Wind Protection for Sugar Beets
(*Beta vulgaris*)
by Cereal Cover Crops and Reduced Tillage

by

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ABSTRACT

Sommer, Karl-Josef. M. Sc., The University of Manitoba, May, 1984. Wind Protection of Sugar Beets (Beta vulgaris) by Cereal Cover Crops and Reduced Tillage. Major Professor: Dr. F. Schwerdtle.

At the field research station of the University of Manitoba at Portage la Prairie different cereal species including spring barley (Hordeum vulgare cv. Bedford), oats (Avena sativa cv. Fidler), fall rye (Secale cereale cv. Puma) and rye grass (Lolium multiflorum cv. Barspectra) were tested for their suitability as cover crops for wind protection of sugar beet seedlings in 1982 and 1983.

Spring planted barley and oats at two seeding rates (15 and 30 kg/ha) did not reduce the yield or stands of the sugar beets. Rye grass (only 1982) was found to be unsuitable because of its slow development in the early growth stages. The grass herbicides (Dowco 453, fluazifop butyl, Hoe 00736, sethoxydim) readily controlled the cover crops without affecting the beets. Wind speed measured 2-4 cm above ground, was reduced by 33 percent for oats and by 42 percent for barley at the denser seeding rate. In addition to protecting the beets fall rye offered a soil cover during winter. However, fall rye could not be controlled readily, and competed with the sugar beets. Fall rye reduced the wind speed by 96 percent.

At the same location during the growing seasons of 1982 and 1983, reduced tillage methods, including rotary strip-tillage and harrowed, zero-tillage, were compared to a conventional method. In 1983 an unharrowed, zero-tillage treatment and the ridging method were included. Emergence, final stand, yield and sugar content were evaluated.

In both years, emergence and stand establishment were best in conventionally tilled plots. Emergence in strip tilled plots was lower than in conventionally tilled plots. For the harrowed, zero-tillage plots variation in emergence between years was high. Emergence in unharrowed, zero-tillage plots was low compared to the other treatments. Conventionally tilled plots yielded highest over the two years. Unharrowed zero-tillage plots yielded significantly lower than conventionally treated plots. There was no difference in sugar content between treatments.

In a wind tunnel sugar beet seedlings, planted in greenhouse flats, were exposed to different wind speeds and blasting sand. Beets in flats without an interplanted barley cover crop were compared to flats where barley was interseeded broadcast and to flats where barley was seeded in rows either in, or perpendicular to, the wind direction.

Higher wind speeds (0, 55, 60 and 65 km/h) significantly decreased beet fresh weight, dry matter and leaf area. With the addition of sand blasting the decrease was aggravated. The barley cover crop seeded perpendicular to the wind direction gave some protection to the beets exposed to the sand blasting. Barley plants seeded broadcast and in rows oriented in the wind direction did not protect the beet seedlings effectively.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Appendix Table page

Chapter I

INTRODUCTION

In Manitoba sugar beets are grown either on summerfallow (35%) or small grain stubble (65%). Summer fallow and conventional tillage practises greatly reduce the amount of plant residue on the surface and leave the soil vulnerable to severe erosion.

In the early growth stages sugar beets are very easily damaged by wind and soil abrasion. In Manitoba damage to sugar beet seedlings by wind erosion is the major reason for replanting in many years. In addition production in many fields that are not replanted is reduced because of stand reductions resulting from wind damage.

Any increase in vegetative cover can reduce wind erosion. Fall- or spring-seeded cereal cover crops are potentially useful to increase the amount of vegetative cover and reduce the impact of wind and soil on beet seedlings. With the new selective grass herbicides now available, removal of the cover crop is possible before competition with the beets can occur. Reduced tillage systems also increase the amount of residues left on the soil surface and might also protect the soil and the beet seedlings.

The objective of the present study was to evaluate fall- and spring-seeded cereals and rye grass as cover crops. The main emphasis was placed on determining the optimum density and time of removal of the cover crops, as well as on selecting the most effective herbicide to control the cover crops.

In addition, conventional and reduced tillage methods were compared to determine if reduced tillage practices could be used in beet production to reduce soil erosion. Windtunnel experiments were also conducted to determine the influence of wind and soil abrasion on beet seedlings and to evaluate the protective effect of cereal cover crops on the beets.

Chapter II

LITERATURE REVIEW

2.1 INTRODUCTION

Wind erosion is particularly a problem in arid and semi arid regions (Chepil and Woodruff, 1963; Fryrear and Lyles, 1977; Lyles, 1977). Reports of plant damage by wind erosion are numerous (Kimberlin et al., 1977; Thompson, 1974; Waister, 1972 a, b; Woodruff, 1975). For many crop plants the effects of wind and blasting soil have been investigated under controlled conditions in wind tunnels. (Armbrust, 1968; Downes et al., 1977; Fryrear and Downes, 1975; Fryrear et al., 1973; Skidmore, 1966). In the Great Plains thousands of hectares are subject to wind-blown soil to the extent of decreasing yield and quality, requiring re-seeding or resulting in complete loss of the crop (Fryrear, 1971).

This review describes the factors that influence soil erosion by wind and the effects of wind and soil abrasion on plants. Methods to prevent damage caused by these factors are discussed with special reference to sugar beets.

2.2 WIND EROSION PROCESS

Wind erosion can occur wherever the soil surface is loose, dry, bare and smooth or where the field is unsheltered and improperly oriented in respect to the prevailing wind direction (Chepil and Woodruff, 1963; Woodruff et al., 1972; Lyles, 1977; Kimberlin et al., 1977).

When soil particles start to move, they are carried by the wind in three types of movement - suspension, saltation or surface creep (Chepil and Woodruff, 1963; Lyles, 1977). Suspended particles less than 0.1 mm in diameter may be carried to high altitudes. Saltation (jumping) is the major process involved in movement of soil by wind. Particles 0.1 to 0.5 mm in diameter leave the surface but are too large to be suspended. On return to the surface their impact initiates movement of other particles. The bulk of the total transport, roughly 50 to 80 percent, is by saltation. Surface creep describes the movement of particles that are pushed and rolled by saltating particles and are too large to leave the surface. Surface creep constitutes 7 to 25 percent of the total transport by wind.

Once erosion begins, saltating particles severely abrade the soil surface, break down clods, destroy stable crusts and wear down residues and living vegetation (Chepil and Woodruff, 1963; Lyles, 1977).

2.3 FACTORS THAT INFLUENCE WIND EROSION

The factors that influence soil erosion are soil aggregation, surface roughness, soil moisture, wind velocity, extent of vegetative cover and field size (Chepil and Woodruff, 1963; Woodruff et al., 1972; Lyles, 1977).

A well-aggregated soil can reduce soil erosion because the aggregates are large enough to resist the wind and they also shelter erodible particles. Aggregates larger than 0.84 mm in diameter are generally resistant to wind erosion (Woodruff et al., 1972). The stability of clods depends on the moisture, organic matter content, clay and lime content and the microbial activity in the soil. Soil moisture content is an important factor as a moist surface will not drift due to the cohesive forces between the particles (Chepil, 1953-1955, 1956).

Coarse textured sandy loams, loamy sands and sands are the most susceptible to wind erosion because they do not form aggregates. Fine textured clay soils form aggregates when cultivated but they are easily broken down by freezing and thawing. The least erodible soils are loams, silt loams, clay loams and silty clay loams (Chepil, 1953-1955; Chepil and Woodruff, 1963).

Little erosion occurs at wind velocities below 5-6 m/sec (18-22 km/h). At greater velocities the increase in the wind's capacity to carry soil is proportional to the cube of the velocity (Brady, 1974).

The absolute wind velocity does not solely determine the effect of wind on soil erosion. The force that the wind exerts on the soil is surface drag. The surface drag is proportional to the drag velocity which includes the gradient of the wind velocity between the soil surface and a certain height. The drag velocity is determined by the surface roughness which depends on variations in height, density and other characteristics of surface features. The drag velocity increases with the strength of the wind (Chepil and Woodruff, 1963; Woodruff and Siddoway, 1965).

Vegetation provides cover for the soil surface. Living or dead vegetative matter protects the soil surface from wind action by reducing the wind speed and by preventing much of the direct wind force from reaching erodible particles. The degree of protection depends on the size and quantity of the cover. Tall vegetation increases the surface roughness more than short plants. The more erect, and the finer and denser the residues, the smaller the amount of erosion (Woodruff et al., 1972; Lyles and Allison, 1976; Mc Calla and Army, 1961).

The distance across a field in the prevailing wind direction affects the amount of erosion that occurs. The greater the length of fetch, the greater the hazards of wind erosion (Chepil and Woodruff, 1963; Woodruff and Siddoway, 1965).

2.4 EFFECT OF WIND ON PLANTS

The effect of wind on plants can be either direct or indirect. Indirect effects are caused by a change in the microclimatic conditions such as air and soil temperatures, turbulence, evapotranspiration, carbon dioxide concentration and soil moisture. Changes in microclimatic conditions can have a marked influence on plants. Research with shelterbelts has contributed most directly to this field (van Eimer et al., 1964; Marshall, 1967).

Direct mechanical damage from exposure to wind is commonly observed. Finnell (1928) reported destruction of tender foliage, deformation of stems and a reduced growth rate when Marigold (Tagetes sp.) plants were exposed to a 25 km/h wind for 60 days. Mechanical damage is often expressed in leaf abrasion, loss of leaf area, leaf scorching or necrosis, and disruption of epicuticular waxes (Thompson, 1974; Waister, 1972 a, b). Plants may respond directly to the effect of shaking (Parkhurst and Pearman, 1972). Kahl (1951) reported a reduction in photosynthetic activity and higher respiratory activity in tissues of Rhoeo discolor and Taraxacum officinale that were shaken compared to those that were not shaken. In wind tunnel trials Wadsworth (1959, 1960) exposed young plants of rapeseed (Brassica napus), barley (Hordeum vulgare) and peas (Pisum sativum), which had been grown in water culture to continuous wind speeds of 1.1, 2.5, 6.1 and 14.4 km/h. He observed a growth stimulating effect at the lower wind speeds. At the higher wind speed growth was reduced.

The combination of wind and drifting soil is a major problem for the establishment of plant seedlings. Eroded soil carried by the wind frequently kills plants by abrasion (Fryrear, 1971). Numerous studies have been conducted to determine plant survival and growth as influenced by wind or windblown sand. Winter wheat (Triticum aestivum) plants were exposed to blowing soil in a wind tunnel at velocities of 28 to 44 km/h (Woodruff, 1956). Heading and ripening of the grain was delayed one week to ten days on exposed plants. The amount of soil striking the plant was the main factor causing damage. Plants recovered faster when given water after abrasive injury compared to plants which had not been watered after the wind treatment.

Seedlings of four range grasses [El Reno sideoats grama (Bouteloua curtipendula), Blackwell switchgrass (Panicum virgatum), sand lovegrass (Erogrostis trichodes), and Indiangrass (Sorghastrum nutans)] were more resistant to soil abrasion than alfalfa (Medicago sativa) seedlings when exposed to windblown soil at velocities of 38 to 50 km/h in a wind tunnel (Lyles and Woodruff, 1960).

Fryrear et al. (1973) subjected four grass species [sideoats grama (Bouteloua curtipendula), cane bluestem (Bothriochloa barbinodis), green sprangletop (Leptochloa dubia), and sand bluestem (Andropogon hallii)] to wind and blowing sand. The blowing sand killed the seedlings or retarded their growth but wind alone had little influence. With increasing age, the young grass plants became more tolerant to wind and sand damage.

Armbrust (1968) exposed cotton (Gossypium hirsutum) plants to blowing soil in a portable wind tunnel at wind speeds of 72, 113 and 132 km/h for a duration of 10 minutes. Cotton plant leaf area, height and dry matter production were significantly reduced by all treatments. In a laboratory wind tunnel Fryrear (1971) exposed cotton plants to a wind speed of 49 km/h and an abrasive sand flux of 0.5 g/cm width/sec for a duration of 10 minutes. Leaf area, height and dry matter production were significantly reduced. Plant growth was delayed from 8 to 25 days.

Wind alone at speeds up to 65 km/h caused only slight damage to green beans (Skidmore, 1966). Introduction of sand into the wind stream increased injury and decreased yield. Plant damage increased linearly with an increase in windspeed and with increasing duration of exposure.

Increasing the duration that tomato (Lycopersicon esculentum) seedlings were exposed to wind and sand flux in a wind tunnel, decreased the dry weight and height of the tops, delayed first bloom and increased the number of plants killed (Armbrust et al., 1969).

Downes et al. (1977) exposed seedlings of six crops [cabbage (Brassica oleracea), carrots (Daucus carotta), cowpeas (Vigna unguiculata), cucumbers (Cucumis sp.), onions (Alium sp.), and peppers (Capsicum sp.)] to four levels of sandstorms. Survival and growth were decreased curvilinearly as the kinetic energy of the sandstorm increased.

Fryrear and Downes (1975) exposed seven different vegetable crops (carrot, onion, pepper, cabbage, cucumber, southern pea, and cotton) to varying wind velocities and particle flux densities. Southern peas withstood five times more sand injury than carrots and about three times more than cotton. Injury was expressed in the number of living plants 40 days after exposure. Increasing the sand flux rate from 0 to 0.25 g/cm width/sec and the exposure time from 5 to 20 minutes reduced seedling survival more than increasing the wind velocity from 36 to 54 km/h.

Fryrear et al. (1975) described some general symptoms characteristic of plants that have been exposed to wind and soil abrasion. Plant growth was slowed because the blowing sand ruptured plant cells, dried out the exposed tissue and exposed the damaged seedling to diseases and insects. Tissue destruction was typified by a darkening or blackening of the leaves and hypocotyl. Photosynthetic production was decreased and respiration increased.

Injuries from sandblasting can change a plant's metabolic processes before there is any visual damage. Exposure of soybean (Glycine max) seedlings to wind and wind plus sand increased the nitrate nitrogen concentration before any visual damage was observed (Armbrust, 1972). Wind- and sand-damaged plants were found to have a reduced photosynthetic production. Activity of the nitrate reductase enzyme was reduced immediately after exposure which indicated shock (Armbrust et al., 1974; Fryrear et al., 1975).

2.4.1 Effect of Wind on Sugar Beets

Wind erosion is particularly serious on sugar beet fields. Conventional tillage and seedbed preparation methods leave a fine soil without ridges that would help reduce the danger of blowing soil (Gahm, 1979). Therefore, sugar beets are especially sensitive to wind erosion during their establishment period (Fornstorm and Boehnke, 1976).

In early growth stages, sugar beet seedlings are not resistant to mechanical wind damage or the abrasive action of drifting soil. The tender leaves and the hypocotyl break off easily (Sojka et al., 1980).

Seedling damage is particularly severe on lighter soils (Luers, 1977; Schwerdtfeger, 1980). In the Netherlands approximately 10 percent of the arable land and 25 percent of the sugar beet fields are susceptible to damage from wind (Lumkes and Te Velde, 1974). In Great Britain 3 percent of the sugar beet area is at risk from damage caused by wind and soil erosion (Matthews, 1983). In East Germany 10,000 ha of sugar beet land is susceptible to damage from wind and soil erosion (Kullmann et al., 1978). Gahm (1979) reports that nearly 100 percent of the sugar beet area in the Red River Valley has potential for wind erosion and beets have to be replanted frequently. In Manitoba wind erosion is a major reason for replanting in most years. In addition, production in remaining fields suffers because of stand reductions (Zednai, 1983).

2.5 METHODS TO PREVENT EROSION

2.5.1 Shelterbelts

The use of shelterbelts is a means to reduce wind erosion. The effect of the shelterbelt is mainly dependent on its height, width, permeability, length and orientation to the main wind direction. Besides reducing the direct influence of wind on plants and soil, shelterbelts may increase soil moisture and temperature and reduce evapotranspiration (van Eimer et al., 1964; Marshall, 1967; Rosenberg, 1966).

2.5.2 Soil Conditioners (Mulches)

Several chemical soil stabilizers, i.e., asphalt (bitumen), polyvinyl alcohol, styrene, butadiene latex emulsion, and resin in water emulsion, have been found to control wind erosion effectively. The chemicals have to be properly diluted and applied in volumes of at least 3800 l/ha to cover the total soil surface (Armbrust, 1977). Kullmann et al. (1978) found a bitumen emulsion most suitable for wind erosion protection. The application of 2.5 m^3 of a 25 percent bitumen emulsion/ha increased sugar beet root yields by 7 to 247 percent. Neururer (1982) applied bitumen mulches at 600 l/ha to give complete coverage. Sugar beet root yield was increased by 1 to 25 percent and sugar content 3 to 4 percent.

In England factory waste lime at 12-15 t/ha was used successfully to stabilize sugar beet seedbeds (Wickens, 1976; Pickwell, 1974; Hollowell, 1979). Polyvinyl alcohol (Vinamyl) applied at 170 l/ha in 1800 l of water prevented sugar beet seedlings from being destroyed by wind erosion (Matthews and Armstrong, 1978; Matthews, 1983).

2.5.3 Reduced Tillage

Vegetative cover is the greatest single factor that influences erosion by wind and water (Fenster, 1975). Maintaining vegetative cover on the soil surface is the simplest way of controlling wind erosion (Fenster and Wicks, 1977).

Reduced tillage systems such as strip-tillage, mulch tillage and zero-tillage have been developed for different crops (Fenster, 1975; Fenster and Wicks, 1977; Woodruff et al., 1972). They all have the objective of reducing tillage operations, thereby maintaining residue cover to protect the soil from erosion. Minimum tillage has potential benefits particularly in semi arid regions where rainfall, wind, intensity of storms and soils are variable.

For small grains, corn and soybeans, reduced tillage systems have been applied successfully. For sugar beets the reduction of soil manipulation was accomplished by replacing the plow-based fall tillage by methods like rotary strip-tillage, no-plow tillage and zero-tillage (Sojka et al., 1980; Simmons and Dotzenko, 1975; Glenn and Dotzenko, 1978).

The rotary strip-tillage method leaves about two thirds of the soil undisturbed (Sojka et al., 1980). For the no-plow method, implements (chisel plow, field cultivator) other than a plow are employed to work the soil. In general, these implements cause less soil disturbance and leave more plant residues and clods on the soil surface (Woodruff et al., 1972). Zero-tillage methods leave the soil undisturbed.

The impact of wind and soil erosion can be substantially reduced by an increase in trash cover. Sojka (1980) found a 50 percent reduction of gust wind speeds in standing stubble when compared to a plowed field.

Simmons and Dotzenko (1975) reported a substantial reduction in potential wind erosion due to the surface vegetation remaining after rotary strip-tillage as compared to conventional tillage.

With an increase in the amount of residues, the soil temperature at seeding time is usually decreased because of an insulating effect of the trash cover (Deibert and Giles, 1979; Willis and Amemiya, 1973; Talley, 1976). However, some authors have reported the opposite effect when a snow layer was present during winter (Sojka et al., 1980). They also found moisture to be higher with increasing amounts of residue. The higher moisture levels were mainly explained by a lower evaporation rate and a greater amount of snow trapped over winter by the plant residues.

Information concerning stand establishment of sugar beets under reduced tillage is somewhat contradictory, with the results seeming to depend very much on the soil type and environmental conditions. Sojka et al. (1980) compared a conventional tillage system with three reduced tillage systems and reported increased emergence under reduced tillage systems. The increased emergence under reduced tillage was considered to result from a decrease in surface crusting and an increase in moisture in the reduced tillage plots compared to in the conventionally tilled plots. Glenn and Dotzenko (1978) found no difference in emergence when rotary strip and no-plow, minimum tillage were compared to conventional plow-based tillage.

Talley (1976) found an increase in emergence in conventionally treated plots compared to strip and zero-tillage plots on heavier textured soils in Colorado. In Manitoba, Sturny (1982) found lower emergence in conventional-tillage plots compared to strip- and zero-tillage plots under drought conditions. In a year with normal rainfall, emergence in conventionally tilled plots tended to be higher than in plots with reduced tillage.

Provided a good stand is established, yield and quality of sugar beets produced under reduced tillage is as good as under conventional tillage. Most authors did not find significantly reduced yields from reduced- or zero-tillage plots compared to conventionally tilled plots (Deibert et al., 1983; Glenn and Dotzenko, 1978; Giles et al., 1980, 1982; Simmons and Dotzenko 1975; Sojka et al., 1980; Sturny, 1982; Talley, 1976).

2.5.4 Cover Crop Cover Crop

Any living or dead plant matter on the soil surface is able to reduce wind erosion. The main purpose of a cover crop is to reduce wind speeds at ground level and thereby reduce erosion. Protection of soil and plants by a cover crop has been tried in many crops.

In Maryland, Beste (1974) planted several vegetable crops directly in a winter rye cover crop mulch on sandy soils. The cover crop was killed with paraquat prior to seeding the vegetable crop. Yields of the vegetables seeded in the rye cover crop were equivalent to those seeded by conventional means and effective wind protection occurred.

In New York State, Hughes and Sweet (1979) used a system called "living mulch". A grassy cover crop (wheat, rye grass) was planted simultaneously with the crop in a reduced tillage system. Cover crops were successfully controlled with grass herbicides. Suppression of the broadleaf weeds by the cover mulch was also reported.

De Frank and Putnam (1979) evaluated the use of fall-planted cover crops (rye, barley, oats) for peas. In addition to providing mechanical protection from the wind, the cover crop suppressed weeds. Fall-killed cover crops (not winter hardy) suppressed the weeds more effectively than spring-killed (chemically killed) cover crops. In one year, winter barley and oats increased the yield of peas over a no-crop control, whereas rye had a detrimental effect on pea growth. Barnes and Putnam (1981) noticed a significant weed suppression when rye was seeded as a cover crop in a no till vegetable production system. Toxicity of the rye leachates was evidence that allelopathic effects may have been involved in the weed suppression.

For sugar beets, fall rye was used as a guard or cover crop seeded before winter and killed with paraquat in the spring prior to beet seeding (Pickwell, 1974; Ascroft and Leigh, 1975; Luers, 1977). Standard sugar beet drills were used for beet planting. To prevent a build up of the rye residues at the coulters and a blockage of the drill, beets were seeded at right angles to the rye crop.

Ascroft and Leigh (1975) listed three factors which contributed to prevention of wind damage. Rye plants held the soil and the dead foliage prevented soil movement. Minimum soil disturbance in the spring resulted in a firm seedbed. They reported good protection of the beets from wind damage and soil abrasion. Problems were encountered where perennial weeds were dominant, because they could not be controlled effectively.

In England, Bastow et al. (1978) investigated a method whereby rye was seeded in the fall, leaving 22 cm wide tram lines in which the beet rows could be drilled subsequently. The best method to kill the rye in the spring was to apply a split application of paraquat before and after seeding the beets. Adequate plant stands could be achieved and no yield reductions were found.

In the Netherlands, a system of minimum cultivation was evaluated in which fall rye, winter wheat and winter barley were tested as cover crops (Lumkes, 1973; Lumkes and Te Velde, 1973, 1974). Sugar beets were drilled into the cereal mulch without any seedbed preparation in the spring. The drill was modified to penetrate the mulch more easily. All tillage operations were carried out in the fall. Fall rye was determined to be a better cover crop than winter wheat and winter barley, as it grew faster in the fall and gave better cover in the spring. Before seeding the sugar beets, the rye was killed chemically with paraquat. With fall rye as a cover crop they found a yield increase of 3-5 percent even when no wind damage occurred. The system was also successfully applied to protect potatoes and maize from wind damage. For fields infested with quack grass (Agropyron repens), which had to be controlled chemically in the fall, a winter hardy cruciferous plant was drilled as a cover crop in the fall and killed with diquat in the spring.

In Wyoming, Fornstorm and Boehnke (1976) used fall rye as a mulch for sugar beets. When the rye was 25-30 cm high it was sprayed with paraquat two days before beet planting. A 25-cm band was rotary tilled and the beets were planted in the band. The rye was not completely killed by the paraquat and competed with the beets, causing yield losses.

Several spring seeded cereals have also been tested for their use as cover crops. In England, spring barley was seeded between the intended beet rows as early as February prior to seeding the beets in April. The final sugar beet seedbed was prepared at barley seeding time. The barley was controlled by applying dalapon or gramoxone with a guarded, inter-row sprayer after beet emergence (Bakewell, 1980; Hollowell, 1979; Armstrong, 1978).

Bakewell (1980) reported successful protection of beets when they were planted into spring barley seeded at a rate of 50 kg/ha. The cover crop was killed with paraquat before the beets emerged. In another method, oats were drilled at a rate of 60 kg/ha at right angles to the intended beet rows. Sugar beets were seeded with a standard drill three weeks later when the oats were just emerging. For control of the cover crops, alloxydim-sodium, a herbicide for grassy weed control, was applied in the band when the oats were in the 3-leaf stage. A second broadcast application of the same herbicide was sprayed when the oats were in the mid-to late-tillering stage. By then the beets had reached a size where they were resistant to wind damage (Atkinson, 1980). Broadleaf herbicides were applied as indicated by weed population and species.

Fornstorm and Boehnke (1976) used spring seeded barley as a "growing mulch" in Wyoming. The barley was solid-seeded in a field which had been plowed in the spring. A 25-cm band was rotary tilled and beets were planted into the band. The barley between the rows was mechanically removed with a rotary tiller. Problems resulted from competition of the sugar beets with the barley plants which had not been completely removed by the rotary strip tiller and both beet stand and yield were reduced. Successful wind protection was reported when barley was planted between the future beet rows with a converted grain drill two weeks prior to beet planting (Fornstorm and Boehnke, 1976). In this system barley was effectively controlled with a rotary cultivator. In plots without protection, 90 percent of the area was destroyed; whereas, the beet yields in the barley mulch plots were average compared to a normal yield in the area. Water use in the early season was higher for the mulch plots but total water use was the same for both tillage methods (Settenmeyer et al., 1975).

In the Netherlands, investigations have also shown that spring-seeded cereals are effective for controlling erosion in sugar beet fields (Lumkes, 1981). Fall rye, winter wheat, oats and barley were tested. All tillage preparations were done in the spring. Spring barley was found to be the most suitable as a cover crop because of its relatively faster development. Row-seeding of barley resulted in a more accurate seeding depth and, therefore, a more even emergence than when barley was broadcast. A method was developed by which barley was seeded in 30-cm strips between the beet rows at the time of beet seeding. The barley was seeded with a fertilizer spreader which was attached to the beet planter. Erosion control proved to be sufficient where barley was used as a cover crop. To remove the barley it was sprayed with the post-emergence grass control herbicide, alloxydim-sodium, at the late tillering stage.

In Germany, Marlander et al. (1981) developed a wind erosion control system for sugar beets. The soil was deep-plowed in the fall. A quick growing catch crop, Phacelia tanacetifolia, was seeded in the fall. The catch crop was killed by winter frosts and left standing until spring when the residue was incorporated into the soil surface before planting the sugar beets. Compared to a conventional system (only fall plowing) emergence was better with the mulch system. Yields did not differ between treatments.

Two similar techniques called "mulch seeding" were described by Bruggemeier (1983) in Germany. Soil was deep-plowed in the fall. Phacelia sp., a cruciferous plant (Raphanus sp.) and yellow mustard (Sinapis sp.) were sown in August. None of the cultivars used in the trials were winter hardy. Sugar beets were either planted directly into the winter-killed residues or the residues were incorporated into the surface prior to sugar beet planting. For direct planting of the sugar beets into the residues the drill had to be equipped with special coulters for improved penetration. Direct planting into winter-killed catch crop residues gave better wind protection than planting into incorporated residues. Compared to a conventional system they reported a 30 percent reduction in weed density when the beets were seeded directly into the mulch.

Chapter III

EVALUATION OF THE USE OF CEREAL COVER CROPS FOR WIND PROTECTION OF SUGAR BEETS

3.1 ABSTRACT

At the field research station of the University of Manitoba at Portage la Prairie different cereal species including spring barley (Hordeum vulgare cv. Bedford), oats (Avena sativa cv. Fidler), fall rye (Secale cereale cv. Puma) and rye grass (Lolium multiflorum cv. Barspectra) were tested for their suitability as cover crops for wind protection of sugar beet seedlings in 1982 and 1983.

Spring planted barley and oats at two seeding rates (15 and 30 kg/ha) did not reduce the yield or stands of the sugar beets. Rye grass (1982 only) was found to be unsuitable because of its slow development in the early growth stages. The grass herbicides (Dowco 453, fluazifop butyl, Hoe 00736, sethoxydim) readily controlled the cover crops without affecting the beets. Wind speed measured 2-4 cm above ground, was reduced by 33 percent for oats and by 42 percent for barley at the denser seeding rate. In addition to protecting the beets, fall rye offered a soil cover during winter. However, fall rye could not be controlled readily, and competed with the sugar beets. Fall rye reduced the wind speed by 96 percent.

3.2 INTRODUCTION

Wind and blowing soil can severely damage plants (Armbrust, 1968, 1972; Armbrust et al., 1969; Downes et al., 1977; Fryrear, 1971; Fryrear et al., 1973, 1975; Fryrear and Downes, 1975; Lyles and Woodruff, 1960; Skidmore, 1966; Woodruff, 1956). Sugar beets are particularly sensitive to wind erosion (Gahm, 1979; Lumkes, 1973, 1981; Sojka et al., 1980; Zednai, 1983).

Several factors including field size, orientation of the field to the prevailing wind direction, erodibility (percent aggregates > 0.84 mm), soil roughness, wind velocity, soil moisture and vegetative cover determine the extent of wind erosion (Woodruff and Siddoway, 1965). The greatest single factor that influences erosion by wind and water is vegetative cover (Fenster, 1975). Also it is the factor which can be most easily influenced by cultural practices.

Planting of cover crops is one way to increase the amount of vegetative material. Techniques to establish fall-and spring-seeded cover crops have been developed for numerous crops (Barnes and Putnam, 1981; De Frank and Putnam, 1979; Hughes and Sweet, 1979).

In sugar beets fall seeded cover crops either killed by frost during winter or removed by a chemical in the spring have been used successfully (Ascroft and Leigh, 1975; Bastow et al., 1978; Luers, 1977; Pickwell, 1974). Sugar beets were seeded in the living or dead mulch using conventional seeders or seeders equipped with special coulters to penetrate residues (Bruggemeier, 1983; Lumkes, 1973; Lumkes and Te Velde, 1973, 1974; Marlander et al., 1981).

Spring seeded cover crops seeded either before or with the sugar beets have been evaluated by several researchers (Armstrong, 1978; Atkinson, 1980; Bakewell, 1980; Fornstorm and Boehnke, 1976; Lumkes, 1981). After protecting the beets, the cover crops or "living mulch" were removed either chemically or mechanically to eliminate competition.

The purpose of this study was to evaluate the use of fall-and spring-seeded cover crops for protection of sugar beet seedlings from wind damage under conditions prevailing in Manitoba.

3.3 MATERIALS AND METHODS

3.3.1 General Procedures

Sugar beet field experiments utilizing different cover crops and herbicides were conducted at the University of Manitoba Plant Science Research Station at Portage La Prairie, Manitoba in 1982 and 1983. The 1982 experiment was located on a Gnadenthal loam soil (14% sand, 51% silt, 35% clay) with an organic matter content of 8.6% and a pH of 8.2. In 1983 the experiments were located on a Fortier silty clay (5% sand, 49% silt, 46% clay) with 3.7% organic matter and a pH of 7.9 (Michalyna and Smith, 1972).

The area has more than 125 frost free days. Average growing season precipitation is 325 mm. During the months of May, June and July in 1982 and 1983, the most frequent wind speeds ranged from 3 to 34 km/h (Appendix Table 10). There is no prevailing wind direction in the area (Appendix Table 11). For the months of May and June maximum wind velocities were 44 km/h in 1982 and 50 km/h in 1983.

In 1982 sugar beets were planted after sugar beets. In 1983 they were planted into a field where winter wheat had been the previous crop.

Land Preparation. Conventional tillage procedures were used for all experiments. The plot area was plowed and deep tilled in the fall. For seedbed preparation in the spring, the plots were harrowed twice using a spring-tooth harrow before planting.

For all experimental sites soil testing was done in the fall. Random samples taken in the field at depth of 0 to 15 cm and 15 to 60 cm. were air dried and analyzed for nitrate nitrogen, available phosphorus and available potassium. Soil analyses were conducted by the Manitoba Provincial Soil Testing Laboratory in Winnipeg. In 1982 soil fertility was supplemented by a band application of 35 kg/ha nitrogen and 35 kg/ha phosphorus .In 1983, 85 kg/ha each of nitrogen and phosphorus were side banded with the seed. Fertilizer was applied as ammonium nitrate phosphate (24-24-0).

Seeding. Monogerm sugar beet seed, Mono Hy R1, was planted to stand with a John Deere Model 71 flexiplanter. Seeding depth was 2.5 cm with a row spacing of 56 cm and a seed spacing of 14 cm within the rows. Depending on the emergence, beets were thinned to a stand of about 65 - 70,000 plants/ha after cover crop control.

Herbicide Application. Spray treatments were applied with a bicycle-wheel sprayer that used compressed air. Tee Jet flat fan nozzles (SS 80015) that delivered 110 l/ha at 276 kPa pressure were mounted on a boom which matched the plot width. In 1982 (Experiment 1) and in 1983 (Experiment 1,2) the sprays were applied to all plot rows as a broadcast application as opposed to a banded application.

Because the plot size was larger in Experiment 4 (1983), a three point hitch Robinson field sprayer mounted to a tractor was employed. It also was equipped with SS 80015 Tee Jet flat fan nozzles that delivered 110 l/ha at 276 kPa pressure.

In both years broadleaf weeds were controlled by two post-emergence broadcast applications (Tables 1, 2). In 1982 (Experiment 1) a 1:1 mixture of desmedipham + phenmedipham at a rate of 1.4 kg/ha active ingredient. was sprayed on June 25, and desmedipham at a rate of 1.4 kg/ha a.i. was sprayed on July 5 (Table 1). The sugar beets were in the 2- to 4- and 8-leaf stages, respectively.

TABLE 1. Herbicides for broadleaf weed control applied in 1982.

Herbicide	Rate (kg/ha a.i.)	Application Date
desmedipham + phenmedipham	1.4	6/25
desmedipham	1.4	7/5

In 1983 all experiments were treated with desmedipham on June 9 (Table 2). Experiment 2 and 3 were sprayed with a rate of 0.7 kg/ha a.i. when the beets were in the 2- to 4 - leaf stage (Table 2). Experiment 1 was sprayed with a rate of 0.4 kg/ha a.i. when the beets were in the early 2-leaf stage (Table 2). On June 20 a tank mix of desmedipham + endothall (1.05 + 1.08 kg/ha a.i.) for control of Polygonum sp. (lady's thumb, wild buckwheat) was sprayed on all experiments when the beets were in the 6- to 8-leaf stage in Experiments 2 and 3 and the 4- to 6-leaf stage in Experiment 1 (Table 2).

TABLE 2. Herbicides for broadleaf weed control applied in 1983.

Herbicide	Rate (kg/ha a.i.)	Application Date
desmedipham	0.7	6/9 (Exp. 1)
desmedipham	0.4	6/9 (Exp. 2,3)
desmedipham + endothall	1.05 + 1.08	6/20 (Exp. 1,2,3)

For control of the cover crops, four new grass herbicides were evaluated. Application dates and rates are mentioned when single experiments are described. For technical information about the herbicides see Appendix Table 12.

3.3.2 Evaluation

Visual assessments of cover crop and weed control were made several times throughout the 1982 and 1983 growing seasons. A visual rating system of 0 to 9 was used (Table 3).

Cover Crops. In 1982, the number of cover crop plants in a 4 m² area in each plot was counted. The growth stages of the cover crops and beets and the height of the cover crops were determined before removal of the cover crops. In 1983, the same parameters were measured in a 4 m² area. Additionally, the cover crops within the 4 m² area were harvested on the day of spraying and dried (85 C) to a constant weight for determination of dry matter production.

Sugar Beets. In 1982, the plants in the centre two rows, and in 1983 in the centre four rows of each plot, were counted when all the beets had emerged.

TABLE 3. Visual rating system of 0-9 adopted by E.C.W. (Western Canada Section).

Rating Scale

Weed Control[1]		Crop Tolerance[1]	
9	complete control	9	complete tolerance
8	excellent control	8	possible effect
7	good control	7	slight effect
6	fair control	6	definite effect
5	poor control	5	severe effect
4	moderate injury	4	" "
3	definite effect	3	" "
2	slight effect	2	" "
1	possible effect	1	" "
0	no effect	0	complete kill

[1] - a value of 7 or above is considered commercially acceptable.

For an indication of wind damage the beets were counted before thinning in the same way as for the emergence count.

Towards the end of the growing season or after topping, the same beets were counted again as described above to determine the final stand.

At harvest, the sugar beets were mechanically topped and lifted using a Gemco 59 two row harvester. In 1982 the beets from the two centre rows were picked up, put into burlap sacks and transported to the Manitoba Sugar Company Laboratory in Winnipeg, where they were washed and weighed. The beets were harvested on October 14. In 1983, the centre four rows of each plot were harvested. Because of the higher number of beets/plot, after lifting they were cleaned and weighed with a portable scale in the field. In 1983, the beets were harvested on September 28 and 29 (Experiment 2), October 6 (Experiment 1) and October 7 (Experiment 3).

For determination of sugar content a sample of 10 beets was randomly collected from each plot (Experiments 1 and 2, 1983). Beets of every sample were washed and sliced at the Manitoba Sugar Company in Winnipeg and three subsamples were collected for sucrose determinations. All analyses were conducted by the Manitoba Sugar Company at Taber, Alberta.

3.3.3 Experimental Design

Experiment 1. The Influence of Different Cover Crops, Cover Crop Densities, Herbicides and Herbicide Timing for Cover Crop Control on Beet Performance, 1982 and 1983.

The 1982 experiment was laid out in a split-plot design replicated four times. It consisted of seven main- and eight sub-plot treatments. Main-plot treatments consisted of different cover crops. Oats (*Avena sativa* cv. Fidler), and barley (*Hordeum vulgare* cv. Bedford), were sown at 15 and 30 kg/ha and rye grass (*Lolium multiflorum* cv. Barspectra) at 5 and 10 kg/ha. The seed was broadcast by hand and harrowed into the soil (May 25). The control treatment was not seeded to a cover crop (Table 4).

TABLE 4. Main plot treatment cover crop and seeding rate of cover crop, 1982.

	Seeding rate of cover crop (kg/ha)	
Cover Crop	Dense	Sparse
Barley	30	15
Oats	30	15
Rye grass	10	5
No cover crop	--	--

Sugar beets were seeded on May 28 with a John Deere flexiplanter. The sub-plots were treated with 4 different grass herbicides for control of the cover crop (Table 5). Each herbicide was applied at two dates (June 23, 30). Plots consisted of four rows of sugar beets and were 5 m long (11.2 m²).

TABLE 5. Herbicide treatments and application dates for subplots, 1982.

Herbicide	Rate (kg/ha a.i.)	Surfactant (% v/v)		Application Date Early	Late
Dowco 453	0.15	Atplus	1.0	6/23	6/30
fluazifop butyl	0.4	Agral 90	0.1	6/23	6/30
Hoe 00736	0.2			6/23	6/30
sethoxydim	0.35	Assist	1.0	6/23	6/30

The 1983 experiment was partly a continuation of Experiment 1, conducted in 1982. It was laid out as a split block, replicated four times, consisting of five main- and four sub-plot treatments. The main plots (Table 6) consisted of oats and barley (15 and 30 kg/ha each) broadcast seeded by hand and harrowed in (May 16). One control treatment received no cover crop. The beets were seeded on May 23.

Sub-plot treatments (Table 7) consisted of the grassy herbicides, sethoxydim (0.35 kg/ha a.i.) + 1% Assist surfactant and Hoe 00736 (0.2 kg/ha a.i.), for control of the cover crop. Each herbicide was applied at two dates (June 12 and 17). Sub-plots were 10 m long and consisted of eight rows of beets (45 m²).

TABLE 6. Main plot treatment cover crop and seeding rate of cover crop, 1983.

	Seeding rate of cover crop (kg/ha)	
Cover Crop	Dense	Sparse
Barley	30	15
Oats	30	15
No cover crop	--	--

TABLE 7. Herbicide treatments and application dates for subplots, 1983.

	Rate	Surfactant		Application Date	
Herbicide	(kg/ha a.i.)	(% v/v)		Early	Late
Hoe 00736	0.2			6/12	6/17
sethoxydim	0.35	Assist	1.0	6/12	6/17

<u>Experiment</u> <u>2</u>. Influence of Herbicide Application Date on the Control of a Barley Cover Crop and on Beet Performance With and Without Previous Interrow Cultivation, 1983.

In this experiment, barley cv. Bedford (30 kg/ha) was seeded as a cover crop with a John Deere press drill perpendicular to the intended beet rows (May 11) and harrowed. Sugar beets were seeded on May 18. There were nine treatments with four replicates, laid out as a randomized complete block design. Treatments consisted of four different dates for cover crop control (June 8, 10, 12, 15). At each date the herbicide, Hoe 00736 (0.2 kg/ha a.i.), was applied to a plot that had previously received inter-row cultivation (May 6) and to a plot that had not been cultivated. One control plot was grown without a cover crop treatment. Plots were 10 m long and consisted of 8 rows (45 m^2).

Experiment 3. Influence of Fall- and Spring-Seeded Cover Crops and Ridging on Beet Performance and Wind Speed, 1983.

This experiment was designed as a randomized complete block with seven treatments replicated four times. Cover crop treatments included fall rye (*Secale cereale* cv. Puma), seeded September 4, 1982 at 30 kg/ha and barley (cv. Bedford) and oats (cv. Fidler), seeded May 17, each at 15 and 30 kg/ha with a John Deere press drill parallel to the future beet rows. The control treatment was not seeded to a cover crop.

One treatment was ridged on September 18, 1982. The ridging system involved two basic operations. In the fall scrapers mounted on a tool bar attached to a tractor with a three point hitch removed soil from a 22 cm band and formed a ridge. With a deridging, mulching operation (May 18) in the spring this ridge was pulled down with the same implement to form a moist seedbed. Beets were seeded on May 18.

Rye was controlled with Hoe 00736 (0.2 kg/ha a.i.) on May 25 with a second treatment at 0.5 kg/ha a.i. being applied on June 1. Barley and oats were removed with the same compound (0.2 kg/ha a.i.) on June 9. Plots were 26 m long and consisted of 12 beet rows (175 m^2).

Wind Speed Measurements. Wind speed measurements were taken 2 to 4 cm above ground with four cup anemometers built according to Unwin (1980). Two anemometers were placed in an uncovered (no cover crop) and two in a covered plot. Wind was measured at different time intervals for each of the cover crops at the higher seeding rate (30 kg/ha). Anemometers placed in the uncovered treatment were used as checks. Measurements were taken during the time period when beets were most sensitive to wind damage. Results were statistically analysed by means of a t-test.

3.4 RESULTS AND DISCUSSION

3.4.1 Experiment 1. The Influence of Different Cover Crops, Cover Crop Densities, Herbicides and Herbicide Timing for Cover Crop Control on Sugar Beet Performance, 1982 and 1983.

Cover Crop Emergence and Development. In 1982, the barley emerged 6 to 8 days after beet seeding (May 28) and oats about two days later, followed by rye grass which emerged with the beets about 14 days after the beets were seeded.

Barley developed fastest and reached the 1- to 2-leaf stage 10 days after beet seeding. Oats reached the same leaf stage two days later. Development of rye grass was slow and even with the higher seeding rate emergence was too spotty to produce an adequate ground cover.

At the first date of control (June 23), 25 days after beet seeding, barley was in the 4- to 5-leaf stage, was 20 - 25 cm high, and had started to tiller. The oats were in the same leaf stage, and had one to two tillers and were 20 cm tall. The rye grass was at the 3- to 4-leaf stage and had started to tiller but was only about 8 cm tall (Table 8).

At the second date of cover crop control, 32 days after beet seeding (June 30), barley had reached the 5- to 6-leaf stage, had 3 tillers and was 30 cm high. The oats were at the same leaf stage and were 25 cm high and had two tillers. Rye grass was only 10 - 12 cm tall and coverage was still spotty (Table 8).

Cover crop density was highest for oats seeded at 30 kg/ha, followed by barley at the 30 kg/ha seeding rate. Because of poor emergence and

TABLE 8. Influence of cover crop, cover crop density and timing of cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL					SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m^2	Height (cm)	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Spring Barley	15	23/6	33	25	78100	75900	66900	44.0
		30/6	33	30	74900	72500	65800	42.0
	30	23/6	55	25	78300	76100	66400	44.3
		30/6	54	30	78300	75700	67100	43.3
Oats	15	23/6	44	20	79600	76600	64700	43.5
		30/6	45	25	73800	71200	62800	45.8
	30	23/6	80	20	79000	76800	65600	44.1
		30/6	73	25	77700	75300	66200	43.4
Rye Grass	5	23/6	18	8	80200	78300	66200	43.3
		30/6	16	10	79800	77700	66900	46.7
	10	23/6	22	8	77200	74000	63900	44.0
		30/6	21	10	74800	72000	64900	42.6
No Cover Crop		23/6	--	--	74600	71400	63400	42.2
		30/6	--	--	76100	73300	64500	40.4
					n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.
June 23 - Cover Crops in the tillering stage.
June 30 - Cover Crops in the late tillering stage.

slow development, rye grass at both seeding rates did not reach the expected plant densities (Table 8).

In 1983 barley and oats emerged about the same time, three days after beet seeding (May 24). Barley plants were always about two to three days ahead of the oats in their development. The 2-leaf stage was reached about five to six days after beet emergence (May 29).

At the first cover crop control date, 19 days after beet seeding (May 23), barley was in the 4-leaf stage and had started to tiller. Oats were in the 3- to 4-leaf stage and were one to two days behind the growth stage of the barley. The barley was 15 - 20 cm high, about 5 cm taller than the oats (Table 9).

At both seeding rates barley had a lower density than oats but produced more dry matter/m². This was most likely due to an earlier emergence and faster development of the barley plants. As expected both cover crops produced more dry matter at the higher seeding rate (Table 9). Twenty four days after beet seeding at the second control date barley was about 20 - 25 cm high, had four to five leaves and two to three tillers. Oats were 15 cm high and had reached the 4-leaf stage and also had begun to tiller (Table 9). For barley an increase in dry matter between control dates is clearly visible and can be explained by a faster development of the barley plants. The oats did not show an increase between control dates likely due to slower early growth (Table 9).

In both years all four herbicides controlled the cover crops effectively at both growth stages. On a visual rating scale all herbicide treatments were rated 9, indicating complete cover crop control and excellent crop tolerance. None of the herbicides showed any visual ef-

TABLE 9. Influence of cover crop, cover crop density and timing of cover crop control on sugar beet stand and yield, 1983.

COVER CROP CONTROL						SUGAR BEETS				
						Stand in Plants/ha				
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m^2	Height (cm)	Dry Weight (g/m^2)	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
Spring Barley	15	12/6	39	15	11.0	70800	70000	65200	46.1	16.1
		17/6	40	20	12.1	71200	70000	66100	45.7	15.7
	30	12/6	60	15	17.3	74100	72900	65200	43.4	16.3
		17/6	68	20	20.2	72700	71600	65900	43.8	16.2
Oats	15	12/6	52	10	9.9	70100	69300	64700	45.1	16.3
		17/6	47	15	10.0	72100	70700	65200	45.2	15.7
	30	12/6	82	10	14.8	71700	70600	64100	44.6	16.0
		17/6	80	15	14.5	71400	70100	64800	44.3	15.5
No Cover Crop		12/6	--	--	--	72200	71100	66400	44.4	15.9
		17/6	--	--	--	71600	70600	65700	44.7	15.7
						n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 12 - Beets in the 2- to 4-leaf stage.
June 17 - Beets in the 4- to 6-leaf stage.
June 12 - Cover Crops in the 3- to 4-leaf stage.
June 17 - Cover Crops in the early tillering stage.

fects on the crop. The only difference between compounds was visible in the time needed for complete cover crop control. Time from spraying to full control ranged from 7 to 12 days, depending on the herbicide. With sethoxidym and Dowco 453, the first symptoms (yellowing) were visible after 2 to 3 days and the plants were completely dead after about one week. For Hoe 00736 and fluazifop butyl, the first symptoms were visible after 4 to 5 days and the plants were killed after 10 to 12 days.

In respect to beet protection a delayed but efficient cover crop kill may have a positive effect. Slowly dying cover crop plants still remained in the beet crop and left a considerable amount of plant matter for wind protection. All compounds tested for cover crop control also effectively controlled annual grassy weeds like wild oats, green foxtail and barnyard grass.

Sugar Beet Emergence and Development. In 1982 below average temperatures slowed the growth of the beets but high moisture (Appendix Table 13) resulted in very good emergence and stand establishment. The first beets emerged on June 10. The overall emergence was 61%, which is above the Manitoba long term farm average of about 50% (Zednai, 1983). Barley, oats and rye grass seeded as cover crops 3 days prior to beet seeding did not influence beet emergence. Differences in emergence for different cover crop treatments were not significant (Table 10).

Although significant differences in emergence were indicated for herbicide treatments (Table 11) these differences could not be attributed to the herbicides because they were applied after the crop emerged. However, these results were included in order to show that there was a non-uniformity in emergence which was not due to treatments. The timing

TABLE 10. Influence of cover crop and cover crop density on sugar beet stand and yield, 1982.

COVER CROP			SUGAR BEETS			
			Stand in Plants/ha			
	Seeding Rate (kg/ha)	Plant Density/ m^2	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)
Spring Barley	15	33	76500	74200	66400	43.0
	30	55	78300	75900	66700	43.8
Oats	15	44	78400	76100	65900	43.7
	30	76	80000	78000	66600	45.0
Rye Grass	5	17	76000	73000	64400	43.3
	10	22	75300	72300	63900	41.3
No Cover Crop	--	--	76700	74000	63800	44.6
			n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

TABLE 11. Influence of herbicide for cover crop control on sugar beet stand and yield, 1982.

COVER CROP	SUGAR BEETS			
	Stand in Plants/ha			
Herbicide for Control	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Dowco 453	78000 ab[1]	75700	65300	42.7
fluazifop butyl	75200 b	72800	65200	44.3
Hoe 00736	77200 ab	74500	65600	43.0
sethoxydim	78900 a	76100	65600	44.2

[1] Means within columns followed by the same letter or no letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).

TABLE 12. Influence of time of cover crop control on sugar beet stand and yield, 1982.

COVER CROP	SUGAR BEETS			
	Stand in Plants/ha			
Time[2] of Control	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
23/6	78100	75600	65300	43.6
30/6	76500	74000	65500	43.4
	n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.

of the herbicide application had no significant influence on emergence (Table 12). Differences in emergence for main treatment interactions were not significant (Table 8, Appendix Tables 1, 2, 3, 4, 5, 6).

In 1983, the first beets emerged on June 3. With precipitation of 4.5 mm on May 23, moisture conditions were fair (Appendix Table 14). Emergence (55%) was lower than in 1982 but still above the Manitoba average.

Only barley and oats were seeded as cover crops in 1983. The cover crops were sown 7 days prior to beet seeding. Neither of the cover crops significantly influenced beet emergence and stand establishment (Table 13). For the main effects, herbicides for cover crop control (Table 14) and timing of herbicide application (Table 15), emergence was uniform and no significant differences occurred. As in 1982 differences in emergence for main effect interactions were not significant (Table 9, Appendix Tables 7, 8, 9).

In both, 1982 and 1983 before thinning the beet stand was counted to determine if any differences occurred in the amount of wind damage between cover crops, cover crop densities and time of cover crop control. In both years stand reductions were observed when the counts were compared to the initial density. The reduction was mainly caused by insect damage (*Agrotis* sp., cutworm). Differences between treatments were not significant (Tables 10, 12, 13, 15). Neither in 1982 nor in 1983 was any wind damage observed. Because the initial stand was fairly dense, some thinning was done in 1982 (65-70,000 plants/ha). Because the initial stand was not as dense in 1983, thinning was not necessary.

TABLE 13. Influence of cover crop and cover crop density on sugar beet stand, yield and sugar content, 1983.

COVER CROP			SUGAR BEETS				
			Stand in Plants/ha				
	Seeding Rate (kg/ha)	Plant Density/ m^2	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
Spring Barley	15	40	71000	70000	65700	45.9	15.8
	30	64	73400	72300	65500	43.6	16.2
Oats	15	50	71100	70000	65000	44.6	16.0
	30	82	71500	70300	64400	45.2	15.8
No Cover Crop	--	--	71900	70900	66000	44.5	15.8
			n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

TABLE 14. Influence of sethoxydim and Hoe 00736 for cover crop control on sugar beet stand, yield and sugar content, 1983.

COVER CROP	SUGAR BEETS				
	Stand in Plants/ha				
Herbicide for Control	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)	Sugar (%)
Hoe 00736	70600	69600	64800	44.6	16.1
sethoxydim	73000	71700	65900	44.9	15.7
	n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

TABLE 15. Influence of time of cover crop control on sugar beet stand, yield and sugar content, 1983.

COVER CROP	SUGAR BEETS				
	Stand in Plants/ha				
Time[2] of Control	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
12/6	71800	70800	65100	44.8	16.1
17/6	71800	70600	65500	44.8	15.7
	n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 12 - Beets in the 2- to 4-leaf stage.
June 17 - Beets in the 4- to 6-leaf stage.

Manitoba farmers aim for a final stand of 60-70,000 plants/ha (Zednai, 1983). With 65,400 plants/ha in 1982 and 65,300 in 1983 final stands were almost identical for both years and in the range considered to be optimum for maximum yields. The main reason for stand reductions in 1982 was thinning. In 1983 a decrease in stand was mainly caused by damage from the broadleaf weed herbicide, endothall. This chemical was applied as an overall treatment to control wild buckwheat (Polygonum convolvulus) and lady's thumb (Polygonum persicaria). Hot, dry weather for several days after the application aggravated the damage. However, beets in all cover crop treatments were affected in a similar way. As expected no significant differences in final stand occurred between cover crops, cover crop densities, herbicides and herbicide timing for cover crop removal (Tables 10,11,12,13,14,15).

The average beet yield of 43.5 t/ha in 1982 was similar to the 44.8 t/ha harvested in 1983. The different cover crops, cover crop densities, timing and herbicides for their removal did not influence final yield of the sugar beets. Neither differences for the main effects (Tables 10,11,12,13,14,15) nor their interactions were significant (Appendix Tables 1, 2, 3, 4, 5, 6, 7, 8, 9).

Percent sucrose content was determined only in 1983. No significant differences for main effects (Tables 13,14,15) and their interactions could be determined (Appendix Tables 7, 8, 9).

3.4.2 Experiment 2. Influence of Herbicide Application Date on the Control of a Barley Cover Crop and on Beet Performance With and Without Previous Interrow Cultivation, 1983.

Cover Crop Emergence and Development. Barley was planted as a cover crop on May 10 and emerged on May 24, 6 days after beet seeding. Emergence was delayed due to a period of cold weather after seeding (Appendix Table 14). On May 29, 11 days after beet planting, the barley was in the 1- to 2-leaf stage and was about 5 - 8 cm high. Subsequent development of the barley plants was more rapid as the growing conditions improved. Dry matter values show the rapid growth of barley. In a period of one week, barley dry matter accumulation tripled in both the cultivated and uncultivated plots. (Table 16).

The number of barley plants in the cultivated plots was reduced by 21% compared to in the uncultivated plots (Table 16). On the assumption that all the barley plants would have been killed in the cultivated area between the beet rows, the reduction was expected to be close to 75%. A reduction of only 21% means that most of the cover crop plants survived the inter-row cultivation treatment. The barley plants were too advanced to be successfully controlled by cultivation. The results also indicate that cover crops cannot be effectively controlled by inter-row cultivation.

Hoe 00736 readily controlled the barley at all application dates. The cover crop turned yellow 4 to 5 days after application but remained upright. The beets were not affected by the herbicide.

Sugar Beet Emergence and Development. Emergence was very high in this experiment (66%). Immediately after seeding (May 18) a rain provided optimum moisture conditions (Appendix Table 14). The first beets

TABLE 16. Influence of herbicide application date on the control of a barley cover crop and on beet performance with and without interrow cultivation, 1983.

COVER CROP[2]					SUGAR BEETS[2]				
					Stand in Plants/ha				
Date of Control	Height (cm)	Interrow Cultivation	Dry Weight (g/m^2)	Plant Density/ m^2	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
8/6	10	No	7.0	56	81400	80300	70200	40.9	17.1
		Yes	5.3	45	86000	84800	69400	41.5	17.2
10/6	10-15	No	10.8	51	81100	80000	71100	43.6	17.2
		Yes	7.8	38	82700	81400	69800	43.4	17.0
12/6	15-20	No	13.4	48	85100	83200	71400	43.4	17.3
		Yes	8.3	38	83900	82700	67100	44.0	17.2
15/6	20-25	No	20.7	52	83800	82400	67000	44.2	17.0
		Yes	15.4	42	84600	84700	72000	41.8	17.1
No Cover Crop	--	--	--	--	83600	82200	70000	43.3	17.0
					n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05 (Duncan's Multiple Range Test).
[2] June 8 - Cover Crops in the 3- to 4-leaf stage, Beets in the 2- to 4-leaf stage.
June 10, 12 - Cover Crops in the early tillering stage, Beets in the 4- to 6-leaf stage.
June 15 - Cover Crops in the full tillering stage, Beets in the 6- to 8-leaf stage.

emerged on May 28, 10 days after seeding. As in the previous experiments no negative influence of the cover crops on beet emergence was observed.

Sugar beets are most susceptible to wind damage during the establishment period (emergence up to the 4- to 6-leaf stage), i.e., May and June (Fornstorm and Boehnke, 1976). In this particular experiment beets reached the cotyledonary stage 11 to 13 days after seeding (May 30). At the first date of cover crop control, 21 days after seeding, they were in the 2- to early 4-leaf stage. Because of the favorable growing conditions subsequent beet development was relatively fast and they reached the 6- to early 8-leaf stage in a period of 8 days (Table 16). By that stage beets were far enough advanced to resist wind damage without protection.

A second stand count before thinning indicated a slight decline in beet population. As in the previous experiments this reduction was mainly caused by insect damage (Agrotis sp., cutworm). Differences in stand between control dates for both uncultivated and cultivated plots were not significant and no wind damage was recorded throughout the season.

A second overall broadleaf weed herbicide application (desmedipham + endothall) on June 20 caused the beets to be severely set back and resulted in some thinning. Continuing hot weather for a few days after treatment increased the damage. However, the stand was still fairly high and the beets were thinned by hand to 70-75,000 plants/ha.

Final stand was in the range of 70-75,000 plants/ha and significant differences between treatments did not occur.

Yield differences between dates of barley removal with and without inter-row cultivation were not significant. As cover crop control was delayed a trend to a slightly higher yield was noticeable (Table 16). A possible explanation is that at the time of the second broadleaf herbicide application, barley plants for later control dates were still present. The barley plants might have intercepted some of the spray and therefore reduced the setback in beet growth.

In addition the cover crops that remained longer for later control dates possibly improved the microclimatic conditions. This might have resulted in more favorable growth conditions and an advanced development.

Mean sugar content for the experiment was 17.1%. Differences between treatments were not significant (Table 16).

3.4.3 Experiment 3. Influence of Fall- and Spring-Seeded Cover Crops and Ridging on Beet Performance and Wind Speed, 1983.

Cover Crop Emergence and Development. Fall rye was seeded on September 4, 1982. The crop germinated after 8 to 10 days and reached the tillering stage before winter. Regrowth in the spring started at the beginning of May. By the time the beets were planted, the rye had reached the late tillering stage and was 15 - 20 cm tall. On May 15, 7 days after beet seeding, the rye was sprayed. At this time the plants were 20 - 25 cm high, were at the jointing stage and had several tillers (Table 17).

Barley and oats at two densities (15 and 30 kg/ha) were seeded on May 18, one day before beet planting. The cover crops were seeded in rows parallel to the intended beet rows.

Barley emerged about 8 days, and oats about 10 days, after beet seeding. As in Experiment 1, the barley developed faster and reached the 2-leaf stage on June 2, 15 days after beet seeding. The oats reached the equivalent growth stage two days later. Both cover crops were about 8 - 10 cm high at this stage. At the control date on June 10 barley was in the 4-leaf stage, had started to tiller and was 15 cm high. Oats were in the 3- to 4-leaf stage and were 12 - 15 cm high (Table 17). They also had started to tiller.

Oat stands at both seeding rates were slightly higher than in experiment 2 (Table 17). This was most propably due to the fact that the cover crops in this experiment were planted with a drill and not seeded broadcast as was done in experiment 1. Therefore conditions for emergence were more favorable. Barley density at the 15 kg/ha rate was the lowest, followed by oats at 15 kg/ha and by barley, rye and oats, all seeded at 30 kg/ha.

The greater the amount of vegetative cover the better the erosion protection (Fenster, 1973). Fall rye with 70 g/m² had by far the highest dry matter production. In this respect rye would be very suitable as a cover crop (Table 17). Dry weight of oats and barley plants at the time of control (June 10) were lower than in Experiment 1, Compared to barley, oats produced relatively more dry matter/m² than in Experiment 1, but barley produced more dry matter per single plant.

Fall rye was not as sensitive to the grass herbicide and growth did not stop after treatment. One week after application, the rye plants expressed no severe injury symptoms or yellowing. Therefore it was sprayed again at twice the normal rate (0.2 kg/ha a.i.) on June 1. Even

TABLE 17. Influence of cover crop and cover crop density on sugar beet stand and yield, compared to a conventional and the ridging method, 1983.

COVER CROP[2]					SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Plant Density/ m²	Height (cm)	Dry Weight (g/m²)	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)
Spring Barley	15	27	15	3.5	74900	73700 a[1]	66700	43.0
	30	65	15	7.5	77000	76100 a	67900	37.7
Oats	15	66	12-15	5.4	77700	77000 a	67400	44.0
	30	133	12-15	8.6	78100	77100 a	63800	38.4
Fall Rye	30	75	25-30	70.0	--	58600 b	56500	38.4
Ridging	--	--	--	--	73500	72400 a	62700	43.1
No Cover Crop	--	--	--	--	74100	73300 a	63100	42.6
C.V. %					11.8	11.0	11.1	12.5

[1] Means within columns followed by the same letter or by no letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).
[2] Barley and Oats in the 3- to 4-leaf stage (June, 10) Fall Rye in the early heading stage (May, 15).

with this higher dosage control was slow and the rye continued to compete with the beets. It can be concluded that at the time the grass herbicide was applied, the plants were so far advanced that they were able to recover more easily. Another reason for the slow reaction of the rye plants might have been due to environmental conditions. Hoe 00736 is a systemic herbicide and its efficacy is dependent on the metabolic activity of the plant (Kocher et al., 1982). Temperatures in May were fairly low (Appendix Table 14) so uptake and transport of the compound may have been too slow to permit control.

Spring seeded cover crops at all seeding rates were readily controlled by Hoe 00736. Growth ceased shortly after application. About one week after spraying, the plants started to yellow and became necrotic. During the next 10 days plants died slowly but still remained upright. The beets were not affected by the herbicide.

Sugar Beet Development. Beets emerged around May 19. Overall emergence, excluding the fall rye plots, was 59%. At the time emergence counts were taken, the beet seedlings were still too small to be visible between the rye plants. However, the second stand count before thinning (Table 17) showed that emergence had been significantly reduced due to competition and possible allelopathic effects (Elliott et al., 1979; Barnes and Putnam, 1981) from the rye plants. Differences in emergence for the other treatments were not significant (Table 17).

When the spring seeded cover crops were controlled, the beets were in the 4- to 6-leaf stage. Cover crops, sprayed with Hoe 00736 died slowly and protected the beet seedlings for another 10 - 14 days after application. This time span allowed the beets to grow into an advanced growth stage and become more resistant to wind damage.

As in the other experiments there was a slight reduction in beet population between emergence and thinning, due mainly to insect damage (*Agrotis* sp., cutworm). Wind damage was not observed and any differences between treatments were not due to wind damage (Table 17). Beets in the rye plots showed a significantly lower stand than all other treatments.

Final stand showed the influence of a lower emergence in the rye plots (Table 17).

Final beet yields were lower in plots sown to rye. This can be attributed to a lower stand and to slower development of the beets due to competition from the rye. Plots seeded to the lower rate of barley yielded the most. However, a significant influence of the cover crop treatments compared to treatments without any cover crop did not occur (Table 17). For the rye plots this demonstrates the ability of the beets to compensate for lower stands by increasing single beet weight. After severe competition from the rye plants and resulting stand reduction the ability of the beets to yield was still relatively high.

Rye could be quite promising as a cover crop provided the plants could be controlled by applying a high rate of a systemic herbicide or by applying a contact herbicide. The main advantage of the rye would be to have a soil cover over winter to prevent soil drifting. Additional snow trapping could increase the available moisture and create an insulating snow layer which, in turn, would lower the frost penetration depth of the soil, with possibly growth-benefitting modifications of the energy budget.

3.4.4 Wind Measurements

Wind measurements in a rye plot showed a 96% reduction in wind speed compared to an uncovered plot (Table 18). This demonstrates the ability of a rye cover crop to protect the soil surface.

The reduction in wind speed by barley, seeded at the higher rate, was more obvious than for oats (Table 18). At the time wind measurements were taken, the barley plants were further advanced than the oats. The higher dry matter production of the barley plants compared to the onts contributed to more efficient wind protection. Barley reduced the wind speed by 42%. Oats at the higher seeding rate reduced the wind speed by 33%. Although less than for rye, this reduction might be enough to prevent severe erosion (Table 18). Because only four anemometers were available, the lack of adequate replication prevented statistical analysis to show differences between covered and uncovered plots. However, the fact that cover crops can reduce wind speed substantially was unequivocally demonstrated.

TABLE 18. Influence of the cover crop on wind speed, measured 2-4 cm above soil surface, 1983.

Cover crop[1] seeded at (30kg/ha)	Height of Cover crop (cm)	Date of Measurement	Time Measured (min)	Windspeed Without Cover Crop (km/h)	Windspeed With Cover Crop (km/h)	Reduction (%)
Fall Rye	25	31/5	145	11.3	0.4	96.8*
	25	1/6	345	11.6	0.3	97.2*
	25	2/6	300	19.3	0.8	96.1**
	25	3/6	360	15.2	0.7	95.7*
Oats	8	5/6	120	7.6	5.3	30.5
	8	6/6	875	5.2	3.4	33.8
	10	7/6	152	27.3	18.4	32.6
	15	10/6	660	21.2	13.7	35.5
Spring Barley	10	7/6	165	20.8	10.6	49.2*
	15	8/6	123	3.5	1.5	56.2
	15	10/6	150	10.6	6.8	35.5
	15	11/6	1140	15.8	7.3	53.9
	15	12/6	150	14.8	7.6	48.7

* significant at p=0.1 (t-test).
** significant at p=0.05 (t-test).
[1] Fall Rye in the early jointing stage.
Oats between the 2- to 3-leaf and early tillering stage.
Barley between the 3- to 4-leaf and early tillering stage.

3.4.5 Broadleaf Weed Control

The use of cover crops, precluded the application of pre-emergence soil-incorporated herbicides. Broadleaf weed control was achieved by using post-emergence applications. Ideally, in order to give effective control, post emergence herbicides have to be applied when the weeds are in early growth stages.

In 1982, broadleaf weeds were at an advanced leaf stage and a high rate of desmedipham was sprayed to give adequate control. This resulted in slight beet damage which caused some stand reduction and a general set-back in growth. The later emerging, smaller beets were affected most. A later application of herbicides controlled a second flush of broadleaf weeds. At this stage the beets were so far advanced that herbicides did not affect them as much as at the earlier treatment.

Similar problems were encountered in the second year. A first, early desmedipham application at a low dosage was applied in order to avoid beet damage and guarantee timely control of broadleaf weeds, including redroot pigweed (Amaranthus retroflexus), lamb's quarter (Chenopodium album), wild mustard (Sinapis arvensis), wild buckwheat (Polygonum convolvulus), and lady's thumb (Polygonum persicaria). Except for the Polygonum species, control was adequate. For improved control of the Polygonum species a tankmix of desmedipham and endothall was sprayed in a second application. Because of hot, dry weather conditions for several days after treatment, the beets were damaged and some thinning and a general setback in growth occurred.

Chapter IV

EVALUATION OF THE EFFECT OF SEVERAL TILLAGE TREATMENTS ON SUGAR BEET PERFORMANCE

4.1 ABSTRACT

At the field research station of the University of Manitoba at Portage la Prairie different tillage methods were evaluated for sugar beet production. During the growing seasons of 1982 and 1983, reduced tillage methods, such as rotary strip-tillage and harrowed,zero-tillage were compared to a conventional method. In 1983 an unharrowed, zero-tillage treatment and the ridging method were included. Emergence, final stand, yield and sugar content were evaluated.

In both years, emergence and stand establishment were best in conventionally tilled plots. Emergence in strip-tilled plots was lower than in conventionally tilled plots. For the harrowed, zero-tillage plots variation in emergence between years was high. Emergence in unharrowed, zero-tillage plots was inferior compared to the other treatments. Conventionally tilled plots yielded the highest over the two years. Unharrowed, zero-tillage plots yielded significantly lower than conventionally treated plots. There were no significant differences in sugar content between treatments.

4.2 INTRODUCTION

Vegetative cover is the greatest single factor that influences erosion by wind and water (Fenster, 1975). Reduced tillage methods leave more plant residues and clods on the soil surface and cause less soil disturbance. Zero-tillage methods leave the soil undisturbed (Woodruff et al., 1972).

For sugar beets a reduction in tillage was accomplished by replacing the plow based fall tillage by rotary strip-tillage and zero-tillage.

Soil erosion by wind and damage of beet seedlings can be reduced by an increase in trash cover. Simmons and Dotzenko (1975) reported substantial reduction in potential wind erosion after applying strip-tillage in sugar beets.

Reduced tillage increases soil moisture but soil temperature is, in general, decreased because of an insulating trash layer (Willis and Amemiya, 1973; Talley, 1976; Sturny, 1982). Emergence and stand establishment of sugar beets is very much dependent on soil seed contact, soil moisture and temperature. Some authors reported an increase in emergence for sugar beets grown under reduced tillage (Sojka et al.,1980) particularly under dry conditions (Sturny, 1982). Talley (1976) found a higher emergence for conventionally tilled beets, particularly on heavier soils.

Provided a good stand was established, yield and quality of sugar beets grown under reduced tillage conditions was not reduced (Glenn and Dotzenko,1975; Giles et al. 1980, 1982; Simmons and Dotzenko, 1975; Sturny, 1982; Talley, 1976).

The objective of this study was to evaluate the use of reduced tillage methods for sugar beet production under the aspect of wind erosion protection.

4.3 MATERIALS AND METHODS

4.3.1 General Procedures

In 1982 and 1983 field experiments were conducted at the Plant Science Research Station at Portage la Prairie.

In 1982 the soil type was a Gnadenthal loam (14% sand, 51% silt, 35% clay) with an organic matter content of 8.6% and a pH of 8.2. In 1983 the experiment was located on a Dugas silty clay (5% sand, 49% sand, 46% clay) with an organic matter content of 3.7% and a pH of 7.9 (Michalyna and Smith, 1972).

In both years sugar beets were planted in a field sown to barley the previous year. Straw from the barley crop was removed in the fall.

For determination of available phosphorus, potassium and nitrate nitrogen, random soil samples were taken at a depth of 0 - 15 cm and 15 - 60 cm. Samples were air dried and analysed by the Manitoba Provincial Soil Testing Laboratory in Winnipeg.

In 1982 nitrogen and phosphorus, each at a rate of 35 kg/ha were side banded with the seed. In 1983 the rates of nitrogen and phosphorus were increased to 85 kg/ha and applied in the same manner. Fertilizer was added as ammonium nitrate phosphate (24-24-0).

Monogerm sugar beet seed, Mono Hy R1, was planted to stand with a John Deere Model 71 flexiplanter. Seeding depth was 2.5 cm with a row spacing of 56 cm and a seed spacing of 14 cm. Plots were 10 m long and consisted of 8 rows (45 m^2).

In 1982 the plots were seeded on May 28 and the first beets emerged on June 10. Emergence stands were recorded on June 18. Final stand counts were taken after beet topping on October 13. Beets were harvested on October 14.

In 1983 the plots were planted on May 18 and the first beets emerged on May 30. Emergence stands were recorded on June 7. Final stand counts were taken after topping on September 27. The beets were harvested on September 29.

In both years the centre four rows of each plot were counted after all beets had emerged. For final stand the same rows were counted again before harvest.

Herbicide Application. All weeds were controlled by post-emergence herbicides. The spray treatments were applied with a bicycle wheel sprayer that used compressed air. Flat fan nozzles (Tee jet SS 80015) that delivered 110 l/ha at 276 kPa pressure, were used mounted on a boom that was the same width as the plots. The chemicals were applied over the entire plot.

For grassy weed control, sethoxydim at a rate of 0.35 kg/ha a.i. + 1% v/v surfactant (Assist) was sprayed in both years. In 1982 it was applied on June 15, when the beets were in the cotyledonary to early 2-leaf stage. In 1983 it was sprayed twice, on June 8 and June 20, when beets were in the 2- and 4- to 6-leaf stages respectively.

In 1982 broadleaf weeds were controlled by an application of a 1:1 tank mix of desmedipham and phenmedipham (1.1 kg/ha a.i.) on June 25 when the beets were in the 4-leaf stage. Desmedipham (1.4 kg/ha a.i.) was sprayed again on July 5 when the beets were in the 6- to 8-leaf stage. In 1983 desmedipham at 0.7 kg/ha a.i. was applied on June 10 at the 2- to 4-leaf stage. On June 20, a tankmix of endothall (1.08 kg/ha a.i.) and desmedipham (1.05 kg/ha a.i.) was sprayed to specifically control Polygonum species (wild buckwheat and lady's thumb). At this time beets were in the 4- to 6-leaf stage.

At harvest sugar beets were mechanically topped and lifted using a Gemco 59 two-row harvester. In both years beets in the centre four rows were harvested. In 1982 beets were picked by hand, put into burlap sacks and transported to the laboratory of the Manitoba Sugar Company in Winnipeg where they were washed and weighed. In 1983 the beets were cleaned and weighed in the field, using a portable scale.

To determine sucrose content a sample of 10 beets was taken from each plot. At the Manitoba Sugar Company Laboratory in Winnipeg the beets were washed and sliced, and 3 subsamples per plot were collected. These samples were sent to the Manitoba Sugar Company in Taber, Alberta for determination of sugar content. Sugar contents were determined only in 1983.

In 1983 the numbers of sprangles (deformed beets) in each plot were counted immediately after the beets were lifted. The deformation (branching of the beet) is due primarily to the mechanical resistance of a compacted soil (Bakermans and De Wit, 1970).

4.3.2 Tillage Treatments

Conventional Tillage. Conventionally tilled plots were plowed and double-disked in the fall. Final seedbed preparation consisted of harrowing the plots twice prior to seeding.

Strip-Tillage. Rotovated strip-tillage was applied in the fall with a strip rotovator that tilled a 10-cm wide band of soil. In a separate operation in the spring, the sugar beets were seeded into the tilled strips.

Harrowed Zero-Tillage. Plots with standing barley stubble were harrowed twice prior to seeding in order to close cracks and prepare a firm seedbed. Sugar beets were planted directly into the harrowed stubble, using only the conventional double disk equipment and no special coulters.

Zero-Tillage. This treatment consisted of seeding into stubble which had not been harrowed prior to seeding.

Ridging. One treatment was fall-ridged on September 18, 1982. Ridging involved two basic operations. In the fall scrapers mounted on a tool bar attached to a tractor with a three point hitch removed soil from a 22 cm band and formed a ridge. With a deridging mulching operation in the spring (May 18) this ridge was pulled down with the same implement to form a moist seedbed.

4.3.3 Experimental Design

In both years the experiments were laid out in a four-replicate randomized complete block design. In 1982, there were three tillage treatments which consisted of conventional tillage, strip-tillage and harrowed zero-tillage. In 1983, the three tillage treatments were repeated and two additional treatments, ridging and non-harrowed, zero-tillage, were included.

4.4 RESULTS AND DISCUSSION

4.4.1 1982.

Emergence in 1982 was significantly higher for the conventional and harrowed zero-tillage treatments (Table 19). The strip-tillage plots had not been harrowed prior to seeding. The seedbed in the strip-tillage plots was loose and cloddy at the time of seeding. This may have prevented good seed placement and good soil seed contact, therefore reducing emergence of the sugar beets.

TABLE 19. Effect of different tillage treatments on sugar beet emergence, final stand, yield and single beet weight, 1982.

Treatment	Emergence (beets/ha)	Final Stand (beets/ha)	Root Yield (t/ha)	Single Beet Weight (g)
Conventional Tillage	76000 a[1]	72000 a	38.9 a	550 a
Strip-Tillage	61000 b	56000 b	36.4 a	710 a
Harrowed Zero-Tillage	76000 a	69000 ab	40.0 a	580 a
C.V.%	11.5	13.2	12.5	22.1

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).

The decrease between emergence and final stand was mainly due to plant losses from insect damage (*Agrotis* sp., cutworm). This was similar for all treatments.

Differences in final stand between the conventional and the strip-tillage treatment remained significant as a result of the lower emergence in the strip-tillage plots (Table 19). Wind damage was not observed in any of the treatments.

Yields were highest for the harrowed, zero-tillage treatment, followed by the conventionally tilled and the strip-tillage plots (Table 19). However, differences were not significant because lower final stands were offset by higher single beet weights. Single beet weight was highest for the strip-tillage treatment, which had the lowest final stand. Differences between treatments were not significant (Table 19).

4.4.2 1983.

In 1983 a non-harrowed zero-tillage treatment and the ridging method were included.

Emergence in the non-harrowed zero-tillage treatment was significantly lower than in all other treatments (Table 20). This was mainly due to a crusted, cracked surface and to stubble residues. This prevented proper seed placement and good soil-seed contact.

Harrowing increased emergence significantly, although emergence was still lower than in the ridging and the strip-tillage treatments. Differences were not significant (Table 20). The effects of harrowing were to provide more uniform distribution of straw residues and to facilitate better seed placement.

In the conventionally tilled plots, emergence was significantly higher than in all other plots (Table 20). This indicates that conditions for emergence, particularly seed placement and soil-seed contact, were more favorable in conventionally prepared plots.

TABLE 20. Effect of different tillage treatments on sugar beet emergence, final stand, yield, single beet weight, number of sprangles and sucrose content, 1983.

Treatment	Emergence (beets/ha)	Final Stand (beets/ha)	Root Yield (t/ha)	Single Beet Weight (g)	Sprangles (%)	Sucrose (%)
Conventional Tillage	69000 a[1]	56000 a	42.6 a	770 c	11.6 a	17.0 a
Strip-Tillage	53000 b	47000 ab	38.3 ab	810 c	20.2 a	16.6 a
Harrowed Zero-Tillage	43000 b	39000 b	38.8 ab	1000 ab	14.8 a	16.5 a
Zero Tillage	29000 c	26000 c	31.9 b	1160 a	18.4 a	16.3 a
Ridging	53000 b	46000 ab	38.2 ab	850 bc	12.8 a	16.6 a
C.V.%	11.8	10.4	11.3	8.2	37.9	4.2

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).

The comparatively larger decrease in plant stand from emergence to final stand for the conventionally tilled plots resulted from thinning. Because of the lower plant emergence in the other treatments the plots were not thinned. Overall stand reductions were mainly due to insect damage as well as from injuries caused by the broadleaf herbicide, endothall. Wind damage was not observed in any of the treatments.

The non-harrowed zero-tillage treatment resulted in a significantly lower stand than all other treatments (Table 20). Final stand in the harrowed zero-tillage plots did not differ significantly from the ridged plots, but was significantly lower than in the conventional tillage and the strip-tillage plots (Table 20).

In general, the conventional tillage methods produced higher yields than the other treatments, although significant differences were only observed between conventional tillage and non-harrowed zero-tillage treatments.

A comparison of single beet weight, final stand and yield shows the resiliency or adaptability of the beet crop. A low stand as occurred in the zero-tillage and harrowed zero-tillage plots resulted in a high single beet weight. Both treatments resulted in significantly higher single beet weights than in the conventionally tilled and strip-tilled plots. Values for non-harrowed zero-tillage plots were also significantly different from those obtained with the ridging treatment (Table 20).

Results show that a decrease in stand was offset by an increase in median beet size. However, there was a point beyond which an increase in beet size could not compensate for a lower plant population. Although the non-harrowed zero-tillage treatment produced the highest single beet weight, it produced the lowest yield. (Table 20).

General trends indicated a higher percentage of sprangled beets in the strip and the zero-tillage treatments. Because of a high variation within the treatments (C.V. 37.9%) treatment differences were not significant (Table 20). Several authors found a relation between tillage or soil compaction and the number of sprangles (Bakermans and De Wit, 1970; Baumer and Pape, 1972).

Sugar content was highest for the conventional and lowest for the unharrowed stubble plots. Differences were minimal and not statistically significant (Table 20).

4.4.3 Comparison of Two Years

Only three tillage treatments (conventional, strip-tillage, zero-tillage) were repeated both years. For each treatment emergence was higher in the first year (Table 21). Emergence for the harrowed zero-tillage treatment was significantly lower in the second year (Table 21). Emergence estimates averaged over treatments were significantly higher in the first year (Table 23). A difference in soil type was one of the major factors contributing to the decrease in emergence observed in the second year. In 1982 the experiment was located on a loamy soil and in 1983 on a much heavier silty clay. In addition, crusting caused by a heavy rainfall immediately after seeding may have inhibited emergence. A comparison of the three treatments combined over two years show that emergence was significantly higher in the conventional plots than in the strip-tillage and the harrowed, zero-tillage plots (Table 22).

TABLE 21. Comparison of 3 tillage treatments used in 1982 and 1983.

Treatment	Year	Stand in plants/ha: Emergence	Stand in plants/ha: Final	Root Yield (t/ha)	Single Beet Weight (g)
Conventional Tillage	1982	76000 a[1]	72000 a	38.9 a	550 c
	1983	69000 a	56000 bc	42.6 a	770 b
Strip-Tillage	1982	61000 ab	56000 bc	36.3 a	710 bc
	1983	53000 bc	47000 cd	38.3 a	810 b
Harrowed Zero-Tillage	1982	76000 a	69000 ab	40.0 a	580 c
	1983	43000 c	39000 d	38.7 a	1000 a
C.V.%		15.2	16.9	11.0	15.3

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).

TABLE 22. Effect of different tillage treatments on sugar beet emergence, final stand, yield and single beet weight.

Treatment[2]	Emergence (beets/ha)	Final Stand (beets/ha)	Root Yield (t/ha)	Single Beet Weight (g)
Conventional Tillage	73000 a[1]	64000 a	40.8 a	660 a
Strip-Tillage	57000 b	52000 b	37.3 a	760 ab
Harrowed Zero-Tillage	59000 b	54000 ab	39.4 a	790 a

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).
[2] Values are averaged over two years (1982, 1983).

The overall final stand was greater in 1982 than in 1983 (Table 23). Each treatment had a lower final stand in the second year. For the unharrowed zero-tillage treatment final stand was significantly lower in the second year (Table 21). Final stand estimates combined over the two years were significantly higher for conventional tillage than for strip-tillage (Table 22). The harrowed, zero-tillage treatment and the conventional treatment were significantly different between years (Table 22). Except for the conventional treatment, for which thinning was conducted only in 1983, these results were mainly a reflection on the difference in emergence (Table 22).

Yield estimates did not differ between treatments and years (Table 21). When yield estimates were combined for treatments, no significant differences were observed between the two years (Table 23). Differences between treatments averaged over years were not significant as well (Tables 22).

Single beet weight was largely a result of final stand. Treatments with low stands yielded high single beet weights and vice versa. Between years differences were similar with differences in stand (Tables 21 and 22).

<u>Conclusion</u>. In both years sugar beet emergence for the conventional treatment indicate that conditions for germination were most suitable with this method. Strip-tillage resulted in a consistently lower emergence indicating less than optimum conditions for germination and development. The harrowed zero-tillage treatment exhibited a high variation in emergence between the two years. This was partly attributed to a difference in soil types and indicates that this method is not suitable

TABLE 23. Effect of years on sugar beet emergence, final stand, yield and single beet weight.

Year[2]	Emergence (beets/ha)	Final Stand (beets/ha)	Root Yield (t/ha)	Single Beet Weight (g)
1982	71000 a[1]	66000 a	38.4 a	610 b
1983	55000 b	47000 b	39.0 a	860 a

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).
[2] Values are averaged over treatments.

for heavier soils. Yields for strip-tillage and harrowed zero-tillage were still acceptable compared to the conventional method. The ridging method gave adequate emergence and yield although there was some reduction compared to the conventional tillage method. Emergence, stand establishment and yields for the unharrowed zero-tillage treatment were generally inferior. The planting technique did not provide good seed placement for optimum soil seed contact on a crusted soil surface.

Chapter V

PROTECTIVE EFFECT OF BARLEY AS A COVER CROP FOR SUGAR BEET SEEDLINGS UNDER DIFFERENT WIND REGIMES

5.1 ABSTRACT

In a wind tunnel, sugar beet seedlings planted in greenhouse flats were exposed to different wind speeds and sand blasting. Beets in flats without an interplanted barley cover crop were compared to flats where barley was interseeded broadcast and to flats in which barley was seeded in rows either in, or perpendicular to, the wind direction.

Higher wind speeds (0, 55, 60, and 65 km/h) significantly decreased beet fresh weight, dry matter and leaf area. With the addition of sand blasting the decrease was aggravated. The barley cover crop seeded perpendicular to the wind direction gave some protection to the beets exposed to the sand blasting. Barley plants seeded broadcast and in rows oriented in the wind direction did not protect the beet seedlings effectively.

5.2 INTRODUCTION

Plant damage resulting from exposure to wind or windblown sand is commonly observed. Mechanical damage is often expressed in deformation of stems, reduced growth, leaf abrasion, loss of leaf area, necrosis and destruction of foliage (Finnel, 1928; Kahl, 1951; Parkhurst and Pearman, 1972; Thompson, 1974; Wadsworth, 1959, 1960; Waister, 1972 a, b; Whitehead, 1963).

In general resistance to wind was found to be a function of wind velocity, abrasive material carried by the wind, exposure time, plant age and crop (Armbrust et al., 1969; Downes et al., 1977; Fryrear and Downes, 1975; Lyles and Woodruff, 1960; Skidmore, 1966; Woodruff, 1956). Wind alone caused less damage than wind and blowing soil (Fryrear et al., 1973; Skidmore, 1966). Plants stressed by wind and blowing soil showed metabolic changes. After exposure, photosynthesis and nitrate reductase were decreased, respiration was increased (Armbrust, 1968). General growth was slowed and plants were more sensitive to diseases (Fryrear et al., 1975).

The purpose of this study was to determine the effect of wind and sand blasting on sugar beet seedlings. Also the use of interseeded barley as a cover crop for erosion protection was evaluated.

5.3 MATERIALS AND METHODS

In September of 1983, sugar beet seedlings were grown in greenhouse flats 32 cm wide, 48 cm long and 8 cm deep. The soil used was a Gnadenthal loam (66% sand, 15% silt, 19% clay), with an organic matter content of 3.4% and a pH of 7.4. To ensure a firm seedbed the soil was packed before planting. On September 20, sugar beet seeds of the variety Mono Hy R1 were planted in two 48 cm rows per flat with 6 seeds per row (3 holes of 2 seeds each) at a depth of 2.5 cm.

Barley was seeded into the flats at the time of beet seeding as a cover crop. There were three cover crop treatments. After seeding, the flats were watered to field capacity and put into the greenhouse at approximately 20 C to ensure even germination. The flats were watered daily. After emergence, the beets were thinned to three plants per row, 16 cm apart. The cover crops were thinned as well to an even number of barley plants for the respective treatments. To harden the plants, the flats were placed outside in an area sheltered by two greenhouses. Thus the flats were grown outdoors until they were subjected to various wind treatments on October 13 and 14, 33 and 34 days after seeding.

After exposure to wind the flats were rated for beet damage using a percentage scale. Damage was considered to be 100% when all the beet seedlings were lying flat on the ground and the hypocotyl and leaves showed lesions.

Treated and untreated flats were brought back to the greenhouse, kept at 20 C and watered daily. On October 23 (11 days after treatment) the cover crops in all of the flats were removed. Fresh weights, dry matter and the number of cover crop plants were determined for every flat. On November 5 (24 days after treatment) the beet plants were harvested. At this time they were in the 4- to 6-leaf stage. Leaf area, fresh weight and dry weight of the beet plants were evaluated. Leaf area in cm^2 was measured using a portable leaf area meter, Model LI-3000, manufactured by Lamda Instruments Corporation.

At the sugar laboratory of the Manitoba Sugar Company a wind tunnel was devised (Fig. 1). An axial ventilating fan (manufactured by Sturtevant Mfg., Boston, U.S.A.) driven by a 10 HP Westinghouse motor served as a wind source. With an air flow of 2072 m^3/min and an opening of 46 cm it produced a windspeed of 124 km/h at the fan opening. To simulate a particular windspeed a rectangular metal duct 46 cm high, 38 cm wide and 4.26 m long was set up at various distances from the fan. By vary-

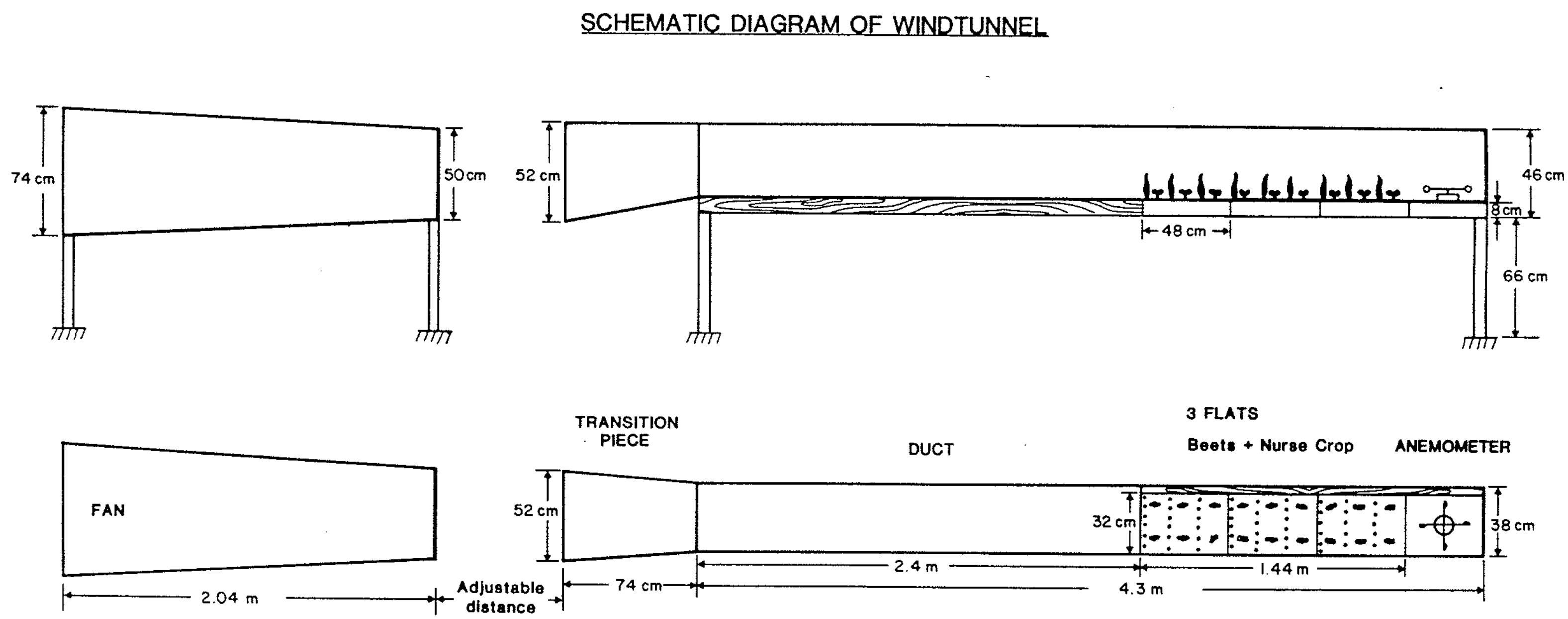

Figure 1: Wind tunnel setup for simulation of wind treatments.

ing the distance between the duct and the fan windspeeds between 30 and 90 km/h could be obtained. To guarantee an even flow in the duct a transition piece (1m long) was attached to the rectangular duct to compensate for the circular opening of the fan (Fig. 1).

The tunnel was calibrated by measuring the windspeed with a cup anemometer at the end of the duct at the site where the plants in the flats would be exposed to the wind treatment. The cup anemometer was built according to the method described by Unwin (1980).

For each run, three plant flats were placed lengthwise at the end of the tunnel and were exposed to a particular wind treatment for 10 minutes. Sandblasting was simulated by scattering 180 g of a sandy soil (Almasippi fine sandy loam, 79% sand, 12% clay, 9% silt) per minute into the windward opening of the duct. The amount of sand corresponded to a sand flux of 0.125 kg/cm width/min. Two experiments were conducted.

Experiment 1. The objective of this experiment was to evaluate the effect of parallel and perpendicular seeded barley cover crops for sugar beet seedling protection under different wind and sand blasting treatments.

Beet seedlings in flats without a cover crop were compared to flats with the cover crop seeded both parallel and perpendicular to the wind direction. For the parallel treatment, barley was seeded between and parallel to the 48 cm beet rows, spaced 4.8 cm apart (130 plants/m^2). For the perpendicular treatment, barley was seeded in three rows perpendicular to the 48 cm beet rows at a density of eight seeds per row spaced 4 cm apart (156 plants/m^2).

Flats were exposed to six wind treatments (0, 55, 55 + sand, 60, 60 + sand, 65 km/h). For each wind treatment, six flats of each of the cover crop treatments were evaluated. Thus, the experiment was laid out in a completely randomized design with six replicates for the main effects (wind treatments, cover crop treatments) and their interactions. An analysis of variance was conducted.

Experiment 2. The objective of this experiment was to investigate the effect of broadcast seeded cover crops under different wind and sand blasting treatments. Barley seed was broadcast to produce a density of 100 plants/m^2. Beet seedlings in flats seeded without and with a cover crop were exposed to three wind treatments which consisted of a wind, (55 km/h) a wind and sand (55 km/h) and a windless treatment. For each wind treatment six to nine flats of each cover crop treatment were evaluated. The experiment was laid out as a completely randomized design. The experiment was statistically analysed by the general linear model procedure. Main treatment effects were compared by contrast and treatment interactions by a t-test procedure.

5.4 RESULTS AND DISCUSSION

5.4.1 Experiment 1

All wind treatments reduced cover crop fresh and dry weight significantly (Table 24). Cover crop number was not affected. Sand blasting had no apparent effect on cover crops as compared with wind alone.

A decrease in beet fresh weight, dry matter and leaf area occurred with an increase in wind speed (Table 24). The growth reduction was most severe when the beets were exposed to a wind speed of 55 km/h combined with sand blasting, with dry weight being reduced to 6.25 g/m^2 and leaf area being reduced to 2220 cm^2/m^2, respectively. Differences in fresh weight, dry matter and leaf area between beets grown in the wind treated and untreated flats were significant (Table 24). As well, differences for measured beet parameters between sand blasting and sandless treatments for the same wind speed were significant (Table 24). Damage rating for beets immediately after treatment rose with an increase in wind speed and additional sand blasting. The results suggest that the sand blasting has more effect on the beets than on the barley.

Because of the different seeding direction the number of parallel seeded barley plants was always lower than the perpendicularly seeded cover crops (Table 25). This was not reflected in the fresh weight and dry weight values. The perpendicularly seeded cover crops were planted more densely hence competition between single plants might have occurred.

Beet fresh weight, dry matter and leaf area were not significantly different between the two cover crop treatments and the treatment without a cover crop (Table 25). Damage ratings were lower for the cover crop treatments than for the unprotected flats (Table 25).

A comparison of each single treatment combination demonstrates again the reduction of cover crop fresh and dry weight when flats were treated with wind or with wind and sand. (Table 26). Differences for measured cover crop parameters between cover crop treatments for each wind and wind + sand treatment were not significant.

Beet fresh weight for the 55 km/h wind + sand treatment was significantly higher with a perpendicularly seeded cover crop than without any protection (Table 26). For the wind + sand treatments there was always

TABLE 24. Effect of wind and sand blasting treatments on sugar beet seedlings and barley as a cover crop.

Wind/Sand Treatment (km/h)	COVER CROP[2]			SUGAR BEETS[3]			
	Barley Plants/m^2	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Leaf Area (cm^2/m^2)	Damage (%)
0	140	155.6 a[1]	16.6 a	148.4 a	8.27 a	2884 a	0
55	134	119.8 b	12.5 b	123.0 c	7.09 b	2480 b	2
55 + sand	137	112.0 b	12.1 b	110.0 d	6.25 c	2220 c	16
60	131	121.7 b	12.5 b	134.1 b	7.16 b	2545 b	13
60 + sand	134	123 b	12.8 b	117.2 cd	6.38 c	2298 c	32
65	137	100.2 b	11.5 b	114.6 cd	6.44 c	2311 c	13

[1] Means within columns followed by the same letter are not significantly different at $p=0.05$ (Duncan's Multiple Range Test).

[2] Values are averaged over 2 cover crop treatments (N1, N2).

[3] Values are averaged over all cover crop treatments (N1, N2, N3).

a trend to a higher performance when beets were protected by a perpendicularly seeded cover crop (Table 26). Wind treatments without sand showed a general trend towards a decrease in beet performance with increasing wind speeds (Table 26).

Differences between cover crop treatments for 55, 60 and 65 km/h without sand were not significantly different and results were not supported by the damage rating immediately after treatment.
Damage ratings were always lowest for the perpendicularly seeded cover crops and therefore support the findings for the wind + sand treatment indicated above (Table 26). Differences in damage ratings and actual values for beet performance could be due to the greater potential for recovery when beets were subjected to wind as compared to wind and sand combined.

TABLE 25. Effect of cover crop treatments on sugar beet performance.

Treatment	COVER CROP[2]			SUGAR BEETS[2]			
	Barley Plants/m^2	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Leaf Area (cm^2/m^2)	Damage (%)
NO[3]	--	--	--	125.0 a[1]	6.71 a	2480 a	18.5
N1[4]	150	126.3	13.15	126.3 a	7.10 a	2441 a	5.2
N2[5]	117	117.8	12.82	121.7 a	6.97 a	2448 a	14.7

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (Duncan's Multiple Range Test).
[2] Values averaged over wind and sand blasting treatments.
[3] NO = no cover crop.
[4] N1 = cover crop perpendicular to beet row.
[5] N2 = cover crop parallel to beet row.

TABLE 26. Effect of different wind and sand blasting treatments on sugar beet seedlings and cover crops under different cover crop regimes.

Wind/Sand Treatment (km/h)	Treatment[2]	COVER CROP: Barley Plants/m^2	COVER CROP: Fresh Weight (g/m^2)	COVER CROP: Dry Weight (g/m^2)	SUGAR BEETS: Fresh Weight (g/m^2)	SUGAR BEETS: Dry Weight (g/m^2)	SUGAR BEETS: Leaf Area (cm^2/m^2)	SUGAR BEETS: Damage (%)
0	NO	--	--	--	8.01 abc[1]	152.3 a	3027 a	0
	N1	156	158.2 a	16.14 a	8.14 ab	139.3 ab	2767 ab	0
	N2	124	154.3 ab	16.99 a	8.59 a	153.6 a	2858 abc	0
55	NO	--	--	--	7.09 bcd	125.6 bcde	2454 cdefg	5
	N1	150	114.6 cdef	12.37 b	7.03 cd	121.1 bcde	2454 cdefg	2
	N2	118	125.0 cde	12.56 b	7.23 bcd	123.0 bcde	2532 cdef	0
55 + sand	NO	--	--	--	5.6 f	108.1 e	2161 g	29
	N1	156	102.2 ef	12.56 b	6.83 de	115.9 cde	2272 efg	6
	N2	117	121.7 cdef	11.59 b	6.38 def	106.1 e	2213 fg	15
60	NO	--	--	--	7.03 cd	135.4 abc	2624 bcd	18
	N1	150	128.9 cd	13.09 b	7.23 bcd	126.9 bcde	2441 cdefg	5
	N2	111	115.2 cdef	11.72 b	7.29 bcd	129.5 bcd	2565 bcde	16
60 + sand	NO	--	--	--	5.86 ef	116.5 cde	2265 efg	41
	N1	150	132.2 bc	13.02 b	6.90 de	126.9 bcde	2474 cdefg	17
	N2	117	113.5 cdef	12.56 b	6.31 def	108.7 e	2148 g	39
65	NO	--	--	--	6.58 def	114.6 de	2337 defg	19
	N1	156	104.2 def	11.72 b	6.64 def	117.2 de	2246 efg	2
	N2	117	97.0 f	11.39 b	6.25 def	110.7 de	2350 defg	18

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (t-test).
[2] NO = no cover crop
N1 = cover crop perpendicular to beet row
N2 = cover crop parallel to beet row

5.4.2 Experiment 2

In contrast to Experiment 1, neither the wind nor the wind + sand treatment significantly influenced cover crop fresh weight or dry matter. This inconsistency might be explained by a highly variable capability of the barley plants to recover from the wind and sand blasting (Table 27).

As in Experiment 1, there was a decrease in beet fresh weight, dry matter and leaf area when beet seedlings were exposed to wind (Table 27). With an additional sand blasting treatment reductions in these parameters were greater. For both the wind and the wind + sand treatments significant differences were determined for all measured beet parameters as compared to a control treatment. However, differences between the wind and the wind + sand treatments were not significant (Table 27). For comparison of the cover crop effect, flats without barley plants were compared to flats interseeded with barley, over all wind treatments (Table 28). No significant differences in fresh weight, dry matter and leaf area could be determined.

A comparison of all treatments demonstrated again a decrease in beet fresh weight, dry matter and leaf area when beets were treated with wind and with wind + sand (Table 29). Difference in measured beet parameters between cover crop treatments for the wind treatments 0 km/h, 55 km/h and 55 km/h + sand were not significant.

TABLE 27. Effect of wind and sand blasting on sugar beet seedlings and cover crops.

Wind/Sand Treatment (km/h)	COVER CROP[2]			SUGAR BEETS[2]			
	Barley Plants/m^2	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Leaf Area (cm^2/m^2)	Damage (%)
0	95 a	87.9 a[1]	7.81 a	137.4 a	7.42 a	2773 a	0
55	93 a	93.7 a	8.27 a	119.1 b	6.38 b	2500 b	15
55 + sand	95 a	94.4 a	8.79 a	109.4 b	6.05 b	2318 b	25

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (t-test).
[2] Values averaged over cover crop treatments.

TABLE 28. Effect of cover crop treatments on sugar beet seedlings.

	COVER CROP[2]			SUGAR BEETS[2]			
Cover Crop Treatment	Barley Plants/m^2	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Leaf Area (cm^2/m^2)	Damage (%)
NO[3]	--	--	--	124.3 a[1]	6.45 a	2558 a	13
N1[4]	95	90.5	8.27	119.1 a	6.70 a	2500 a	17

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (t-test).
[2] Values are averaged over wind and sand blasting treatments.
[3] NO = no cover crop.
[4] N1 = cover crop seeded broadcast.

TABLE 29. Effect of wind and sand blasting on protected (barley broadcast) and unprotected sugar beet seedlings and on cover crops.

Wind/Sand Treatment (km/h)	Treatment	COVER CROP			SUGAR BEETS			
		Barley Plants/m^2	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Fresh Weight (g/m^2)	Dry Weight (g/m^2)	Leaf Area (cm^2/m^2)	Damage (%)
0	NO[2]	--	--	--	146.5 a[1]	7.49 a	2923 a	0
	N1[3]	95 a	87.9 a	7.81 a	127.6 ab	7.29 ab	2624 ab	0
55	NO	--	--	--	123.7 bc	6.44 b	2584 b	21
	N1	93 a	93.7 a	8.27 a	114.6 bc	6.31 bc	2415 bc	9
55 + sand	NO	--	--	--	102.2 c	5.53 c	2168 c	25
	N1	94 a	94.4 a	8.79 a	115.9 abc	6.51 bc	2461 bc	25

[1] Means within columns followed by the same letter are not significantly different at p=0.05 (t-test).
[2] NO = no cover crop.
[3] N1 = cover crop seeded broadcast.

Chapter VI

SUMMARY AND RECOMMENDATIONS

The data obtained from the study indicate that spring barley and oats, either broadcast or seeded in rows, have potential for wind protection of sugar beet seedlings in Manitoba. These crops seeded at 15 and 30 kg/ha did not reduce stand or yield of the sugar beets. At a seeding rate of 30 kg/ha both crops produced more dry matter and provided and a denser cover than at the lower seeding rate. Therefore, seeding at 30 kg/ha is probably more suitable for wind protection.

Barley developed faster in early growth stages and produced more dry matter at the date of control. Wind speed measured at the ground surface for the denser seeding rate of the cover crops was reduced 33 percent for the oats and 42 percent for the barley.

All of the compounds tested (Table 5, page 28) adequately controlled the spring seeded cover crops without affecting the sugar beets. The cover crops should be controlled when they reach the mid- to end- of tillering growth stage, approximately two to three weeks after emergence of the beets.

Fall rye as a cover crop seeded at a rate of 30 kg/ha in the fall offered a soil cover during winter and reduced wind speed on the ground surface by 96 pecent. Fall rye could not be controlled readily and competed with the sugar beets. Therefore, fall seeded rye is not suitable as a cover crop, unless it can be controlled adequately.

Data from the wind tunnel study indicate that higher winds of 55, 60 and 65 km/h decrease the growth of sugar beet seedlings. With additional sand blasting the decrrease was aggravated. Barley as a cover crop seeded in rows perpendicular to the beet rows and the wind direction is likely to provide best protection from the wind.

Zero-tillage and minimum tillage methods also have potential for wind protection of sugar beets by taking advantage of crop residues. However, improper seed placement due to a lack of suitable equipment may result in decreased emergence. Results indicate that conditions for emergence and stand establishment were most suitable for a conventional tillage method when a standard planter was used for seeding. The harrowed, zero-tillage method exhibited a high variation between years. This was attributed to a difference in soil types and indicates that this method is unsuitable for heavier textured soils. Yield for the harrowed, zero-tillage method and the strip-tillage method were still acceptable, compared to the conventional method. Emergence, stand establishment and yields for the unharrowed, zero-tillage method were inferior.

LITERATURE CITED

ARMBRUST, D.V. 1968. Windblown soil abrasive injury to cotton plants. Agron. J. 60:622-625.

ARMBRUST, D.V. 1972. Recovery and nutrient content of sandblasted soybean seedlings. Agron. J. 64:707-708.

ARMBRUST D.V. 1977. A review of mulches to control wind erosion. Transactions of the ASAE 20:904-905,910.

ARMBRUST, D.V., DICKERSON, J.D. and GREIG, J.K. 1969. Effect of soil moisture on the recovery of sandblasted tomato seedlings. J. Amer. Soc. Hort. Sci. 94:214-217.

ARMBRUST, D.V., PAULSEN, G.M. and ELLIS, R. 1974. Physiological responses to wind and sandblast damaged winter wheat plants. Agron. J. 66:421-423.

ARMSTRONG, J. 1978. Two more ways to beat the blow. British Sugar Beet Review 46(4):46-44.

ASCROFT-LEIGH, W. J. A. 1975. The rye technique. British Sugar Beet Review 43(4):179-180.

ATKINSON, M. 1980. Oats versus the blow. British Sugar Beet Review 48(4):17.

BAEUMER, K. and PAPE, G. 1972. Ergebnisse und Aussichten des Anbaus von Zuckerruben im Ackerbausystem ohne Bodenbearbeitung (Results and aspects of growing sugar beets within a zero-tillage system). Zucker 25(22):711-718.

BAKERMANS, W.A.P. and DE WIT, C.T. 1970. Crop husbandry on naturally compacted soils. Netherl. J. Agric. Sci. 18:225-246.

BAKEWELL, D. 1980. Wind erosion control: an assessment of methods available. British Sugar Beet Review 48(3):7-9.

BARNES, J.P. and PUTNAM, A.R. 1981. Weed suppression with rye cover crops in vegetable cropping systems. Proc. North Central Weed Control Conf. 36, pp. 64.

BASTOW, J., PECK, W., ASTILL, C., BAKEWELL AND ROEBUCK, D. 1978. Wind erosion. Three methods of lessening the damage caused by the big blow. British Sugar Beet Review 46(3):14-17.

BESTE, C.E. 1974. Evaluation of no tillage vegetables in a rye cover crop. Proc. Weed Sci. Soc. Amer., Las Vegas, Nevada. Feb. 12-14, pp. 105-106.

BRADY, N.C. 1974. The Nature and Properties of Soils. Mc Millan Publishing, New York. pp. 245-250.

BRUGGEMEIER, U. 1983. Mulchsaat bei Ruben: Welche Technik auf welchem Standort (Mulch seeding of beets: which technique at which location). Top Agrar 9:44-49.

CHEPIL, W.S. 1953-55. Factors that influence clod structure and erodibility of soil by wind. Soil Sci. 75:473-483. 76:389-394. 77:473-480. 80:155-162, 413-421.

CHEPIL, W.S. 1956. Influence of moisture on erodibility of soil by wind. Proc. Soil Sci. Soc. Amer. 20:288-292.

CHEPIL, W.S. and WOODRUFF, N.P. 1963. The physics of wind erosion and its control. Adv. in Agronomy 15:211-302.

DE FRANK, J. and PUTNAM, A.R. 1979. The use of allelopathic cover crops in no tillage vegetable production.. Proc. North Central Weed Control Conf. 34:5.

DEIBERT, E.J. and GILES, J.F. 1979. A look at reduced tillage sugar beets. Crystalized Facts 30(4):26-30.

DEIBERT, E.J., GILES, J.F., LIZOTTE, D.A. and CATTANACH, N.R. 1983. Reduced tillage sugar beet production. Sugar Beet Research and Extension Reports 13:106-110.

DOWNES, J D., FRYREAR, D.W., WILSON, R.L. and SABOTA, C.M. 1977. Influence of wind erosion on growing plants. Transactions of the ASAE 20(5):885-889.

ELLIOTT, L.F., MILLER, D. and RICHARDS, A.W. 1979. Phytotoxicity of incorporated cover crops to sugar beet seedlings. Plant Disease Reporter 63(10):882-886.

FENSTER, C.R. 1975. Erosion control tillage: method and application. Proc. Soil Conserv. Soc. Amer. 30:144-146.

FENSTER, C.R. and WICKS, G.A. 1977. Minimum tillage fallow system for reducing wind erosion. Transactions of the ASAE 20:906-910.

FINNEL, H. H. 1928. Effect of wind on plants. J. Am. Soc. Agron. 20:1,206-1,210.

FORNSTORM, K.J. and BOEHNKE, R.D. 1976. A growing mulch tillage system to reduce wind erosion losses of sugar beets. Journal of the A.S.S.B.T. 19(1):65-73.

FRYREAR, D.W. 1971. Survival and growth of cotton plants damaged by windblown sand. Agron. J. 63:638-642.

FRYREAR, D.W., STUBBENDIECK, J. and MC CULLY, W.G. 1973. Grass seedling response to wind and windblown sand. Crop Science 13:622-625.

FRYREAR, D.W. and DOWNES, J.D. 1975. Estimating seedling survival from wind erosion parameters. Transactions of the ASAE 18:888-891.

FRYREAR, D.W., ARMBRUST, D.V. and DOWNES, J.D. 1975. Plant response to wind erosion damage. Proc. Soil Conserv. Soc. Amer. 30:144-146.

FRYREAR, D.W. and LYLES, L. 1977. Wind erosion research accomplishments and needs. Transactions of the ASAE 20:916-918.

GAHM, C. 1979. Erosion is a serious problem in the valley. Crystalized facts 30(2):14-14.

GILES, J.F., DEIBERT, E.J., FITTS, J.B., ENZ, J. and SMITH, L. 1980. Sugar beet production with reduced primary tillage. Sugar Beet Research and Extension Reports 11:95-102.

GILES, J.F., DEIBERT, E.J., SMITH, L., CATTANACH, N.R. and LAZOTTE, D.A. 1982. Sugar beet production with reduced primary tillage. Sugar Beet Research and Extension Reports 13:111-118.

GLENN, D.M. and DOTZENKO, A.D. 1978. Minimum versus conventional tillage in commercial sugar beet production. Agron. J. 70:341-344.

HOLLOWELL, B. 1979. Anti blow techniques work well. British Sugar Beet Review 47(3):52-54.

HUGHES, B.J. and SWEET, R.D. 1979. Living mulch: a preliminary report on grassy cover crops interplanted with vegetables. Proc. Northeastern Weed Sci. Soc. 33:109.

KAHL, H. 1951. Uber den Einfluss von Schuttelbewegungen auf Struktur und Funktion des pflanzlichen Plasmas (Influence of shaking on structure and function of the cell plasma). Planta 39:346-376.

KIMBERLIN, L.W., HIDLEBAUGH, A.L. and GRUNEWALD, A.R. 1977. The potential wind erosion problem in the United States. Transactions of the ASAE 20:872-879.

KOCHER, H., KELLER, H.M., LOTZSCH, K. and DORN, E. 1982. Mode of action and metabolic fate of the herbicide fenoxaprop ethyl Hoe 33,171. Proc. British Crop Protection Conference - Weeds.

KULLMANN, A., FICHTNER, F., LEHFELDT, J. AND MORSTEIN, K. 1978. Bekampfung der Winderosion mit synthetischen Bodenverbesserungsmitteln (Control of wind erosion with synthetic soil conditioners). Archiv fur Acker und Planzenbau und Bodenkunde 22:713-719.

LUERS, H. 1977. An effective low-cost anti-blow system. Arable Farming 4(7):14-16.

LUMKES, L.M. 1973. Bieten en ardappelen in doodgespoten rogge (Beets and potatoes in spray-killed rye). Landbouwmechanisatie 24(4):353-358.

LUMKES. L.M. 1981. Bestrijding van winderosie bij bieten met gerst (Control of wind erosion of beets with barley). Landbouwmechanisatie 32(3):223-226.

LUMKES, L.M. and TE VELDE, H.A. 1973. Akkerbouw op stuifgevoelige gronden (Arable farming on blowing soils). Proefstation voor de Akkerbouw, Publication No. 2, Sep. 1973.

LUMKES, L.M. and TE VELDE, H.A. 1974. Protection of wind erosion: minimum cultivation techniques on soils susceptible to blowing when growing sugar beet, potatoe etc. in rye as a cover crop. Proc. British Weed Control Conf. 12:1,073-1,079.

LYLES, L. 1977. Wind erosion: processes and effect on soil productivity. Transactions of the ASAE 20:880-884.

LYLES, L. and ALLISON, B.E. 1976. Wind erosion: the protective role of simulated stubble. Transactions of the ASAE 19(1):61-64.

LYLES, L. and WOODRUFF, N.P. 1960. Abrasive action of windblown soil on plant seedlings. Agron. J. 52:533-536.

MARLANDER, B., ACKMAN, I. and DEKING, G. 1981. Schutz vor Winderosion auf sandigen Boden (Protection from wind erosion on sandy soils). DLG Mitteilungen 96(14):767-769.

MARSHALL, J.K. 1967. The effects of shelter on the productivity of grasslands and field crops. Field Crop Abstracts 20:1-14.

MATTHEWS, K. and ARMSTRONG, J. 1978. Two ways more to beat the blow. British Sugar Beet Review 46(4):43-44.

MATTHEWS, K. 1983. Beating the blow. British Sugar Beet Review 51(1):67-69.

MC CALLA, T.M. and ARMY, T.J. 1961. Stubble mulch farming. Adv. in Agronomy 13:125-196.

NEURURER, H. 1982. Bitumenmulch im Planzenbau (Bitumenmulch in crop production). Planzenarzt 35(12):114-116.

PARKHURST, D.F. and PEARMAN, G.I. 1972. Tree seedling growth: effects of shaking. Science 175:918.

PICKWELL, G.C. 1974. Wind damage on sandy land. British Sugar Beet Review 42(3):177-181.

ROSENBERG, N.S. 1966. Influence of snow fence and corn windbreaks on microclimate and growth of irrigated sugar beets. Agron. J. 58:469-475.

SCHWERDTFEGER, G. 1980. Winderosion auf leichten Boden und ihre Bekampfung (Wind erosion on light soils and its control). Mitteilgn. Dtsch, Bodenkundl. Gesellsch. 30:411-420.

SETTENMEYER, H.R., BURMAN, R.D. and FORNSTORM, K.J. 1975. Water requirements for mulch and conventional sugar beets. Am Soc. of Agr. Engr., paper No. 75-2,003.

SIMMONS, S.R. and DOTZENKO, A.D. 1975. Evaluation of conservation tillage effectiveness on sugar beet fields in northeastern Colorado. Journal of the A.S.S.B.T. 18(4):307-311.

SKIDMORE, E.L. 1966. Wind and sandblast injury to seedling green beans. Agron. J. 58:311-315.

SOJKA, R.E., DEIBERT, E.J., ARNOLD, F.B. and ENZ, J. 1980. Sugar beeet production under reduced tillage - prospects and problems. North Dakota Farm Research 38:14-18.

STURNY, W.G. 1982. Sugar beet under minimum- and zero-tillage. M. Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

TALLEY, C.H. 1976. Minimum versus conventional tillage in sugar beets. M. Sc. Thesis, Colorado State University, Fort Collins Colorado.

THOMPSON, S.R. 1974. The effect of wind on grasses: mechanical damage in Festuca arundinacia. J. of Experimental Botany 25:965-972.

UNWIN, D.M. 1980. Microclimate measurements for ecologists. Acad. Press, London, New York. 97 pp.

VAN EIMER, J., KARSCHON, R., RAZUMOVA, L.A. AND ROBERTSON, G.W. 1964. Windbreaks and shelterbelts. Tech. Note 59, W. M. O. No. 147, 70TP, Secretariat of the World Metereol. Org., Geneva, Switzerland.

WADSWORTH, R.M. 1959. An optimum wind speed for plant growth. Ann. of Bot. 23:195-199.

WADSWORTH, R.M. 1960. The effect of artificial wind on the growth rate of plants in water culture. Ann. of Bot. 24:200-211.

WAISTER, P.D. 1972 a. Wind damage in horticulture crops. Hort. Abstr. 42609-615.

WAISTER, P.D. 1972 b. Wind as a limitation on the growth and yield of strawberries. J. Hort. Sci. 47:411-418.

WHITEHEAD, F.H. 1963. Experimental studies of the effect of wind on plant growth and anatomy. New Phytol. 62:80-85.

WICKENS, B. 1976. Beating the blow. British Sugar Beet Review 44(4):28-29.

WILLIS, W.O. and AMEMIYA, M. 1973. Tillage management principles: soil temperature effects. Conservation Tillage Conf. Proc., Soil Conservation Soc. of Am., pp. 22-42.

WOODRUFF, N.P. 1956. Wind blown soil abrasive injuries to winter wheat plants. Agron. J. 48:499-504.

WOODRUFF, N.P. 1975. Wind erosion research - past, present, future. Proc. Soil Conserv. Soc. Am. 30:147-152.

WOODRUFF, N.P. and SIDDOWAY, F.H. 1965. A wind erosion equation. Soil Sci. Soc. Amer. Proc. 29:602-608.

WOODRUFF, N.P., LYLES, L., SIDDOWAY, F.H. and FRYREAR, D.W. 1972. How to control wind erosion. USDA Agr. Inf. Bul. 354.

ZEDNAI, J. 1984. Manitoba Sugar Company, Winnipeg, Manitoba. Personal communications.

Appendix A

APPENDIX

TABLE 1. Influence of timing and herbicide for cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL		SUGAR BEETS			
		Stand in Plants/ha			
Herbicide	Date[2]	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Dowco 453	23/6	79000	76500	64300	43.2
	30/6	77000	75000	66300	42.1
fluazifop butyl	23/6	74300	72200	64700	42.9
	30/6	76100	73300	65700	45.7
Hoe 00736	23/6	79500	76700	66800	44.2
	30/6	74900	72200	64100	41.9
sethoxydim	23/6	79800	76900	65400	44.2
	30/6	78000	75300	65700	44.1
		n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.

TABLE 2. Influence of cover crop, cover crop density and herbicides for cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL				SUGAR BEETS			
				Stand in Plants/ha			
	Seeding Rate (kg/ha)	Herbicide for Control	Plant Density/ m^2	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)
Spring Barley	15	sethoxydim	33	74200	72300	62300	44.8
		fluazifop butyl	31	77900	75300	67900	44.7
		Dowco 453	35	77200	74900	65600	41.2
		Hoe 00736	33	76800	74200	69700	41.3
	30	sethoxydim	53	80900	78300	69000	46.6
		fluazifop butyl	57	76800	73800	66000	42.5
		Dowco 453	53	77900	75700	67100	44.0
		Hoe 00736	58	77600	75700	64900	42.0
Oats	15	sethoxydim	44	81700	78700	67100	43.6
		fluazifop butyl	43	76400	74900	65200	45.4
		Dowco 453	46	76400	74600	65200	45.9
		Hoe 00736	45	79000	76100	66000	40.0
	30	sethoxydim	83	83500	81300	70100	44.5
		fluazifop butyl	77	74200	72300	62300	45.5
		Dowco 453	73	83100	81000	66400	45.7
		Hoe 00736	73	79000	77600	67500	44.2
Rye Grass	5	sethoxydim	19	73800	71200	62300	42.6
		fluazifop butyl	17	73500	71200	65600	44.1
		Dowco 453	16	79800	76400	65600	42.4
		Hoe 00736	18	76800	73100	64100	44.2
	15	sethoxydim	19	78300	74900	64500	42.1
		fluazifop butyl	21	72300	69000	66400	43.9
		Dowco 453	26	76100	73500	63800	38.1
		Hoe 00736	21	74600	72000	61100	41.1
No Cover Crop		sethoxydim	--	79800	76100	63800	45.1
		fluazifop butyl	--	74900	72700	63000	43.7
		Dowco 453	--	75700	74200	63400	41.3
		Hoe 00736	--	76400	72700	64900	48.5
				n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

TABLE 3. Influence of cover crop, cover crop density, herbicide (Dowco 453) for cover crop control and timing of cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL					SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m^2	Height (cm)	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Spring Barley	15	23/6	34	25	79000	76100	64100	44.4
		30/6	35	30	75300	73800	67100	38.1
	30	23/6	56	25	75300	73100	65600	45.9
		30/6	49	30	80500	78300	68600	42.1
Oats	15	23/6	47	20	76800	74600	61100	44.1
		30/6	45	25	76100	74600	69400	45.8
	30	23/6	75	20	82800	80500	64100	45.2
		30/6	71	25	83500	81300	68600	46.3
Rye Grass	5	23/6	18	8	80500	78600	65600	44.1
		30/6	14	10	79000	76100	65600	40.7
	10	23/6	29	8	76800	74600	64100	39.2
		30/6	22	10	75300	72300	63400	37.0
No Cover Crop		23/6	--	--	82000	79800	63560	40.0
		30/6	--	--	69400	68600	61100	42.6
					n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in 6- to 8-leaf stage.
[3] June 23 - Cover Crops in the tillering stage.
June 30 - Cover Crops in the late tillering stage.

TABLE 4. Influence of cover crop, cover crop density, herbicide (fluazifop butyl) for cover crop control and timing of cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL					SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m^2	Height (cm)	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Spring Barley	15	23/6	35	25	80500	78300	67900	43.2
		30/6	28	30	75300	72300	67900	46.3
	30	23/6	54	25	76100	73100	63400	40.2
		30/6	59	30	77600	74600	68600	44.9
Oats	15	23/6	38	20	79800	79000	70100	46.0
		30/6	48	25	73100	70800	60400	44.8
	30	23/6	82	20	73800	71000	60400	42.9
		30/6	71	25	73100	74600	64100	48.2
Rye Grass	5	23/6	16	8	68600	67900	63400	43.6
		30/6	17	10	74600	78300	67900	44.5
	10	23/6	23	8	68600	65600	64100	42.4
		30/6	18	10	76100	72300	68600	45.4
No Cover Crop		23/6	--	--	72300	70100	63400	41.8
		30/6	--	--	77600	75300	62600	45.5
					n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.
[3] June 23 - Cover Crops in the tillering stage.
June 30 - Cover Crops in the late tillering stage.

TABLE 5. Influence of cover crop, cover crop density, herbicide (Hoe 00736) for cover crop control and timing of cover crop control on sugar beet stand and yield, 1982.

COVER CROP CONTROL					SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m^2 [3]	Height (cm)	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Spring Barley	15	23/6	34	25	77600	75300	71600	41.8
		30/6	32	30	76100	73100	67900	40.7
	30	23/6	60	25	83500	81300	65600	43.0
		30/6	55	30	71600	70100	64100	41.1
Oats	15	23/6	47	20	82000	79000	67100	40.8
		30/6	43	25	76100	73100	64900	39.2
	30	23/6	77	20	79000	77600	70800	46.1
		30/6	68	25	79000	77600	71000	42.2
Rye Grass	5	23/6	23	8	82000	77600	65600	45.5
		30/6	12	10	71600	68600	65600	43.0
	10	23/6	21	8	71600	69400	65600	44.8
		30/6	21	10	77600	74600	60400	37.3
No Cover Crop		23/6	--	--	80500	76800	61100	47.0
		30/6	--	--	72300	70100	64900	50.0
					n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.
[3] June 23 - Cover Crops in the tillering stage.
June 30 - Cover Crops in the late tillering stage.

TABLE 6. Influence of cover crop, cover crop density, herbicide (sethoxydim) for cover crop control and timing of cover crop control on sugar beet stand and yield, 1982.

	COVER CROP CONTROL				SUGAR BEETS			
					Stand in Plants/ha			
	Seeding Rate (kg/ha)	Date of Control[2]	Plant Density/ m²	Height (cm)	Emergence 19/6	Pre-Thinning 5/7	Final 12/10	Yield (t/ha)
Spring Barley	15	23/6	29	25	75300	73800	64100	46.7
		30/6	37	30	73100	70800	60400	42.8
	30	23/6	50	25	78300	76800	70800	48.1
		30/6	55	30	83500	79800	67100	45.2
Oats	15	23/6	44	20	77600	74600	64100	45.5
		30/6	43	25	85800	82800	70100	41.7
	30	23/6	86	20	85000	83500	69400	39.0
		30/6	81	25	82000	79000	70800	50.0
Rye Grass	5	23/6	15	8	77600	73800	59700	42.9
		30/6	22	10	70100	68600	64900	42.2
	10	23/6	13	8	81300	76100	64900	42.3
		30/6	25	10	75300	73800	64100	41.8
No Cover Crop		23/6	--	--	83500	79800	64900	45.1
		30/6	--	--	76100	72300	62600	45.1
					n.s.[1]	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 23 - Beets in the 4- to 6-leaf stage.
June 30 - Beets in the 6- to 8-leaf stage.
June 23 - Cover Crops in the tillering stage.
June 30 - Cover Crops in the late tillering stage.

TABLE 7. Influence of timing and herbicide for cover crop control on sugar beet stand, yield and sugar content, 1983.

COVER CROP CONTROL		SUGAR BEETS				
		Stand in Plants/ha				
Herbicide	Date[2]	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
Hoe 00736	12/6	71000	70100	65700	45.8	16.2
	17/6	70200	69100	63900	43.4	16.0
sethoxydim	12/6	72600	71400	64600	43.7	15.9
	17/6	73400	72100	67100	46.1	15.5
		n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

[2] June 12 - Beets in the 2- to 4-leaf stage.
June 17 - Beets in the 4- to 6-leaf stage.

TABLE 8. Influence of cover crop, cover crop density and herbicide (Hoe 00736, sethoxydim) for cover crop control on sugar beet stand, yield and sugar content, 1983.

COVER CROP CONTROL				SUGAR BEETS				
				Stand in Plants/ha				
	Seeding Rate (kg/ha)	Herbicide	Plant Density/ m^2	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
Spring Barley	15	Hoe 00736	39	69800	69000	65900	48.1	15.9
		sethoxydim	40	72200	71000	65500	43.8	15.7
	30	Hoe 00736	62	72400	71100	64800	43.9	16.4
		sethoxydim	67	74400	73400	66200	43.3	16.0
Oats	15	Hoe 00736	49	71000	69700	65500	43.5	16.2
		sethoxydim	52	71300	70900	64500	45.5	15.8
	30	Hoe 00736	76	70600	70000	64500	44.0	16.1
		sethoxydim	86	72500	70000	64400	46.5	15.4
No Cover Crop		Hoe 00736	--	69200	68400	63300	43.8	15.9
		sethoxydim	--	74600	73300	68700	45.4	15.7
				n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.

TABLE 9. Influence of cover crop, cover crop density, herbicide and timing of cover crop control on sugar beet stand, yield and sugar content, 1983.

COVER CROP CONTROL							SUGAR BEETS				
							Stand in Plants/ha				
	Seeding Rate (kg/ha)	Herbicide	Date of Control[2]	Plant Density/ m^2	Height (cm)	Dry Weight (g/m^2)	Emergence 5/6	Pre-Thinning 19/6	Final 6/10	Yield (t/ha)	Sugar (%)
Spring Barley	15	Hoe 00736	12/6	39	15	11.1	68900	68200	66400	49.6	16.0
			17/6	39	20	12.1	70700	69700	65400	46.5	15.8
		sethoxydim	12/6	39	15	10.1	72700	71600	64100	42.6	16.0
			17/6	41	20	12.1	71700	70400	66800	44.9	15.5
	30	Hoe 00736	12/6	60	15	17.0	73300	71900	64600	44.6	16.5
			17/6	64	20	21.0	71500	70400	65000	43.2	16.3
		sethoxydim	12/6	60	15	17.7	74900	73900	65700	42.3	16.0
			17/6	73	20	19.5	73900	72800	66700	44.3	16.0
Oats	15	Hoe 00736	12/6	55	10	9.7	71100	70500	66600	45.6	16.6
			17/6	43	15	10.2	70800	69500	64400	42.2	15.9
		sethoxydim	12/6	51	10	10.2	69100	68100	62900	44.7	16.1
			17/6	53	15	9.9	73400	71900	66100	48.3	15.5
	30	Hoe 00736	12/6	79	10	13.7	71500	70700	65900	44.6	16.2
			17/6	76	15	13.8	69700	68800	63100	42.4	16.1
		sethoxydim	12/6	86	10	16.0	71900	70500	62300	44.7	15.7
			17/6	85	15	15.2	73000	71400	66500	46.3	15.0
No Cover Crop		Hoe 00736	12/6	--	--	--	70200	69400	64900	44.7	15.8
			17/6	--	--	--	68200	67500	61800	42.9	15.9
		sethoxydim	12/6	--	--	--	74200	72800	67800	44.2	16.0
			17/6	--	--	--	75100	73800	69600	46.6	15.4
							n.s.[1]	n.s.	n.s.	n.s.	n.s.

[1] Means within columns are not significantly different at p=0.05.
[2] June 12 - Beets in the 2- to 4-leaf stage.
June 17 - Beets in the 4- to 6-leaf stage.
June 12 - Cover Crops in the 3- to 4-leaf stage.
June 17 - Cover Crops in the early tillering stage.

TABLE 10. Percentage wind speed frequencies for May, June, & July in 1982 and 1983 at Portage la Prairie.

Month		Calm	Wind Speed Frequencies km/hr						
			1-5	6-11	12-19	20-28	29-38	39-49	50-61
		%							
May	1982	6	5	31	34	20	4	+	
	1983	3	3	26	26	25	13	4	+
June	1982	9	5	34	30	17	5	+	+
	1983	10	5	29	24	23	9	+	-
July	1982	11	5	36	28	16	3	1	+
	1983	7	4	36	33	15	3	2	-

TABLE 11. Monthly percentage wind direction for May, June, & July at Portage la Prairie, (mean of 20 years: 1953 - 1972).

		Wind Direction															
Month	Calm	NNE	NE	ENE	EAST	ESE	SE	SSE	SOUTH	SSW	SW	WSW	WEST	WNW	NW	NNW	North
	%																
May	5.4	6.3	3.5	3.2	4.3	5.2	5.8	7.4	6.2	4.4	4.7	5.2	4.3	5.1	4.8	10.6	13.8
June	6.7	5.7	3.3	2.8	3.3	3.9	6.5	9.5	7.7	4.7	5.4	7.0	6.5	6.8	4.8	6.7	8.9
July	8.6	4.1	2.8	2.3	2.7	3.5	4.4	7.8	7.2	5.0	6.1	8.1	9.2	8.5	5.8	6.5	7.3

TABLE 12. Generic or code name, trade name, chemical name, active ingredient and formulation of herbicides used in the study.

Generic or Code Name	Trade Name	Chemical Name	Active Ingredient and Formulation
Desmedipham	Betanex	ethyl m-hydroxycarbanilate carbanilate (ester)	150 g/L EC
Dowco 453 ME	-	methyl 2-[4-((3 chloro-5-(trifluoromethyl)-2-pyridinyl)oxy)phenoxy]-propanoate	250 g/L EC
Endothall	Herbicide 273	7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid	360 g/L EC
Fenthiaprop Ethyl (HOE 35609)	-	ethyl 2[4(6-chloro-2-benzothiazolyloxy)-phenoxy]-propanoate	120 g/L
Fenaxoprop Ethyl (HOE 33171)	-	ethyl 2[4(6-chloro-2-benzoxazolyloxy)-phenoxy]-propanoate	60 g/L
Fluazifop butyl (TF 1169)	Fusilade	butyl 2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy]propionate	250 g/L EC
HOE 00736 (HOE 35609 + HOE33171)	-	-	180 g/L EC
Phenmedipham	Betanal	methyl m-hydroxycarbanilate m-methylcarbanilate	150 g/L EC
Sethoxydim (BAS 9052)	Poast	2-[-1-(ethoxyimino)butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexene-1-one	184 g/L EC

[1]EC = emulsifiable concentrate

TABLE 13. Maximum, minimum and mean temperature and precipitation for the growing season at Portage la Prairie in 1982.

Date	May				June				July				August				September			
	Temperature °C[1]			Rain[2] mm	Temperature °C			Rain mm	Temperature °C			Rain mm	Temperature °C			Rain mm	Temperature °C			Rain mm
	Max.	Min.	Mean		Max.	Min.	Mean		Max.	Min.	Mean		Max.	Min.	Mean		Max.	Min.	Mean	
1	23.7	0.3	12.0		13.2	4.4	8.8		27.6	8.5	18.1		21.3	11.3	16.3		16.7	6.6	11.7	2.3
2	28.3	6.1	17.2		17.6	- 0.2	8.7		24.3	17.1	20.7		22.3	16.0	19.2		20.8	8.4	14.6	
3	28.3	15.7	22.0		24.9	4.4	14.7		30.0	16.8	23.4	10.4	30.4	14.0	22.2		27.9	6.8	17.4	
4	21.8	7.8	14.8		24.1	10.7	17.4		31.6	14.0	22.8		25.5	15.3	20.4		20.8	11.2	16.0	
5	17.8	4.1	11.0		25.7	14.3	20.0	21.6	27.6	17.4	22.5	5.3	27.5	11.9	19.7		17.2	8.1	12.7	
6	10.3	0.3	5.6	1.3	16.4	12.1	14.3		24.0	12.4	18.2		28.2	18.1	23.2		15.3	6.9	11.1	
7	8.0	0.6	4.3		14.2	3.2	8.7	3.8	22.9	9.0	16.0		25.8	15.0	20.4	3.8	27.1	6.2	16.7	
8	7.6	- 0.4	3.6	1.3	11.2	0.4	5.8		23.8	9.8	16.8	0.3	20.2	11.8	16.0		30.1	11.9	23.0	
9	13.5	2.4	8.0		17.0	6.8	11.9		25.3	14.5	19.9		17.8	9.0	13.4		34.3	14.6	24.5	
10	8.1	5.7	6.9	11.2	24.2	4.4	14.3		26.2	14.4	20.3	3.8	21.5	5.6	13.6		32.3	10.4	21.4	
11	16.4	5.0	10.7		17.2	7.9	12.6		27.5	12.5	20.0		25.2	8.4	16.8		23.7	7.8	15.8	
12	17.6	1.7	9.7		24.3	4.1	14.2	0.8	28.2	15.2	21.7	6.1	20.3	14.1	17.2	1.3	20.0	5.6	12.8	
13	19.9	5.9	12.9		24.7	9.6	17.2		20.8	14.6	17.7	0.3	27.7	14.1	20.9		15.8	7.8	11.8	
14	21.9	8.3	15.1		21.2	8.7	15.0		24.9	9.4	17.2		31.0	15.1	22.6	23.4	11.3	- 0.8	5.3	
15	13.1	8.8	11.0	10.7	20.4	6.3	13.4	0.8	29.8	18.2	24.0	20.3	24.4	14.2	19.3		15.2	- 2.9	6.2	
16	14.0	9.9	12.0		22.9	10.3	16.6		25.3	16.4	20.9		26.0	14.4	18.7		20.8	5.2	13.2	
17	12.5	9.4	11.0	7.6	13.7	6.4	10.1		22.1	12.6	17.4		29.9	12.8	20.4	2.0	13.5	5.8	9.7	2.8
18	14.9	8.8	11.9		18.9	8.5	13.7		23.7	9.4	16.6	25.7	28.7	16.9	22.8	0.8	21.4	7.9	14.7	
19	13.9	7.5	10.7		15.8	10.3	13.1	6.9	26.8	12.5	19.7		26.1	13.6	19.9		13.2	1.7	7.5	3.1
20	19.6	6.0	12.8		19.8	8.9	14.4		25.3	16.0	20.1		25.6	11.9	18.8		17.8	0.1	9.0	
21	22.3	4.2	13.3		20.2	7.5	13.9		22.8	12.8	17.8		23.8	13.7	18.8	17.3	23.4	5.8	14.6	
22	24.7	6.1	15.4		19.5	7.8	13.7	0.8	23.2	11.7	17.5	4.6	21.8	12.3	17.2		24.4	4.4	14.4	0.6
23	25.5	6.3	15.9		28.7	11.5	20.1		26.8	16.8	21.8		22.1	9.1	15.6		14.4	9.1	11.8	
24	21.5	11.5	16.5		18.0	6.9	12.5		27.7	17.5	22.6		18.3	11.0	14.7	0.3	14.0	1.0	7.5	
25	26.3	8.8	17.6		23.2	4.2	13.7		24.6	14.5	19.6		13.0	4.2	8.8		18.4	3.0	11.7	
26	27.8	13.1	20.5		25.2	12.7	19.0	0.5	27.5	12.6	20.1	34.5	16.0	3.2	8.4		15.1	5.8	10.5	
27	28.1	12.0	20.1		23.4	10.8	17.1		25.3	15.7	20.5		14.9	1.4	8.2		7.4	4.4	5.9	36.5
28	22.9	11.5	17.2		21.0	10.5	15.8		26.9	12.8	19.9	43.2	20.7	4.9	12.8		13.2	4.6	8.9	8.0
29	19.3	8.2	13.8	2.3	19.6	6.4	13.0		23.2	12.2	17.7		19.7	5.6	12.7		10.8	3.9	7.4	
30	16.2	6.9	11.6		24.0	4.2	14.1		26.3	12.9	19.6		17.1	4.5	10.8		7.9	1.4	4.7	
31	11.3	3.4	7.4	0.3					30.0	15.9	23.0		24.5	8.3	16.4					
	18.6	6.7	12.7	34.7	21.0	7.5	13.9	35.2	25.9	13.7	19.8	154.5	23.1	10.9	17.0	48.9	18.8	5.9	12.4	53.3

[1] From Canadian Forces Base, Portage la Prairie.

[2] From the field station, Portage la Prairie.

TABLE 14. Maximum, minimum and mean temperatures and precipitation for the growing season at Portage la Prairie in 1983.

Date	May Temperature °C[1] Max.	Min.	Mean	Rain[2] mm	June Temperature °C Max.	Min.	Mean	Rain mm
1	16.7	-3.2	6.8		21.4	2.5	12.0	
2	20.3	-0.5	9.9		23.8	6.7	15.3	6.2
3	9.8	-2.0	3.9		17.6	8.2	12.9	
4	11.8	-7.0	2.4		14.3	4.4	9.4	
5	13.2	0.9	7.1		17.7	2.0	9.9	
6	13.2	-1.6	5.8		21.5	5.4	13.5	
7	12.5	-3.6	4.5		26.7	4.2	15.5	1.6
8	20.8	-1.9	9.5		20.1	10.9	15.5	
9	20.3	10.3	15.3		27.9	8.7	18.4	
10	21.8	7.8	14.8		32.8	16.7	24.8	
11	4.2	-1.1	1.6		32.8	17.4	25.1	
12	4.1	-1.5	1.3	17.0	28.4	17.3	22.9	0.4
13	4.7	-2.0	1.4		17.9	12.6	15.3	4.9
14	-0.4	-5.5	-3.0		22.8	9.3	16.1	10.8
15	5.8	-8.9	-1.6	1.2	14.1	5.7	9.9	
16	12.5	-4.9	3.8		20.1	4.4	5.7	
17	21.4	4.1	12.8		25.9	8.6	17.3	
18	23.7	3.8	13.8		27.0	9.0	18.0	
19	10.6	1.2	5.9		22.9	15.5	19.2	7.5
20	19.1	-2.9	8.1		26.5	13.5	20.0	0.9
21	20.8	6.2	13.5		26.3	12.8	19.6	13.3
22	19.2	3.5	11.4		24.9	14.2	19.6	
23	21.4	5.2	13.3	4.5	26.3	11.8	19.1	
24	12.1	1.6	6.9		27.3	15.9	21.6	
25	20.0	-0.5	9.8		26.6	18.1	22.4	
26	25.2	9.1	17.2	1.0	22.3	12.0	17.2	
27	23.7	7.3	15.5		22.3	10.0	16.2	
28	17.8	6.8	12.3		25.0	12.7	18.9	
29	14.2	6.9	10.6		21.2	11.4	16.3	12.0
30	14.0	8.5	11.3		17.5	14.2	15.9	1.6
31	17.7	4.1	10.9					
	17.0	4.6	10.8	37.9	22.9	10.6	16.8	58.8

Date	July Temperature °C Max.	Min.	Mean	Rain mm	August Temperature °C Max.	Min.	Mean	Rain mm	September Temperature °C Max.	Min.	Mean	Rain mm
1	23.0	14.4	18.7		31.3	16.0	23.7		33.2	19.8	26.5	
2	19.2	15.4	17.3		32.6	18.8	25.7		37.8	15.0	26.4	
3	25.9	16.5	21.2	20.8	33.7	19.5	26.6		28.0	14.8	21.4	
4	19.1	7.1	13.1	0.2	40.2	22.6	31.4		28.0	12.7	20.9	
5	22.4	3.5	13.0		30.6	17.2	23.9		21.6	10.7	16.2	
6	33.4	12.8	23.1		37.2	15.7	26.5		17.7	9.6	13.7	2.2
7	30.7	17.8	24.3		30.0	17.2	23.6		26.3	7.3	16.8	
8	31.8	17.7	24.8		26.2	12.6	19.4		17.7	8.9	13.3	7.8
9	30.4	18.8	24.6		28.1	16.6	22.4		19.2	5.4	12.3	
10	33.2	18.9	26.1	3.0	25.3	13.9	24.6		15.5	8.3	11.9	
11	24.7	16.0	20.4		29.7	11.5	20.6		16.1	6.0	11.1	
12	32.8	14.0	23.4		32.0	16.3	24.2		17.2	4.1	10.7	2.6
13	31.0	19.9	25.5		28.1	14.1	21.1		15.1	3.8	9.5	3.2
14	32.8	17.7	25.3		33.6	12.9	23.3		17.2	0.4	8.8	6.7
15	34.4	20.2	27.3		31.6	15.8	23.7		12.7	9.3	11.0	2.3
16	26.4	15.7	21.1		26.0	14.7	20.4	2.0	15.7	6.8	11.3	
17	28.2	13.4	20.8		33.9	15.1	24.5		17.0	8.8	12.9	
18	27.8	14.3	21.1		37.2	14.6	25.9		13.1	6.3	9.7	
19	29.3	16.7	23.0		25.0	12.0	18.5		10.5	4.0	9.3	
20	31.9	18.3	25.1		15.1	10.0	12.6	25.2	8.8	4.0	6.4	0.4
21	32.3	18.3	25.3		25.8	12.4	19.1		7.4	2.4	4.9	
22	31.0	16.1	23.6		26.2	10.4	18.3		11.0	0.4	5.7	
23	24.7	15.0	19.9		24.7	15.1	19.9	9.7	18.8	8.1	10.5	
24	26.4	12.8	19.6		27.8	16.4	22.1	0.1	23.3	8.4	13.4	
25	31.0	14.2	22.6		31.4	16.6	24.0		22.3	8.8	15.6	
26	29.0	19.4	24.2		29.0	16.5	27.8		27.6	8.2	17.9	
27	31.8	18.9	25.4		31.9	15.0	23.5		25.4	10.2	17.8	1.8
28	31.4	16.1	24.3		31.2	15.5	23.4	9.6	19.5	5.5	12.5	
29	27.9	15.1	21.5		29.2	17.1	23.2		6.8	1.5	4.2	5.8
30	27.4	15.9	21.7	10.0	30.2	14.4	22.3	3.7	7.6	2.2	4.9	10.4
31	27.2	14.9	21.0		35.6	17.1	26.4					
	25.6	13.5	39.1	34.0	24.7	12.0	18.4	50.3	18.6	7.0	12.8	43.2

[1]From Canadian Forces Base, Portage la Prairie.

[2]From the field station, Portage la Prairie.