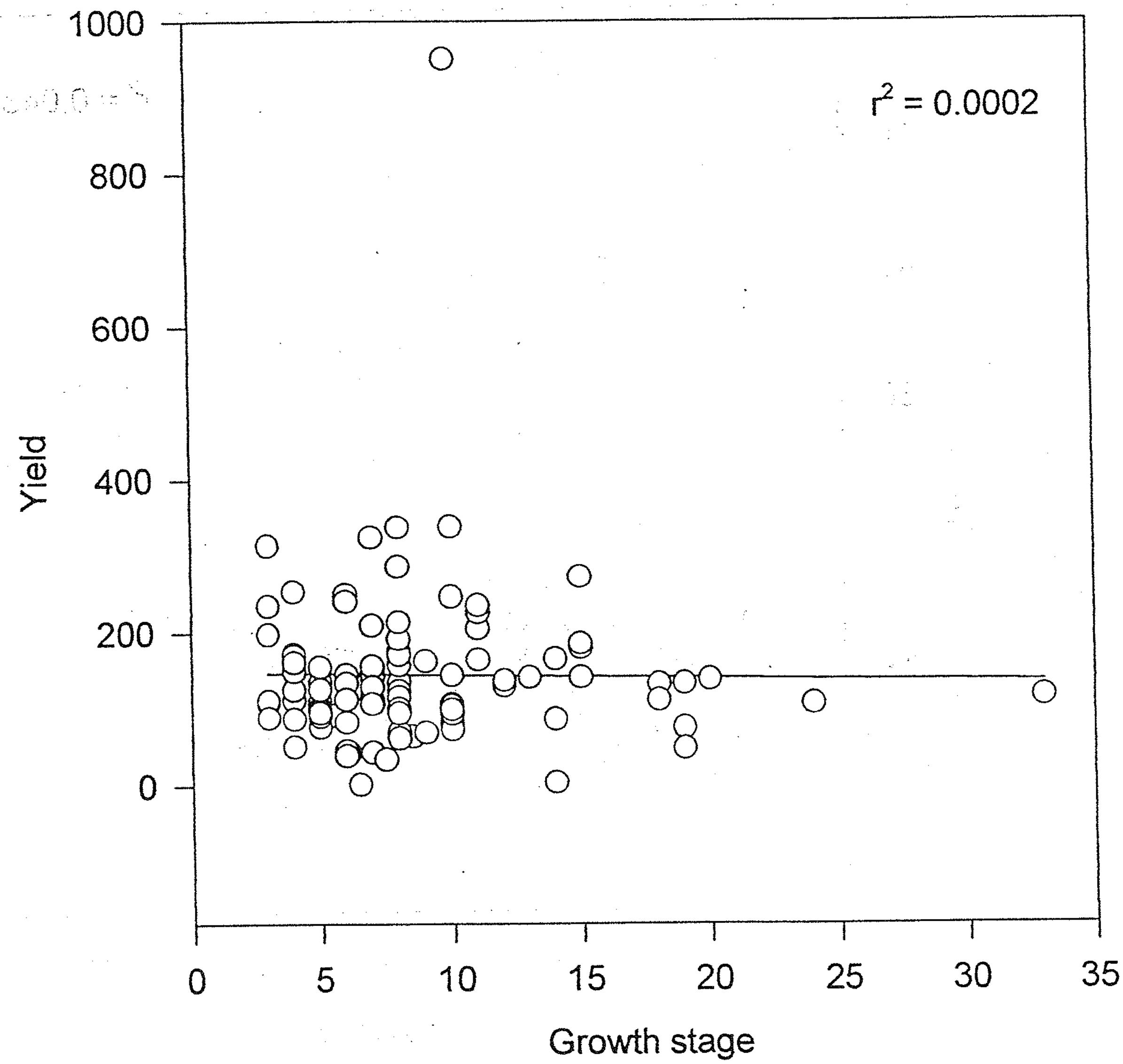


Fig #11

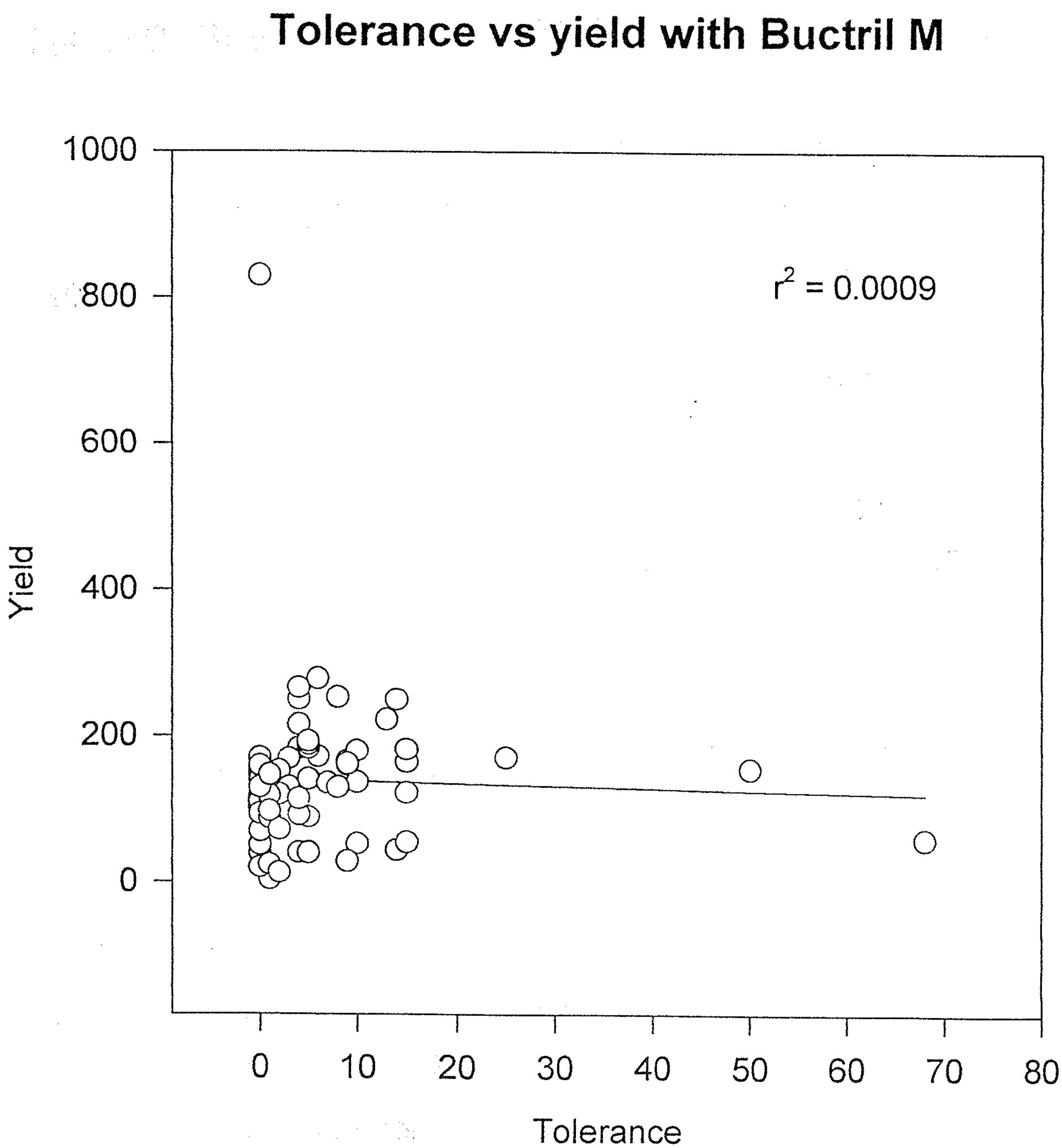

Tolerance vs yield with Buctril M
1000
800
600
400
200
0
Yield
r2 = 0.0009
0
10
20
30
40
50
60
70
80
Tolerance

Fig #13

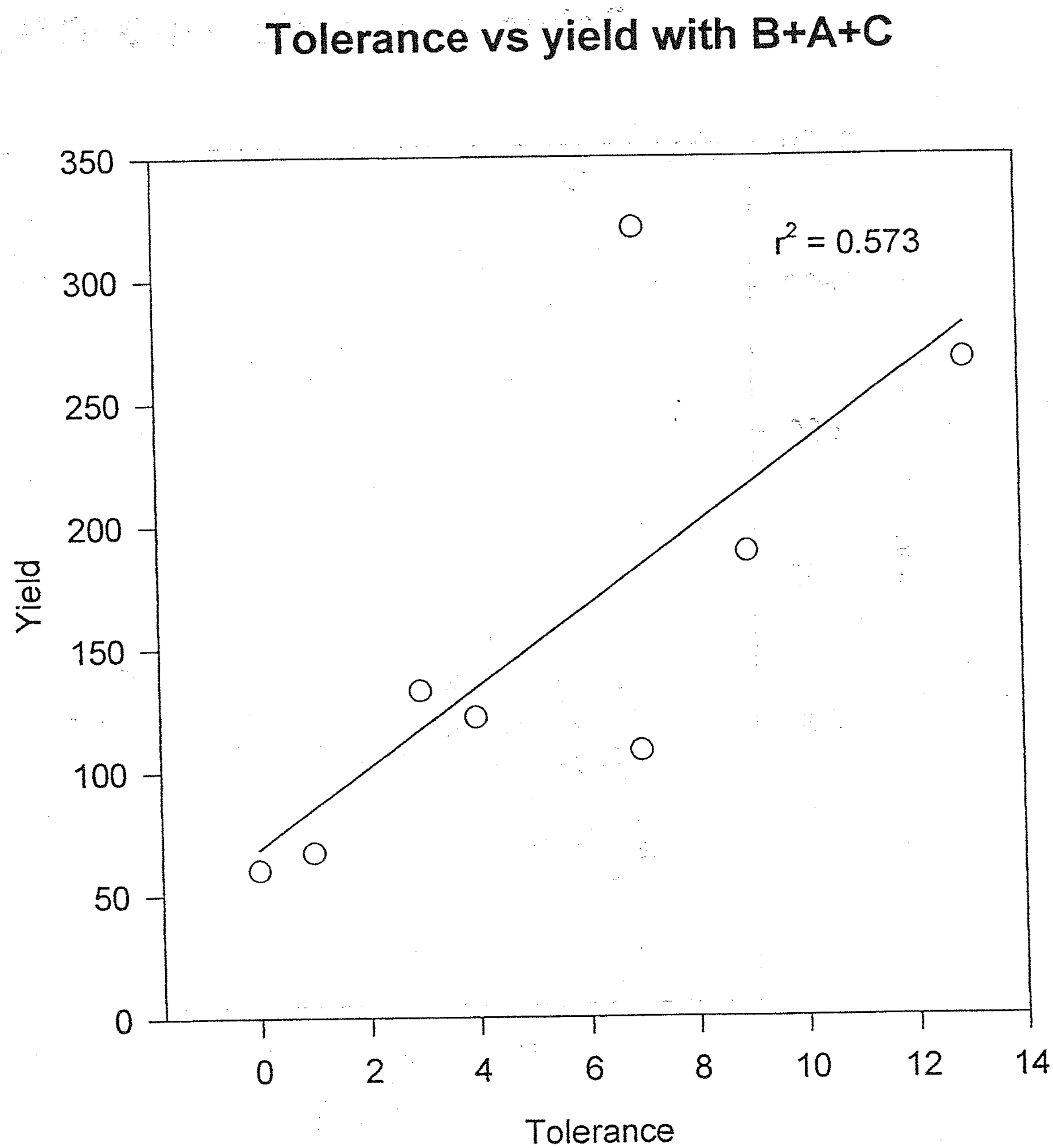
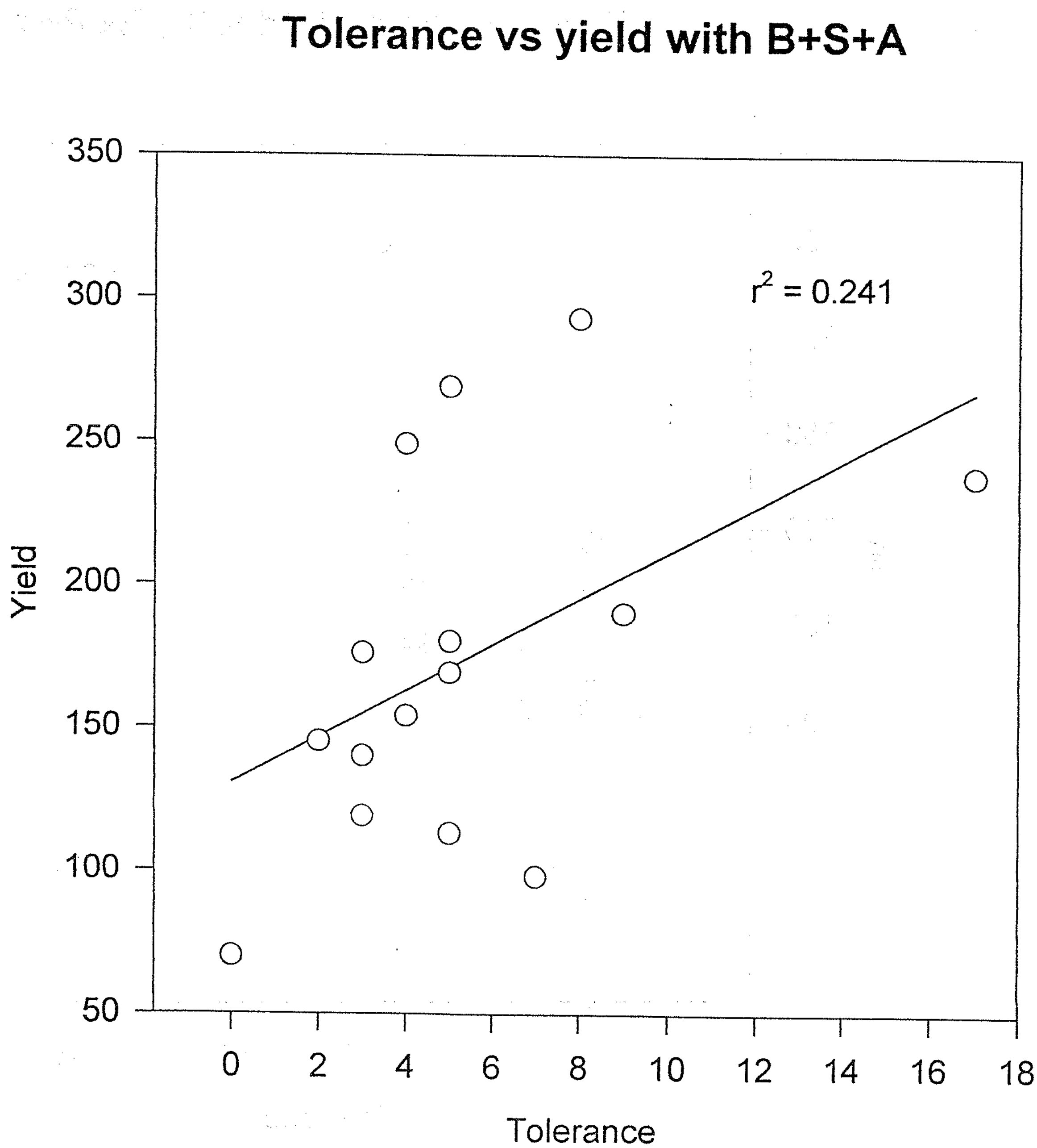

Tolerance vs yield with B+A+C
350
300
250
200
150
100
50
0
Yield
r² = 0.573
0
2
4
6
8
10
12
14
Tolerance

Fig #15



Tolerance vs yield with B+S+A
r² = 0.241
Yield
350
300
250
200
150
100
50
0
2
4
6
8
10
12
14
16
18
Tolerance

Fig #17

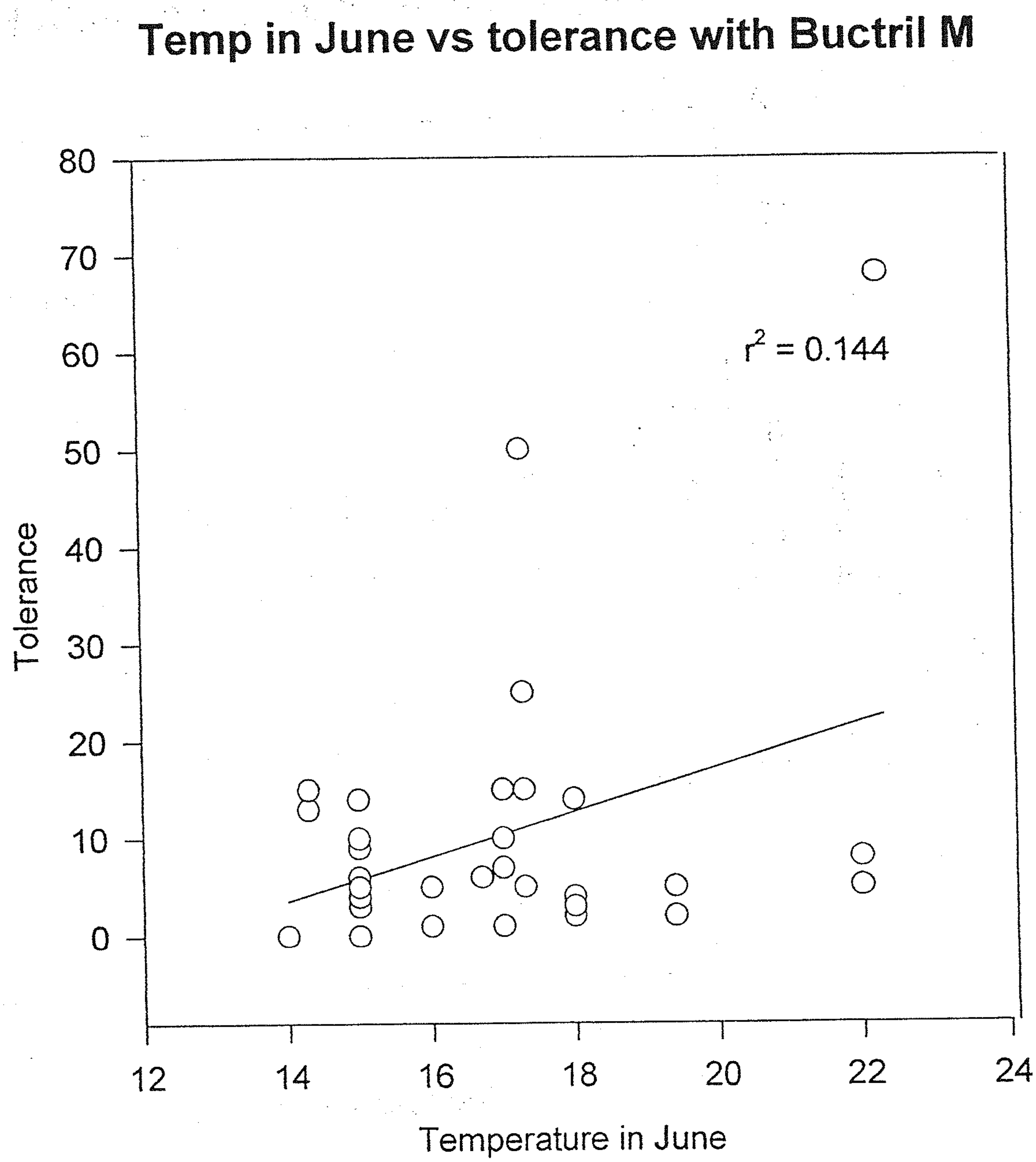

Temp in June vs tolerance with Buctril M
80
70
60
50
40
30
20
10
0
Tolerance
r^2 = 0.144
12
14
16
18
20
22
24
Temperature in June

Fig #19

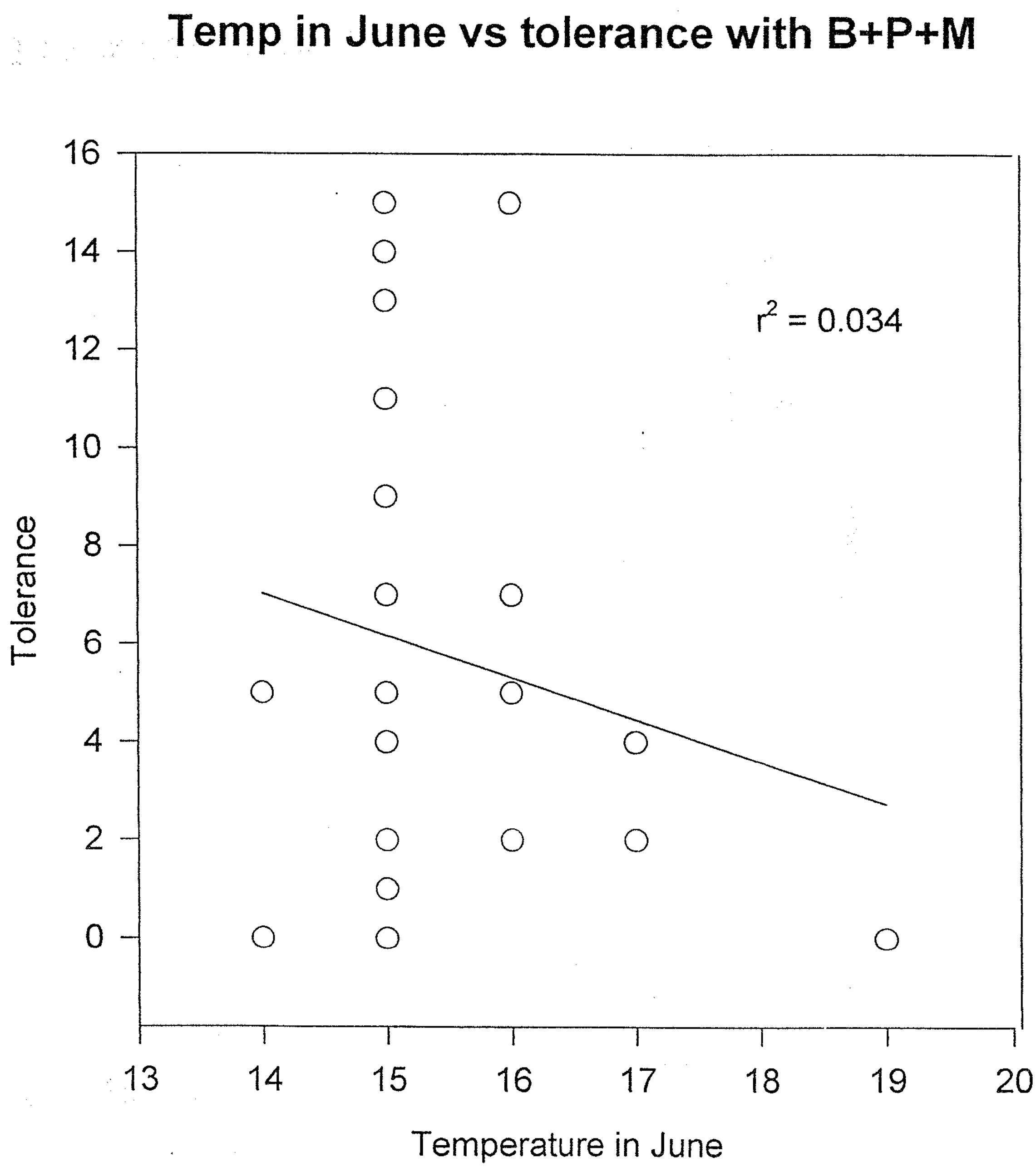

Temp in June vs tolerance with B+P+M
16
14
12
10
8
6
4
2
0
Tolerance
r^2 = 0.034
13
14
15
16
17
18
19
20
Temperature in June

Fig #21

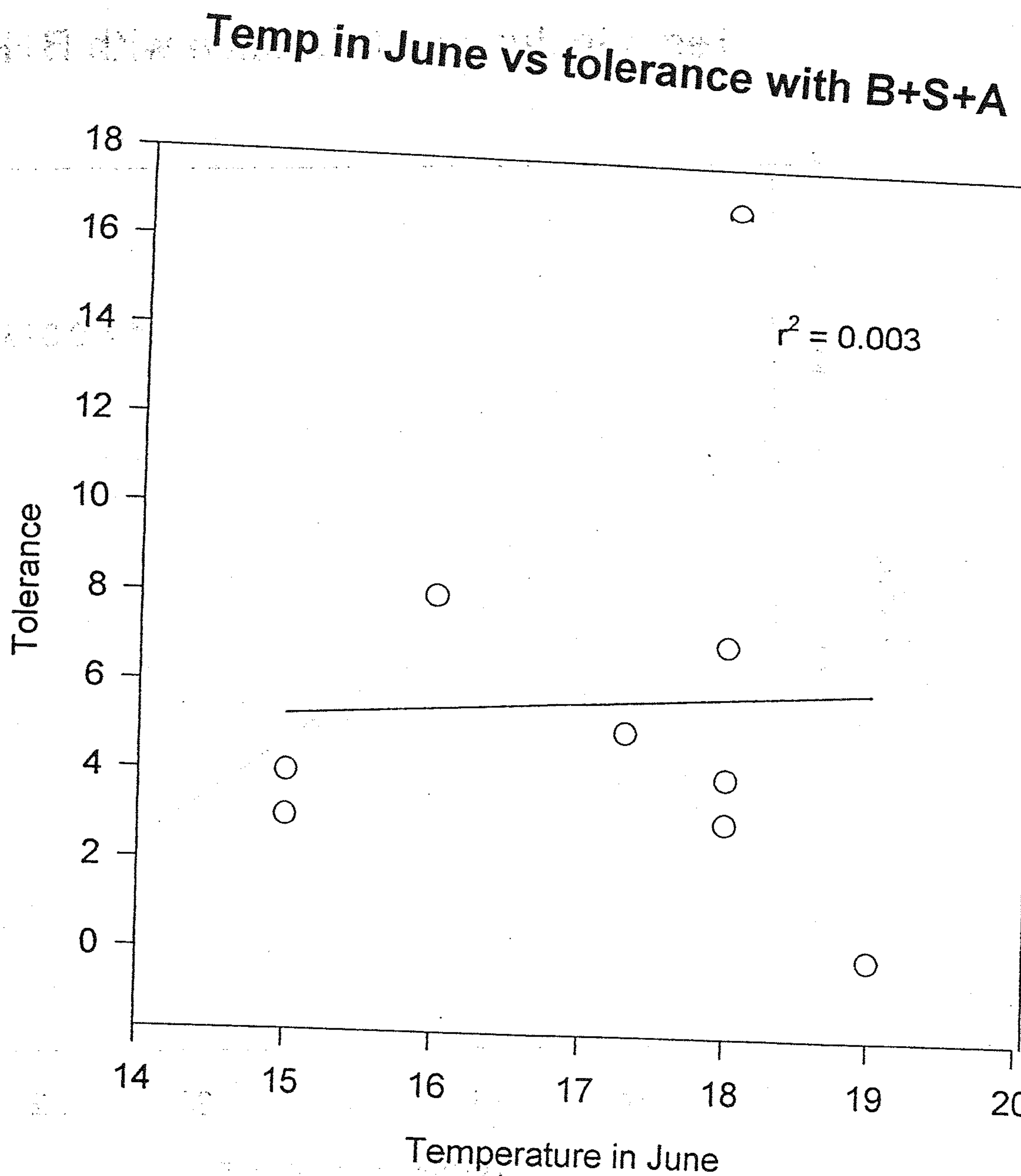

Temp in June vs tolerance with B+S+A
$r^2 = 0.003$
Tolerance
Temperature in June
18
16
14
12
10
8
6
4
2
0
14
15
16
17
18
19
20

Fig #23

Temp at application vs tolerance with Buctril M

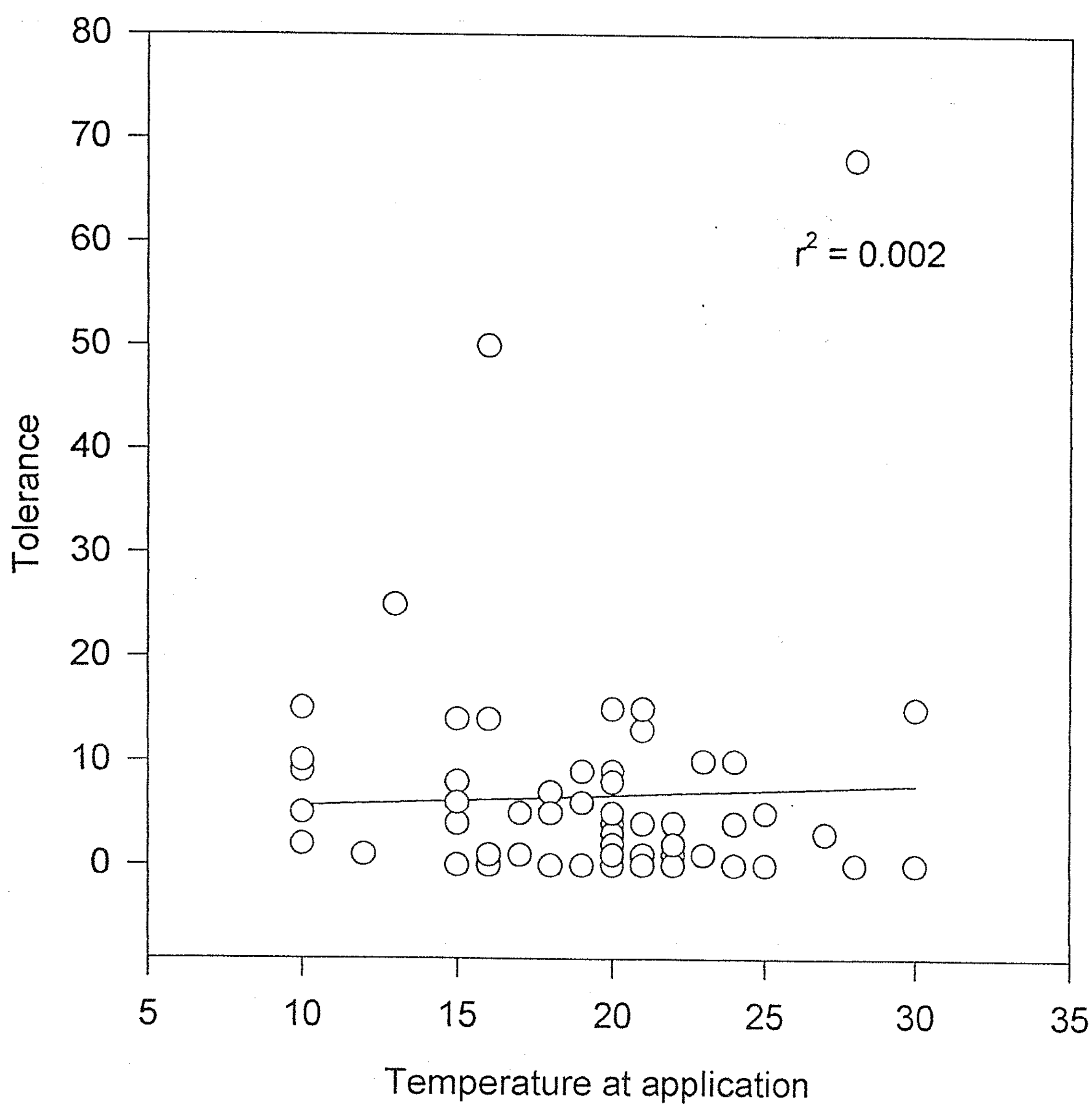


Fig # 25

Temp at application vs tolerance with B+P+A

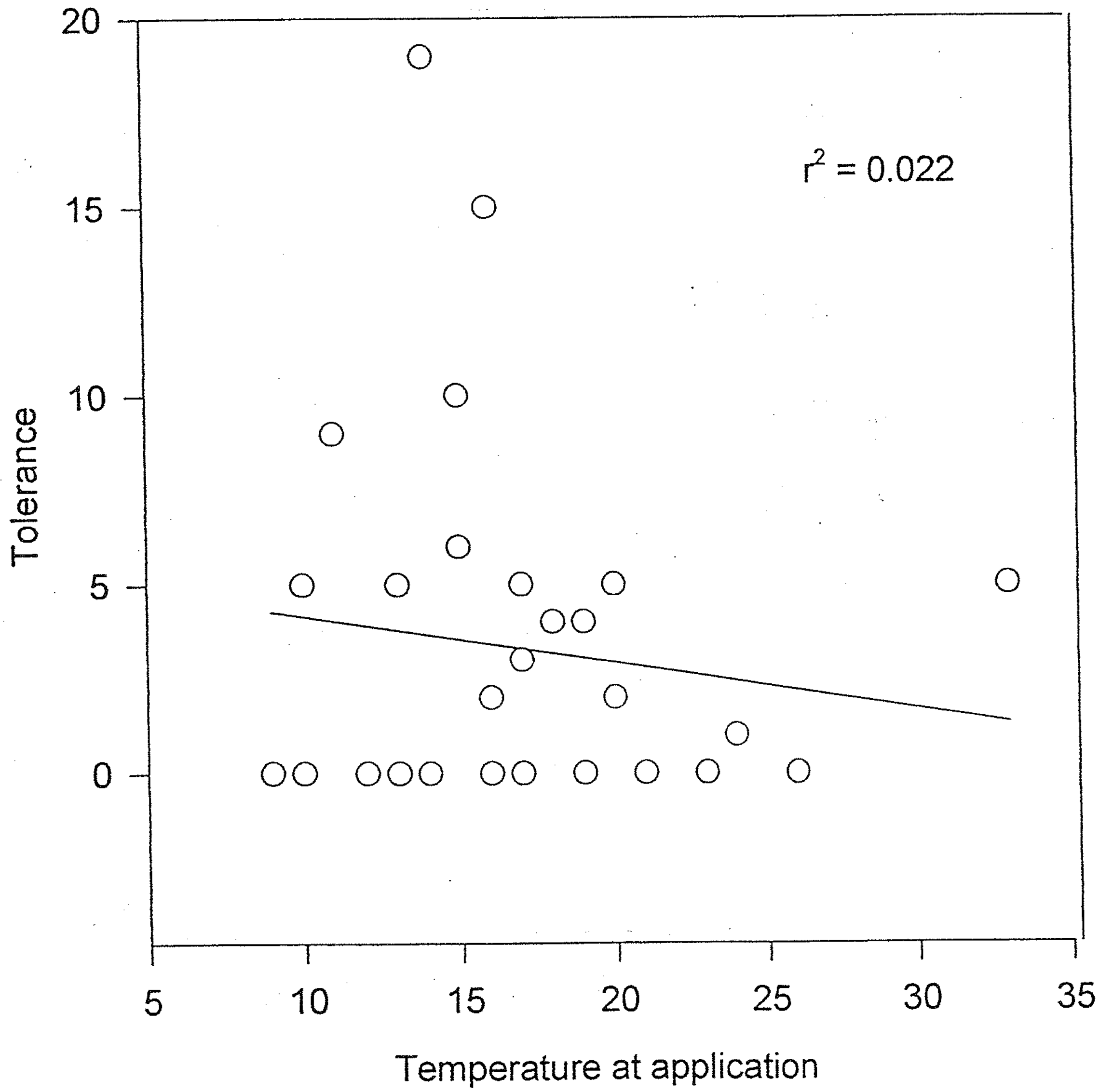


Fig #27

Temp at application vs tolerance with B+A+C

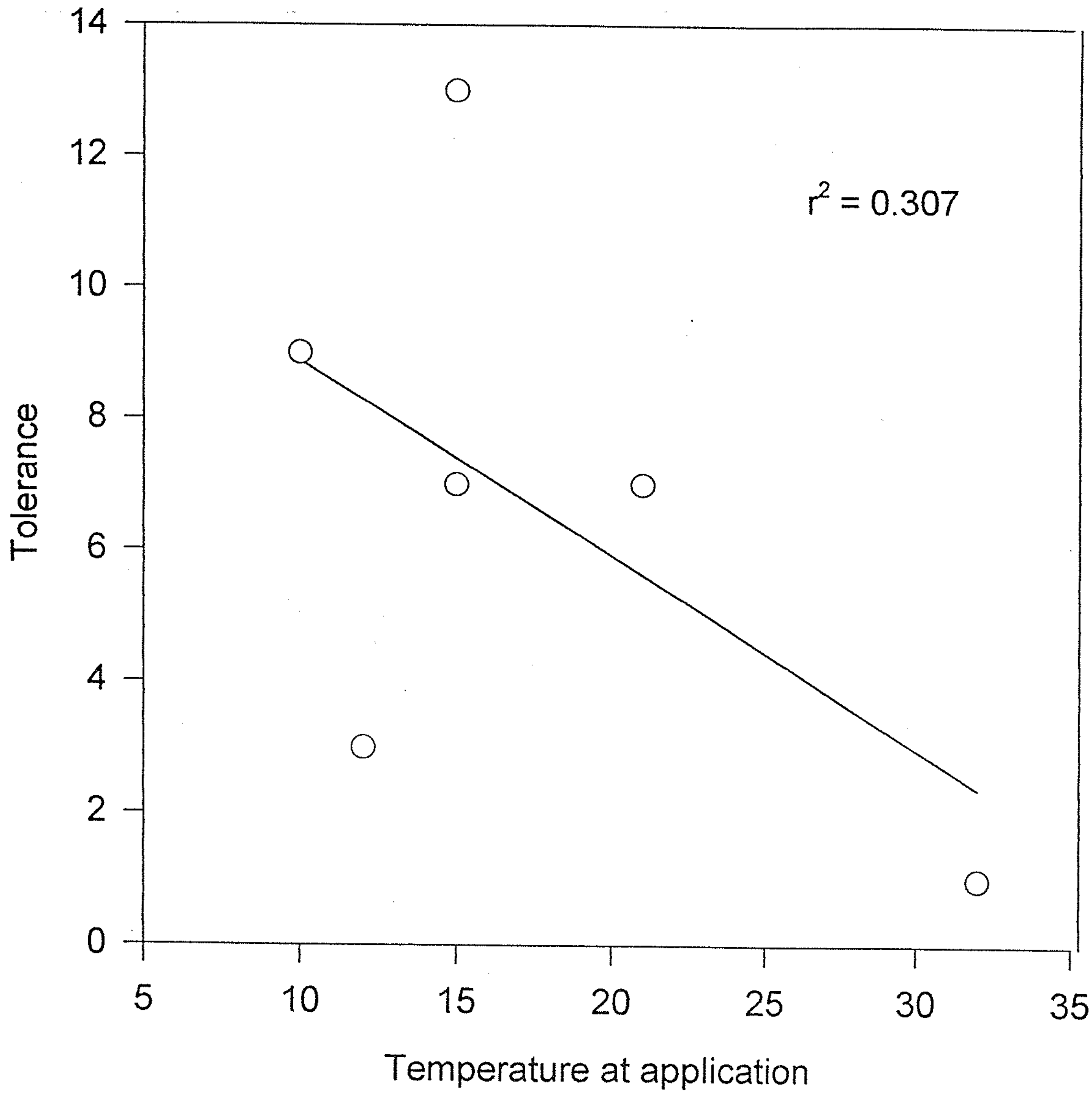


Fig #29

SECTION D

FIELD STUDIES '96 - FERTILIZER MANAGEMENT

Executive Summary

Field Study #1: N and P Management

The objective of this study was to determine the effects of P placement on flax yields and the implications of dual bands of N&P using different nitrogen sources for a one- pass direct seeding and fertilizing system. A summary of the results is given in Table E1.

Table E1. Summary of yield results (bus/ac) for the N&P Management Study at four locations in 1996.

N - Forms	N - Placement	P - Placement	Indian Head	Melfort	Brandon	Morden
Urea	Spring Band	Side-Band	31.7 bc	35.5 ab	37.7	33.4 bc
Urea	Spring Band	Seed-Placed	29.9 c	36.0 ab	41.3	33.9 abc
Amm Sulf	Spring Band	Side-Band	31.2 c	32.6 c	36.9	33.9 abc
Urea	Side-Band	Side-Band	33.8 ab	33.8 bc	42.1	35.3 a
Amm Nitr	Side-Band	Side-Band	35.1 a	36.9 a	39.5	34.1 abc
Amm Sulf	Side-Band	Side-Band	34.3 a	34.1 bc	39.0	33.9 abc
Urea+NBPT	Side-Band	Side-Band	33.6 a	33.9 bc	40.0	35.3 a
Urea	Spring Band	Spring Band	30.6 c	36.8 a	39.4	32.8 c
Urea	Spring-Band (3-4" spread)	Spring Band	-	34.9 ab	37.3	33.2 bc
Urea	Spring Band	Control-No P	30.1 c	36.0 ab	39.8	33.4 bc
Notes: Spring band means that the fertilizer was banded in a separate operation while side-banding means that the fertilizer was placed to the side and below the seed during the seeding operation.						
Yields followed by the same letter are significantly different at the 5% level.						

At Indian Head, Brandon and Morden when P was placed with the nitrogen in a dual band, nitrogen form had no effect. At Melfort, ammonium nitrate in the dual band gave a better yield than urea or ammonium sulphate. The current understanding is that ammonium sulphate gives a better response to P when it is placed in a dual band. When ammonium sulphate was put down as a spring band and the P side-banded, there was no difference with urea except at Melfort where it was significantly lower. We can conclude that urea is an appropriate source of nitrogen for flax, especially in a dual banded situation as is the case for a one-pass seeding and fertilizing system.

The use of the urease inhibitor, NBPT, did not improve the response to P fertilizer at any of the locations. At Melfort, it actually reduced the yields.

Field Study #1: N & P Management

Objective(s): To conduct field studies on the impact of side-banding P in flax and the implications of dual N & P bands using urea and ammonium nitrate on P uptake and grain yield as currently used in a one-pass direct seeding and fertilizing system.

Person(s) Responsible: Cindy Grant, Adrian Johnston, Guy Lafond and Dave McAndrew.

Experimental Protocol:

Rates:

70 kg/ha for N
20 kg/ha for P_2O_5

Variety: Norlin

Seeding Rate: 62 kg/ha or 1 bus/ac

List of Treatments:

1. Early spring band of N (urea) and side-band P at seeding time.
2. Early spring band of N (urea) and seed-placed P at seeding time
3. Early spring band of N (ammonium sulphate) and side-band P at seeding time.
4. Dual N & P (urea + MAP) side-banded at seeding time.
5. Dual N & P (ammonium nitrate + MAP) side-banded at seeding time.
6. Dual N & P (ammonium sulphate + MAP) side-banded at seeding time.
7. Dual N & P (urea + MAP) using a urease inhibitor.
8. Spring pre-plant dual band of N (urea) & P(MAP) Band width of 1".
9. (Optional) Spring pre-plant dual band of N (urea) & P(MAP) Band width of 3-4" (if equipment available).
10. Control N (urea) only applied pre-plant in a banding operation.

Experimental Design:

Randomized complete block design with **6 replicates.**

Measurements:

1. Dry matter production and N & P tissue content at 7, 14, 21, and 28 days after emergence and at flowering (2x one meter of row per plot)
2. Cd content of grain (sample size ... send to Brandon c/o C. Grant)
3. Oil content and fatty acid composition and iodine values of grain using NMR (50 g sample size ... send to Morden)

Table 2. Indian Head 1996 - N-P Management Study

Treatment	Plants/m^2	Height	7 day DM	14 day DM	21 day DM	28 day DM	Flower DM	Grain Yield
Bd U - Sb P	512 a	54 bc	57 ab	71 bc	232 ab	439 a	1127 b	1984 bc
Bd U - Sr P	441 bc	54 bc	57 ab	100 a	223 ab	435 a	1096 b	1869 c
Bd AS - Sb P	499 ab	52 c	57 ab	98 a	264 a	480 a	1256 ab	1947 c
Sb U + P	431 c	55 ab	49 b	67 c	198 b	451 a	1161 b	2112 ab
Sb AN + P	474 abc	56 ab	61 ab	81 abc	255 ab	470 a	1278 ab	2194 a
Sb AS + P	481 abc	55 bc	54 ab	99 ab	204 b	477 a	1407 a	2146 a
Sb Ua + P	421 c	57 a	50 b	84 abc	204 b	429 a	1255 ab	2098 ab
Bd 1" U + P	508 ab	54 bc	49 b	84 abc	210 ab	386 a	1100 b	1911 c
Bd 8" U + P (Sweep)	-	-	-	-	-	-	-	-
Bd 1" U + check P	500 ab	55 bc	65 a	92 ab	205 b	424 a	1166 b	1884 c
Pr>F								
Treatment	0.046	0.016	0.098	0.061	ns	ns	ns	0.0001
CV	12.1	3.8	21.9	22.9	22.5	19.6	17.1	5.7

Table 3. Melfort 1996 - N-P Management Study

Treatment	Plants/m^2	Height	7 day DM	14 day DM	21 day DM	28 day DM	Flower DM	Grain Yield
Bd U - Sb P	442 ab	65.0 bcd	47.0	92.6 abc	187.4 bcd	546.1	2656	2218 ab
Bd U - Sr P	425 ab	65.8 abc	41.9	72.5 cd	197.2 bcd	495.0	2639	2249 ab
Bd AS - Sb P	397 abc	64.6 cd	59.1	107.5 a	250.8 a	576.3	2861	2038 c
Sb U + P	353 c	67.0 a	38.6	61.6 d	150.9 d	447.3	2628	2111 bc
Sb AN + P	466 a	65.3 abc	45.6	95.1 abc	180.1 cd	540.6	2787	2305 a
Sb AS + P	436 ab	66.8 ab	54.0	78.4 bcd	187.4 bcd	584.0	2825	2129 bc
Sb Ua + P	381 bc	66.7 ab	48.8	78.7 bcd	180.1 cd	473.9	2801	2116 bc
Bd 1" U + P	445 ab	65.5 abc	43.0	78.0 cd	172.8 cd	519.1	2719	2299 a
Bd 8" U + P (Sweep)	452 a	63.2 d	50.3	100.3 ab	234.4 ab	607.7	2504	2180 ab
Bd 1" U + check P	454 a	65.2 abc	52.1	74.7 cd	201.6 bc	543.2	2529	2248 ab
Pr>F								
Treatment	0.0427	0.0108	0.3552	0.0655	0.0595	0.5742	0.8771	0.0041
CV	14	3	29	30	26	25	16	6

Table 4. Brandon N-P Management Study

Treatment	Plants/m^2	Height	7 day DM	14 day DM	21 day DM	28 day DM	Flower DM	Grain Yield
Bd U - Sb P	62	-	13	49	171	300	1586	2359
Bd U - Sr P	70	-	21	43	160	287	1394	2580
Bd AS - Sb P	64	-	16	40	167	285	1571	2304
Sb U + P	72	-	17	52	195	285	1410	2631
Sb AN + P	76	-	19	56	186	322	1597	2470
Sb AS + P	75	-	26	52	193	299	1460	2440
Sb Ua + P	73	-	19	47	175	346	1626	2480
Bd 1" U + P	69	-	18	46	159	313	1583	2465
Bd 8" U + P (Sweep)	65	-	16	36	108	247	1546	2333
Bd 1" U + check P	70	-	19	38	133	317	1507	2488
Pr>F								
Treatment	ns	-	0.06	0.007	0.0004	0.045	ns	ns
CV	14.7	-	30.9	20.5	19.4	15.0	15.7	10.3

Table 5.Morden 1996 - N-P Management Study Continued...

Treatment	Oil	Iodine #	Palmitic Acid (%)	Stearic Acid (%)	Oleic Acid (%)	18:2	18:3
Bd U - Sb P	44.8 a	191 ab	5.0 ab	2.4 ab	22.8	13.0 ab	56.9
Bd U - Sr P	44.6 ab	191 ab	5.0 ab	2.4 ab	22.7	12.9 ab	56.9
Bd AS - Sb P	44.5 ab	191 ab	5.0 ab	2.4 ab	23.0	12.8 ab	56.9
Sb U + P	44.5 ab	190 ab	5.0 ab	2.4 ab	23.3	12.8 ab	56.3
Sb AN + P	44.5 ab	190 ab	5.0 ab	2.4 ab	23.2	13.0 a	56.5
Sb AS + P	44.5 ab	191 ab	5.0 ab	2.4 ab	22.8	12.9 ab	56.8
Sb Ua + P	44.5 ab	190 ab	4.9 b	2.4 ab	23.2	13.0 ab	56.5
Bd 1" U + P	44.3 b	189 b	5.0 ab	2.4 ab	21.5	12.8 ab	56.6
Bd 8" U + P (Sweep)	44.0 ab	190 ab	5.0 ab	2.4 ab	23.1	12.9 ab	56.6
Bd 1" U + check P	44.2 b	190 ab	5.1 a	2.5 a	22.9	12.8 b	56.7
Pr>F							
Treatment	ns	ns	ns	ns	ns	ns	ns
CV	1	1	2	2	6	1	1

Table 6. Zinc Management Study - Agronomic Information- 1996

	Morden
Seeding Date	May 24
Dry Matter- Sampling Date	
Day 7	-
Day 14	June 20
Day 21	-
Day 28	July 3
Flowering	July 10
Soil Fertility	
Nitrogen (kg/ha) NO_3-N 0-6" 6-24"	 16 20
Phosphorus (kg/ha) PO_4-P 0-6"	 56
pH 0-6" 6-12"	 7.8 8.2
Conductance 0-6" 6-12"	 0.6 0.8
Harvest Date	Sept 11
Broadcast Application Date	May 23

Table 7. Morden 1996 - Zinc Management Study Continued...

Treatment	Oil	Iodine #	16:0	18:0	18:1
Zn-SO4-broad	43.2 ab	192 c	5.0 a	2.6 a	21.8 a
Zn-SO4-band	43.1 ab	193 abc	5.0 a	2.6 a	21.5 ab
EDTA-broad	42.9 b	193 abc	5.0 a	2.6 a	21.4 ab
EDTA-band	42.9 b	192 bc	5.0 a	2.6 a	21.6 ab
Zn-SO4-sausage	43.3 a	193 ab	5.1 a	2.6 a	21.3 ab
EDTA-sausage	42.9 b	193 a	5.1 a	2.6 a	21.2 b
Control	42.9 b	193 abc	5.1 a	2.6 a	21.5 ab
Pr>F					
Treatment	0.06	0.064	ns	ns	ns
CV	1	1	1	1	2

Measurements:

1. Plant counts (2x - 1 m of row)
2. Plant height
3. Lodging
4. Maturity
5. Grain Yield
6. Grain N & P
7. Oil content using NMR
8. Fatty acid composition

Table 8. Nitrogen and Phosphorus Rate Study - Agronomic Information - 1996.

	Indian Head	Melfort	Lemberg
Seeding Date	May 14	May 24	May 13 and May 23
Flowering	July 5	July 17	July 5
Soil Fertility			
Nitrogen (kg/ha) NO_3-N 0-6" 6-12" 12-24"	 4.1 1.9 2.1	 - - -	 10.1 5.2 5.3
Phosphorus (kg/ha) PO_4-P 0-6"	 51.5	 -	 30.4
Harvest Date	Sept 12	Oct 3	Oct 11

80N 0P	393	55	1966	43.1	194	5.0	2.5	20.3	13.6	58.7
80N 15P	382	55	2003	43.6	194	4.9	2.5	20.7	13.5	58.5
80N 30P	430	55	1774	43.9	195	5.0	2.4	20.0	13.5	59.1
80N 45P	465	55	1875	42.9	195	4.9	2.4	20.3	13.6	58.9
120N 0P	375	56	2214	42.6	194	4.9	2.6	21.0	13.3	58.3
120N 15P	388	58	2159	42.6	193	5.0	2.5	21.1	13.6	57.8
120N 30P	362	57	2063	42.7	193	5.0	2.5	21.1	13.5	58.0
120N 45P	409	56	1991	42.3	193	4.9	2.5	20.9	13.6	58.0
Pr>F										
N rate	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.02	0.0001
P rate	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x P	ns	ns	ns	ns	ns	ns	0.08	ns	ns	ns
CV	13.7	4.5	12.5	1.2	0.5	2.4	0.3	3.1	1.8	0.5

80N 30P	351	66.8	2243	43.48	195.3	4.93	2.40	19.90	13.75	59.0
80N 45P	337	68.4	2207	43.48	195.3	4.93	2.43	20.03	13.53	59.1
120N 0P	312	70.9	2100	43.30	194.9	4.90	2.40	20.38	13.55	58.8
120N 15P	344	69.6	2096	42.60	194.3	4.88	2.40	20.78	13.58	58.4
120N 30P	269	71.1	2142	42.53	194.2	4.85	2.45	20.80	13.43	58.5
120N 45P	330	69.8	2153	41.90	194.3	4.88	2.43	20.83	13.33	58.6
Pr>F										
N rate	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001	0.0001
P rate	0.9772	0.1608	0.0019	0.0002	0.5102	0.9639	0.7317	0.2414	0.0001	0.4531
N x P	0.0493	0.0272	0.0647	0.0942	0.8545	0.7511	0.1026	0.8566	0.4333	0.8420
CV	18	2	7	1	0.4	2	2	2	1	1

80N 30P	302	53	1352	43.2	194	5.0	2.6	20.3	13.7	58.4
80N 45P	347	53	1390	43.3	194	5.0	2.6	20.4	13.6	58.5
120N 0P	224	53	1584	42.5	192	5.0	2.7	21.5	13.3	57.6
120N 15P	276	49	1386	42.7	193	5.0	2.6	21.4	13.4	57.6
120N 30P	284	53	1570	42.2	192	5.0	2.7	21.3	13.7	57.4
120N 45P	257	52	1568	42.0	192	5.0	2.7	21.9	13.3	57.2
Pr>F										
N rate	0.0001	0.004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.056	0.0001
P rate	0.09	ns	ns	0.07	ns	ns	ns	ns	ns	ns
N x P	0.006	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	13.5	5.5	17.8	0.8	0.4	1.4	2.4	2.0	1.7	0.7

Results:

Table 13. Indian Head Results

Treatments	Plants/m²	Plant height (cm)	Yield kg/ha	Oil %	Iodine #	Palmitic acid %	Stearic acid %	Oleic acid %	Linoleic acid %	Linolienic acid %
N	391	56	1945	43.9	195	5.0	2.5	19.7	13.8	59.1
N & P	397	57	1948	43.6	195	4.9	2.4	19.8	13.9	59.0
N & P & K	430	57	1876	43.8	196	4.9	2.5	19.6	13.8	59.3
N & P & S	402	55	1963	43.5	195	4.9	2.5	20.2	13.7	58.8
N & P & K & S	385	59	1943	43.4	196	5.0	2.5	19.7	13.7	59.2
Check	513	51	847	46.5	199	5.1	2.3	17.6	13.9	61.2
s.e.	31	1.0	60	0.2	0.3	0.05	0.03	0.2	0.07	0.2
Contrast[1]										
Check vs rest	***	***	***	***	***	***	***	***	*	***
N vs rest (no check)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N vs N & P only	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N vs NPKS	ns	**	ns	*	ns	ns	ns	ns	ns	ns
N + P vs rest (no check)	ns	ns	ns	ns	ns	ns	ns	ns	*	ns
N + P vs NPKS (only)	ns	*	ns	ns	ns	ns	ns	ns	*	ns

[1] Values followed by ***, **, * or ns are significant at the 1%, 5% and 10% level and no significant, respectively.

Table 14.Melfort Results

Treatments	Plants/m²	Plant height (cm)	Yield kg/ha	Oil %	Iodine #	Palmitic acid %	Stearic acid %	Oleic acid %	Linoleic acid %	Linolienic acid %
N	373 c	68.1 a	2283 a	42.8 a	192.9 c	5.07	2.43 a	21.0 a	13.8 a	58.7 c
N & P	446 a	67.3 a	2312 a	42.1 c	193.5 bc	5.15	2.40 ab	20.5 ab	13.7 ab	58.2 bc
N & P & K	451 a	68.1 a	2348 a	42.1 c	194.3 b	5.10	2.40 ab	20.2 b	13.8 a	58.5 b
N & P & S	454 a	67.6 a	2250 a	41.4 d	193.6 bc	5.13	2.40 ab	20.7 ab	13.6 bc	58.2 b
N & P & K & S	385 bc	68.3 a	2301 a	41.8 c	193.9 b	5.18	2.38 bc	20.4 b	13.5 c	58.5 b
Check	431 ab	61.4 b	1498 b	47.0 a	198.0 a	5.18	2.35 c	18.1 c	13.6 bc	60.7 a
cv	11	2	6	0.7	0.3	1.5	1.4	1.7	1.0	0.6
Pr>F										
Treatment	0.0770	0.0001	0.0001	0.0001	0.0001	0.3955	0.0866	0.0001	0.0504	0.0001

[1] Values followed by te same letter are not significant at the LSD (5%).

Table 17. Nitrogen Management at Indian Head.

Treatments	Plants/m²	Plant height (cm)	Yield kg/ha	Oil %	Iodine #	Palmitic acid %	Stearic acid %	Oleic acid %	Linoleic acid %	Linolienic acid %
Check	463	52	1130	45.1	194	4.8	2.4	20.7	13.7	58.4
UR-FB	488	52	1815	43.3	194	4.9	2.5	20.6	13.5	58.6
AN-FB	494	52	1855	43.2	194	4.9	2.5	20.6	13.6	58.7
UR-Side BD	489	55	2086	42.9	194	4.8	20.5	20.8	13.7	58.2
AN-Side BD	435	53	1961	42.6	197	4.9	2.5	19.3	13.6	59.8
UR-Broadcast	485	53	2060	42.8	194	4.8	2.5	20.9	13.5	58.3
AN-Broadcast	479	53	2025	42.6	195	4.9	2.5	20.2	13.6	58.9
Contrast[1]	33	1.2	75	0.2	0.6	0.05	0.03	0.4	0.1	0.3
Check vs rest	ns	ns	***	***	ns	ns	ns	ns	ns	ns
Banding vs Broadcast	ns	ns	*	*	ns	ns	ns	ns	ns	ns
Fall Banding vs Side Banding	ns	*	**	**	ns	ns	ns	ns	ns	ns
Urea vs Ammonium Nitrate	ns	ns	ns	ns	*	ns	ns	*	ns	*

[1] Values followed by ***, **, * or ns are significant at the 1%, 5% and 10% level and no significant, respectively.