PEST MANAGEMENT OF WHEAT STEM SAWFLY, *CEPHUS CINCTUS* NORTON (HYMENOPTERA: CEPHIDAE), IN WESTERN NORTH DAKOTA

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Joseph Henry Stegmiller

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Janet J. Knodel
Chair

Dr. David A. Rider

Dr. Malcolm G. Butler

Dr. David K. Weaver

Approved:

11 Jan 2013 — Dr. Frank Casey

Date — Department Chair

ABSTRACT

The wheat stem sawfly, *Cephus cinctus* Norton, is regarded as a major pest of dryland wheat in the Upper Great Plains. For peak emergence of wheat stem sawfly, the most accurate base was 0 C using air temperature, and then degree-day base of 0 C using soil temperatures. For *Bracon cephi*, the most accurate base temperature was the lower degree-day base using air (0 C) and soil (0 C) temperatures. The solid-stemmed varieties, Mott and Choteau, exhibited the highest stem solidity and also experienced the lowest percentage of wheat stem sawfly damaged stems. The hollow-stemmed varieties, Glenn, Reeder and Steele ND, had the lowest levels of solidity and usually the highest percentage of wheat stem sawfly damaged stems. When wheat stem sawfly populations were high, the solid-stemmed wheat varieties, Mott and Choteau, had yield, test weight, and protein that were comparable to the hollow-stemmed varieties, Glenn, Reeder and Steele ND.

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GENERAL INTRODUCTION

The wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae), is regarded as a major pest of wheat and other cereals in the Upper Great Plains (Beres et al. 2011). *Cephus cinctus* exhibits a unique life cycle, in that the larva is protected within the stem, which limits the methods of management that can be utilized by growers. Before the 1980's, the wheat stem sawfly primarily infested spring wheat, but recently it has become more prevalent in durum and winter wheat (Morrill et al. 1998). Common pest management strategies for control of agricultural pests, such as insecticide application are not recommended, because of the long window of emergence and short life span of adults (Knodel et al. 2009). As a result, wheat stem sawfly research has focused on cultural control, biological control, and host plant resistance.

The first objective of this study was to determine a degree day model for emergence of adult wheat stem sawfly and for one of specialist parasitoid, *Bracon cephi* (Gahan) (Hymenoptera: Braconidae). This will be useful for timing when to scout for adult wheat stem sawflies and to determine potential infestation and damage risks when population densities are high. Growers will be able to adapt their practices to deter wheat stem sawfly damage by other strategies, such as swathing fields before harvest to prevent lodging and yield losses.

The second objective of this study is to correlate the stem solidity of wheat with sawfly infestation and the level of damage caused by wheat stem sawfly. Wheat stem sawfly resistant varieties of wheat that are solid-stemmed have more pith within the stem, which make them less susceptible to wheat stem sawfly damage. This study compared the percentage of damaged stems between resistant solid-stemmed and susceptible hollow-stemmed varieties of hard red spring wheat varieties. In addition to wheat stem sawfly infestation, agronomic data for these hard red spring wheat varieties were collected at multiple sites, providing varying population levels of wheat stem sawfly, along with different weather conditions across environments.

LITERATURE REVIEW

Wheat Production

Wheat, *Triticum aestivum* L., plays a major role towards the economy of North Dakota and the surrounding Great Plains states. A total of 8.4 million acres of wheat is grown in North Dakota annually and valued at 2.3 billion U.S.dollars (USDA NASS 2011). North Dakota ranks in the top two states for wheat production in the U.S. Wheat is planted on more than 45.7 million acres of land each year in the U.S., and is valued at 14.4 billion U.S. dollars (USDA NASS 2011).

Natural History of Wheat Stem Sawfly

The first recorded documentation of wheat stem sawfly infesting wheat was made in 1895 in Canada near Souris, Manitoba, and Indian Head, Saskatchewan (Ainslie 1920). Since then, growers of the Upper Great Plains have been battling the negative impacts of wheat stem sawfly.

Wheat stem sawfly is included in the tribe Cephini, which includes three other grass-mining species found in North America (Ivie 2001). The earliest record of wheat stem sawfly infesting wheat in North Dakota was in 1906 (Wallace 1966). Today, wheat stem sawfly infestation occurs primarily in the western wheat growing areas of North Dakota. Hosts attacked by wheat stem sawfly include native grasses and cultivated cereals. Downy brome grass, *Bromus tectorum* L., has been identified as a marginal alternative host for the wheat stem sawfly (Perez-Mendoza et al. 2006). Wheat stem sawfly most frequently targets wheat as its host and is considered a major insect pest in North Dakota. Areas where wheat stem sawfly is economically important include Montana, North Dakota, Alberta, Saskatchewan, and Manitoba (Shanower and Hoelmer 2004). Currently, wheat stem sawfly is expanding its range further south into South

Dakota, Nebraska, and Colorado. It is not known whether the wheat stem sawfly is a native species that adapted to wheat or if the species was introduced from overseas (Beres et al. 2007).

Economic Importance of Wheat Stem Sawfly

After oviposition, damage caused by the larva begins when it starts to feed on parenchyma tissue. Wheat stem sawfly infested stems showed a 12% lower photosynthetic rate than uninfested stems (Macedo et al. 2006). Head weight of winter wheat was found to be 2.8-10% lower when infested by wheat stem sawfly compared to uninfested winter wheat (Morrill et al. 1992).

The most obvious damage attributed to wheat stem sawfly infestation occurs when the larva cuts a groove around the inside of the stem near ground level, which makes the plant more susceptible to lodging (Ainslie 1920, Delaney et al. 2008, McCallum and DePauw 2008). When plants lodge, harvest becomes more difficult or impossible due to wheat heads on the ground. Lowering the header of the combine to pick up lodged plants increases the likelihood of damaging the equipment. Also, when plants lodge, seeds are scattered on the ground, which could result in more volunteer wheat for the upcoming growing season.

The majority of wheat stem sawfly damage is concentrated towards the edge of the field. This phenomenon is known in ecology as an edge effect. This edge effect has previously been explained by the short life span and weak flying capabilities of wheat stem sawfly (Ainslie 1920). However; the edge effect can also be explained by their foraging strategy (Nansen et al. 2005).

Life Cycle of Wheat Stem Sawfly

Adults emerge in the spring, typically mid-to late June in North Dakota, from the stubble of last year’s cereal crop. As they emerge, they will fly to adjacent fields of spring wheat (Beres et al. 2011). Males typically emerge earlier than females (Piesik et al. 2008). After the adults mate, females will often deposit their eggs in the upper most internode of the plant (Beres et al. 2007). Eggs can be laid either as fertilized diploid egg that will develop into females or as unfertilized haploid eggs that will develop into males (Beres et al 2011). Females use a saw-like ovipositor to puncture the wheat stem and insert an egg inside the stem. Typically, eggs are laid in the stem elongation phase of wheat development. Although a female will only lay one egg in each stem, multiple female sawflies may lay an egg in the same wheat stem (Buteler et al. 2009). This often results in the larger larvae cannibalizing the other smaller larvae (Shanower and Hoelmer 2004). Studies have shown that ovipositing females prefer larger diameter stems to lay eggs that will develop into females (Morrill et al. 2000).

The larva will feed on the parenchyma tissue throughout the stem and later move down to the base (Beres et al. 2007). When larvae of the wheat stem sawfly bore within the stem, a reduction of 10-20% in photosynthetic rate was observed (Macedo et al. 2006). When the infested wheat plant starts to mature, the larva is triggered to move down the plant based on increasing light that is transmitted through the stem (Holmes 1975). As the larva moves down the stem towards the base in late summer, it cuts a notch around the base of the stem, which will increase the chances of the wheat lodging. It then will plug the cut stem with frass. This plug is used as an exit for the adult wheat stem sawflies the following year (Morrill et al. 1998). During the winter, the larva goes through obligatory diapause inside a thin membrane within the stem lumen (Shanower and Hoelmer 2004).

Integrated Pest Management of Wheat Stem Sawfly

Integrated Pest Management (IPM) combines aspects of numerous disciplines to form a multi-dimensional approach for managing pests.

Chemical Control

The life cycle of the wheat stem sawfly makes it a difficult pest to control using insecticides. As an adult, the wheat stem sawfly does not have functional mouth parts and subsequently do not eat or drink water (Wallace 1966). The egg, larva, and pupa reside inside the stem, which protects them from threats from the external environment, such as weather or insecticides (Knodel et al. 2010). These traits make insecticide usage not only ineffective but economically impracticable. Currently, there are no insecticides recommended for control of wheat stem sawfly (Knodel et al. 2009).

Studies conducted in the 1950's and 1960's showed that certain insecticides, heptachlor and parathion, showed significant, but inconsistent reductions in wheat stem sawfly damage (Holmes and Peterson 1963, Wallace 1962, Holmes and Hurtig 1952). However, these insecticides are no longer available due to Environmental Protection Agency (EPA) regulations.

Foliar broadcast treatments have been proven to provide little efficacy in decreasing wheat stem sawfly damage (Wallace 1962, Knodel et al. 2009). This is due to the relatively long window of emergence of wheat stem sawfly adults (up to six weeks) and the short life-span of adults (usually one week). Chemical treatments would require multiple applications during the emergence period. A field demonstration conducted at Mott, ND showed a net loss of $13.50 per acre when pyrethroid insecticide (zeta-cypermethrin, active ingredient) was applied three times during the emergence period of wheat stem sawfly (Knodel et al. 2010). Another disadvantage of using insecticides is the unwanted damage to beneficial insects that naturally attack wheat stem sawfly and other insect pest populations.

Cultural Control

For cultural practices, fall or spring tillage has been used as a means of control. However, there are mixed reviews on how effective this practice is. Tilling the field will disrupt the soil and the stubble, exposing wheat stem sawflies to the weather and predators. Tillage was recommended to a depth of 15 cm to bury stubs underground (Criddle 1922). A variety of equipment has been evaluated to determine which is more efficient. However, the main factor for management is to separate soil from the base of stems (Shanower and Hoelmer 2004). This method will kill some larvae, but the majority will still survive. The main disadvantage to tilling is soil erosion. Another downfall to tillage is that it can be detrimental to native parasitoids that feed on wheat stem sawflies (Runyon et al. 2002). The trend for minimal tillage in recent years has had an extensive impact on the populations of both wheat stem sawfly and its natural enemies. Populations of wheat stem sawfly may be better sustained as overwintering larvae in undisturbed stubble to enhance biological control (Beres et al. 2009).

Planting Date

Delaying the time of seeding has proven to reduce damage caused by wheat stem sawfly (Jacobson and Farstad 1952). Delaying the planting date by 14-15 days does not significantly reduce yield (Morrill and Kushnak 1999). However, in temperate climates with short growing seasons this approach is economically risky (Beres et al. 2007).

Burning

Early recommendations consisted of burning any stubble that was not plowed under during the fall (Beres et al. 2011). However, Ainslie (1920) showed little mortality of wheat stem sawfly larvae from fire. Also, burning resulted in soil erosion and destruction of natural enemies (Beres et al. 2011).

Host Plant Resistance

One of the most practical and effective strategies to mitigate wheat stem sawfly damage is host plant resistance through the use of solid-stemmed wheat varieties. There are three different mechanisms that plants can be resistant to insect damage. One way is through antibiosis, which occurs when a plant affects the biology of the insect (Painter 1958). Antixenosis is another mechanism of resistance, this is when a plant is not preferred by an insect (Painter 1958). Plants can also be resistant through tolerance, this happens when a plant can undergo levels of damage that would severely injure a susceptible plant (Painter 1958). Solid-stemmed wheat varieties control wheat stem sawflies through preventing larvae from moving down to the base of the plant, thus inhibiting further life stages, which is antibiosis.

Varieties with more pith inside the stem have greater mortality of wheat stem sawfly larvae (Holmes and Peterson 1962). Solid-stemmed varieties reduced stem cutting and female fecundity (Carcamo et al. 2005). The solidity of the lower internodes is crucial for minimizing wheat stem sawfly damage (Wallace 1966). Hollow-stemmed varieties also showed significantly more lodging then solid-stemmed varieties (Beres et al. 2007). Carcamo et al. (2011) found that overwintering mortality and cold hardiness of wheat stem sawfly larvae was not affected by solid-stemmed varieties.

Growers have been reluctant to utilize solid-stemmed wheat varieties because of the lower yield (Weiss and Morrill 1992, Beres et al. 2009). This proves to be an important factor that negatively affects grower’s decisions on wheat variety selection and whether to sacrifice yield for less wheat stem sawfly damage. The first commercially available solid-stemmed wheat variety was Rescue, which was released in the late 1940’s (Beres et al. 2009). Wheat varieties with hollow stems allow wheat stem sawflies to develop into larger larvae, while the solid-stemmed varieties inhibit growth of the larvae resulting in smaller larvae (Carcamo et al. 2005).

Planting Strategies

The practice of incorporating more than one variety or crop into a field to combat pest damage has been gaining popularity. Instead of planting whole fields into solid-stemmed wheat varieties, the fields' outer margins are planted with solid-stemmed varieties, while the inner portion of the field is planted to a hollow-stemmed variety to take advantage of the field edge behavior exhibited by the wheat stem sawfly (Nansen et al. 2005). The process of planting blends, using two varieties of wheat instead of a monoculture, reduces damage to only a moderate degree (Beres et al. 2007).

Another strategy to take advantage of the edge effect of wheat stem sawfly is to combine narrow strip fields into wider block fields to reduce the amount of surface area to overall area (Runyon et al. 2002, Weaver et al. 2004). This allows a larger proportion of wheat to avoid any edge effect and thereby mitigating wheat stem sawfly infestation and damage.

Using trap crops have also been utilized. Trap cropping consists of planting solid-stemmed wheat or another species of cereal around the field's perimeter to deter wheat stem sawfly infestation (Criddle 1922, Nansen et al. 2005, Beres et al. 2009). The resistance of cultivated oat, *Avena sativa*, against wheat stem sawfly has been documented in numerous experiments (Wallace and McNeal 1966, Weaver et al. 2004).

Biological Control

<u>Introduction</u>

The wheat stem sawfly rapidly adapted from native grasses towards wheat, but the natural enemies have adapted more slowly. Parasitism levels approached nearly 100% in wild grasses, but were observed at less than 2% in wheat (Criddle 1923). The vast change to the natural landscape of the north Great Plains has had a tremendous impact on the tritrophic interaction between hosts (native grasses versus wheat), wheat stem sawflies, and its parasitoids (Morrill et al. 1998).

There are nine hymenopteran parasitoids known to parasitize wheat stem sawfly larvae infesting native grasses (Morrill et al. 1998). *Bracon cephi* (Gahan) is currently the most abundant parasitoid of wheat stem sawfly in North Dakota (Beres et al. 2011). Another parasitoid that attacks wheat stem sawflies in wheat is *Bracon lissogaster* Muesebeck (Somsen and Lugenbill 1956). Parasitoid levels are heavily influenced by environmental conditions (Homes et al. 1963).

Biology of *Bracon cephi* and *B. lissogaster*

Both species of braconid wasps are host specific ectoparasitoids of the wheat stem sawfly (Buteler et al. 2008). The female parasitoid locates the wheat stem sawfly larvae in the stem by traversing the stem and inserting her ovipositor into an infested stem and injects the larvae with venom, thus paralyzing it (Beres et al. 2011). The parasitoid egg is laid near or on the paralyzed larva and after the egg hatches, the parasitoid larva starts to feed (Beres et al. 2011). *Bracon cephi* will lay one egg per larva, while *B. lissogaster* may lay several eggs per larvae (Nelson and Farstad 1953). Both parasitoid larvae are protected within the stem for their entire development. Parasitism can cause significant mortality of wheat stem sawfly larvae and be important for its biological control (Peterson et al. 2011).

Both *B. cephi* and *B. lissogaster* exhibit a bivoltine life cycle. The first generation of parasitoids is synchronized with the emergence of sawflies (Beres et al. 2011). The second generation of *B. cephi* emerges in August, which may be negatively affected by early harvest or fall tillage (Beres et al. 2011).

Predators of Wheat Stem Sawfly

The clerid beetle, *Phyllobaenus dubius* (Wolcott) (Coleoptera: Cleridae), has recently been observed feeding on wheat stem sawflies larvae in wheat stems and stubs (Morrill et al. 2001). However, the economic importance of *P. dubius* is uncertain (Morrill et al. 2001). Clerid beetles are generalist predators and do not usually specialize on any one host.

Plant Pathogens that Infect Wheat Stem Sawfly

Certain *Fusarium* spp. are known to be entomopathogens (Teetor-Barsch and Roberts 1983). Larvae that were collected from the field showed signs of *Fusarium* fungal growth (Wenda-Piesik et al. 2009). *Fusarium* species were found to cause lethal mycoses of wheat stem sawfly larvae (Wenda-Peisik et al. 2009). Since *Fusarium* species are the causal agent of several diseases of wheat (for example, root rot, head scab), these pathogens are unlikely to be manipulated for biological control.

DEGREE DAY MODEL FOR EMERGENCE OF *CEPHUS CINCTUS* NORTON (HYMENOPTERA: CEPHIDAE) AND *BRACON CEPHI* (GAHAN) (HYMENOPTERA: BRACONIDAE)

Abstract

The wheat stem sawfly, *Cephus cinctus* Norton, is regarded as a major pest of dryland wheat in the Upper Great Plains. The objective of this research is to determine the most accurate weather parameters, degree day base, and degree day accumulations for predicting the first and peak occurrences of the adult wheat stem sawfly and its specialist parasitoid, *Bracon cephi* (Gahan). Temperature data (air and soil temperatures) were accumulated at five locations throughout western North Dakota over two years (2010 and 2011). The Julian date and the degree day accumulations at four different base temperatures (0 C, 4.4 C, 7.2 C, and 10 C) were used to determine the most accurate base for predicting emergence of wheat stem sawfly and *B. cephi*. The first occurrence of wheat stem sawfly was observed from mid-June to late June, and peak occurrence during late June to early July. The most accurate degree day base for predicting first emergence of wheat stem sawfly was a degree day base of 4.4 C using air temperature, and then degree-day base of 0 C using soil temperatures. For peak emergence of wheat stem sawfly, the most accurate degree day base was of 0 C using air temperature, and then degree-day base of 0 C using soil temperatures. For the adult *B. cephi*, the lower degree-day base of air (0 C) and soil (0 C) temperatures were determined to be the best estimates for the first and peak emergence of *B. cephi.*

Introduction

The wheat stem sawfly, *Cephus cinctus* Norton, is regarded as a major pest of wheat in the upper Great Plains (Runyon et al. 2002). The unique life cycle of the wheat stem sawfly has limited the pest management strategies that can be utilized by the grower. That is why Integrated Pest Management (IPM) has proven to be essential when dealing with the wheat stem sawfly. Numerous strategies are utilized in IPM to allow for better control of pest insects. Having an accurate means of predicting emergence of pest insects is crucial for an IPM approach. This will allow for better timing of scouting and management practices based on insect abundance.

The adult female wheat stem sawfly lays its egg inside the stem of a grass plant (Holmes 1975). After the egg hatches, the larva feed on the parenchyma tissue of the plant (Beres et al 2007). As the plant matures, the larva migrate down towards the base of the plant (Buteler et al. 2008). The larva will then cut a notch around the base of the stem, which causes the plant to lodge. Larvae begin an obligatory diapause inside the wheat stubble, which is terminated after a long exposure to low temperatures (Salt 1947). Although larvae overwinter protected inside the stem, weather conditions still effect the development of larvae (Seamans 1945). Temperature effects the duration of diapausing larvae of the wheat stem sawfly (Perez-Mendoza et al. 2006). During obligatory diapause, the pre-pupa is inside thin membrane within the stem lumen (Shanower and Hoelmer 2004). After at least 90 days of exposure to 10 C or less, the larva can complete diapause (Beres et al. 2011). After diapause, pupae develop in late May (Holmes 1979).

Adult wheat stem sawflies emerge from the stubble of the previous year’s crop. If crop rotations are utilized, wheat stem sawflies will then emigrate to a surrounding cereal crop. If crop rotation is not utilized and wheat is followed by wheat, then wheat stem sawflies do not have to travel to find suitable hosts.

Materials and Methods

Location

Five sites were chosen in Western North Dakota, which had high populations of wheat stem sawfly during previous years. The sites included: Scranton (Bowman Co.), Mott (Hettinger Co.), Regent (Hettinger Co.), Hettinger (Adams Co.), and Makoti (Ward Co.) (Fig. 1).

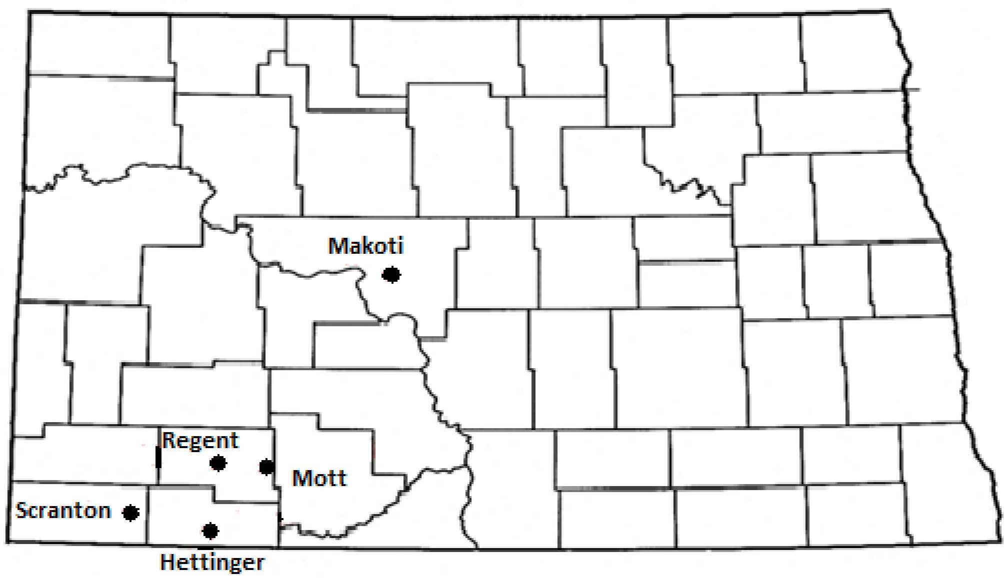

Figure 1. Map of sampling locations.

Sampling

Sweep-net sampling was conducted biweekly to monitor adult wheat stem sawfly populations in a 100 m by 50 m block of a hollow-stemmed hard red spring wheat variety, Steele ND. Twenty sweeps with a 38 cm sweep net were conducted at ten spots in the field for a total of 200 sweeps per field visit. These sweeps were conducted from June until wheat stem sawflies and parasitoids were no longer captured. Insects were placed in 4 liter plastic zip lock bags, which were be labeled with the date, location and crop stage and then stored in a freezer.

Sample Processing

Samples from sweeping were sorted to find all species of interest. Wheat stem sawflies were sorted by sex and the total number of each was recorded. *Bracon* spp. parasitoids were separated and identified under a dissecting microscope to determine whether they were *B. cephi* or *B. lissogaster*. The clerid beetles, *P. dubious*, were pinned and identified by Dr. G. Fauske of the Department of Entomology, NDSU. Voucher specimens were deposited in the North Dakota Insect Museum at NDSU.

Temperature Recording

Air and soil temperatures were collected in 2010 field season by using WatchDog 450 series data loggers (Spectrum Technologies, Inc Plainfield, IL). During the 2011 field season, WatchDog 1000 series data loggers were used. In 2010, data loggers were fastened to PVC pipes approximately 1.07 m above the ground. In 2011, steel fence posts (1.5 m high) were used to situate data loggers in field. The WatchDog soil temperature sensor was placed two inches below the soil surface. Data loggers recorded temperature readings every half an hour, 24 hours a day. Data was transferred from the Watchdog data loggers onto a laptop at an interval of once a month. Data were uploaded to Microsoft Excel where the maximum and minimum temperatures for each day were found. On certain occasions (e.g., the data logger was hit by the sprayer boom), the soil temperature sensor became unplugged from the data logger which left gaps in the recordings. In these situations, data from the closest North Dakota Agricultural Weather Network (NDAWN) was substituted for the missing data. The NDAWN weather station in Mott was used for the Mott (Grant Co.) and Regent (Hettinger Co.) sites. The Mott field site was about 5 km from the Mott NDAWN field site, whereas the Regent field site was about 24 km from the Mott NDAWN site. The NDAWN weather station in Hettinger was used for Hettinger (Adams Co.) and Scranton (Bowman Co.) sites. The Hettinger field site was about <1 km from Hettinger NDAWN. Scranton field site was about 45 km from the Hettinger NDAWN site. The NDAWN weather station in Plaza was used for the Makoti (Ward Co.) site, which was about 42 km from the NDAWN site.

From the data that were collected, the Growing Degree Days (GDD) were calculated using the following formula from Pedigo (2008).

$$GDD = [(T_{MAX} + T_{MIN})/2] – Th$$

When: $T_{MAX} > Th, T_{MIN} > Th$

$$GDD = [(T_{MAX} + Th)/2] – Th$$

When: $T_{MAX} > Th, T_{MIN} < Th$

$$GDD = 0$$

When: $T_{Max}<Th$

This method uses a daily mean temperature that is found using the maximum and minimum temperature from each day. The Threshold Temperature (Th), which represents the minimum temperature at which the insect will develop, is then subtracted from the daily mean temperature. A total of four potential threshold temperatures were used to determine which one produced the most constant degree day accumulations for emergence of wheat stem sawfly and *B. cephi*. The threshold (base) temperatures included: 0 C (32 F), 4.4 C (~40 F), 7.2 C (~45 F), and 10 C (50 F). These threshold temperatures are common bases that are typically used in IPM (Pruess 1983), The different models based on calendar date (Julian dates) and various degree-day summations were compared using Arnold's Method (Arnold 1959). Arnold's Method (1959) states that the best estimate for the actual development threshold temperature is the one with the lowest coefficient of variation [C.V. = (standard deviation/mean) x 100].

Results

Numerous environmental factors can impact insect populations (Pedigo 2008). Weather conditions, such as wind and temperature play a major role in the number of insects collected by sweep net sampling (Pedigo 2008). In our study, the majority of samples were taken during the afternoon in the absence of inclement weather. However, a small proportion of samples were taken during adverse weather conditions, such as high wind, which resulted in a lower densities of wheat stem sawfly adults and other insects collected.

Populations of wheat stem sawfly can be highly sporadic within their geographic distribution. Numerous ecological factors contribute to individual populations. Since populations varied from field to field, data are presented for each individual location (5) from 2010 and 2011.

2010 Field Season

In 2010, all sites (5 total) sampled had substantial populations of wheat stem sawflies with Mott and Regent field locations having the highest populations (Fig. 2). On 18 June, sweep net samples were taken from Mott, Regent, Scranton, and Hettinger, field sites had lower number of insects per 200 sweeps due to inclement weather conditions and high winds.

Mott

Wheat stem sawflies were first observed at Mott on 11 June, with peak population occurring on 28 June (Table 1). Peak populations at Mott contained 775 individuals collected in 200 sweeps (Fig. 2). A total of 2,086 individuals were collected during the field season over a 32 day period (11 June to 13 July) when adult wheat stem sawflies were active (Table 1).

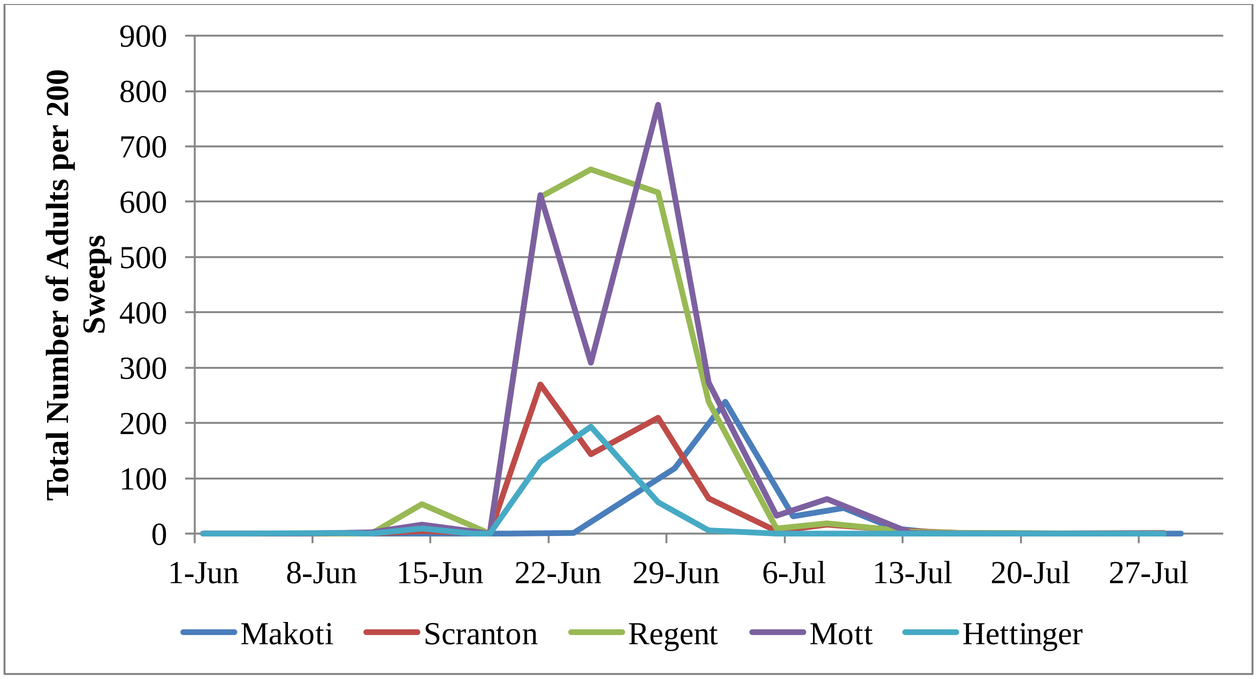

Figure 2. Emergence of wheat stem sawfly in 2010.

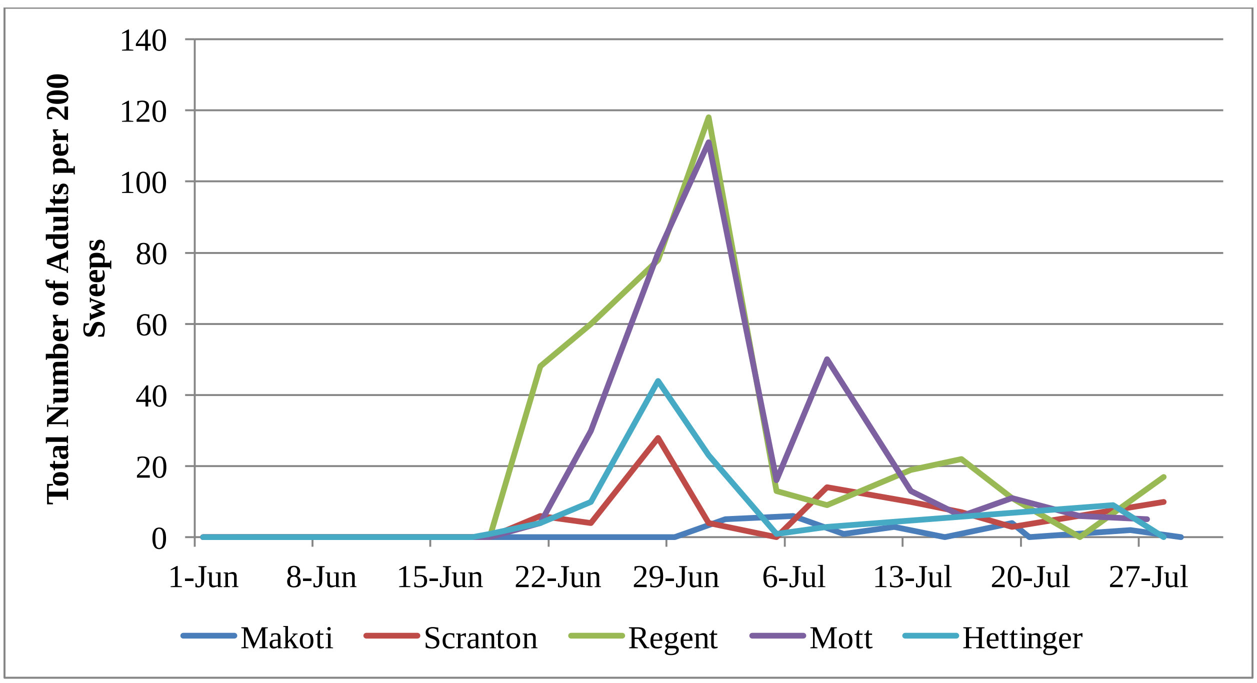

Figure 3. Emergence of *B. cephi* in 2010.

Bracon cephi was first collected in sweep samples on 21 June, with peak populations on 1 July (Fig. 3). Peak populations consisted of 111 parasitoids collected in 200 sweeps (Fig. 3). A second spike in *B. cephi* numbers occurred on 8 July and corresponded to the emergence of the second generation (Fig. 3). Populations of *B. cephi* were collected from 21 June to 8 August for a total of 48 days (Fig. 3). A total of six *P. dubius* beetles also were found at Mott. The majority of these predacious beetles were collected on July 1.

<u>Regent</u>

Wheat stem sawflies were first observed on 14 June, with peak populations on 24 June (Fig. 2). Peak populations consisted of 658 individuals per 200 sweeps (Table 1). Wheat stem sawfly populations were observed at the field from 14 June to 19 July (Table 1). A total of 2,210 wheat stem sawflies were collected at Regent (Table 1). The first date that *B. cephi* was collected was 21 June at Regent, while populations peaked on 1 July (Fig. 3). Peak populations of *B. cephi* consisted of 118 individuals in 200 sweep net samples (Fig. 3). A total of four clerid beetles, *P. dubius*, were collected during the season.

<u>Scranton</u>

During 2010 at Scranton, wheat stem sawflies were first collected on 14 June (Fig. 2). Peak populations of wheat stem sawfly occurred on 21 June with a total of 722 individuals (Table 1). Populations of wheat stem sawfly were active for 32 days, from 14 June to 16 July (Table 1). *Bracon cephi* populations at Scranton in 2011 were relatively low. *Bracon cephi* was first collected on 21 June with peak populations on 28 June (Fig. 3). A total of 17 *B. cephi* were collected per 200 sweep net samples during peak populations (Fig. 3). Scranton had a total of 19 *P. dubius* beetles collected over the field season, and the majority were obtained in late June to early July.

Makoti

Makoti being located north of the other sites had its first observation of wheat stem sawflies later than the other sites, which was on 23 June. Peak population occurred on 2 July which consisted of 239 wheat stem sawflies per 200 sweeps (Fig. 2). A total of 445 individuals were collected throughout the 19 days of adult wheat stem sawflies activity at Makoti (Table 1). At Makoti populations of *B. cephi* were first observed at Makoti on 2 July, with peak populations occurring on 6 July (Fig. 3). *Bracon cephi* populations were relatively low during 2010 compared to other field sites. A total of 21 *B. cephi* were collected during the field season (Fig. 3). Three clerid beetles, *P. dubius*, were also collected.

Hettinger

The Hettinger location had the lowest population of adult wheat stem sawflies of all the locations sampled in 2010. Adult wheat stem sawflies were first observed on 9 June, which was the earliest emergence of wheat stem sawflies during 2010 (Fig. 2). Peak populations occurred on 24 June with 194 individuals being caught in 200 sweeps (Table 1). A total of 398 adult wheat stem sawflies were collected over in a 22 day period (Table 1). Populations of *B. cephi* were first observed on 18 June with peak populations occurring on 28 June (Fig. 3). Peak populations consisted of 44 *B. cephi* being caught in 200 sweep net samples (Fig. 3). No clerid beetles, *P. dubius*, were collected.

2011 Field Season

The 2011 field season had lower populations of wheat stem sawflies compared to the 2010 field season. Scranton was the only site that had substantial wheat stem sawfly populations that year. The 2011 field season in western North Dakota was characterized by a cool, late spring with above average precipitation. *Bracon cephi* populations were also lower in 2011 than in 2010. Regent and Scranton field sites showed the highest populations of *B. cephi*. *Bracon cephi* populations had a distinct second generation that was similar at most locations. No clerid beetles, *P. dubius*, were collected.

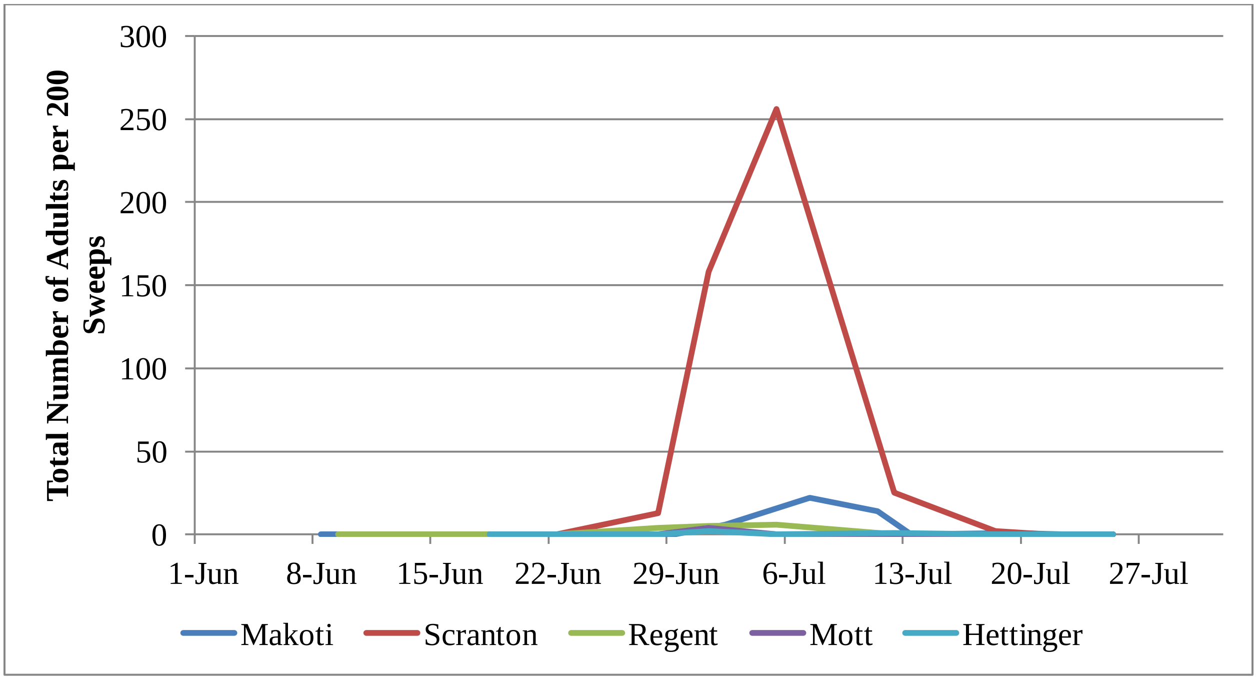

Figure 4. Emergence of wheat stem sawfly in 2011.

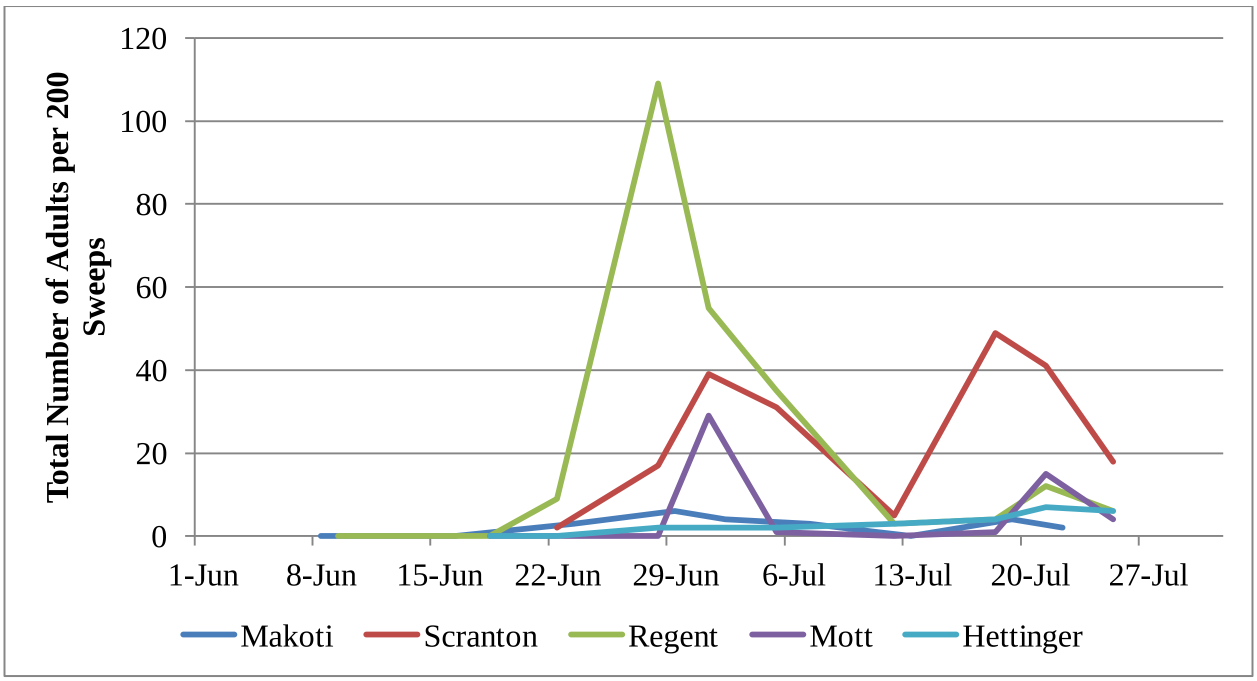

Figure 5. Emergence of *B. cephi* in 2011.

Scranton

Sawflies were first observed on 28 June at Scranton, with the peak populations occurring on 5 July (Fig. 4). At the peak population, 256 wheat stem sawflies were collected from 200 sweeps (Table 1). Adult wheat stem sawfly populations were active from 28 June to 18 July (Table 1). During the 20 days of adult activity, a total of 454 individuals were caught at Scranton (Table 1). *Bracon cephi* were first observed on 22 June. There were two distinct population spikes of the *B. cephi* during the season corresponding to the bivoltine life cycle. The peaks occurred on 1 July and 18 July (Fig. 5). No clerid beetles, *P. dubius*, were collected.

Regent

Sweep samples at Regent showed a lower density of adult wheat stem sawflies during 2011. Adult wheat stem sawflies were found from 28 June to 5 July, with a total of only 15 individuals being caught in sweep net samples (Table 1). However, Regent had the largest population of *B. cephi* with a peak population of 109 individuals caught in 200 sweeps on 28 June (Fig. 5). No clerid beetles, *P. dubius*, were collected.

Mott

A total of four adult wheat stem sawfly adults were caught at Mott (Table 1). Wheat stem sawflies were observed on one day during the season, 1 July. *Bracon cephi* populations peaked on 1 July with a second population jump on 21 July (Fig. 5). A total of 50 *B. cephi* individuals were caught during the season at Mott. No clerid beetles, *P. dubius*, were collected.

Hettinger

A total of three adult wheat stem sawflies were collected during the field season at Hettinger without a clear peak in population (Table 1 and Fig. 4). *Bracon cephi* populations were also relatively small with a total of 26 individuals being caught (Fig. 5). No clerid beetles, *P. dubius*, were collected.

Makoti

A total of 43 adult wheat stem sawflies were collected in sweep samples at Makoti in 2011 (Table 1). Wheat stems sawflies were first observed on 2 July with the peak population on 7 July (Table 1). The peak population consisted of 22 individuals per 200 sweep net samples (Table 1). *Bracon cephi* were first observed on 23 June with a total of 23 individuals being collected in 2011 (Fig. 5).

Table 1. Table of wheat stem sawfly emergence for 2010 and 2011.

Location	Total	Males	Females	Obs. Period	Sawflies/ Day	First Emergence	Peak Emergence
Hettinger	398	255	143	22	18	9 June 2010	24 June 2010
Makoti	445	231	214	19	23	23 June 2010	2 July 2010
Mott	2086	1581	505	32	65	11 June 2010	28 June 2010
Regent	2210	1787	423	35	63	14 June 2010	24 June 2010
Scranton	722	544	178	32	23	14 June 2010	21 June 2010
Hettinger	3	0	3	11	0	1 July 2011	1 July 2011
Makoti	43	16	27	17	3	2 July 2011	7 July 2011
Mott	4	2	2	1	4	1 July 2011	1 July 2011
Regent	15	3	12	7	2	28 June 2011	5 July 2011
Scranton	454	320	134	20	23	28 June 2011	5 July 2011
Sum	***6380***	***4739***	***1641***	***196***	***224***		
Average	***638***	***473.9***	***164.1***	***19.6***	***22.4***		

Growing Degree Days

Weather data from the Watchdog data loggers were used in the growing degree-day (DD) summations. Starting on 1 March, the growing DD's were accumulated for first emergence and peak emergence of adult wheat stem sawfly and adult *B. cephi* emergence. The mean, standard deviation, and the C.V. were determined for four different base temperatures and the Julian date using Arnold's Method (Arnold 1959). The base temperature or Julian date with the lowest C.V. was recognized as being the best indicator of emergence for its lower levels of variation (Arnold 1959). In 2010, two locations, Mott and Hettinger, did not have a large enough wheat stem sawfly population to determine degree day calculations, and thus data were omitted.

<u>Prediction for Wheat Stem Sawfly Emergence</u>

The first emergence of wheat stem sawfly was best predicted using the average of the Julian dates compared to the DD's based on air or soil temperatures. The Julian date of the first observations had a C.V. of 3.2 with an average date of 165.2 (~14 June) (Table 1). The second lowest C.V. for first emergence was a base temperature of 0 C using air temperature with a C.V. of 9.69 (Table 2).

Prediction of the peak populations of adult wheat stem sawfly was more precise using the Julian date compared to using a degree day accumulations based on air or soil temperature. The C.V. for the peak emergence of sawflies using the Julian date was 3.0 (Table 2). The average Julian date for peak emergence for adult wheat stem sawflies was 180.8, which would be around June 29 (Table 2). The growing DD's of air and soil temperature with a 0 C base temperature had the next lowest C.V. with 8.67 and 8.66 (respectively)(Table 2 and 3).

Male wheat stem sawflies first emerged from 160 to 183 Julian days (Table 4). Peak emergence occurred from 172 to 188 Julian days for male wheat stem sawflies (Table 4). Growing DD's ranged from 720.36 to 978.73 for the first emergence of male wheat stem sawfly using a 0 C threshold soil temperature (Table 4). Peak emergence based on soil temperatures with a 0 C threshold temperature had a range from 948.06 to 1176.13 for male wheat stem sawflies (Table 4). Growing DD's based on air temperature using a 0 C threshold temperature was from 949.15 to 1196.81 for the peak emergence of male wheat stem sawflies (Table 5).

Female wheat stem sawflies first emerged from 162 to 183 Julian days (dates) and had peak emergence from 175 to 192 Julian days (28 June to 11 July) (Table 6). Growing DD's ranged from 936.43 to 1107.18 using a 0 C threshold soil temperature for peak emergence of female wheat stem sawflies (Table 6). Peak emergence had a range of 1031.25 to 1207.86 degree days based on air temperature using a 0 C (Table 7).

Prediction for *Bracon cephi* Emergence

Similar to the emergence of wheat stem sawfly, *B. cephi* was best predicted using a Julian date for first and peak emergence compared to growing degree days based on either soil or air temperature. The C.V. for first and peak emergence of *B. cephi* was 2.7 and 4.6 (respectively) (Table 8). The average Julian date for first emergence was 174.9 (~24 June) and for the peak emergence it was 185.1 (~4 July) (Table 9).

Table 2. Accumulated degree days for adult wheat stem sawfly emergence interval based on soil temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/2010	162	751.82	445.46	286.68	188.60	6/28/2010	179	1051.87	670.71	464.33	319.55
Regent	6/14/2010	165	791.62	471.83	313.43	201.95	6/24/2010	175	990.82	627.03	440.63	301.15
Scranton	6/14/2010	165	837.25	550.03	404.19	286.65	6/21/2010	172	949.15	632.63	468.59	335.50
Hettinger	6/9/2010	160	720.36	456.85	322.69	215.86	6/24/2010	175	985.91	656.40	480.24	331.41
Makoti	6/23/2010	174	978.73	623.11	441.09	291.21	7/2/2010	183	1176.13	780.91	573.69	398.61
Regent	6/28/2011	179	878.40	534.19	356.45	209.40	7/5/2011	186	1030.45	655.44	458.10	291.45
Scranton	6/28/2011	179	869.28	515.75	346.85	210.75	7/5/2011	186	1026.63	642.30	453.80	298.10
Makoti	7/2/2011	183	838.01	530.89	352.97	208.05	7/7/2011	188	948.06	618.94	427.02	268.10
	Mean	***170.88***	***833.18***	***516.02***	***353.04***	***226.56***	***Mean***	***180.50***	***1019.88***	***660.55***	***470.80***	***317.98***
	St. Dev.	***8.90***	***80.75***	***58.08***	***49.73***	***39.35***	***St. Dev.***	***6.07***	***73.44***	***51.55***	***44.72***	***39.39***
	C.V.	***5.21***	***9.69***	***11.25***	***14.09***	***17.37***	***C.V.***	***3.36***	***7.20***	***7.80***	***9.50***	***12.39***

Table 3. Accumulated degree days for adult wheat stem sawfly emergence interval based on air temperature.

Site	First Occurance						Peak Occurrence					
	Date	Julian Day	Cumulative Degree Days				Date	Julian Day	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/2010	162	832.96	565.23	427.73	307.44	6/28/2010	179	1124.31	784.07	601.78	440.64
Regent	6/14/2010	165	863.81	569.47	423.61	305.16	6/24/2010	175	1040.06	701.72	528.81	384.46
Scranton	6/14/2010	165	837.25	550.03	404.19	286.65	6/21/2010	172	949.15	632.63	468.59	335.50
Hettinger	6/9/2010	160	809.40	532.65	394.60	275.15	6/24/2010	175	1056.60	714.85	536.45	379.05
Makoti	6/23/2010	174	1004.31	679.50	504.60	358.15	7/2/2010	183	1196.81	832.40	632.30	460.65
Regent	6/28/2011	179	970.64	573.30	377.58	222.15	7/5/2011	186	1123.79	695.65	480.33	305.30
Scranton	6/28/2011	179	964.65	557.78	352.54	199.55	7/5/2011	186	1112.70	675.03	450.19	277.60
Makoti	7/2/2011	183	1014.41	644.05	450.31	282.62	7/7/2011	188	1125.51	733.15	525.41	343.72
	Mean	***170.88***	***912.18***	***584.00***	***416.89***	***279.61***	***Mean***	***180.50***	***1091.12***	***721.19***	***527.98***	***365.86***
	St. Dev.	***8.90***	***84.43***	***50.54***	***46.78***	***49.83***	***St. Dev.***	***6.07***	***74.59***	***62.69***	***63.53***	***63.21***
	C.V.	***5.21***	***9.26***	***8.65***	***11.22***	***17.82***	***C.V.***	***3.36***	***6.84***	***8.69***	***12.03***	***17.28***

Table 4. Accumulated degree days for adult male wheat stem sawfly emergence interval based on soil temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/2010	162	751.82	445.46	286.68	188.60	6/28/10	179	1051.87	670.71	464.33	319.55
Regent	6/14/2010	165	791.62	471.83	313.43	201.95	6/24/10	175	990.82	627.03	440.63	301.15
Scranton	6/14/2010	165	837.25	550.03	404.19	286.65	6/21/10	172	949.15	632.63	468.59	335.50
Hettinger	6/9/2010	160	720.36	456.85	322.69	215.86	6/24/10	175	985.91	656.40	480.24	331.41
Makoti	6/23/2010	174	978.73	623.11	441.09	291.21	7/2/10	183	1176.13	780.91	573.69	398.61
Regent	7/1/2011	182	942.20	584.79	398.65	243.20	7/1/11	182	942.20	584.79	398.65	243.20
Scranton	6/28/2011	179	869.28	515.75	346.85	210.75	7/5/11	186	1026.63	642.30	453.80	298.10
Makoti	7/2/2011	183	838.01	530.89	352.97	208.05	7/7/11	188	948.06	618.94	427.02	268.10
	Mean	***171.25***	***841.16***	***522.34***	***358.32***	***230.78***	***Mean***	***180***	***1008.85***	***651.72***	***463.37***	***311.95***
	St. Dev.	***9.35***	***88.62***	***62.89***	***52.32***	***39.06***	***St. Dev.***	***5.71***	***78.10***	***58.18***	***51.55***	***46.99***
	C.V.	***5.46***	***10.54***	***12.04***	***14.60***	***16.92***	***C.V.***	***3.17***	***7.74***	***8.93***	***11.13***	***15.06***

Table 5. Accumulated degree days for adult male wheat stem sawfly emergence interval based on air temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/10	162	832.96	565.23	427.73	307.44	6/28/10	179	1124.31	784.07	601.78	440.64
Regent	6/14/10	165	863.81	569.47	423.61	305.16	6/24/10	175	1040.06	701.72	528.81	384.46
Scranton	6/14/10	165	837.25	550.03	404.19	286.65	6/21/10	172	949.15	632.63	468.59	335.50
Hettinger	6/9/10	160	809.40	532.65	394.60	275.15	6/24/10	175	1056.60	714.85	536.45	379.05
Makoti	6/23/10	174	1004.31	679.50	504.60	358.15	7/2/10	183	1196.81	832.40	632.30	460.65
Regent	7/1/11	182	1039.39	628.85	424.73	260.90	7/1/11	182	1039.39	628.85	424.73	260.90
Scranton	6/28/11	179	964.65	557.78	352.54	199.55	7/5/11	186	1112.70	675.03	450.19	277.60
Makoti	7/2/11	183	1014.41	644.05	450.31	282.62	7/7/11	188	1125.51	733.15	525.41	343.72
	Mean	***171.25***	***920.77***	***590.94***	***422.79***	***284.45***	***Mean***	***180.00***	***1080.57***	***712.84***	***521.03***	***360.31***
	St. Dev.	***9.35***	***94.17***	***52.63***	***44.00***	***45.11***	***St. Dev.***	***5.71***	***75.27***	***70.53***	***71.97***	***70.78***
	C.V.	***5.46***	***10.23***	***8.91***	***10.41***	***15.86***	***C.V.***	***3.17***	***6.97***	***9.89***	***13.81***	***19.64***

Table 6. Accumulated degree days for adult female wheat stem sawfly emergence interval based on soil temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/10	162	751.82	445.46	286.68	188.60	6/28/10	179	1051.87	670.71	464.33	319.55
Regent	6/14/10	165	791.62	471.83	313.43	201.95	6/24/10	175	990.82	627.03	440.63	301.15
Scranton	6/21/10	172	949.15	632.63	468.59	335.50	6/28/10	179	972.49	597.65	397.36	240.15
Hettinger	6/14/10	162	804.01	518.50	370.34	249.51	6/24/10	175	985.91	656.40	480.24	331.41
Makoti	6/29/10	180	1107.18	725.16	526.34	359.66	6/29/10	180	1107.18	725.16	526.34	359.66
Regent	6/28/11	179	878.40	534.19	356.45	209.40	7/5/11	186	1030.45	655.44	458.10	291.45
Scranton	6/28/11	179	869.28	515.75	346.85	210.75	7/1/11	182	936.43	569.70	392.40	247.90
Makoti	7/2/11	183	838.01	530.89	352.97	208.05	7/11/11	192	1030.96	684.24	481.12	311.00
	Mean	***172.75***	***873.68***	***546.80***	***377.71***	***245.43***	***Mean***	***181.00***	***1013.26***	***648.29***	***455.06***	***300.28***
	St. Dev.	***8.68***	***112.10***	***90.43***	***80.04***	***65.68***	***St. Dev.***	***5.71***	***53.10***	***49.30***	***44.65***	***40.39***
	C.V.	***5.03***	***12.83***	***16.54***	***21.19***	***26.76***	***C.V.***	***3.15***	***5.24***	***7.60***	***9.81***	***13.45***

Table 7. Accumulated degree days for adult female wheat stem sawfly emergence interval based on air temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/11/10	162	832.96	565.23	427.73	307.44	6/28/10	179	1124.31	784.07	601.78	440.64
Regent	6/14/10	165	863.81	569.47	423.61	305.16	6/24/10	175	1040.06	701.72	528.81	384.46
Scranton	6/21/10	172	949.15	632.63	468.59	335.50	6/28/10	179	1083.15	735.83	552.19	400.65
Hettinger	6/14/10	162	883.55	584.80	433.00	301.00	6/24/10	175	1056.60	714.85	536.45	379.05
Makoti	6/29/10	180	1125.51	774.30	582.60	419.35	6/29/10	180	1125.51	774.30	582.60	419.35
Regent	6/28/11	179	970.64	573.30	377.58	222.15	7/5/11	186	1123.79	695.65	480.33	305.30
Scranton	6/28/11	179	964.65	557.78	352.54	199.55	7/1/11	182	1031.25	611.18	397.54	236.15
Makoti	7/2/11	183	1014.41	644.05	450.31	282.62	7/11/11	192	1207.86	797.90	578.96	386.07
	Mean	***172.75***	***950.58***	***612.69***	***439.49***	***296.59***	***Mean***	***181.00***	***1099.07***	***726.94***	***532.33***	***368.96***
	St. Dev.	***8.68***	***93.45***	***72.67***	***68.94***	***67.56***	***St. Dev.***	***5.71***	***58.46***	***60.69***	***66.35***	***66.55***
	C.V.	***5.03***	***9.83***	***11.86***	***15.69***	***22.78***	***C.V.***	***3.15***	***5.32***	***8.35***	***12.46***	***18.04***

Table 8. Accumulated degree days for adult *B. cephi* emergence interval based on soil temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/21/2010	172	913.07	562.71	375.93	250.75	7/1/2010	182	1113.52	719.16	504.38	351.20
Regent	6/21/2010	172	923.07	572.48	394.48	263.40	7/1/2010	182	1164.73	770.14	564.14	405.06
Scranton	6/21/2010	172	834.22	490.18	309.48	171.88	6/28/2010	179	972.49	597.65	397.36	240.15
Hettinger	6/18/2010	169	870.36	567.25	407.89	275.86	6/28/2010	179	1069.41	722.30	534.94	374.91
Makoti	7/2/2010	183	1176.13	780.91	573.69	398.61	7/6/2010	187	1257.68	844.86	626.44	440.16
Mott	7/1/2011	182	1028.35	667.99	479.95	308.55	7/1/2011	182	1028.35	667.99	479.95	308.55
Regent	6/22/2011	173	766.60	448.79	287.85	157.60	6/28/2011	179	878.40	534.19	356.45	209.40
Scranton	6/22/2011	173	753.68	426.55	274.45	155.15	7/18/2011	199	1324.43	882.90	658.00	465.90
Hettinger	6/28/2011	179	745.25	388.16	227.77	103.91	7/21/2011	202	1429.07	970.78	746.00	557.73
Makoti	6/23/2011	174	667.21	399.69	246.97	127.25	6/29/2011	180	775.96	482.04	312.52	176.00
	Mean	***174.90***	***867.79***	***530.47***	***357.85***	***221.29***	***Mean***	***185.10***	***1101.40***	***719.20***	***518.02***	***352.90***
	St. Dev.	***4.72***	***151.14***	***125.72***	***110.09***	***93.19***	***St. Dev.***	***8.49***	***201.19***	***155.05***	***137.54***	***121.16***
	C.V.	***2.70***	***17.42***	***23.70***	***30.76***	***42.11***	***C.V.***	***4.59***	***18.27***	***21.56***	***26.55***	***34.33***

Table 9. Accumulated degree days for adult *B. cephi* emergence interval based on air temperature.

Site	First Emergence						Peak Emergence					
	Date	Julian Date	Cumulative Degree Days				Date	Julian Date	Cumulative Degree Days			
			(0 C)	(4.4 C)	(7.2 C)	(10 C)			(0 C)	(4.4 C)	(7.2 C)	(10 C)
Mott	6/21/2010	172	988.26	678.82	516.13	373.44	7/1/2010	182	1195.11	841.67	650.98	472.44
Regent	6/21/2010	172	982.36	657.22	492.71	356.76	7/1/2010	182	1193.41	824.27	631.76	467.91
Scranton	6/21/2010	172	949.15	632.63	468.59	335.50	6/28/2010	179	1083.15	735.83	552.19	400.65
Hettinger	6/18/2010	169	945.90	630.55	468.95	328.25	6/28/2010	179	1138.20	778.85	589.25	589.25
Makoti	7/2/2010	183	1196.81	832.40	632.30	460.65	7/6/2010	187	1264.21	882.20	670.90	488.05
Mott	7/1/2011	182	1028.35	667.99	479.95	308.55	7/1/2011	182	1028.35	667.99	479.95	308.55
Regent	6/22/2011	173	863.99	493.05	314.13	175.50	6/28/2011	179	970.64	573.30	377.58	222.15
Scranton	6/22/2011	173	859.65	479.18	290.74	154.55	7/18/2011	199	1390.20	895.33	634.09	425.10
Hettinger	6/28/2011	179	971.82	565.06	358.19	204.76	7/21/2011	202	1486.02	978.06	706.79	488.96
Makoti	6/23/2011	174	833.91	503.15	334.61	192.12	6/29/2011	180	950.21	593.05	407.71	248.42
	Mean	***174.90***	***962.02***	***614.00***	***435.63***	***289.01***	***Mean***	***185.10***	***1169.95***	***777.05***	***570.12***	***411.15***
	St. Dev.	***4.72***	***104.16***	***107.90***	***107.77***	***101.49***	***St. Dev.***	***8.49***	***174.83***	***133.68***	***113.30***	***117.24***
	C.V.	***2.70***	***10.83***	***17.57***	***24.74***	***35.12***	***C.V.***	***4.59***	***14.94***	***17.20***	***19.87***	***28.51***

Discussion

Population levels of both wheat stem sawfly and *B. cephi* are affected by a variety of factors including weather, variety selection, tillage, and methods of harvesting (Beres et al. 2011). Each field location had its own unique environment and conditions that contributed to different levels of infestation of wheat stem sawfly. For example, the Mott field site in 2010 was planted to sunflowers the previous year, and this could be an explanation for why the population of wheat stem sawflies was low that year.

During 2010, we observed relatively high population densities of wheat stem sawflies at all of the field locations. However, populations were lower at four of the five locations (except Scranton) during 2011. An abrupt change in population from year to year is difficult to explain, since numerous factors can be involved. The wet spring in 2011, could explain a drop in the population due to wheat stem sawfly development being negatively affected by weather conditions (Seamans 1945, Salt 1946, Perez-Menoza and Weaver 2006). The low population of wheat stem sawflies in 2011 could also be explained by high levels of parasitism by *B. cephi* in 2010. *Bracon cephi* could have had a functional response, the higher populations of wheat stem sawfly the more larvae that are available to be parasitized, resulting in an increase the rate of parasitism. However, parasitoids experienced low populations in 2011, which would support the idea that wet field conditions deterred emergence of wheat stem sawfly and *B. cephi*.

Using Julian Date, the first and peak emergence for adult wheat stem sawfly was an average of 170.88 (~June 20) and 180.5 (~June 29) for first and peak emergence (respectfully). For degree days, the temperature base using air performed slightly better than soil. Adult wheat stem sawfly first emerged at 912.18 growing degree days (base air temperature of 0 C) and a peak emergence at 1091.12 growing degree days (base air temperature of 0 C). Male wheat stem sawflies emerged sooner than the females, which were also seen by Perez-Mendoza and Weaver (2006). Male wheat stem sawflies first emerged at 920.77 growing degree days (base air temperature of 0 C) and had peak emergence at 1080.57 growing degree days (base air temperature of 0 C). Females needed more accumulated growing degree days with first emergence at 950.88 growing degree days (base air temperature of 0 C) and peak emergence at 1099.07 growing degree days (base air temperature of 0 C).

For Julian date, the average first emergence of *B. cephi* occurred at 174.9 (~ June 25) Julian days and peak emergence at 185.1 (~ July 4) Julian days. *Bracon cephi* populations often exhibited two distinct population peaks due to its bivoltinism. However, only degree days for the first peak were determined. For the base, air temperature had the lower C.V. compared to soil temperature. *Bracon cephi* first emerged at 962.02 growing degree days (base air temperature of 0 C) and had peak emergence at 1169.95 growing degree days (base air temperature of 0 C).

Julian Date always had the lowest C.V. for 2010 and 2011 compared to the C.V. of the different degree day bases of soil and air temperatures for wheat stem sawfly and *B. cephi* development. Less variation was seen with the Julian dates because fields were only visited twice a week resulting in fewer observations. In contrast, temperature recordings were taken more frequently (every half an hour) at each site resulting in increased variability and a larger C.V.

This research will help forecast the emergence and determine the optimal time for scouting for the wheat stem sawfly and its parasitoid, *B. cephi*. Forecasting when wheat stem sawfly emerges could be used with other IPM strategies. For example, trap crops of spring wheat varieties that have attractive volatiles could be planted to coincide with the peak emergence of wheat stem sawfly (Beres et al. 2011). This could help to concentrate sawflies in a certain area of field, which could be destroyed before wheat stem sawfly completes their development.

COMPARISON OF WHEAT STEM SAWFLY, *CEPHUS CINCTUS* NORTON (HYMENOPTERA: CEPHIDAE), DAMAGE IN DIFFERENT VARIETIES OF HARD RED SPRING WHEAT

Abstract

The wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae), is regarded as a major pest of wheat and other cereals in the Upper Great Plains. Solid-stemmed wheat varieties are used as host plant resistance to mitigate wheat stem sawfly damage. This research evaluated seven hard red spring wheat varieties (both hollow-stemmed and solid-stemmed) and compared stem solidity, wheat stem sawfly damage, and agronomic traits. The solid-stemmed varieties, Mott and Choteau, had the most solid stems and also had the lowest wheat stem sawfly damaged stems. In contrast, the hollow-stemmed varieties, Glenn, Reeder and Steele ND, had he least solid stem and as a result the highest percentage of wheat stem sawfly damaged stems. Agronomic traits varied across the 13 site years. However, the two solid-stemmed wheat varieties, Mott and Choteau, had competitive yield, test weight, and protein that were compared to hollow-stemmed wheat varieties tested. The visual solidity scale of 1-5 was positively correlated to the measured solidity (R^2= 0.9251), and thus a good tool for wheat breeder to measure stem solidity.

Introduction

The wheat stem sawfly, *Cephus cinctus* Norton, is a significant threat to the wheat producing states of the Upper Great Plains. One of the most practical and effective strategies for minimizing wheat stem sawfly damage is host plant resistance through the use of solid-stemmed wheat varieties (Berzonsky et al. 2003). There are three ways plants can be resistant to insects. One way is through antibiosis, which occurs when a plant affects the biology of the insect

(Painter 1958). Antixenosis is another means of resistance, this is when a plant is not preferred by an insect (Painter 1958). When a plant exhibits resistant through tolerance, a plant can withstand certain levels of insect damage that would severely injure a susceptible plant (Painter 1958).

The first commercially available resistant solid-stemmed wheat variety was 'Rescue' which was released in the late 1940's (Beres et al. 2009). Resistant varieties with more pith inside the stem have an increased mortality for wheat stem sawfly larva (Holmes and Peterson 1962). Wheat varieties with hollow stems allow wheat stem sawfly larvae to become larger, while the solid-stemmed varieties have smaller larvae and growth of larvae is inhibited (Carcamo et al. 2005). Carcamo et al. (2005) found that solid-stemmed varieties can reduce stem cutting and female fecundity. The solidity of the lower stem internodes was determined to be crucial for minimizing wheat stem sawfly damage (Wallace and McNeal 1966). Solid-stemmed wheat varieties showed significantly less lodging then hollow-stemmed wheat varieties (Beres et al. 2007). Growers have been reluctant to utilize solid-stemmed wheat varieties because of the lower yield (Weiss and Morrill 1992, Beres et al. 2009). This proves to be an important factor that negatively affects grower's decisions on wheat varieties and whether to sacrifice yield for less wheat stem sawfly damage.

In this study, we evaluated current varieties of hard red spring wheat for host plant resistance against wheat stem sawfly and agronomic performance from 13 site years in Western North Dakota. These data will provide producers and agronomists with valuable information about performances of solid-stemmed versus hollow-stemmed wheat varieties under different wheat stem sawfly pressure.

Materials and Methods

Trials were planted in areas with natural infestations of wheat stem sawfly to evaluate hard red spring wheat variety performance. Trials were planted at five sites in western North Dakota, including Hettinger (Adams Co.), Scranton (Bowman Co.), Regent (Hettinger Co.), Makoti (Ward Co.), and Grenora (Williams Co.) in 2009, 2010, and 2011 (Figure 6).

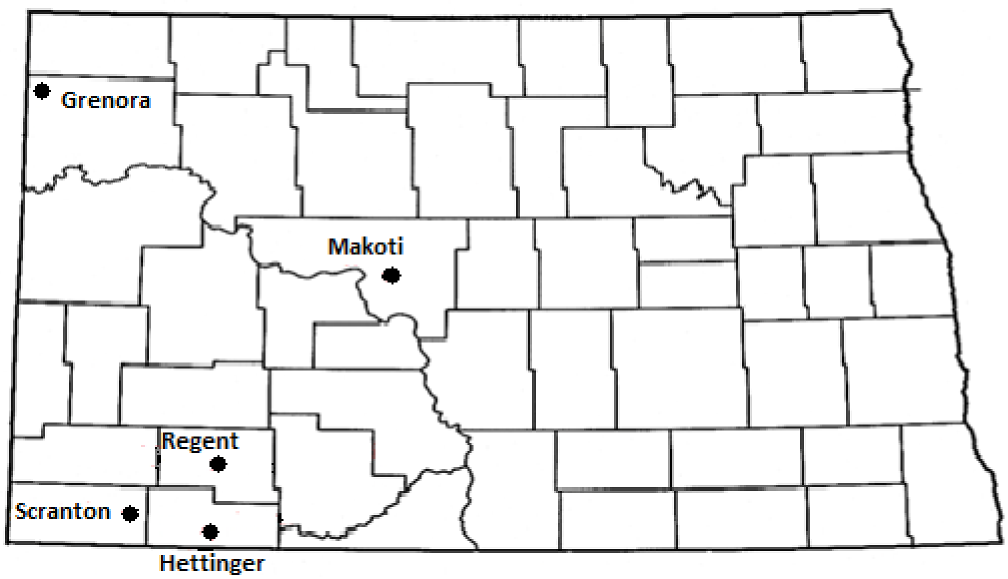

Figure 6. Locations of variety trial test plots.

Each site, trials were planted in a Randomized Complete Block Design with four replications. Each treatment plot was 1.37 m by 5.49 m and was seeded at a rate of 73.9 kg/ha. The experiment consisted of the following hollow-stemmed, semi-solid and solid-stemmed varieties:

Hollow-stemmed: Glenn, Steele ND, and Reeder

Semi-solid stemmed: AC Lillian and Vida

Solid-stemmed: Mott and Choteau

At maturity, 25 wheat stems were taken from each treatment by pulling wheat plants from the second row of the plot. The bundles of stems were identified with labels that specified the location, treatment, and replication. Samples were transported to a storage facility in Fargo, ND.

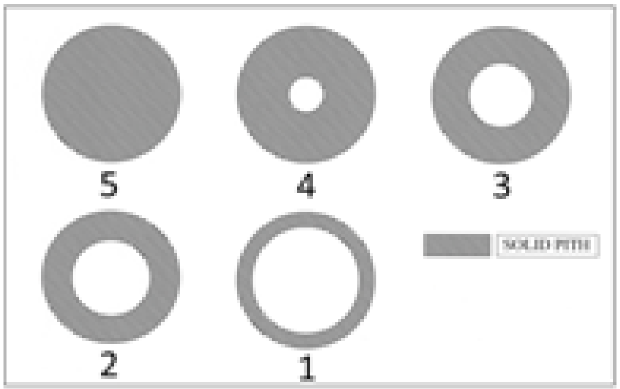

Figure 7. Stem solidity scale.

A total of 25 central stems were dissected from each treatment with the results being recorded on data sheets. The lower three internodes of each plant were dissected and a visual solidity rating was taken using a scale of 1 (hollow) to 5 (solid) (Fig. 7). Also, each internode was observed for the presence of wheat stem sawfly and any parasitoids. The presence of wheat stem sawfly was noted as being either a larvae (dead or alive) or by the presence of frass. Although the presence of parasitoids was noted as being an emergence hole or a parasitoid cocoon, parasitiod data is not presented in this thesis.

An additional ~10 stems were taken from each treatment in the 2009 and 2010 field seasons. These stems were cut in the middle of each the lower three internodes, which were visually rated using the same 1 to 5 scale as discussed earlier (Fig. 7). After the visual rating, each internode was measured using a stage micrometer (Mitutoyo, 958 Corporate Blvd. Aurora, IL 60502) mounted on a dissecting microscope. The outside diameter of each cross-section was measured and the outside diameter of the plant lumen was measured at right angles to each other. The total area of the cross section was calculated by using the equation $A= \pi(r1)(r2)$. The solid area was calculated by subtracting the area of lumen from the total area of the solid area of the stem cross section. This data was analyzed using polynomial regression analysis (PROC REG, SAS Institute Inc. 2008) to determine whether the visual solidity scale is a good predictor of the measured solidity.

All agronomic, solidity and damaged stems data were analyzed as generalized linear mixed models using PROC GLIMMIX in SAS version 9.2 (SAS Institute Inc. 2008), with variety as a fixed effect and year, location and replication as random effects. Post-hoc treatment least squares mean comparisons were made using Fisher's LSD at $\alpha = 0.05$.

Results

Agronomy Performance across all Locations and Years

The year*location*variety interaction was significant for yield ($Z = 4.34$, $P < 0.0001$). Therefore, each site-year was analyzed independently. The year*location*variety interaction was also significant for test weight ($Z = 3.99$, $P < 0.0001$), which resulted in the test weight being analyzed independently. The year*location*variety interaction for protein content was not significant at $\alpha = 0.05$ ($Z = 1.40$, $P = 0.0803$), but was significant at $\alpha = 0.10$. So, individual locations were analyzed independently for consistency with yield and test weight results.

Agronomy Performance at Individual Locations in 2009

<u>Grenora 2009</u>

The variety trial had significant differences between varieties for yield ($F = 3.07$; df = 6,18; $P = 0.0299$) and test weight ($F = 82.75$; df = 6, 18; $P < 0.0001$). Vida had the highest yield at Grenora in 2009. Vida had significantly higher yield than AC Lillian and Choteau (Table 10). Glenn had a test weight that was significantly higher than all other varieties (Table 11). AC Lillian had the lowest test weight and was significantly lower than the other varieties at Grenora (Table 11).

Makoti 2009

Varieties showed significant different at Makoti in 2009 for yield and test weight, (F = 4.45; df = 6, 18; P = 0.0062) and (F = 4.47; df = 6, 18; P = 0.0061)(respectively). For yield, Vida was significantly higher than AC Lillian, Reeder, Steele ND, and Glenn (Table 10). Mott was significantly higher than Glenn (Table 10). Choteau was significantly higher in yield than Steele ND and Glenn (Table 10). Varieties were not significantly different for test weight except for AC Lillian, which was significantly lower than the other varieties (Table 11).

Regent 2009

The variety trial at Regent, ND in 2009 showed a significant difference among varieties for yield (F = 15.85; df = 6, 18; P = 0.001) and test weight (F = 9.74; df = 6,18; $P \leq 0.0001$). The variety, Vida, yielded significantly higher than all other varieties at Regent in 2009 (Table 10). Reeder and Choteau were significantly higher in yield than AC Lillian, Mott, and Steele ND (Table 10). For test weight, Glenn had significantly higher yield than AC Lillian, Choteau, Vida, and Reeder (Table 11). Vida and Reeder were significantly lower in test weight than the other varieties (Table 11).

Scranton 2009

Varieties showed a significant difference for yield and test weight (F = 3.15; df = 6, 18; P = 0.0272),(F = 3.83; df = 6, 18; P = 0.0105), (respectively). The variety Mott had a significantly higher yield than AC Lillian and Glenn (Table 10). However, Mott was not significantly higher than Vida, Steele ND, Choteau, and Reeder (Table 10). AC Lillian and Vida had significantly lower test weight than Glenn, Choteau, Mott, Reeder, and Steele ND but not AC Lillian (Table 11).

Table 10. Mean yield (± S.E.) of hard red spring wheat varieties at each location in 2009.

Solidity	Variety	Mean Yield ± S.E. (kg/ha)				
		Grenora	Hettinger	Makoti	Regent	Scranton
Hollow-Stemmed	Glenn	3311.30 ± 320.80 ab	N/A[1]	1985.20 ± 57.20 d	3384.60 ± 103.50 cd	2971.70 ± 162.70 c
	Reeder	3196.30 ± 381.90 ab	N/A[1]	2408.20 ± 102.20 bc	3696.70 ± 93.48 b	3525.20 ± 201.10 ab
	Steele ND	3267.60 ± 410.90 ab	N/A[1]	2165.40 ± 75.32 cd	3351.70 ± 110.90 d	3571.69 ± 225.30 ab
	Vida	3443.20 ± 342.30 a	N/A[1]	2786.10 ± 160.72 a	3924.70 ± 129.10 a	3692.00 ± 88.09 ab
Semi-Solid	AC Lillian	2837.90 ± 60.50 bc	N/A[1]	2372.50 ± 85.40 bc	3299.90 ± 55.81 d	3182.20 ± 230.70 bc
Solid-Stemmed	Choteau	2629.40 ± 326.20 c	N/A[1]	2546.10 ± 213.20 ab	3546.70 ± 62.54 bc	3564.90 ± 182.20 ab
	Mott	3339.60 ± 277.10 ab	N/A[1]	2456.60 ± 84.10 abc	3211.10 ± 65.23 d	3931.40 ± 184.30 a

Means within a column followed by the same letter are not significanlty different (P ≤ 0.05, LSD).

[1] Field plots at Hettinger site were were hail out in 2009.

Table 11. Mean test weight (± S.E.) of hard red spring wheat varieties at each location in 2009.

Solidity	Variety	Test Weight ± S.E. (kg/hL)				
		Grenora	Hettinger	Makoti	Regent	Scranton
Hollow-Stemmed	Glenn	80.06 ± 0.31 a	N/A[1]	72.45 ± 0.48 a	75.85 ± 0.74 a	79.26 ± 0.95 a
	Reeder	77.01 ± 0.69 c	N/A[1]	71.26 ± 0.55 a	70.59 ± 0.48 c	77.24 ± 0.46 ab
	Steele ND	78.00 ± 0.50 b	N/A[1]	72.24 ± 0.74 a	73.92 ± 0.47 ab	77.95 ± 0.49 ab
	Vida	75.94 ± 0.44 d	N/A[1]	71.82 ± 0.37 a	72.12 ± 0.84 bc	74.30 ± 1.06 c
Semi-Solid	AC Lillian	74.31 ± 0.06 e	N/A[1]	68.72 ± 1.20 b	72.87 ± 0.72 b	75.61 ± 0.11 bc
Solid-Stemmed	Mott	76.94 ± 0.44 c	N/A[1]	72.80 ± 0.55 a	73.88 ± 0.53 ab	77.07 ± 1.42 ab
	Choteau	76.00 ± 0.25 d	N/A[1]	71.58 ± 0.67 a	73.35 ± 0.47 b	77.42 ± 0.21 ab

Means within a column followed by the same letter are not significanlty different ($P \leq 0.05$, LSD).

[1] Field plots at Hettinger site were were hail out in 2009.

Agronomy Performance at Individual Locations in 2010

Scranton 2010

Yield was not significantly different among varieties at Scranton in 2010 ($F = 2.17$; df = 6, 18; $P = 0.0952$). However, varieties were significantly different with test weight and protein ($F = 14.59$; df = 6, 18; $P < 0.0001$) and ($F = 4.23$; df = 6, 18; $P = 0.0079$) (respectively). Glenn had significantly higher test weight than the other varieties (Table 13). Choteau, Reeder, and AC Lillian had significantly lower test weight than Glenn, Mott, and Steele ND (Table 13). AC Lillian, Reeder, and Glenn had significantly higher protein than Vida, Mott, and Choteau (Table 14).

Regent 2010

Yield was significantly different among varieties and Regent in 2010 ($F = 10.78$; df = 6, 18; $P < 0.0001$). Glenn, Mott, and Vida had significantly higher yield than the other varieties (Table 12). Test weight was significantly different among varieties at Regent in 2010 ($F = 14.15$; df = 6, 18; $P < 0.0001$). Glenn had a significantly higher test weight than the other varieties (Table 13). Mott had test weight that was significantly lower than Glenn but significantly higher than Choteau, Vida, and AC Lillian (Table 13). Choteau was significantly lower test weight than Glenn and Mott (Table 13). Protein content was significantly different between varieties ($F = 5.48$; df = 6, 18; $P = 0.0022$). AC Lillian had significantly higher protein content than all other varieties (Table 14).

Makoti 2010

Varieties at Makoti in 2010, were significantly different in yield ($F = 31.63$; df = 6, 18; $P < 0.0001$). Mott and Vida had significantly higher yield than all other varieties (Table 12). Choteau was significantly lower than Mott and Vida but significantly higher yield than Steele

ND, AC Lillian, and Glenn (Table 12). Glenn was significantly lower than other varieties (Table 12).

Test weight among varieties was significantly different at Makoti in 2010 ($F = 88.5$; $df = 6, 18$; $P < 0.0001$). Glenn had a significantly higher test weight than all other varieties (Table 13). Mott had significantly lower test weight than Glenn, but was significantly higher than Choteau and AC Lillian (Table 13).

Protein content was significantly different among varieties ($F = 5.23$; $df = 6, 18$; $P = 0.0028$). AC Lillian had a protein content that was significantly higher than the other varieties (Table 14).

Grenora 2010

In 2010, Grenora showed a significant difference between varieties for yield ($F = 14.19$; $df = 6, 18$; $P < 0.0001$). Vida had a significantly higher yield than all other varieties in the study (Table 12). Mott was significantly lower than Vida and Reeder, but was significantly higher than Glenn (Table 12). Mott was comparable to other solid-stemmed varieties, AC Lillian and Choteau.

Test weight was significantly different among varieties at Grenora during 2010 ($F = 21.19$; $df = 6, 6$; $P = 0.0009$). Glenn was significantly higher in test weight than all other varieties (Table 13). Choteau and AC Lillian had the lowest test weight and was significantly lower than Glenn, Reeder, Steele ND, Vida, and Mott (Table 13).

Protein content was also significant among varieties ($F = 12.24$; $df = 6 ,6$; $P = 0.0038$). AC Lillian showed significantly higher protein content than all other varieties in the study (Table 14). Mott had a significantly lower protein than AC Lillian, Glenn, Reeder, and Vida (Table 14).

Table 12. Mean yield (± S.E.) of hard red spring wheat varieties at each location in 2010.

Solidity	Variety	Mean Yield ± S.E. (kg/ha)				
		Grenora	**Hettinger**	**Makoti**	**Regent**	**Scranton**
Hollow-Stemmed	Glenn	2800.20 ± 171.50 d	3785.50 ± 127.80 c	2386.00 ± 115.20 e	3251.50 ± 66.58 a	4297.90 ± 106.20 ab
	Reeder	3601.90 ± 98.86 b	4328.80 ± 50.44 a	3097.50 ± 61.65 bc	2883.00 ± 86.75 b	4322.80 ± 133.80 ab
	Steele ND	3071.30 ± 138.50 cd	4369.20 ± 94.82 a	2891.70 ± 106.40 cd	2885.00 ± 122.40 b	4154.00 ± 108.30 b
	Vida	3977.10 ± 201.70 a	4071.90 ± 63.89 b	3663.10 ± 98.24 ab	3308.70 ± 85.40 a	4467.40 ± 118.30 a
Semi-Solid	AC Lillian	2907.80 ± 151.90 cd	3412.20 ± 135.85 d	2837.90 ± 118.56 d	2684.60 ± 116.30 b	4134.50 ± 186.30 b
Solid-Stemmed	Choteau	3051.80 ± 75.32 cd	4082.00 ± 60.53 b	3299.20 ± 84.69 b	2915.90 ± 30.26 b	4491.60 ± 84.06 a
	Mott	3227.30 ± 66.58 c	4182.90 ± 149.30 ab	3793.50 ± 32.52 a	3465.30 ± 62.54 a	4384.00 ± 57.83 ab

Means within a column followed by the same letter are not significanlty different (P ≤ 0.05, LSD).

Table 13. Mean test weight (± S.E.) of hard red spring wheat varieties at each location in 2010.

Solidity	Variety	Test Weight ± S.E. (kg/hL)				
		Grenora	**Hettinger**	**Makoti**	**Regent**	**Scranton**
Hollow-Stemmed	Glenn	76.64 ± 0.02 a	76.07 ± 0.65 a	74.87 ± 0.15 a	74.39 ± 1.24 a	76.49 ± 0.39 a
	Reeder	73.38 ± 0.22 b	72.79 ± 0.75 b	72.12 ± 0.19 bc	70.53 ± 0.67 bc	71.53 ± 0.51 cd
	Steele ND	73.21 ± 0.40 b	71.07 ± 1.14c	71.78 ± 0.11 c	70.32 ± 1.67 bcd	73.01 ± 0.27 b
	Vida	71.98 ± 0.60 b	70.27 ± 1.50 bc	72.68 ± 0.31 b	68.89 ± 1.57 de	72.39 ± 0.20 bc
Semi-Solid	AC Lillian	69.86 ± 0.55 c	67.87 ± 1.25 c	68.43 ± 0.29 e	68.47 ± 1.02 e	70.64 ± 0.15 d
Solid-Stemmed	Choteau	70.02 ± 0.92c	72.61 ± 0.25 b	70.68 ± 0.21 d	69.11 ± 1.15 cde	72.08 ± 0.76 bcd
	Mott	73.16 ± 0.37 b	72.84 ± 0.87 b	72.24 ± 0.09 bc	71.76 ± 1.15 b	73.42 ± 0.96 b

Means within a column followed by the same letter are not significanlty different (P ≤ 0.05, LSD).

Table 14. Mean protein (± S.E.) content of hard red spring wheat varieties at each location in 2010.

Solidity	Variety	Mean % Protein ± S.E.				
		Grenora	**Hettinger**	**Makoti**	**Regent**	**Scranton**
Hollow-Stemmed	Glenn	16.54 ± 0.40 b	15.50 ± 0.07 a	13.15 ± 0.23 b	15.40 ± 0.12 b	13.50 ± 0.09 abc
	Reeder	16.08 ± 0.41 bc	15.00 ± 0.20 b	13.08 ± 0.41 b	14.98 ± 0.46 b	13.65 ± 0.17 ab
	Steele ND	15.79 ± 0.28 bcd	14.85 ± 0.09 bc	13.70 ± 1.15 b	15.18 ± 0.24 b	13.33 ± 0.17 bcd
	Vida	16.64 ± 0.06 b	14.33 ± 0.14 d	13.73 ± 0.44 b	14.90 ± 0.19 b	13.10 ± 0.27 cd
Semi-Solid	AC Lillian	17.86 ± 0.07 a	15.53 ± 0.11 a	14.95 ± 0.29 a	16.18 ± 0.30 a	13.95 ± 0.18 a
Solid-Stemmed	Choteau	15.41 ± 0.20 cd	14.73 ± 0.09 bc	12.95 ± 0.35 b	14.85 ± 0.27 b	12.90 ± 0.15 d
	Mott	14.99 ± 0.23 d	14.68 ± 0.08 c	13.48 ± 0.24 b	15.25 ± 0.32 b	13.00 ± 0.21 cd

Means within a column followed by the same letter are not significanlty different ($P \leq 0.05$, LSD).

Agronomy Performance at Individual Locations in 2011

Scranton 2011

Yield was significantly different among varieties at Grenora in 2011 ($F = 38.09$; $df = 6, 18$; $P < 0.0001$). Mott yielded significantly higher than all other varieties tested (Table 15). Steele ND, Reeder, Vida, and Glenn were significantly higher in yield than AC Lillian and Choteau (Table 15).

Scranton showed a significant difference among varieties for test weight in 2011 ($F = 46.8$; $df = 6, 18$; $P < 0.0001$). Glenn had highest test weight was significantly higher than all other varieties for test weight, while AC Lillian had the lowest test weight and was significantly lower than all other varieties (Table 16). Mott had significantly higher test weight than Choteau, Vida, Reeder, and AC Lillian (Table 16). Choteau had significantly lower test weight than Glenn, Mott, Steele ND, but had significantly higher test weight than AC Lillian (Table 16).

Protein content among varieties were significantly different at Scranton in 2011 ($F = 36.57$; $df = 6, 18$; $P < 0.0001$). AC Lillian was significantly higher in protein content than all other varieties (Table 17). Mott had comparable protein to Glenn and Steele ND, but had significantly higher protein content than Choteau, Reeder, and Vida (Table 17).

Regent 2011

Yield was significantly different among varieties at Regent in 2011 ($F = 33.4$; $df = 6, 18$; $P < 0.0001$). Reeder had significantly higher yield than all other varieties (Table 15). Steele ND and Vida had significantly higher yield than Glenn, Choteau, and AC Lillian (Table 15). Mott was significantly higher in yield than other varieties except Reeder (Table 15). Choteau was significantly lower in yield than Reeder, Mott, Steele ND, and Vida but was significantly higher than AC Lillian (Table 15).

In 2011, hard red spring wheat varieties at Regent had a significant difference test weight among varieties (F = 29.26; df = 6, 18; P < 0.0001). Glenn, Mott, and Steele ND had the significantly highest test weight among the varieties (Table 16). AC Lillian had the lowest test weight and was significantly lower than all other varieties (Table 16).

Protein content varied significantly among varieties (F = 34.05; df = 6, 18; P < 0.0001). AC Lillian had significantly higher protein content than all other varieties (Table 17). Mott had a significantly lower yield than AC Lillian, Glenn, and Steele ND (Table 17). Choteau had comparable protein to Mott and Reeder, but was only significantly higher than Vida (Table 17).

Makoti 2011

Yield was significantly different among varieties at Makoti in 2011 (F = 7.42; df = 6, 18; P = 0.0004). Mott had a significantly higher yield than Glenn, Reeder, AC Lillian, Vida, and Choteau, but not Steele ND (Table 15). Choteau had the lowest yield and was significantly lower than Mott, Steele ND, Glenn, and Reeder (Table 15).

Test weight was significantly different among varieties (F = 15.48; df = 6, 18; P < 0.0001). Glenn and Steele ND were significantly higher in test weight than AC Lillian, Choteau, and Vida (Table 16). Mott had test weight that was significantly lower than Glenn but was significantly higher than AC Lillian, Choteau, and Vida (Table 16).

Makoti had a significant difference among varieties in protein content (F = 3.36; df = 6, 18; P = 0.0212). AC Lillian had significantly higher protein than Mott and Reeder (Table 17).

Hettinger 2011

Yield was significantly different among varieties at Hettinger in 2011 (F = 20.42; df = 6, 18; P < 0.0001). Reeder had significantly higher yield than all other varieties in the study (Table

15). Mott's yield was significantly higher than Steele ND, AC Lillian, and Choteau (Table 15). Choteau had the significantly lowest yield among the varieties (Table 15).

Test weight was significantly different among varieties at Hettinger ($F = 15.44$; $df = 6, 18$; $P < 0.0001$). Glenn and Mott had significantly higher test weight than other varieties (Table 16). Choteau's test weight was significantly lower than Glenn and Mott, but was comparable to AC Lillian, Reeder, Steele ND, and Vida (Table 16).

Protein was significantly different among varieties at Hettinger ($F = 104.13$; $df = 6, 18$; $P < 0.0001$). AC Lillian had significantly higher protein content than the other varieties (Table 17). Mott's protein content was significantly higher than Glenn, Steele ND, Choteau, Reeder, and Vida (Table 17). Choteau's protein was comparable to Reeder and Steele ND, and was only significantly higher than Vida (Table 17).

Table 15. Mean yield (± S.E.) of hard red spring wheat varieties at each location in 2011.

Solidity	Variety	Mean Yield ± S.E. (kg/ha)				
		Grenora	**Hettinger**	**Makoti**	**Regent**	**Scranton**
Hollow-Stemmed	Glenn	N/A[1]	1523.80 ± 68.59 b	1702.70 ± 251.50 bc	1815.70 ± 78.68 d	1867.50 ± 47.07 c
	Reeder	N/A[1]	1702.00 ± 39.69 a	1728.30 ± 153.30 bc	2502.40 ± 61.20 a	1963.00 ± 46.40 bc
	Steele ND	N/A[1]	1316.10 ± 48.42 cd	1926.00 ± 233.40 ab	2068.60 ± 47.08 c	2024.90 ± 53.13 b
	Vida	N/A[1]	1445.20 ± 41.69 bc	1488.20 ± 102.40 cd	2062.50 ± 70.61 c	1934.10 ± 47.07 bc
Semi-Solid	AC Lillian	N/A[1]	1221.90 ± 84.06 d	1492.30 ± 167.50 cd	1463.40 ± 53.80 e	1501.70 ± 87.43 d
Solid-Stemmed	Choteau	N/A[1]	999.30 ± 43.71 e	1217.20 ± 303.30 d	1750.50 ± 75.99 d	1428.40 ± 67.25 d
	Mott	N/A[1]	1540.70 ± 9.42 b	2200.40 ± 214.50 a	2272.40 ± 57.83 b	2307.30 ± 59.85 a

Means within a column followed by the same letter are not significanlty different (P ≤ 0.05, LSD).

[1] **Field plots at Grenora were not planted due too wet field conditions in 2011.**

Table 16. Mean test weight (± S.E.) of hard red spring wheat varieties at each location in 2011.

Solidity	Variety	Test Weight ± S.E. (kg/hL)				
		Grenora	Hettinger	Makoti	Regent	Scranton
Hollow-Stemmed	Glenn	N/A[1]	73.77 ± 0.46 a	72.78 ± 0.47 a	74.39 ± 0.62 a	76.03 ± 0.72 a
	Reeder	N/A[1]	69.17 ± 0.55 bc	68.62 ± 0.19 b	70.24 ± 0.74 b	68.53 ± 0.44 d
	Steele ND	N/A[1]	68.22 ± 0.99 b	70.72 ± 0.72 ab	73.17 ± 0.55 a	70.67 ± 0.56 c
	Vida	N/A[1]	69.47 ± 0.61 bc	62.74 ± 1.47 c	69.28 ± 0.47 b	68.68 ± 0.50 d
Semi-Solid	AC Lillian	N/A[1]	69.89 ± 0.59 b	65.18 ± 1.02 c	67.12 ± 0.72 c	66.27 ± 0.29 e
Solid-Stemmed	Choteau	N/A[1]	69.76 ± 0.07 b	63.97 ± 1.30 c	69.62 ± 0.42 b	68.89 ± 0.22 d
	Mott	N/A[1]	72.58 ± 0.51 a	96.16 ± 1.41 b	73.27 ± 0.59 a	72.71 ± 0.39 b

Means within a column followed by the same letter are not significanlty different ($P \leq 0.05$, LSD).

[1] Field plots at Grenora were not planted due too wet field conditions in 2011.

Table 17. Mean protein (± S.E.) content of hard red spring wheat varieties at each location in 2011.

Solidity	Variety	Mean % Protein ± S.E.				
		Grenora	Hettinger	Makoti	Regent	Scranton
Hollow-Stemmed	Glenn	N/A[1]	16.75 ± 0.06 c	16.78 ± 0.45 ab	17.18 ± 0.09 b	16.75 ± 0.18 b
	Reeder	N/A[1]	16.48 ± 0.13 d	16.53 ± 0.31 b	16.48 ± 0.20 cd	16.13 ± 0.05 c
	Steele ND	N/A[1]	16.65 ± 0.14 cd	17.0 ± 0.17 ab	17.15 ± 0.09 b	16.65 ± 0.13 b
	Vida	N/A[1]	15.55 ± 0.06 e	17.08 ± 0.48 ab	16.33 ± 0.05 d	15.50 ± 0.04 d
Semi-Solid	AC Lillian	N/A[1]	17.83 ± 0.08 a	17.68 ± 0.19 a	18.08 ± 0.08 a	17.65 ± 0.16 a
Solid-Stemmed	Choteau	N/A[1]	16.55 ± 0.13 d	16.93 ± 0.22 ab	16.73 ± 0.11 c	16.13 ± 0.11 c
	Mott	N/A[1]	16.98 ± 0.10 b	16.43 ± 0.37 b	16.48 ± 0.09 cd	16.48 ± 0.08 b

Means within a column followed by the same letter are not significanlty different ($P \leq 0.05$, LSD).

[1] Field plots at Grenora were not planted due too wet field conditions in 2011.

Solidity Ratings for Varieties

Solidity was significantly different among varieties across all locations (F = 107.94; df = 6, 72; P < 0.0001). Choteau and Mott had significantly higher solidity than the other varieties. Vida and AC Lillian had solidity that grouped them in the middle, significantly lower than Choteau and Mott but significantly higher solidity than Steele ND, Reeder, and Glenn. Due to a significant year*location*variety interaction at each internode and across all internodes (Internode 1 Z = 4.92, P < 0.0001; Internode 2 Z = 5.05, P < 0.0001; Internode 3 Z = 5.38, P < 0.0001; Across all internodes Z = 5.20, P < 0.0001), solidity was interpreted for each location and year.

<u>Grenora 2009</u>

First Internode (damaged internodes not removed). Solidity was significantly different at the first internode among varieties at Grenora in 2009 (F = 173.44; df = 6, 690; P < 0.0001). Mott had the highest solidity rating at 4.90, which was significantly higher than all other varieties (Table 18). Choteau had the second highest mean solidity at the first internode and was significantly higher than all varieties except Mott (Table 18). AC Lillian, Glenn, and Vida had intermediate solidity and were significantly different. Reeder and Steele ND had the lowest mean solidity rating at 2.17 and 2.12, respectfully, which was significantly lower than all other varieties (Table 18).

First Internode (damaged internodes removed). Solidity was significantly different among varieties at the first internode with only undamaged internodes (F = 204.15; df = 6, 633; P < 0.0001). The varieties Mott and Choteau were significantly higher than the other varieties (Table 18). Reeder and Steele ND had the lowest solidity rating and were significantly lower than the other varieties (Table 18).

Second Internode (damaged internodes not removed). Solidity was significantly different at the second internode among varieties at Grenora in 2009 ($F = 240.23$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had the mean solidity rating at 4.35 and 4.24, respectfully, which was significantly higher than the other varieties (Table 18). AC Lillian was intermediate among varieties at a mean solidity rating of 3.36 at the second internode (Table 18). Glenn, Reeder, and Steele ND had significantly lower mean solidity rating at the second internode than the other varieties (Table 18).

Second Internode (damaged stems removed). Solidity rating among varieties was significantly different with damage stems removed ($F = 261.34$; $df = 6, 546$; $P < 0.0001$). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 18). The varieties Glenn, Reeder, and Steele ND were significantly were significantly lower in solidity rating than the other varieties (Table 18).

Third Internode (damaged internodes not removed). Solidity rating was significantly different at the third internode among the varieties at Grenora in 2009 ($F = 174.74$; $df = 6, 690$; $P < 0.0001$). Choteau had the highest mean solidity at the third internode with 3.75, which was significantly higher than the other varieties (Table 18). Mott had the second highest mean solidity at 3.14, which was significantly lower than Choteau, but significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 18). AC Lillian and Vida were intermediate for solidity. Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 18).

Third Internode (damaged internodes removed). Solidity rating was significantly different with damaged stems removed among varieties at the third internode at Grenora in 2009 ($F = 121.68$; $df = 6, 466$; $P < 0.0001$). Choteau was significantly higher in solidity rating than all other varieties (Table 18). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Vida, Glenn, Steele ND, and Reeder (Table 18). Glenn, Steele ND, and Reeder were significantly lower than the other varieties (Table 18).

Across All Internodes (damage internodes not removed). Solidity was significantly different among varieties across all internodes at Grenora in 2009 ($F = 309.08$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had significantly higher solidity ratings across all internodes compared to the other varieties (Table 18). Reeder and Steele ND were significantly lower than the other varieties (Table 18). AC Lillian had the third highest solidity rating and was significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 18).

Across All Internodes (damage internodes removed). Solidity ratings were significantly different across all internodes with damaged internodes removed ($F = 255.32$; d f= 6, 443; $P < 0.0001$). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 18). Steele ND had the lowest solidity rating and was significantly lower than Choteau, Mott, AC Lillian, Vida, and Reeder (Table 18).

<u>Grenora 2010</u>

First Internode (damaged internodes not removed). Varieties were significantly different for solidity at the first internode at Grenora in 2010 ($F = 45.59$; $df = 6, 690$; $P < 0.0001$). Mott had the highest mean solidity rating at the first internode with 4.16, which was significantly higher than the other varieties (Table 19). Choteau was significantly lower than Mott in mean solidity rating, but was significantly higher than the rest of the varieties (Table 19). AC Lillian and Vida were intermediate in solidity with 2.86 and 2.94, respectfully (Table 19). Reeder and Steele ND were significantly lower than AC Lillian, Choteau, Glenn, Mott, and Vida in solidity (Table 19).

First Internode (damaged internodes removed). Solidity rating was significantly different at the first internode with damage internodes removed among varieties ($F = 46.81$; df = 6, 451; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 19). Glenn, Reeder, and Steele ND were significantly lower than all other varieties (Table 19).

Second Internode (damaged internodes not removed). Solidity was significantly different among varieties at the second internode at Grenora in 2010 ($F = 72.53$; df = 6, 690; $P < 0.0001$). The variety with the highest mean solidity rating at the second internode was Mott with 3.31, which was significantly higher than the varieties (Table 19). Choteau was the second highest mean solidity rating with 3.01, which was significantly lower than Mott and significantly higher than the rest varieties (Table 19). AC Lillian and Vida were intermediate with 2.02 and 2.54, respectfully (Table 19). The lowest mean solidity ratings were Glenn, Reeder, and Steele ND.

Second Internode (damaged internodes removed). Varieties were significantly different for solidity rating at the second internode with damaged stems removed ($F = 50.08$; df = 6, 195; $P < 0.0001$). Choteau and Mott were significantly higher in solidity than the other varieties (Table 19). AC Lillian was significantly lower than Choteau and Mott but was significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 19).

Third Internode (damaged internodes not removed). Varieties were significantly different for solidity at the third internode at Grenora in 2010 ($F = 53.39$; df = 6, 690; $P < 0.0001$). Choteau, Mott, and Vida had the highest mean solidity rating at the third internode with 2.27, 2.4, and 2.35, respectfully, which were significantly higher than the other varieties (Table 19). AC Lillian had solidity that was intermediate among the varieties with 1.61 (Table 19). Glenn, Reeder, and Steele ND were significantly lower than all other varieties (Table 19).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the third internode with damaged internodes removed ($F = 18.11$; $df = 6, 117$; $P < 0.0001$). Mott was significantly higher in solidity than all varieties except Choteau (Table 19). Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 19).

Across All Internodes (damaged internodes not removed). Varieties were significantly different for solidity across all internodes ($F = 83.81$; $df = 6, 690$; $P < 0.0001$). Mott had the significantly highest solidity rating among the varieties (Table 19). Choteau was significantly lower than Mott, but was significantly higher than all other varieties (Table 19). AC Lillian was intermediate and significantly higher than Glenn, Reeder, and Steele ND (Table 19). Glenn, Reeder, and Steele ND were significantly lower than the other varieties for solidity across all internodes (Table 19).

Across All Internodes (damaged internodes removed). Varieties were significantly different for solidity rating across all internodes with damaged internodes removed ($F = 20.31$; $df = 6, 68$; $P < 0.0001$). Choteau and Mott were significantly higher than Glenn, Reeder, Steele ND, and Vida in solidity (Table 19).

<u>Hettinger 2010</u>

First Internode (damaged internodes not removed). Varieties were significantly different for solidity at the first internode at Hettinger in 2010 ($F = 214.63$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had significantly higher mean solidity rating at the first internode than the other varieties with 3.60 and 3.46, respectfully (Table 20). AC Lillian had a mean solidity rating of 2.49, which was significantly lower than Choteau and Mott, but was significantly than Glenn, Reeder, Steele ND, and Vida (Table 20). Glenn had the significantly lowest mean solidity rating at the second internode (Table 20).

First Internode (damaged internodes removed). Solidity rating at the first internode with damaged internodes removed was significantly different among varieties ($F = 180.67$; $df = 6, 584$; $P < 0.0001$). Choteau and Mott had the highest solidity ratings and were significantly higher than the other varieties (Table 20). Glenn and Steele ND were significantly lower than the other varieties (Table 20).

Second Internode (damaged internodes not removed). Solidity rating was significantly different among varieties at the second internode at Hettinger in 2010 ($F = 180.08$; $df = 6, 690$; $P < 0.0001$). Choteau had the highest mean solidity rating at 3.13, which was significantly higher than the other varieties (Table 20). Mott was the second highest variety with a mean solidity rating of 2.68, which was significantly lower than Choteau, but was significantly higher than the rest of the varieties (Table 20). AC Lillian and Vida had solidity rating at the second internode that intermediate. Glenn, Reeder, and Steele ND had significantly lower mean solidity rating than the other varieties with 1.02, 1.06, and 1.04, respectfully (Table 20).

Second Internode (damaged internodes removed). Varieties were significantly different for solidity rating at the second internode with damaged internodes removed ($F = 118.49$; $df = 6, 461$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 20). Mott was significantly lower than Choteau, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 20).

Third Internode (damaged internodes not removed). Varieties were significantly different for solidity at the third internode at Hettinger in 2010 ($F = 129.59$; $df = 6, 690$; $P < 0.0001$). Choteau had the highest mean solidity rating with 2.75, which was significantly higher than the other varieties (Table 20). AC Lillian and Mott were significantly lower than Choteau, but were significantly higher in mean solidity at the third internode than the rest of the varieties (Table 20). Glenn, Reeder, and Steele ND had the lowest solidity rating with 1.01, 1.01, and 1.02, respectfully, which was significantly lower than the other varieties (Table 20).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the third internode with damaged internodes removed ($F = 75.12$; $df = 6, 444$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 20). AC Lillian and Mott were significantly lower than Choteau but were significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 20).

Across All Internodes (damaged internodes not removed). Solidity across all internodes was significantly different among varieties at Hettinger in 2010 ($F = 223.33$; $df = 6, 663$; $P < 0.0001$). Choteau had the significantly highest mean solidity rating, while Mott was significantly lower than Choteau but significantly higher than the other varieties (Table 20). AC Lillian was intermediate and significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 20). Glenn, Reeder, and Steele ND had the significantly lowest solidity rating (Table 20).

Across All Internodes (damaged internodes removed). Solidity rating across all internodes was significantly different among varieties with damaged internodes removed ($F = 112.7$; $df = 6, 364$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 20). Mott was significantly lower than Choteau, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 20). Glenn, Reeder, and Steele ND had the significantly lowest solidity rating (Table 20).

Hettinger 2011

First Internode (damaged internodes not removed). Varieties were significantly different for solidity rating at the first internode at Hettinger in 2011 ($F = 234.73$; $df = 6, 690$; $P < 0.0001$). Mott had the highest mean solidity rating with 4.35, which was significantly than the other varieties (Table 21). Choteau had a mean solidity rating that was significantly lower than Mott, but was significantly higher than all other varieties. Reeder and Steele ND had the lowest mean solidity rating at the first internode with 1.07 and 1.00, which was significantly lower than the other varieties (Table 21).

First Internode (damaged internodes removed). Solidity rating at the first internode with damaged internodes removed was significantly different among varieties ($F = 228.54$; $df = 6, 650$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 21). Choteau was significantly lower than Mott, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 21).

Second Internode (damaged internodes not removed). Varieties were significantly different for solidity at the second internode at Hettinger in 2011 ($F = 136.34$; $df = 6, 690$; $P < 0.0001$). Mott had the highest mean solidity rating with 3.62, which was significantly higher than the other varieties (Table 21). Choteau had the second highest mean solidity rating with 2.40, which was significantly lower than Mott, but was significantly higher than the other varieties (Table 21). AC Lillian, Glenn, Reeder, Steele ND, and Vida were not significantly different for mean solidity at the second internode (Table 21).

Second Internode (damaged internodes removed). Solidity rating among varieties was significantly different at the second internode with damaged internodes removed ($F = 133.32$; $df = 6, 650$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 21). Choteau was significantly lower than Mott, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 21).

Third Internode (damaged internodes not removed). Solidity was significantly different among varieties at eh third internode at Hettinger in 2011 ($F = 74.23$; $df = 6, 690$; $P < 0.0001$). Mott had the highest mean solidity rating with 2.76, which was significantly higher than the other varieties (Table 21). AC Lillian, Glenn, Reeder, Steele ND, and Vida were not significantly different for mean solidity at the second internode (Table 21).

Third Internode (damaged internodes removed). Solidity rating at the third internode with damaged internodes removed was significantly different among varieties ($F = 73.28$; $df = 6, 656$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 21). AC Lillian, Glenn, Reeder, Steele ND, and Vida were significantly lower in solidity than Choteau and Mott (Table 21).

Across All Internodes (damaged internodes not removed). Varieties were significantly different for solidity rating across all internodes ($F = 251.22$; $df = 6, 690$; $P < 0.0001$). Mott had the significantly highest solidity rating followed by Choteau, and both varieties had a significantly higher solidity across all internodes than other varieties (Table 21). AC Lillian was intermediate and comparable to Glenn and Vida (Table 21). Reeder was significantly lower than Mott, Choteau, and AC Lillian (Table 21).

Across All Internodes (damaged internodes removed). Solidity ratings across all internodes was significantly different among varieties with damaged internodes removed ($F = 239.64$; $df = 6, 640$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 21). Choteau was significantly lower than Mott, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 21).

Makoti 2009

First Internode (damaged internodes not removed). Varieties were significantly different for solidity at the first internode at Makoti in 2009 ($F = 105.52$; $df = 6, 516$; $P < 0.0001$). Choteau and Mott had the highest mean solidity rating with 4.31 and 4.41, respectfully, which were significantly higher than the other varieties (Table 22). AC Lillian and Vida had mean solidity that was intermediate. Glenn, Reeder, and Steele ND had significantly lower mean solidity at the first internode than the other varieties (Table 22).

First Internode (damaged internodes removed). Solidity rating at the first internode with damaged internodes removed was significantly different among varieties ($F = 45.12$; $df = 6, 250$; $P < 0.0001$). Choteau and Mott had the highest solidity ratings and were significantly higher than the other varieties (Table 22). AC Lillian, Glenn, Reeder, Steele ND, and Vida were significantly lower in solidity than AC Lillian, Choteau, Mott, and Vida (Table 22).

Second Internode (damaged internodes not removed). Varieties were significantly different for solidity at the second internode at Makoti in 2009 ($F = 108.64$; $df = 6, 516$; $P < 0.0001$). Choteau and Mott were significantly higher than the other varieties for mean solidity rating at the second internode with 4.05 and 4.00, respectfully (Table 22). AC Lillian had the second highest mean solidity rating with 3.27, which was significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 22). Reeder and Steele ND had significantly lower mean solidity rating than the other varieties (Table 22).

Second Internode (damaged internodes removed). Solidity rating among varieties was significantly different at the second internode with damaged internodes removed ($F = 39.56$; $df = 6, 201$; $P < 0.0001$). Choteau and Mott had the highest solidity ratings and were significantly higher than the other varieties (Table 22). AC Lillian and Vida were significantly lower than Choteau and Mott but were significantly higher than Glenn, Reeder, and Steele ND (Table 22).

Third Internode (damaged internodes not removed). Solidity rating among varieties at the third internode was significantly different at Makoti in 2009 ($F = 121.51$; $df = 6, 516$; $P < 0.0001$). Choteau had the highest mean solidity rating with 4.13, which was significantly higher than the other varieties (Table 22). Mott had the second highest mean solidity at the third internode with 3.27 (Table 22). AC Lillian had and intermediate mean solidity rating that was significantly lower than Choteau and Mott, but was significantly higher than Glenn, Reeder, Steele ND, and Vida (Table 22).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the third internode with damaged internodes removed ($F = 52.50$; $df = 6, 181$; $P < 0.0001$). Choteau was significantly higher in solidity than the other varieties (Table 22). Glenn, Reeder, and Steele ND were significantly lower in solidity than the other varieties (Table 22).

Across All Internode (damaged internodes not removed). Solidity rating among varieties was significantly different across all internodes at Makoti in 2009 ($F = 174.1$, $df = 6, 690$; $P < 0.0001$). Choteau and Mott had the significantly highest solidity rating across all internodes (Table 22). AC Lillian had the third highest solidity rating across all internodes (Table 22). Glenn, Steele ND, and Reeder had significantly lower solidity than Choteau, Mott, AC Lillian, and Vida (Table 22).

Across All Internodes (damaged internodes removed). Solidity rating across all internodes was significantly different among varieties with damaged internodes removed ($F = 37.04$; $df = 6, 139$; $P < 0.0001$). Choteau and Mott were significantly higher than AC Lillian, Glenn, Reeder, and Steele ND (Table 22). Reeder and Steele ND were significantly lower in solidity than AC Lillian, Choteau, Mott, and Vida (Table 22).

Makoti 2010

First Internode (damaged internodes not removed). Varieties were significantly different for solidity at the first internode at Makoti in 2010 ($F = 103.61$; $df = 6, 690$; $P < 0.0001$). Mott had the highest mean solidity rating with 4.68, which was significantly higher than the other varieties (Table 23). The second highest mean solidity was held by the variety Choteau, at 3.52, which was significantly lower than Mott and significantly higher than AC Lillian, Glenn, Reeder, and Steele ND (Table 23). Glenn and Steele ND had significantly lower mean solidity rating than the others with 2.2 and 2.11, respectfully (Table 23).

First Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the first internode with damaged internodes removed ($F = 74.05$; $df = 6, 435$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 23). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, Mott and Vida (Table 23).

Second Internode (damaged internodes not removed). Varieties were significantly different for solidity at the second internode at Makoti in 2010 ($F = 125.56$; $df = 6, 690$; $P < 0.0001$). Mott was the variety with the highest mean solidity rating at the second internode with a rating of 4.00, which was significantly higher than the other varieties (Table 23). Choteau and Vida were comparable in mean solidity rating with 2.86 and 2.7, respectfully, which were significantly lower than Mott, but were significantly higher than AC Lillian, Glenn, Reeder, and Steele ND (Table 23). Glenn and Steele ND had the lowest mean solidity rating with 1.26 and 1.34, respectfully, which were significantly lower than the other varieties (Table 23).

Second Internode (damaged internodes removed). Solidity rating at the first internode with damaged internodes removed was significantly different among varieties ($F = 43.97$; $df = 6, 286$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 23). Choteau was significantly lower than Mott but was significantly higher in solidity than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 23).

Third Internode (damaged internodes not removed). Varieties were significantly different for mean solidity rating at the third internode at Makoti in 2010 ($F = 76.72$; $df = 6, 690$; $P < 0.0001$). Mott had the significantly highest mean solidity rating at 2.78 (Table 23). Choteau had the second highest and was significantly different. AC Lillian, Glenn, Reeder, and Steele ND had the lowest mean solidity rating and were significantly lower than the other varieties (Table 23).

Third Internode (damaged internodes removed). Solidity ratings among varieties was significantly different at the third internode with damaged internodes removed ($F = 39.39$; $df = 6, 304$; $P < 0.0001$). Choteau and Mott were significantly higher than the other varieties (Table 23). Glenn, Reeder, and Steele ND were significantly lower than Choteau, Mott, and Vida (Table 23).

Across All Internode (damaged internodes not removed). Solidity rating across all internodes was significantly different among varieties ($F = 159.49$; $df = 6, 690$; $P < 0.0001$). Mott had a significantly higher solidity rating across all internodes than all other varieties tested at Makoti in 2010 (Table 23). Choteau and Vida were not significantly different, but both were significantly higher than AC Lillian, Reeder, Glenn, and Steele ND (Table 23).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties across all internodes with damaged internodes removed ($F = 53.30$;

df = 5, 217; P < 0.0001). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 23). Reeder and Steele ND had the lowest solidity and were significantly lower than Choteau, Mott and Vida (Table 23).

Makoti 2011

First Internode (damaged internodes not removed). Mean solidity at the first internode was significantly different among varieties at Makoti in 2011 (F = 126.72; df = 6, 690; P < 0.0001). Mott had the highest mean solidity rating at the first internode with 4.01, which was significantly higher than the other varieties (Table 24). Choteau had the second highest solidity which was significantly lower than Mott, but was significantly higher than the rest of the varieties (Table 24). AC Lillian and Vida were intermediate for mean solidity of the first internode with 1.97 and 1.72, respectfully (Table 24). Glenn, Reeder, and Steele ND were the significantly lowest varieties for solidity at the first internode.

First Internode (damaged internodes removed). Solidity rating at the first internode with damaged internodes removed was significantly different among varieties (F = 117.54; df = 6, 645; P < 0.0001). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 24). Choteau was significantly lower than Mott, but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 24).

Second Internode (damaged internodes not removed). Varieties were significantly different for solidity at the second internode at Makoti in 2011 (F = 78.53; df = 6, 690; P < 0.0001). Mott had the significantly highest mean solidity rating with 3.32 (Table 24). Choteau had the second highest mean solidity rating with 2.28, which was significantly lower than Mott, but was significantly higher than the rest of the varieties (Table 24). AC Lillian and Vida were intermediate in mean solidity at the second internode with 1.55 and 1.33, respectfully

(Table 24). Glenn, Reeder, and Steele ND had the lowest mean solidity rating with 1.02, 1.02, and 1.00, respectfully, and were significantly lower than the other varieties (Table 24).

Second Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the second internode with damaged internodes removed ($F = 68.08$; $df = 6, 622$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 24). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, and Mott (Table 24).

Third Internode (damaged internodes not removed). Mean solidity at the third internode was significantly different among varieties at Makoti in 2011 ($F = 37.19$; $df = 6, 690$; $P < 0,0001$). Choteau and Mott had the highest mean solidity rating with 2.07 and 2.27, respectfully, which were significantly higher than the other varieties (Table 24). AC Lillian, Glenn, Reeder, Steele ND, and Vida were comparable in mean solidity (Table 24).

Third Internode (damaged internodes removed). Solidity rating at the third internode with damaged internodes removed was significantly different among varieties ($F = 31.64$; $df = 6, 630$; $P < 0.0001$). Choteau and Mott were significantly higher than the other varieties (Table 24).

Across All Internodes (damaged internodes not removed). At Makoti in 2011, solidity among varieties was significantly different ($F = 109.96$; $df = 6, 690$; $P < 0.0001$). Mott was significantly higher in solidity across all internodes than other varieties (Table 24). Choteau was second highest in solidity rating. AC Lillian and Vida were grouped within the middle of varieties for solidity and were significantly higher than Glenn, Reeder, and Steele ND (Table 24). Glenn, Reeder, and Steele ND were significantly lower than other varieties (Table 24).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties across all internodes with damaged internodes removed ($F = 88.94$;

df = 6, 583; P < 0.0001). Choteau and Mott were significantly higher than the other varieties (Table 24). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, Mott, and Vida (Table 24).

Regent 2009

First Internode (damaged internodes not removed). Varieties were significantly different for mean solidity at the first internode at Regent in 2009 (F = 91.71; df = 6, 690; P < 0.0001). Choteau and Mott were the highest varieties for mean solidity rating with 4.09 and 4.34, respectfully, which were significantly higher than the other varieties (Table 25). AC Lillian and Vida were intermediate for mean solidity at the first internode with 2.89 and 2.93, respectfully (Table 25). Glenn had the significantly lowest mean solidity with 1.49 (Table 25).

First Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the first internode with damaged internodes removed (F = 41.07; df = 6, 474; P < 0.0001). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 25). Glenn was significantly lower than the other varieties (Table 25).

Second Internode (damaged internodes not removed). Mean solidity rating at the second internode was significantly different among varieties at Regent in 2009 (F = 77.5; df = 6, 690; P < 0.0001). Choteau and Mott had the significantly highest mean solidity rating with 3.65 and 3.78, respectfully (Table 25). AC Lillian and Vida were significantly lower than Mott and Choteau, but were significantly higher than Glenn, Reeder, and Steele ND (Table 25). Glenn had the lowest mean solidity rating with 1.09, which was significantly lower than the rest of the varieties (Table 25).

Second Internode (damaged internodes removed). Solidity at the second internode with damaged internodes removed was significantly different among varieties (F = 79.99; df = 6, 445;

P < 0.0001). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 25). Glenn was significantly lower than the other varieties (Table 25).

Third Internode (damaged internodes removed). Varieties were significantly different for mean solidity at the third internode at Regent in 2009 (F = 130.12; df = 6, 690; P < 0.0001). Choteau and Mott were significantly higher than the other varieties with mean solidity at the third internode with 3.34 and 3.47, respectfully (Table 25). Glenn, Reeder, and Steele ND had the lowest mean solidity rating and were significantly lower than Choteau, Mott, and Vida (Table 25).

Third Internode (damaged internodes removed). Solidity was significantly different among varieties (F = 79.66; df = 6, 483; P < 0.0001). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 25).

Across All Internodes (damaged internodes not removed). Solidity ratings across all internodes at Regent 2009 was significantly different (F = 122.5; df = 6, 690; P < 0.0001). Choteau and Mott had significantly higher solidity rating than other varieties tested (Table 25). AC Lillian and Vida tested significantly in the middle among the varieties (Table 25). Glenn had the significantly lowest solidity rating (Table 25).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties across all internodes with damaged internodes removed (F = 47.50; df = 6, 407; P < 0.0001). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 25). Glenn was significantly lower than the other varieties (Table 25).

Regent 2010

First Internode (damaged internodes not removed). Varieties were significantly different at the first internode for mean solidity rating at Regent in 2010 ($F = 167.81$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had the highest mean solidity ratings with 3.92 and 3.94, respectfully, which were significantly higher than the other varieties (Table 26). Vida had an intermediate mean solidity rating with 2.52, which was significantly higher than Glenn, Reeder, and Steele ND (Table 26).

First Internode (damaged internodes removed). Varieties were significantly different among varieties at the first internode with damage internodes removed ($F = 106.50$; $df = 6, 394$; $P < 0.0001$). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 26). Glenn, Reeder, and Steele ND were significantly lower in solidity than the other varieties (Table 26).

Second Internode (damaged internodes not removed). Mean solidity rating was significantly different among varieties at the second internode at Regent in 2010 ($F = 182.70$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had the significantly highest mean solidity rating with 3.66 and 3.73, respectfully (Table 26). AC Lillian was significantly lower than Choteau and Mott, but was significantly higher than Glenn, Reeder, and Steele ND (Table 26). Glenn, Reeder, and Steele ND had the lowest mean solidity rating and were significantly lower than the other varieties.

Second Internode (damaged internodes removed). Solidity was significantly different among varieties at the second internode with damaged internodes removed ($F = 67.51$; $df = 6, 225$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 26). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau and Mott (Table 26).

Third Internode (damaged internodes not removed). Varieties were significantly different at the second internode for mean at the third internode at Regent in 2010 ($F = 132.44$; $df = 6, 690$; $P < 0.0001$). Choteau and Mott had mean solidity ratings at the third internode of 2.93 and 3.12, respectfully which was significantly higher than the other varieties (Table 26). Glenn, Reeder, Steele ND, and Vida were significantly lower than AC Lillian, Choteau, and Mott (Table 26).

Third Internode (damaged internodes removed). Varieties were significantly different among varieties at the third internode with damaged internodes removed ($F = 34.12$; $df = 6, 213$; $P < 0.0001$). Choteau and Mott had the highest solidity rating and were significantly higher than the other varieties (Table 26). Glenn, Reeder, Steele ND, and Vida were significantly lower in solidity than the other varieties (Table 26).

Across All Internodes (damaged internodes not removed). Varieties at Regent in 2010 were significantly different in solidity across all internodes ($F = 257.06$; $df = 6, 684$; $P < 0.0001$). Choteau and Mott were significantly higher in solidity across all internodes than the other varieties (Table 26). AC Lillian was significantly lower than Choteau and Mott, but was significantly higher than Vida, Glenn, Reeder, and Steele ND (Table 26). Glenn, Reeder, and Steele ND were significantly lower than other varieties tested for solidity across all internodes (Table 26).

Across All Internodes (damaged internodes removed). Varieties were significantly different for solidity rating across all internodes ($F = 39.44$; $df = 6, 118$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 26).

Choteau was significantly lower than Mott but was significantly higher than AC Lillian, Glenn, Reeder, and Steele ND (Table 26). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau and Mott (Table 26).

Regent 2011

First Internode (damaged internodes not removed). Varieties were significantly different at the first internode for mean solidity rating at Regent in 2011 ($F = 183.87$; $df = 6, 684$; $P < 0.0001$). Mott had the highest mean solidity rating at the first internode with 4.43, which was significantly higher than the other varieties (Table 27). Choteau had the second highest mean solidity rating with 4.05, which was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27). Glenn, Reeder, and Steele ND had the lowest solidity ratings and were significantly lower than the other varieties (Table 27).

First Internode (damaged internodes removed). Solidity ratings were significantly different among varieties at the first internode with damaged internodes removed ($F = 170.60$; $df = 6, 650$; $P < 0.0001$). Mott had the highest solidity rating and was significantly higher than the other varieties (Table 27). Choteau was significantly lower than Mott but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, Mott, and Vida (Table 27).

Second Internode (damaged internodes not removed). Mean solidity at the second internode was significantly different among varieties at Regent in 2011 ($F = 143.23$; $df = 6, 684$; $P < 0.0001$). Choteau had the highest mean solidity rating with 3.69, which was significantly higher than the other varieties. Mott was significantly lower than Choteau, but was significantly higher in solidity at the second internode than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27). AC Lillian and Vida had intermediate mean solidity rating with 1.52 and 1.6, respectfully (Table 27). Glenn, Reeder, and Steele ND had significantly lower mean solidity than the other varieties (Table 27).

Second Internode (damaged internodes removed). Solidity rating was significantly different among varieties ($F = 133.89$; $df = 6, 635$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 27). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, Mott, and Vida (Table 27).

Third Internode (damaged internodes not removed). Varieties were significantly different for mean solidity rating at the third internode at Regent in 2011 ($F = 201.29$; $df = 6, 684$; $P < 0.0001$). Choteau was significantly higher in mean solidity at the third internode than the other varieties with a mean solidity of 3.79 (Table 27). Mott was significantly lower than Choteau, but had a mean solidity that was significantly higher than the other varieties (Table 27). AC Lillian, Glenn, Reeder, and Steele ND were significantly lower than the other varieties for mean solidity (Table 27).

Third Internode (damaged internodes removed). Varieties were significantly different for solidity rating at the third internode with damaged internodes removed ($F = 185.54$; $df = 6, 644$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 27). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27).

Across All Internodes (damaged internodes not removed). Solidity rating across all internodes were significantly different among varieties at Regent in 2011 ($F = 245.38$; $df = 6, 685$; $P < 0.0001$). Choteau had the significantly highest solidity ratings across all internodes

(Table 27). Mott was significantly lower than Choteau in solidity rating but was significantly higher than AC Lillian, Vida, Glenn, Reeder, and Steele ND (Table 27). AC Lillian and Vida had solidity that tested in the middle of the varieties. Glenn, Reeder, and Steele ND were significantly lower than all other varieties tested (Table 27).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties across all internodes with damaged internodes removed ($F = 209.97$; $df = 6, 597$; $P < 0.0001$). Choteau had the highest solidity rating and was significantly higher than the other varieties (Table 27). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 27). Glenn, Reeder, and Steele ND were significantly lower than AC Lillian, Choteau, Mott, and Vida (Table 27).

<u>Scranton 2009</u>

First Internode (damaged internodes not removed). Varieties were significantly different for mean solidity at the first internode at Scranton in 2009 ($F = 100.65$; $df = 6,690$; $P < 0.0001$). Mott had the highest mean solidity with 4.54, which was significantly higher than the other varieties (Table 28). Choteau was significantly lower than Mott, but was significantly higher than the rest of the varieties (Table 28). AC Lillian and Vida were intermediate with 3.26 and 3.00, respectfully, which was significantly higher than Glenn, Reeder, and Steele ND (Table 28).

First Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the first internode with damaged internodes removed ($F = 86.07$; $df = 6, 438$; $P < 0.0001$). Choteau and Mott were significantly higher in solidity than the other varieties (Table 28). Reeder and Steele ND were significantly lower than the other varieties (Table 28).

Second Internode (damaged internodes not removed). Mean solidity rating was significantly different among varieties at the second internode at Scranton in 2011 (F = 91.39; df = 6, 690; P < 0.0001). Choteau and Mott had the highest mean solidity rating at the second internode with 3.66 and 3.78, respectfully, which was significantly higher than the other varieties (Table 28). Reeder and Steele ND had the lowest solidity rating with 1.13 and 1.32, respectfully, which was significantly lower than AC Lillian, Choteau, Mott, and Vida (Table 28).

Second Internode (damaged internodes removed). Varieties were significantly different for solidity rating at the second internode with damaged internodes removed (F = 53.88; df = 6, 370; P < 0.0001). Choteau and Mott were significantly higher in solidity than the other varieties (Table 28). Reeder and Steele ND were significantly lower than the other varieties (Table 28).

Third Internode (damaged internodes not removed). Varieties were significantly different for mean solidity rating at the third internode at Scranton in 2009 (F = 67.11; df = 6, 690; P < 0.0001). Choteau had the highest mean solidity rating with 3.32, which was significantly higher than the other varieties (Table 28). Mott was significantly lower than Choteau but was significantly higher than the other varieties (Table 28). AC Lillian and Vida were intermediate with 1.95 and 1.93, respectfully, which were significantly higher than Glenn, Reeder, and Steele ND (Table 28).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the third internode with damaged internodes removed (F = 40.61; df = 6, 406; P < 0.0001). Choteau had the highest solidity and was significantly higher than the other varieties (Table 28). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 28).

Across All Internodes (damaged internodes not removed). Solidity rating across all internodes was significantly different among varieties (F = 118.46; df = 6, 690; P < 0.0001). Choteau and Mott had the significantly highest solidity across all internodes rating among the varieties (Table 28). AC Lillian was intermediate and significantly higher than Vida, Glenn, Steele ND, and Reeder (Table 28). Glenn, Steele ND, and Reeder were significantly lower in solidity than Choteau, Mott, AC Lillian, and Vida (Table 28).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties (F = 61.60; df = 6, 325; P < 0.0001). Choteau and Mott were significantly higher in solidity than the other varieties (Table 28). Reeder and Steele ND were significantly lower than the other varieties (Table 28).

Scranton 2010

First Internode (damaged internodes not removed). Varieties were significantly different for mean solidity at the first internode at Scranton 2010 (F = 197.64; df = 6, 690; P < 0.0001). Choteau was significantly higher than the other varieties with a mean solidity rating of 4.24 (Table 29). Mott had the second highest mean solidity rating with 3.6 (Table 29). Reeder and Steele ND had the lowest mean solidity rating with 1.56 and 1.55, respectfully, which were significantly lower than the other varieties (Table 29).

First Internode (damaged internode removed). Solidity rating was significantly different among varieties (F = 154.46; df = 6, 517; P < 0.0001). Choteau had the highest solidity and was significantly higher than the other varieties (Table 29). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 29). Reeder and Steele ND were significantly lower than the other varieties (Table 29).

Second Internode (damaged internodes not removed). Mean solidity rating was significantly different among varieties at the second internode at Scranton in 2010 ($F = 226.60$; $df = 6, 690$; $P < 0.0001$). Choteau had the highest mean solidity rating of 3.8, and was significantly higher than the other varieties (Table 29). Mott had the second highest mean solidity rating and was significantly higher than all varieties except Choteau (Table 29). Glenn, Reeder, and Steele ND had the lowest mean solidity rating with 1.02, 1.07, and 1.05, respectfully, which were significantly lower than the other varieties (Table 29).

Second Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the second internode with damaged internodes removed ($F = 139.35$; $df = 6, 357$; $P < 0.0001$). Choteau had the highest solidity and was significantly higher than the other varieties (Table 29). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 29). Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 29).

Third Internode (damaged internodes not removed). Varieties were significantly different for mean solidity at the third internode at Scranton 20010 ($F = 126.29$; $df = 6, 690$; $P < 0.0001$). Choteau was significantly higher than the other varieties with a mean solidity rating of 3.05 (Table 29). Mott had the second highest mean solidity rating which was significantly higher than all varieties except Choteau (Table 29). Glenn, Reeder, and Steele ND had significantly lower mean solidity ratings than the other varieties (Table 29).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties ($F = 73.32$; $df = 6, 383$; $P < 0.0001$). Choteau had the highest solidity and was significantly higher than the other varieties (Table 29). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida

(Table 29). Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 29).

Across All Internodes (damaged internodes not removed). At Scranton in 2010, solidity rating was significantly different among varieties ($F = 305.75$; $df = 6, 690$; $P < 0.0001$). Choteau was significantly higher than all other varieties tested for solidity across all internodes (Table 29). Mott was significantly lower than Choteau in solidity, but was higher than the other varieties (Table 29). AC Lillian and Vida had solidity that was significantly lower than Choteau and Mott, but were significantly higher than Glenn, Reeder, and Steele ND (Table 29). Glenn, Reeder, and Steele ND had the lowest solidity ratings across all internodes and were significantly lower than the other varieties (Table 29).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties across all internodes with damaged internodes removed ($F = 92.32$; $df = 6, 232$; $P < 0.0001$). Choteau had the highest solidity and was significantly higher than the other varieties (Table 29). Mott was significantly lower than Choteau but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 29). Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 29).

<u>Scranton 2011</u>

First Internode (damaged internodes not removed). Varieties were significantly different for mean solidity rating at the first internode at Scranton in 2011 ($F = 197.64$; $df = 6, 684$; $P < 0.0001$). Mott had the highest mean solidity with 4.17, which was significantly higher than the other varieties (Table 30). Choteau had the second highest mean solidity rating with 2.8 (Table 30). AC Lillian and Vida had solidity ratings of 1.99 and 1.74, respectfully, which were significantly lower than Mott and Choteau, but was significantly higher than Glenn, Reeder, and Steele ND (Table 30).

First Internode (damaged internodes removed). Solidity rating was significantly different among varieties ($F = 131.31$; $df = 6, 428$; $P < 0.0001$). Choteau and Mott were significantly higher in solidity than the other varieties (Table 30). Glenn, Reeder, and Steele ND were significantly lower than the other varieties (Table 30).

Second Internode (damaged internodes not removed). Mean Solidity rating at the second internode was significantly different at Scranton 2011 ($F = 112.49$, $df = 6, 684$, $P < 0.0001$). Mott was significantly higher than the other varieties with a mean solidity rating of 3.76 at the second internode (Table 30). Choteau was significantly higher than all varieties except Mott, with a mean solidity rating of 2.60 (Table 30). Glenn, Reeder, and Steele ND had the significantly lowest mean solidity ratings (Table 30).

Second Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the second internode with damaged internodes removed ($F = 62.41$; $df = 6, 306$; $P < 0.0001$). Mott had the highest solidity and was significantly higher than the other varieties (Table 30). Choteau was significantly lower than Mott but was significantly higher than AC Lillian, Glenn, Reeder, Steele ND, and Vida (Table 30). Glenn, Reeder, and Steele ND had the significantly lower than AC Lillian, Choteau, and Mott (Table 30).

Third Internode (damaged internodes not removed). Varieties were significantly different for mean solidity rating at the third internode at Scranton in 2011 ($F = 75.83$; $df = 6, 684$; $P < 0.0001$). Choteau and Mott had the highest mean solidity ratings with 2.72 and 2.92, respectfully, which were significantly higher than the other varieties (Table 30). Glenn, Reeder, and Steele ND were significantly lower than Choteau, Mott, and Vida (Table 30).

Third Internode (damaged internodes removed). Solidity rating was significantly different among varieties at the third internode with damaged internodes removed (F = 32.85; df = 3, 341; P < 0.0001). Choteau and Mott were significantly higher solidity than the other varieties (Table 30).

Across All Internodes (damaged internodes not removed). Solidity rating across all internodes was significantly different across varieties (F = 138.28; df = 6, 690; P < 0.0001). Mott had a significantly higher solidity across all internodes than all other varieties tested (Table 30). AC Lillian and Vida were intermediate in solidity across all internodes and were significantly higher than Glenn, Reeder, and Steele ND (Table 30). Glenn, Reeder, and Steele ND were significantly lower in solidity (Table 30).

Across All Internodes (damaged internodes removed). Solidity rating was significantly different among varieties (F = 54.05; df = 6, 182; P < 0.0001). Choteau and Mott were significantly higher solidity than the other varieties (Table 30).

Table 18. Means solidity (± SE) rating at first three internodes and across all internodes at Grenora in 2009.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	4.30 ± 0.08 b (n=91)	3.75 ± 0.11 b (n=76)	2.54 ± 0.19 c (n=71)	3.64 ± 0.10 b (n=71)	4.10 ± 0.09 c	3.36 ± 0.12 b	2.27 ± 0.18 c	3.24 ± 0.11 b
Choteau	4.77 ± 0.08 a (n=95)	4.56 ± 0.10 a (n=91)	3.85 ± 0.19 a (n=80)	4.41 ± 0.10 a (n=80)	4.65 ± 0.09 b	4.35 ± 0.12 a	3.75 ± 0.18 a	4.25 ± 0.11 a
Glenn	2.60 ± 0.08 d (n=95)	1.39 ± 0.11 d (n=79)	1.19 ± 0.19 d (n=77)	1.75 ± 0.10 d (n=77)	2.59 ± 0.09 e	1.36 ± 0.12 d	1.16 ± 0.18 d	1.7 ± 0.11 d
Mott	4.96 ± 0.08 a (n=97)	4.40 ± 0.10 a (n=87)	3.23 ± 0.19 b (n=71)	4.22 ± 0.10 a (n=71)	4.90 ± 0.09 a	4.24 ± 0.12 a	3.14 ± 0.18 b	4.09 ± 0.11 a
Reeder	2.28 ± 0.08 e (n=85)	1.27 ± 0.11 d (n=77)	1.00 ± 0.20 d (n=61)	1.59 ± 0.10 de (n=61)	2.17 ± 0.09 f	1.21 ± 0.12 d	1.00 ± 0.18 d	1.46 ± 0.11 e
Steele ND	2.20 ± 0.08 e (n=87)	1.20 ± 0.11 d (n=66)	1.02 ± 0.21 d (n=46)	1.50 ± 0.11 e (n=46)	2.12 ± 0.09 f	1.16 ± 0.12 d	1.00 ± 0.18 d	1.43 ± 0.11 e
Vida	3.87 ± 0.08 c (n=93)	3.35 ± 0.11 c (n=80)	2.51 ± 0.19 c (n=70)	3.29 ± 0.10 c (n=70)	3.73 ± 0.09 d	3.09 ± 0.12 c	2.28 ± 0.18 c	3.03 ± 0.11 c
F-value	*204.15*	*261.34*	*121.68*	*255.32*	*173.44*	*240.23*	*174.74*	*309.08*
df	*6, 633*	*6, 546*	*6, 466*	*6, 443*	*6, 690*	*6, 690*	*6, 690*	*6, 690*
P-value	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 19. Means solidity (± SE) rating at first three internodes and across all internodes at Grenora in 2010.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	3.33 ± 0.14 c (n=59)	3.25 ± 0.21 b (n=20)	2.37 ± 0.32 c (n=14)	3.31 ± 0.27 bc (n=10)	4.10 ± 0.09 c	3.36 ± 0.12 b	2.27 ± 0.18 c	3.24 ± 0.11 b
Choteau	4.04 ± 0.12 b (n=75)	4.06 ± 0.17 a (n=33)	3.17 ± 0.28 ab (n=21)	3.83 ± 0.22 ab (n=17)	4.65 ± 0.09 b	4.35 ± 0.12 a	3.75 ± 0.18 a	4.25 ± 0.11 a
Glenn	2.63 ± 0.14 d (n=55)	1.41 ± 0.18 d (n=29)	1.07 ± 0.26 d (n=26)	1.69 ± 0.24 e (n=14)	2.59 ± 0.09 e	1.36 ± 0.12 d	1.16 ± 0.18 d	1.7 ± 0.11 d
Mott	4.38 ± 0.12 a (n=82)	4.04 ± 0.14 a (n=50)	3.50 ± 0.28 a (n=20)	4.30 ± 0.22 a (n=16)	4.90 ± 0.09 a	4.24 ± 0.12 a	3.14 ± 0.18 b	4.09 ± 0.11 a
Reeder	2.30 ± 0.12 d (n=73)	1.26 ± 0.22 d (n=19)	1.25 ± 0.43 d (n=7)	2.05 ± 0.38 de (n=5)	2.17 ± 0.09 f	1.21 ± 0.12 d	1.00 ± 0.18 d	1.46 ± 0.11 e
Steele ND	2.43 ± 0.14 d (n=51)	1.31 ± 0.24 d (n=16)	0.98 ± 0.32 d (n=14)	1.43 ± 0.47 e (n=3)	2.12 ± 0.09 f	1.16 ± 0.12 d	1.00 ± 0.18 d	1.43 ± 0.11 e
Vida	3.06 ± 0.13 c (n=66)	2.42 ± 0.16 c (n=38)	2.60 ± 0.26 bc (n=25)	2.73 ± 0.24 cd (n=13)	3.73 ± 0.09 d	3.09 ± 0.12 c	2.28 ± 0.18 c	3.03 ± 0.11 c
***F* -value**	*46.81*	*50.08*	*18.11*	*20.31*	*173.44*	*240.23*	*174.74*	*309.08*
df	*6, 451*	*6, 195*	*6, 117*	*6, 68*	*6, 690*	*6, 690*	*6, 690*	*6, 690*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 20. Means solidity (± SE) rating at first three internodes and across all internodes at Hettinger in 2010.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	2.51 ± 0.18 b (n=85)	2.25 ± 0.15 c (n=69)	2.14 ± 0.09 b (n=75)	2.38 ± 0.14 c (n=57)	2.49 ± 0.23 b	2.21 ± 0.24 b	2.08 ± 0.22 b	2.26 ± 0.20 b
Choteau	3.63 ± 0.18 a (n=90)	3.27 ± 0.14 a (n=73)	2.81 ± 0.10 a (n=68)	3.22 ± 0.14 a (n=54)	3.60 ± 0.24 a	3.13 ± 0.24 a	2.75 ± 0.22 a	3.16 ± 0.20 a
Glenn	1.10 ± 0.18 e (n=80)	1.04 ± 0.15 e (n=58)	1.03 ± 0.11 d (n=53)	1.06 ± 0.15 e (n=45)	1.09 ± 0.24 d	1.02 ± 0.24 c	1.01 ± 0.22 c	1.04 ± 0.20 c
Mott	3.43 ± 0.18 a (n=95)	2.76 ± 0.14 b (n=84)	2.24 ± 0.09 b (n=80)	2.83 ± 0.14 b (n=74)	3.46 ± 0.24 a	2.68 ± 0.24 ab	2.18 ± 0.22 ab	2.77 ± 0.20 ab
Reeder	1.55 ± 0.18 d (n=76)	1.10 ± 0.15 e (n=58)	1.00 ± 0.10 d (n=56)	1.20 ± 0.15 e (n=46)	1.41 ± 0.24 cd	1.06 ± 0.24 c	1.01 ± 0.22 c	1.16 ± 0.20 c
Steele ND	1.27 ± 0.18 e (n=82)	1.03 ± 0.15 e (n=63)	1.00 ± 0.10 d (n=59)	1.08 ± 0.15 e (n=48)	1.30 ± 0.24 cd	1.04 ± 0.24 c	1.02 ± 0.22 c	1.12 ± 0.20 c
Vida	1.90 ± 0.18 c (n=86)	1.53 ± 0.15 d (n=66)	1.31 ± 0.10 c (n=63)	1.64 ± 0.15 d (n=50)	1.82 ± 0.24 c	1.46 ± 0.24 c	1.34 ± 0.22 c	1.54 ± 0.20 c
***F* -value**	*180.67*	*118.49*	*75.12*	*112.7*	*29.99*	*14.69*	*10.55*	*20.25*
df	*6, 584*	*6, 461*	*6, 444*	*6, 364*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 21. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Hettinger in 2011.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	1.46 ± 0.10 c (n=96)	1.13 ± 0.17 c (n=95)	1.15 ± 0.12 c (n=96)	1.26 ± 0.10 c (n=94)	1.44 ± 0.26 c	1.14 ± 0.37 c	1.14 ± 0.19 c	1.24 ± 0.21 c
Choteau	2.55 ± 0.09 b (n=100)	2.40 ± 0.15 b (n=100)	1.71 ± 0.11 b (n=100)	2.22 ± 0.09 b (n=100)	2.55 ± 0.23 b	2.40 ± 0.32 b	1.71 ± 0.17 b	2.22 ± 0.18 b
Glenn	1.16 ± 0.09 de (n=99)	1.03 ± 0.15 c (n=98)	1.00 ± 0.11 c (n=100)	1.06 ± 0.09 d (n=98)	1.16 ± 0.23 c	1.02 ± 0.32 c	1.00 ± 0.17 c	1.06 ± 0.18 c
Mott	4.35 ± 0.09 a (n=100)	3.62 ± 0.15 a (n=100)	2.76 ± 0.11 a (n=100)	3.58 ± 0.09 a (n=100)	4.35 ± 0.23 a	3.62 ± 0.32 a	2.76 ± 0.17 a	3.58 ± 0.18 a
Reeder	1.07 ± 0.09 e (n=98)	1.00 ± 0.15 c (n=99)	1.00 ± 0.11 c (n=100)	1.02 ± 0.09 d (n=97)	1.07 ± 0.23 c	1.00 ± 0.32 c	1.00 ± 0.17 c	1.02 ± 0.18 c
Steele ND	1.00 ± 0.09 e (n=97)	1.00 ± 0.15 c (n=98)	1.00 ± 0.11 c (n=98)	1.00 ± 0.09 d (n=95)	1.00 ± 0.23 c	1.00 ± 0.32 c	1.00 ± 0.17 c	1.00 ± 0.18 c
Vida	1.33 ± 0.09 dc (n=97)	1.01 ± 0.015 c (n=97)	1.00 ± 0.11 c (n=99)	1.12 ± 0.09 dc (n=93)	1.32 ± 0.23 c	1.02 ± 0.32 c	1.00 ± 0.17 c	1.11 ± 0.18 c
***F* -value**	*228.54*	*133.32*	*73.28*	*239.64*	*28.57*	*10.66*	*16.87*	*28.69*
df	*6, 650*	*6, 650*	*6, 656*	*6, 640*	*6,17*	*6,17*	*6,17*	*6,17*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 22. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Makoti in 2009.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	4.35 ± 0.12 b (n=54)	3.92 ± 0.15 b (n=46)	3.18 ± 0.19 c (n=46)	3.82 ± 0.15 c (n=35)	3.67 ± 0.27 a	3.27 ± 0.22 b	2.71 ± 0.22 b	3.30 ± 0.22 b
Choteau	4.80 ± 0.12 a (n=60)	4.66 ± 0.15 a (n=54)	4.72 ± 0.20 a (n=41)	4.76 ± 0.14 a (n=37)	4.31 ± 0.27 a	4.05 ± 0.22 a	4.13 ± 0.22 a	4.25 ± 0.22 a
Glenn	2.53 ± 0.21 d (n=19)	3.02 ± 0.30 c (n=10)	1.63 ± 0.37 d (n=8)	2.59 ± 0.31 d (n=6)	1.53 ± 0.27 c	1.44 ± 0.22 d	1.13 ± 0.22 c	1.53 ± 0.22 d
Mott	4.78 ± 0.11 a (n=67)	4.55 ± 0.14 a (n=60)	4.06 ± 0.19 b (n=51)	4.52 ± 0.13 ab (n=48)	4.41 ± 0.27 a	4.00 ± 0.22 a	3.27 ± 0.22 b	3.98 ± 0.22 a
Reeder	1.90 ± 0.28 d (n=10)	1.48 ± 0.30 d (n=9)	1.12 ± 0.27 d (n=16)	1.52 ± 0.26 e (n=9)	1.24 ± 0.27 c	1.05 ± 0.22 d	1.01 ± 0.22 c	1.19 ± 0.22 d
Steele ND	2.25 ± 0.22 d (n=16)	1.15 ± 0.31 d (n=9)	1.00 ± 0.30 d (n13)	1.88 ± 0.38 de (n=4)	1.52 ± 0.27 c	1.12 ± 0.22 d	1.00 ± 0.22 c	1.41 ± 0.22 d
Vida	3.76 ± 0.16 c (n=33)	3.92 ± 0.21 b (n22)	3.50 ± 0.29 bc (n=15)	4.11 ± 0.26 bc (n=9)	2.44 ± 0.27 b	2.15 ± 0.22 c	1.80 ± 0.22 c	2.10 ± 0.22 c
***F* -value**	*45.12*	*39.56*	*52.50*	*37.04*	*26.21*	*36.28*	*22.44*	*35.90*
df	*6, 250*	*6, 201*	*6, 181*	*6, 139*	*6,12*	*6,12*	*6,12*	*6,12*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 23. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Makoti in 2010.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	3.29 ± 0.13 c (n=72)	2.45 ± 0.26 c (n=53)	1.17 ± 0.28 c (n=60)	2.33 ± 0.26 c (n=46)	3.15 ± 0.24 cb	2.27 ± 0.31 cb	1.17 ± 0.35 bc	2.20 ± 0.27 bc
Choteau	3.64 ± 0.13 b (n=67)	3.01 ± 0.27 b (n=39)	2.56 ± 0.30 a (n=37)	2.89 ± 0.27 b (n=28)	3.52 ± 0.24 b	2.86 ± 0.31 b	2.30 ± 0.35 a	2.89 ± 0.27 b
Glenn	2.35 ± 0.18 d (n=27)	1.00 ± 0.53 e (n=4)	1.00 ± 0.39 d (n=10)	(n=0)	2.20 ± 0.24 d	1.26 ± 0.31 d	1.00 ± 0.35 c	1.49 ± 0.37 c
Mott	4.73 ± 0.12 a (n=97)	4.08 ± 0.24 a (n=93)	2.85 ± 0.27 a (n=91)	3.90 ± 0.24 a (n=86)	4.68 ± 0.24 a	4.00 ± 0.31 a	2.78 ± 0.35 a	3.82 ± 0.37 a
Reeder	2.56 ± 0.14 d (n=55)	1.77 ± 0.30 d (n=23)	1.00 ± 0.32 cd (n=23)	1.93 ± 0.31 cd (n=11)	2.50 ± 0.24 cd	1.70 ± 0.31 cd	1.04 ± 0.35 c	1.75 ± 0.37 c
Steele ND	2.36 ± 0.14 d (n=53)	1.47 ± 0.30 de (n=22)	1.00 ± 0.30 cd (n=32)	1.84 ± 0.31 d (n=11)	2.11 ± 0.24 d	1.34 ± 0.31 d	1.00 ± 0.35 c	1.48 ± 0.3 c
Vida	3.35 ± 0.13 c (n=74)	2.61 ± 0.25 c (n=62)	1.91 ± 0.27 b (n=61)	2.67 ± 0.25 b (n=44)	3.37 ± 0.24 b	2.70 ± 0.31 b	2.06 ± 0.35 ab	2.71 ± 0.37 b
***F* -value**	*74.05*	*43.97*	*39.39*	*53.30*	*14.04*	*11.24*	*5.68*	*10.74*
df	*6, 435*	*6, 286*	*6, 304*	*5, 217*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0018*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 24. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Makoti in 2011.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	1.96 ± 0.15 c (n=97)	1.56 ± 0.17 c (n=98)	1.21 ± 0.18 b (n=95)	1.58 ± 0.16 c (n=91)	1.97 ± 0.29 c	1.55 ± 0.31 bc	1.20 ± 0.28 b	1.57 ± 0.28 b
Choteau	3.22 ± 0.15 b (n=93)	2.31 ± 0.17 b (n=93)	2.06 ± 0.18 a (n=97)	2.54 ± 0.16 b (n=90)	3.18 ± 0.29 a	2.28 ± 0.31 b	2.07 ± 0.28 a	2.51 ± 0.28 a
Glenn	1.21 ± 0.15 d (n=86)	1.03 ± 0.18 e (0.18)	1.03 ± 0.18 b (n=88)	1.09 ± 0.17 d (n=77)	1.21 ± 0.29 bc	1.02 ± 0.31 c	1.00 ± 0.28 b	1.08 ± 0.28 b
Mott	4.01 ± 0.15 a (n=100)	3.32 ± 0.17 a (n=100)	2.27 ± 0.18 a (n=100)	3.20 ± 0.16 a (n=100)	4.01 ± 0.29 a	3.32 ± 0.31 a	2.27 ± 0.28 a	3.20 ± 0.28 a
Reeder	1.11 ± 0.15 d (n=96)	1.01 ± 0.18 e (n=87)	1.00 ± 0.18 b (n=88)	1.02 ± 0.17 d (n=80)	1.11 ± 0.29 c	1.02 ± 0.31 c	1.00 ± 0.28 b	1.04 ± 0.28 b
Steele ND	1.04 ± 0.15 d (n=84)	1.07 ± 0.18 de (n=70)	1.07 ± 0.19 b (n=73)	1.07 ± 0.18 d (n=57)	1.02 ± 0.27 c	1.00 ± 0.31 c	1.00 ± 0.28 b	1.01 ± 0.28 b
Vida	1.73 ± 0.15 c (n=99)	1.33 ± 0.17 cd (n=100)	1.24 ± 0.18 b (n=99)	1.43 ± 0.16 c (n=98)	1.72 ± 0.27 bc	1.33 ± 0.31 c	1.24 ± 0.28 b	1.43 ± 0.28 b
***F* -value**	*117.54*	*68.08*	*31.64*	*88.94*	*16.04*	*7.85*	*4.1*	*9.89*
df	*6, 645*	*6, 622*	*6, 630*	*6, 583*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0003*	*<0.0091*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 25. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Regent in 2009.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	3.12 ± 0.14 b (n=81)	2.47 ± 0.27 b (n=81)	1.25 ± 0.27 bc (n=87)	2.33 ± 0.25 b (n=73)	2.89 ± 0.32 b	2.33 ± 0.42 b	1.21 ± 0.43 b	2.14 ± 0.37 b
Choteau	4.25 ± 0.13 a (n=91)	3.79 ± 0.27 a (n=94)	3.35 ± 0.27 a (n=96)	2.82 ± 0.24 a (n=89)	4.09 ± 0.32 a	3.65 ± 0.42 a	3.34 ± 0.43 a	3.69 ± 0.37 a
Glenn	1.73 ± 0.19 c (n=39)	1.27 ± 0.31 c (n=38)	1.17 ± 0.29 bc (n=52)	1.44 ± 0.29 c (n=29)	1.49 ± 0.32 c	1.09 ± 0.42 b	1.02 ± 0.43 b	1.20 ± 0.37 b
Mott	4.39 ± 0.13 a (n=98)	3.95 ± 0.27 a (n=93)	3.56 ± 0.27 a (n=93)	3.97 ± 0.24 a (n=93)	4.34 ± 0.32 a	3.78 ± 0.42 a	3.47 ± 0.43 a	3.86 ± 0.37 a
Reeder	2.93 ± 0.16 b (n=60)	2.33 ± 0.29 b (n=50)	1.13 ± 0.29 c (n=57)	2.20 ± 0.27 b (n=42)	2.43 ± 0.32 bc	1.74 ± 0.42 b	1.05 ± 0.43 b	1.74 ± 0.37 b
Steele ND	2.79 ± 0.21 b (n=30)	2.80 ± 0.37 b (n=20)	1.39 ± 0.33 bc (n=27)	2.34 ± 0.35 b (n=14)	1.81 ± 0.32 c	1.43 ± 0.42 b	1.17 ± 0.43 b	1.47 ± 0.37 b
Vida	3.12 ± 0.14 b (n=85)	2.24 ± 0.27 b (n=79)	1.54 ± 0.28 b (n= 81)	2.31 ± 0.24 b (n=77)	2.93 ± 0.32 b	2.09 ± 0.42 b	1.46 ± 0.43 b	2.16 ± 0.37 b
F **-value**	*41.07*	*34.34*	*79.66*	*47.50*	*11.32*	*6.27*	*7.04*	*8.23*
df	*6, 474*	*6, 445*	*6, 483*	*6, 407*	*6,18*	*6,18*	*6,18*	*6,18*
P **-value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0011*	*<0.0006*	*<0.0002*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 26. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Regent in 2010.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	3.69 ± 0.13 b (n=76)	2.85 ± 0.12 c (n=64)	2.04 ± 0.15 b (n=73)	2.91 ± 0.12c (n=44)	3.65 ± 0.24 a	2.66 ± 0.24 b	2.01 ± 0.23 b	2.77 ± 0.20 b
Choteau	4.08 ± 0.13 a (n=77)	4.02 ± 0.15 b (n=42)	3.18 ± 0.20 a (n=32)	3.52 ± 0.16b (n=22)	3.92 ± 0.24 a	3.66 ± 0.24 a	2.93 ± 0.23 a	3.50 ± 0.20 a
Glenn	1.68 ± 0.17 d (n=31)	1.05 ± 0.21 e (n=22)	1.00 ± 0.21 c (n=32)	1.14 ± 0.24e (n=9)	1.58 ± 0.24 c	1.05 ± 0.24 c	1.01 ± 0.23 c	1.21 ± 0.20 c
Mott	4.30 ± 0.13 a (n=72)	4.50 ± 0.13 a (n=54)	3.58 ± 0.19 a (n=36)	4.17 ± 0.14a (n=29)	3.94 ± 0.24 a	3.73 ± 0.24 a	3.12 ± 0.23 a	3.60 ± 0.20 a
Reeder	1.91 ± 0.15 d (n=45)	1.38 ± 0.34 de (n=8)	1.00 ± 0.31 c (n=12)	1.35 ± 0.72de (n=1)	1.70 ± 0.24 c	1.13 ± 0.24 c	1.00 ± 0.23 c	1.28 ± 0.20 c
Steele ND	1.91 ± 0.15 d (n=51)	1.05 ± 0.22 e (n=19)	1.00 ± 0.25 c (n=20)	1.22 ± 0.26e (n=8)	1.76 ± 0.24 c	1.20 ± 0.24 c	1.01 ± 0.23 c	1.32 ± 0.20 c
Vida	2.89 ± 0.14 c (n=52)	2.01 ± 0.19 d (n=26)	1.07 ± 0.26 c (n=18)	1.95 ± 0.19d (n=15)	2.52 ± 0.24 b	1.69 ± 0.24 c	1.18 ± 0.23 c	1.80 ± 0.20 c
***F* -value**	*106.60*	*67.51*	*34.12*	*39.44*	*20.61*	*24.23*	*16.09*	*27.74*
df	*6, 394*	*6, 225*	*6, 213*	*6, 118*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 27. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Regent in 2011.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	2.43 ± 0.13 c (n=99)	1.52 ± 0.17 c (n=98)	1.04 ± 0.11 d (n=100)	1.66 ± 0.12 c (n=97)	2.42 ± 0.31 b	1.52 ± 0.30 b	1.04 ± 0.23 cb	1.66 ± 0.25 b
Choteau	4.07 ± 0.13 b (n=99)	3.77 ± 0.17 a (n=93)	3.80 ± 0.11 a (n=99)	3.89 ± 0.12 a (n=92)	4.05 ± 0.31 a	3.69 ± 0.30 a	3.79 ± 0.23 a	3.84 ± 0.25 a
Glenn	1.40 ± 0.13 e (n=94)	1.00 ± 0.17 d (n=90)	1.00 ± 0.12 d (n=82)	1.12 ± 0.13 d (n=76)	1.38 ± 0.31 cd	1.02 ± 0.30 b	1.00 ± 0.23 c	1.13 ± 0.25 b
Mott	4.43 ± 0.13 a (n=100)	3.23 ± 0.17 b (n=100)	1.71 ± 0.11 b (n= 100)	3.12 ± 0.12 b (n=100)	4.43 ± 0.31 a	3.23 ± 0.30 a	1.71 ± 0.23 b	3.11 ± 0.25 a
Reeder	1.34 ± 0.13 e (n=89)	1.05 ± 0.17 d (n=94)	1.00 ± 0.11 d (n=98)	1.13 ± 0.12 d (n=88)	1.32 ± 0.31 cd	1.03 ± 0.30 b	1.00 ± 0.23 c	1.12 ± 0.25 b
Steele ND	1.12 ± 0.14 e (n= 87)	1.05 ± 0.17 d (n=82)	1.01 ± 0.12 d (n=86)	1.05 ± 0.13 d (n=72)	1.12 ± 0.31 d	1.01 ± 0.30 b	1.00 ± 0.23 c	1.04 ± 0.25 b
Vida	2.06 ± 0.13 d (n=98)	1.63 ± 0.17 c (n=94)	1.30 ± 0.11 c (n=95)	1.68 ± 0.12 c (n=88)	2.04 ± 0.31 cb	1.60 ± 0.30 b	1.28 ± 0.23 cb	1.64 ± 0.25 b
***F* -value**	*170.60*	*133.89*	*185.54*	*209.97*	*18.84*	*14.33*	*20.47*	*19.71*
df	*6, 650*	*6, 635*	*6, 644*	*6, 597*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 28. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Scranton 2009.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	3.65 ± 0.24 b (n=68)	3.24 ± 0.21 b (n=68)	2.00 ± 0.19 cd (n=73)	3.03 ± 0.19 b (n=55)	3.26 ± 0.12 c	2.91 ± 0.30 ab	1.95 ± 0.34 bc	2.71 ± 0.29 b
Choteau	4.54 ± 0.24 a (n=77)	4.36 ± 0.22 a (n=66)	3.79 ± 0.18 a (n=75)	4.24 ± 0.19 a (n=58)	3.99 ± 0.30 bc	3.66 ± 0.30 a	3.32 ± 0.34 a	3.66 ± 0.29 a
Glenn	2.41 ± 0.26 d (n=44)	2.11 ± 0.27 c (n=30)	1.65 ± 0.23 d (n=39)	2.15 ± 0.24 d (n=26)	1.92 ± 0.30 d	1.58 ± 0.30 cd	1.30 ± 0.34 c	1.60 ± 0.29 cd
Mott	4.81 ± 0.24 a (n=90)	4.06 ± 0.20 a (n=86)	2.90 ± 0.18 b (n=85)	3.95 ± 0.18 a (n=84)	4.54 ± 0.30 a	3.78 ± 0.30 a	2.65 ± 0.34 ab	3.66 ± 0.29 a
Reeder	1.92 ± 0.26 e (n=47)	1.34 ± 0.27 d (n=30)	1.08 ± 0.23 e (n=36)	1.36 ± 0.26 e (n=24)	1.56 ± 0.30 d	1.13 ± 0.30 d	1.03 ± 0.34 c	1.24 ± 0.29 d
Steele ND	1.75 ± 0.26 e (n=49)	1.44 ± 0.25 d (n=40)	1.04 ± 0.22 e (n=43)	1.45 ± 0.22 e (n=35)	1.69 ± 0.30 d	1.32 ± 0.30 d	1.03 ± 0.34 c	1.35 ± 0.29 d
Vida	3.30 ± 0.24 c (n=73)	2.61 ± 0.22 c (n=60)	2.14 ± 0.19 c (n=65)	2.61 ± 0.20 c (n=53)	3.00 ± 0.30 c	2.24 ±0.30 bc	1.93 ± 0.34 bc	2.39 ± 0.29 bc
***F* -value**	*86.07*	*53.88*	*40.61*	*61.60*	*15.73*	*13.20*	*6.46*	*12.60*
df	*6, 438*	*6, 370*	*6, 406*	*6, 325*	*6,18*	*6,18*	*6,18*	*6,18*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0009*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 29. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Scranton 2010.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	2.34 ± 0.14 c (n=72)	2.14 ± 0.16 c (n=43)	1.67 ± 0.17 c (n=51)	2.12 ± 0.19 c (n=23)	2.27 ± 0.10 c	1.88 ± 0.08 c	1.58 ± 0.08 c	1.91 ± 0.06 c
Choteau	4.31 ± 0.13 a (n=85)	4.06 ± 0.14 a (n=74)	3.33 ± 0.17 a (n=56)	3.95 ± 0.16 a (n=44)	4.24 ± 0.08 a	3.80 ± 0.11 a	3.05 ± 0.12 a	3.70 ± 0.08 a
Glenn	2.01 ± 0.14 d (n=77)	1.05 ± 0.15 e (n=50)	1.00 ± 0.17 d (n=58)	1.33 ± 0.18 e (n=31)	1.98 ± 0.01 d	1.02 ± 0.01 e	1.00 ± 0.00 d	1.33 ± 0.01 d
Mott	3.70 ± 0.13 b (n=85)	2.96 ± 0.15 b (n=59)	2.25 ± 0.17 b (n=62)	2.99 ± 0.16 b (n=43)	3.60 ± 0.10 b	2.94 ± 0.12 b	2.42 ± 0.13 b	2.99 ± 0.10 b
Reeder	1.63 ± 0.15 e (n=51)	1.06 ± 0.16 e (n=40)	1.00 ± 0.17 d (n=54)	1.14 ± 0.20 e (n=18)	1.56 ± 0.05 e	1.07 ± 0.03 e	1.02 ± 0.01 d	1.22 ± 0.02 d
Steele ND	1.58 ± 0.14 e (n=64)	1.03 ± 0.18 e (n=27)	1.04 ± 0.19 d (n=36)	1.27 ± 0.21 e (n=16)	1.55 ± 0.05 e	1.05 ± 0.02 e	1.00 ± 0.00 d	1.20 ± 0.02 d
Vida	2.28 ± 0.13 c (n=93)	1.63 ± 0.14 d (n=74)	1.43 ± 0.16 c (n=76)	1.79 ± 0.15 d (n=67)	2.26 ± 0.08 c	1.67 ± 0.07 d	1.47 ± 0.06 c	1.80 ± 0.06 c
***F* -value**	*154.46*	*139.35*	*73.32*	*92.32*	*197.64*	*226.6*	*126.29*	*305.75*
df	*6, 517*	*6, 357*	*6, 383*	*6, 232*	*6,690*	*6,690*	*6,690*	*6,690*
***P* -value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Table 30. Mean solidity (± S.E.) rating at first three internodes and across all internodes at Scranton 2011.

Variety	Damaged Internodes Removed				Damaged Internodes Not Removed			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	2.08 ± 0.13 b (n=69)	1.88 ± 0.18 c (n=44)	1.35 ± 0.18 b (n=50)	1.97 ± 0.20 b (n=23)	1.99 ± 0.10 c	1.83 ± 0.11 c	1.28 ± 0.07 bc	1.70 ± 0.08 c
Choteau	4.02 ± 0.15 a (n=40)	3.22 ± 0.17 b (n=49)	2.73 ± 0.16 a (n=71)	3.96 ± 0.17 a (n=30)	2.80 ± 0.16 b	2.60 ± 0.17 b	2.72 ± 0.19 a	2.71 ± 0.16 b
Glenn	1.30 ± 0.13 d (n=56)	1.00 ± 0.22 e (n=27)	1.00 ± 0.21 b (n=36)	1.05 ± 0.26 c (n=13)	1.22 ± 0.04 d	1.01 ± 0.01 e	1.00 ± 0.00 d	1.08 ± 0.01 d
Mott	4.31 ± 0.12 a (n=90)	4.08 ± 0.14 a (n=81)	2.96 ± 0.16 a (n=73)	3.78 ± 0.13 a (n=64)	4.17 ± 0.12 a	3.76 ± 0.13 a	2.92 ± 0.15 a	3.62 ± 0.18 a
Reeder	1.42 ± 0.14 d (n=50)	1.17 ± 0.22 de (n=28)	1.08 ± 0.20 b (n=41)	1.27 ± 0.23 c (n=17)	1.31 ± 0.06 d	1.06 ± 0.04 e	1.03 ± 0.02 cd	1.13 ± 0.04 d
Steele ND	1.16 ± 0.14 d (n=53)	1.00 ± 0.23 e (n=312)	1.00 ± 0.21 b (n=40)	1.00 ± 0.28 c (n=17)	1.08 ± 0.03 d	1.00 ± 0.00 e	1.00 ± 0.00 d	1.09 ± 0.03 d
Vida	1.78 ± 0.11 c (n=86)	1.62 ± 0.15 cd (n=62)	1.24 ± 0.19 b (n=46)	1.55 ± 0.16 bc (n=34)	1.74 ± 0.08 c	1.49 ± 0.09 d	1.30 ± 0.07 b	1.51 ± 0.06 c
***F*-value**	*143.31*	*62.41*	*32.85*	*54.05*	*142.2*	*112.49*	*75.83*	*138.28*
df	*6, 428*	*6, 306*	*6, 341*	*6, 182*	*6,684*	*6,684*	*6,684*	*6,690*
***P*-value**	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

Solidity ratings within a column followed by the same letters are not significanlty different (α = 0.05, LSD).

Percentage of Wheat Stem Sawfly Damaged Stems across all Internodes among Varieties

The year*location*variety interaction for percentage of wheat stem sawfly infestation was significant at each internode and across all internodes (Internode 1 $Z = 3.03$, $P < 0.0012$; Internode 2 $Z = 3.76$, $P < 0.0001$; Internode 3 $Z = 3.47$, $P < 0.0003$; Across all internodes $Z = 3.71$, $P < 0.0001$). Therefore, each site-year was analyzed independently.

<u>Grenora 2009</u>

First Internode. Mean percentage of damaged stems was significantly different among varieties at the first internode ($F = 2.4$; df = 6, 690; $P = 0.0267$). Reeder and Steele ND were significantly higher in mean percentage of wheat stem sawfly damaged stems than Choteau, Glenn, and Mott (Table 31). AC Lillian and Vida were intermediate for mean percentage of wheat stem sawfly damaged stems and were not significantly different than any other varieties (Table 31). Mott had the lowest percentage of damaged stems at the first internode and was significantly lower than Reeder and Steele ND (Table 31).

Second Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the second internode ($F = 3.71$; df = 6, 690; $P = 0.0012$). Steele ND had the highest percentage of damaged stems at the second internode which was significantly higher than Choteau, Glenn, Mott, and Vida (Table 31). AC Lillian had the second highest percentage of damaged stems which was significantly higher than Choteau and Mott (Table 31). Mott had a percentage of damaged stems that was significantly lower than AC Lillian and Steele ND (Table 31). Choteau had the lowest percentage of wheat stem sawfly damaged stems and was significantly lower than all varieties except Mott (Table 31).

Third Internode. Wheat stem sawfly damaged stems at the third internode was significantly different among varieties at Grenora in 2009 ($F = 5.78$; df = 6, 690; $P < 0.0001$).

Steele ND had the highest percentage of wheat stem sawfly damaged stems which was significantly higher than all the other varieties (Table 31). Choteau had the significantly lowest percentage of wheat stem sawfly damaged stems which was significantly lower than Reeder and Steele ND (Table 31).

Across All Internodes. Wheat stem sawfly damaged stems across all internodes of the plant was significantly different among varieties at Grenora field site in 2009 ($F = 5.83$; $df = 6, 690$; $P < 0.0001$). Steele ND had a significantly higher percent of damaged stems than AC Lillian, Vida, Mott, Glenn, and Choteau (Table 31). Mott had significantly lower infestation than Steele ND and Reeder but was not significantly different than AC Lillian, Choteau, Glenn, and Vida (Table 31). Choteau was significantly lower damaged stems than Steele ND, Reeder, and AC Lillian (Table 31).

Grenora 2010

First Internode. Varieties were significantly different for mean wheat stem sawfly damaged stems at the first internode at Grenora 2010 ($F = 5.66$; $df = 6, 690$; $P < 0.0001$). Steele ND had the highest mean percentage of wheat stem sawfly damaged stems, which was significantly higher than Choteau, Mott, Reeder, and Vida (Table 31). Choteau, Reeder, and Mott had the lowest mean percentage of wheat stem sawfly damaged stems, which were significantly lower than AC Lillian, Glenn, and Steele ND (Table 31).

Second Internode. Wheat stem sawfly damaged stems was significantly different among varieties at the second internode at Grenora in 2010 ($F = 6.97$; $df = 6, 690$; $P < 0.0001$). AC Lillian, Reeder, and Steele ND had the highest mean percentage of damaged stems, which were significantly higher than Choteau, Mott, and Vida (Table 31). Mott had the lowest mean percentage of wheat stem sawfly damaged stems which was significantly lower than all varieties except Vida (Table 31).

Third Internode. Varieties were significantly different for mean wheat stem sawfly damaged stems at the third internode at Grenora in 2010 ($F = 2.90$; $df = 6, 690$; $P = 0.0084$). Reeder had the highest mean percentage of wheat stem sawfly damaged stems, which was significantly higher than Choteau, Glenn, Mott, and Vida (Table 31). Mott and Choteau had intermediate wheat stem sawfly damaged stems (Table 31).

Across All Internodes. Wheat stem sawfly damaged stems across all internodes of the plant was significantly different among varieties at Grenora in 2010 ($F = 2.55$; $df = 6, 690$; $P < 0.0001$). Glenn had the highest percentage of damaged stems and was significantly higher than Choteau, AC Lillian, Vida, and Reeder (Table 31). Mott had a 95 percentage of damaged stems, which was significantly higher than AC Lillian, Vida, and Reeder (Table 31). Choteau had an 87 percentage of damaged stems which was not significantly lower than AC Lillian, Mott, and Vida, but was significantly lower than Glenn (Table 31).

Hettinger 2010

First Internode. Damaged stem rates were significantly different among varieties at the first internode ($F = 2.84$; $df = 6, 690$; $P = 0.0098$). Glenn and Reeder were significantly higher in mean percentage of damaged stems and were significantly higher than Mott (Table 32).

Second Internode. Varieties were significantly different for mean percentage of damaged stems ($F = 3.68$; $df = 6, 690$; $P = 0.0013$). Glenn, Reeder, and Steele ND had the highest mean percentage of damaged stems. Mott had the lowest mean percentage of damaged stems and was significantly lower than Glenn, Reeder, and Steele ND (Table 32).

Third Internode. Varieties were significantly different for mean percentage of damaged stems at the third internode (F = 4.24; df = 6, 690; P = 0.0003). Glenn had the highest mean percentage of damaged stems and was significantly higher than AC Lillian and Mott (Table 32). Mott was significantly lower than Glenn, Reeder, and Steele ND (Table 32).

Across All Internodes. Mean percentage of damaged stems was significantly different among varieties (F = 3.87; df = 6, 690; P = 0.0008). Mott and the lowest mean percentage of damaged stems and was significantly lower than Glenn, Reeder, Steele ND, and Vida (Table 32).

Hettinger 2011

Wheat stem sawfly damage was too low to provide statistical analysis.

Makoti 2009

First Internode. Mean wheat stem sawfly damaged stems at the first internode at Makoti in 2009 was significantly different among varieties (F = 27.33; df = 6, 690; P < 0.0001). Reeder and Steele ND had the highest mean percentage of damaged stems at 85.42% and 75.45%, respectfully, which were significantly higher than all other varieties (Table 33). Mott had the lowest mean percentage of damaged stems which was significantly lower than the other varieties except Choteau (Table 33).

Second Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at Makoti in 2009 (F = 28.14; df = 6, 690; P < 0.0001). Reeder and Steele ND had the highest mean percentage of damaged stems at the second internode, which was significantly higher than AC Lillian, Choteau, Glenn, and Mott (Table 33). Glenn and Vida had mean percentage of wheat stem sawfly damaged stems that was intermediate and was significantly lower than Reeder, but were significantly higher than AC Lillian, Choteau, and Mott (Table 33).

Third Internode. The mean percentage of wheat stem sawfly damaged stems at the third internode was significantly different among varieties at Makoti in 2009 (F = 19.37; df = 6, 690; P < 0.0001). AC Lillian, Choteau, and Mott had the lowest mean percentage of damaged stems, which was significantly lower than Glenn, Reeder, Steele ND, and Vida (Table 33).

Across All Internodes. Infestation rates at Makoti in 2009 where significantly different among varieties (F = 20.48; df = 6, 690; P= <.0001). Reeder, Steele ND, and Vida had significantly higher percentages of damaged stems across all internodes than other varieties. Choteau and Mott had significantly lower percentage of damaged stems than Reeder, Steele ND, Vida, and Glenn (Table 33).

<u>Makoti 2010</u>

First Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at Makoti in 2010 (F = 14.7; df = 6, 690; P < 0.0001). Glenn had the highest mean percentage of wheat stem sawfly damaged stems at the first internode and was significantly higher than the other varieties (Table 33). Mott had the lowest mean wheat stem sawfly damaged stems which was significantly lower than the other varieties (Table 33).

Second Internode. Mean percentage of wheat stem sawfly damaged stems was significantly different among varieties at the second internode at Makoti in 2010 (F = 23.12; df = 6, 690; P < 0.0001). Glenn had the highest mean percentage of wheat stem sawfly damaged stems and was significantly higher than the other varieties (Table 33). Choteau had mean percentage damaged stems that was intermediate and was significantly lower than Glenn, Reeder, and Steele ND, but was significantly higher than AC Lillian, Mott, and Vida (Table 33). Mott had the lowest mean percentage of damaged stems and was significantly lower than the other varieties (Table 33).

Third Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the third internode at Makoti in 2011 ($F = 23.40$; $df = 6, 690$; $P < 0.0001$). Glenn had the highest mean percentage of damaged stems and was significantly higher than the other varieties (Table 33). Choteau and Steele ND had mean percentage of damaged stems that was significantly lower than Glenn and was significantly higher AC Lillian, Mott, and Vida (Table 33). Mott had the lowest mean percentage of damaged stems and was significantly lower than the other varieties (Table 33).

Across All Internodes. Wheat stem sawfly damaged stems was significantly different among varieties ($F = 23.58$; $df = 6, 690$; $P \leq 0.0001$). Glenn had a significantly higher percentage of damaged stems across all internodes rate than all other varieties (Table 33). Choteau was significantly lower in percentage of damaged stems than Glenn, Reeder, and Steele ND but was significantly higher than Vida, AC Lillian, and Mott. Mott had the lowest percentage of damaged stems at 13.17, which was significantly lower than all other varieties tested (Table 33).

<u>Makoti 2011</u>

First Internode. Varieties were significantly different among varieties for mean percentage of damaged stems from wheat stem sawfly at the first internode at Makoti in 2011 ($F = 4.47$; $df = 6, 690$; $P = 0.002$). Steele ND and Glenn were significantly higher than AC Lillian, Mott, Reeder, and Vida (Table 33).

Second Internode. Wheat stem sawfly damage was too low, to provide statistical analysis.

Third Internode. Varieties were significantly different among varieties for mean percentage of damaged stems from wheat stem sawfly at the third internode at Makoti in 2011 ($F = 7.59$; $df = 6, 690$; $P < 0.0001$). Steele ND had the highest mean percentage of damaged stems and was significantly higher than the other varieties (Table 33). Mott had the lowest percentage of damaged stems and was significantly lower than Glenn, Reeder, and Steele ND (Table 33).

Across All Internodes. Wheat stem sawfly damaged stems was significantly different among varieties across all internodes (F = 10.95; df = 6, 690; P = <0.0001). Steele ND had the highest percent of damaged stems across all internodes at 42.85, which was significantly higher than the other varieties tested (Table 33). Mott and Vida had the lowest percentage of damaged stems across all internodes at 0.97 and 1.94, respectfully, and were significantly lower than the other varieties. Choteau was significantly lower percentage of damaged stems than Steele ND and Glenn, but was significantly higher than Vida and Mott (Table 33).

<u>Regent 2009</u>

First Internode. Varieties were significantly different for mean percentage of damaged stems at the first internode (F = 24.04; df = 6, 690; P < 0.0001). Glenn and Steele ND had the highest mean percentage of damaged stems and were significantly higher than the other varieties (Table 34). Mott was significantly lower than the other varieties for mean percentage of damaged stems (Table 34).

Second Internode. Mean percentage of damaged stems from wheat stem sawfly at the second internode was significantly different among varieties at Regent in 2009 (F = 28.14; df = 6, 690; P < 0.0001). Steele ND had the highest mean percentage of damaged stems and was significantly higher than the other varieties (Table 34). Glenn and Reeder were significantly higher in percentage of damaged stems than AC Lillian, Choteau, Mott, and Vida (Table 34). Choteau and Mott had the lowest mean percentage of damaged stems and were significantly lower than the other varieties (Table 34).

Third Internode. Mean percentage of damaged stems was significantly different among varieties at the third internode at Regent in 2010 (F = 23.80; df = 6, 690; P < 0.0001). Steele ND had the highest percentage of damaged stems and was significantly higher than the other varieties (Table 34). Mott and Choteau had the lowest infestation levels and were significantly lower than Glenn, Reeder, Steele ND, and Vida (Table 34).

Across All Internodes. Wheat stem sawfly damaged stems was significantly different among varieties at Regent in 2009 (F = 30.55; df = 6, 690; P < 0.0001). Steele ND had a percentage of damaged stems at 87.21%, which was significantly higher than all the other varieties (Table 34). Choteau and Mott had significantly lower percentage of damaged stems than all other varieties. AC Lillian and Vida were significantly lower than Steele ND, Glenn, and Reeder but had significantly higher than Choteau and Mott (Table 34).

<u>Regent 2010</u>

First Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the first internode ant Regent 2010 (F = 11.86; df = 6, 690; P < 0.0001). Glenn had the highest mean percentage of damaged stems and was significantly higher than the other varieties (Table 34). AC Lillian, Choteau, and Mott had the lowest mean percentage of solidity and were significantly lower than the other varieties (Table 34).

Second Internode. Mean percentage of damaged stems at the second internode was significantly different among varieties at Regent in 2010 (F = 15.94; df = 6, 690; P < 0.0001). Reeder was significantly higher than the other varieties for mean percentage of wheat stem sawfly damaged stems (Table 34). Glenn, Steele ND, and Vida were comparable for wheat stem sawfly damaged stems and were significantly higher than AC Lillian, Choteau, and Mott (Table 34).

Third Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the third internode at Regent in 2010 ($F = 15.40$; df = 6, 690; $P < 0.0001$). Reeder, Steele ND and Vida had the highest mean percentage of damaged stems and were significantly higher than AC Lillian and Mott (Table 34). Choteau, Glenn, and Steele ND had mean percentages that were intermediate and were significantly higher than AC Lillian (Table 34).

Across All Internodes. Wheat stem sawfly damaged stems was significantly different among varieties at Regent in 2010 ($F = 10.2$; df = 6, 690; $P < 0.0001$). Reeder had significantly higher percentage of damaged stems at 99, than other varieties (Table 34). Choteau had significantly lower damaged stems than Reeder, Steele ND, and Glenn, but was significantly higher than AC Lillian. Mott was significantly lower than Reeder, Steele ND, Glenn, and Vida but was significantly higher than AC Lillian (Table 34).

<u>Regent 2011</u>

First Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the first internode at Regent in 2011 ($F = 3.91$; df = 6, 684; $P = 0.0007$). Reeder and Steele ND were the two highest varieties for mean percentage of damaged stems and were significantly higher than AC Lillian, Choteau, Mott, and Vida (Table 34).

Second Internode. Mean percentage of wheat stem sawfly damaged stems at the second internode was significantly different among varieties at Regent in 2011 ($F = 3.77$; df = 6, 684; $P = 0.0011$). Steele ND had the highest percentage of damaged stems at the second internode and was significantly different among than AC Lillian, Choteau, Mott, Reeder, and Vida (Table

34). Mott had the lowest percentage of wheat stem sawfly damaged stems and was significantly lower than Glenn and Steele ND (Table 34).

Third Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the third internode at Regent in 2011 ($F = 5.8$; $df = 6, 684$; $P < 0.0001$). Glenn and Steele ND had the highest mean percentage of wheat stem sawfly damaged stems and were significantly higher than the other varieties (Table 34).

Across All Internodes. Wheat stem sawfly damaged stems among varieties was significantly different ($F = 6.94$; $df = 6, 690$; $P < 0.0001$). Steele ND and Glenn had the significantly highest percent of damaged stems across all internodes with 24.47 and 24.00, respectfully compared with other varieties that were tested (Table 34). Reeder and Vida were intermediate in percentage of damaged stems across internodes and significantly higher than AC Lillian, Choteau, and Mott. Mott (1.01) was significantly lower than varieties, but was not significantly different than AC Lillian. Choteau was significantly lower in damaged stems than Steele ND and Glenn but was significantly higher than Mott (Table 34).

<u>Scranton 2009</u>

First Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the first internode at Scranton 2009 ($F = 11.89$; $df = 6, 690$; $P < 0.0001$). Glenn, Reeder, and Steele ND had the highest percentage of damaged stems and were significantly higher than the other varieties (Table 35). AC Lillian, Choteau, and Vida had intermediate mean percentage of damaged stems and were significantly lower than Glenn, Reeder, and Steele ND, but were significantly higher than Mott (Table 35). Mott was significantly lower than the other varieties for mean percentage of damaged stems by wheat stem sawfly (Table 35).

Second Internode. Mean percentage of damaged stems by wheat stem sawfly at the second internode was significantly different among varieties at the second internode at Scranton in 2009 (F = 16.31; df = 6, 690; P < 0.0001). Glenn, Reeder, and Steele ND had the highest mean percentage of damaged stems and were significantly higher than the other varieties (Table 35). AC Lillian, Choteau, and Vida had intermediate mean percentage of damaged stems and were significantly lower than Glenn, Reeder, and Steele ND, but were significantly higher than Mott (Table 35). Mott was significantly lower than the other varieties for mean percentage of stems damaged by wheat stem sawfly (Table 35).

Third Internode. Varieties were significantly different for mean percentage of damaged stems at the third internode at Scranton in 2009 (F = 14.87; df = 6, 690; P < 0.0001). Glenn, Reeder, and Steele ND had the highest mean percentage of damaged stems and were significantly higher than the other varieties (Table 35). Choteau and Mott had the lowest mean percentage of damage at the third internode and were significantly lower than Glenn, Reeder, and Steele ND (Table 35).

Across All internodes. Wheat stem sawfly damaged stems was significantly different among varieties (F = 15.53; df = 6, 690; P < 0.0001). Reeder, Glenn, and Steele ND had significantly higher percentage of damaged stems across all internodes that the other varieties that were tested (Table 35). Vida, AC Lillian, and Choteau were significantly lower than Reeder, Glenn, and Steele ND but were significantly higher than Mott. Mott had the lowest percent of damaged stems at 15.92%, which was significantly lower than all other varieties (Table 35).

Scranton 2010

First Internode. Varieties were significantly different for mean percentage of damaged stems at the first internode at Scranton in 2010 ($F = 9.71$; df = 6, 690; $P < 0.0001$). Reeder and Steele ND had the highest mean percentage of damaged stems and were significantly higher than Choteau, Glenn, Mott, and Vida (Table 35). AC Lillian and Glenn were significantly lower than Reeder, but were significantly higher than Vida damaged stems (Table 35). Choteau, Mott, and Vida had the lowest mean percentage of damaged stems and was significantly lower than AC Lillian, Reeder, and Steele ND (Table 35).

Second Internode. Mean percentage was significantly different among varieties at the second internode at Scranton in 2010 ($F = 11.61$; df = 6, 690; $P < 0.0001$). Reeder and Steele ND had the highest mean percentage at the second internode and were significantly higher than Choteau, Mott, and Vida (Table 35). Choteau and Vida had the lowest mean percentage of wheat stem sawfly damaged stems and were significantly lower than the other varieties (Table 35).

Third Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the third internode at Scranton in 2010 ($F = 5.64$; df = 6, 690; $P < 0.0001$). Steele ND had the highest mean percentage of mean percentage of damaged stems and was significantly higher than the other varieties (Table 35). AC Lillian, Choteau, Glenn, Mott, and Reeder had a mean percentage of damaged stems that was intermediate and were significantly lower than Steele ND, but significantly higher than Vida (Table 35).

Across All Internodes. Wheat stem sawfly damaged stems was significantly different among varieties ($F = 13.13$; df = 6, 690; $P < 0.0001$). Reeder and Steele ND had the highest percentage of damaged stems at 82.18% and 84. 17%, respectfully, which were significantly different that Choteau, Glenn, and Vida (Table 35). Mott and Choteau had significantly lower percentage of damaged stems than Steele ND, Reeder, and AC Lillian but were significantly higher than Vida (Table 35). Vida had a percentage of damaged stems that was significantly lower than all other varieties tested.

Scranton 2011

First Internode. Varieties were significantly different for mean percentage of wheat stem sawfly damaged stems at the first internode at Scranton in 2011 (F = 13.43; df = 6, 684; P < 0.0001). Choteau, Reeder, and Steele ND had the highest mean percentage of damaged stems and were significantly higher than AC Lillian, Mott, and Vida (Table 35). Mott and Vida had the lowest mean percentage of wheat stem sawfly damaged stems and were significantly lower than the other varieties (Table 35).

Second Internode. Mean percentage of wheat stem sawfly damaged stems at the second internode was significantly different among varieties at Scranton in 2011 (F = 15.15; df = 6, 684; P < 0.0001). Glenn, Reeder, and Steele ND had the highest mean percentage of damaged stems and were significantly higher than the other varieties (Table 35). AC Lillian and Choteau had mean percentage of damaged stems that was intermediate and were significantly lower than Glenn, Reeder, and Steele ND, but were significantly higher than Mott (Table 35). Mott was significantly lower in mean percentage of damaged stems than the other varieties (Table 35).

Third Internode. Mean percentage of damaged stems at the third internode was significantly different among varieties at Scranton in 2011 (F = 9.24; df = 6, 684; P < 0.0001). Glenn Reeder, Steele ND and Vida were significantly comparable and significantly higher than Choteau and Mott (Table 35). Choteau and Mott had the lowest mean percentage of damaged stems and were significantly lower than the other varieties (Table 35).

Across All Internodes. Percentage of wheat stem sawfly damaged stems was significantly different among varieties ($F = 14.04$; $df = 6,684$; $P < 0.0001$). Steele ND, Glenn, and Reeder had the highest percentage of damaged stems which were significantly higher than Choteau, Vida, and Mott. Choteau was significantly lower than Steele ND, Glenn, and Reeder but was significantly higher than Mott. Mott had the lowest percentage of damaged stems at 35.76%, which was significantly lower than all other varieties tested (Table 35).

Table 31. Mean percentage (± S.E.) of damaged stems at each internode and across all internodes at Grenora in 2009 and 2010.

Variety	2009				2010			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC Lillian	9.00 ± 2.90 abc	23.98 ± 4.43 ab	28.53 ± 6.24 cb	36.81 ± 6.24 bc	40.79 ± 6.87 ab	80.93 ± 5.74 ab	86.03 ± 3.59 ab	90.00 ± 3.02 abc
Choteau	5.00 ± 2.20 bc	8.986 ± 2.91 d	19.47 ± 5.14 c	19.67 ± 4.79 d	24.54 ± 5.65 cd	67.73 ± 7.59 c	79.03 ± 4.27 bc	83.00 ± 3.80 c
Glenn	5.00 ± 2.20 bc	20.98 ± 4.21 bc	22.47 ± 5.55 c	28.71 ± 5.70 cd	44.88 ± 7.00 ab	71.84 ± 7.12 bc	74.03 ± 4.64 c	86.00 ± 3.51 c
Mott	3.00 ± 1.71 c	12.98 ± 3.44 cd	28.53 ± 6.24 cb	29.72 ± 5.79 cd	17.54 ± 4.74 d	49.98 ± 8.48 d	80.03 ± 4.19 bc	84.00 ± 3.71 c
Reeder	15.00 ± 3.64 a	22.98 ± 4.36 abc	38.74 ± 7.00 b	43.92 ± 6.50 ab	26.56 ± 5.86 dc	81.92 ± 5.55 ab	93.02 ± 2.60 a	95.00 ± 2.19 ab
SteeleND	13.00 ± 3.42 ab	33.99 ±4.96 a	54.15 ± 7.24 a	56.12 ± 6.50 a	48.98 ± 7.05 a	84.88 ± 4.97 a	86.03 ± 3.59 ab	97.00 ± 1.71 a
Vida	7.00 ± 2.59 abc	19.98 ± 4.13 bc	29.55 ± 6.33 cb	30.73 ± 5.86 bcd	33.65 ± 6.48 bc	62.54 ± 8.03 dc	75.03 ± 4.57 bc	87.00 ± 3.40 bc
F-value	***2.40***	***3.71***	***5.78***	***5.83***	***5.66***	***6.97***	***2.9***	***2.55***
df	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***
P-value	***0.0267***	***0.0012***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***0.0084***	***0.0190***

Infestation Rates within a column followed by the same letters are not significantly different (P ≤ 0.05, LSD).

Table 32. Mean percentage (± S.E.) of damaged stems at each internode and across all internodes at Hettinger in 2010 and 2011.

Variety	2009				2010			
	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3	
AC_Lillian	16.78 ± 4.02 ab	30.06 ± 4.79 ab	25.83 ± 4.48 bc	41.20 ± 5.08 ab	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Choteau	11.25 ± 3.39 ab	26.10 ± 4.56 ab	32.97 ± 4.80 abc	44.19 ±5.14 ab	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Glenn	22.25 ± 4.48 a	41.04 ± 5.19 a	48.13 ± 5.09 a	53.25 ± 5.19 a	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Mott	5.66 ± 2.47 b	15.32 ± 3.66 b	20.71 ± 4.14 c	24.51 ± 4.36 b	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Reeder	26.58 ± 4.76 a	41.04 ± 5.19 a	45.12 ± 5.07 ab	52.24 ± 5.19 a	N/A[1]	N/A[1]	N/A[1]	N/A[1]
SteeleND	20.07 ± 4.31 ab	36.03 ± 5.04 a	42.09 ± 5.04 ab	50.22 ± 5.19 a	N/A[1]	N/A[1]	N/A[1]	N/A[1]
Vida	15.68 ± 3.91 ab	33.04 ± 4.93 ab	38.05 ± 4.96 abc	48.20 ± 5.18 a	N/A[1]	N/A[1]	N/A[1]	N/A[1]
F-value	***2.84***	***3.68***	***4.24***	***3.87***	***N/A[1]***	***N/A[1]***	***N/A[1]***	***N/A[1]***
df	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***N/A[1]***	***N/A[1]***	***N/A[1]***	***N/A[1]***
P-value	***0.0098***	***0.0013***	***0.0003***	***0.0008***	***N/A[1]***	***N/A[1]***	***N/A[1]***	***N/A[1]***

Infestation Rates within a column followed by the same letters are not significantly different ($P \leq 0.05$, LSD).

[1] Wheat stem sawfly damage was too low for analysis.

Table 33. Mean percentage (± S.E.) of damaged stems at each internode and across all internodes at Makoti in 2009, 2010, and 2011.

Variety	2009				2010				2011			
	Internode			Across all Internodes	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3		1	2	3	
AC Lillian	24.56 ± 5.66 c	32.44 ± 6.93 d	32.76 ± 5.87 b	43.38 ± 9.34 c	27.97 ± 4.73 d	46.97 ± 7.91 d	39.09 ± 12.09 d	54.28 ± 8.45 d	2.47 ± 1.79 c	N/A[1]	3.20 ± 2.56 bc	8.77 ± 3.17 d
Choteau	20.54 ± 5.17 cd	26.36 ± 6.31 de	39.83 ± 6.23 b	43.38 ± 9.34 c	32.97 ± 4.98 cd	61.47 ± 7.59 c	65.14 ± 11.54 c	72.87 ± 7.00 c	5.88 ± 3.32 bc	N/A[1]	1.88 ± 1.67 c	9.75 ± 3.36 cd
Glenn	61.27 ± 6.79 b	70.53 ± 6.66 c	72.25 ± 5.51 a	75.19 ± 7.39 b	73.03 ± 4.67 a	96.24 ± 2.05 a	91.73 ± 4.34 a	99.08 ± 0.95 a	12.16 ± 5.73 ab	N/A[1]	8.26 ± 5.70 b	22.65 ± 5.29 b
Mott	10.64 ± 3.59 d	18.37 ± 5.19 e	36.80 ± 6.10 b	39.15 ± 9.09 c	2.999 ± 1.17 e	6.561 ± 2.85 e	7.097 ± 3.87 e	13.17 ± 4.58 e	0.82 ± 0.89 c	N/A[1]	0.61 ± 0.74 c	0.97 ± 0.98 e
Reeder	85.42 ± 4.29 a	88.56 ± 3.93 a	82.28 ± 4.47 a	90.07 ± 4.08 a	44.99 ± 5.31 cb	77.73 ± 5.93 b	79.67 ± 8.44 b	89.68 ± 3.91 b	3.31 ± 2.19 c	N/A[1]	8.26 ± 5.70 b	19.65 ± 4.93 bc
SteeleND	75.45 ± 5.65 a	82.65 ± 5.03 ab	78.28 ± 4.47 a	88.17 ± 4.60 a	47.00 ± 5.33 b	78.73 ± 5.78 b	70.50 ± 10.63 cb	89.68 ± 3.91 b	14.02 ± 6.37 a	N/A[1]	21.79 ± 12.24 a	42.85 ± 6.73 a
Vida	58.20 ± 6.91 b	72.57 ± 6.44 bc	80.28 ± 4.71 a	87.20 ± 4.85 a	25.97 ± 4.61 d	37.63 ± 7.54 d	37.95 ± 11.97 d	56.37 ± 8.39 d	0.82 ± 0.89 c	N/A[1]	0.61 ± 0.74 c	1.94 ± 1.40 e
F-value	***27.33***	***28.14***	***19.37***	***20.48***	***14.17***	***23.12***	***23.4***	***23.58***	***4.47***	N/A[1]	***7.59***	***10.95***
df	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	N/A[1]	***6, 690***	***6, 690***
P-value	***<.0001***	***<.0001***	***<.0001***	***<.0001***	***<.0001***	***<.0001***	***<.0001***	***<.0001***	***0.0002***	N/A[1]	***<.0001***	***<.0001***

Infestation Rates within a column followed by the same letters are not significantly different (P ≤ 0.05, LSD).

[1] Wheat stem sawfly damage was too low for analysis.

Table 34. Mean percentage (± S.E.) of damaged stems at each internode and across all internodes at Regent in 2009, 2010, and 2011.

Variety	2009				2010				2011			
	Internode			Across all Internodes	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3		1	2	3	
AC Lillian	18.08 ± 5.58 c	18.00 ± 5.72 c	12.25 ± 4.34 cd	25.71 ± 7.55 d	24.00 ± 4.27 c	35.93 ± 5.41 d	26.89 ± 4.98 d	56.00 ± 5.02e	0.96 ± 0.98 b	2.97 ± 1.73 bc	0.92 ± 0.96 b	3.00 ± 1.71 cd
Choteau	8.37 ± 3.43 d	5.52 ± 2.67 d	3.69 ± 2.06 e	10.07 ± 4.13 e	23.00 ± 4.21 c	58.04 ± 5.60 c	68.10 ± 5.29 bc	78.00 ± 4.17 cd	0.96 ± 0.98 b	6.93 ± 2.68 bc	0.92 ± 0.96 b	8.00 ± 2.71 bc
Glenn	61.53 ± 8.16 a	62.51 ± 8.36 b	47.85 ± 8.43 b	72.07 ± 7.92 b	69.00 ± 4.63 a	78.10 ± 4.53 b	68.10 ± 5.29 bc	91.00 ± 2.87 b	5.80 ± 2.60 ab	9.91 ± 3.23 ab	17.09 ± 5.73 a	24.00 ± 4.27 a
Mott	1.83 ± 1.38 e	6.45 ± 2.95 d	6.51 ± 2.91 de	6.34 ± 3.02 e	28.00 ± 4.49 c	45.98 ± 5.67 cd	64.08 ± 5.49 c	71.00 ± 4.58 d	0.98 ± 0.99 b	1.00 ± 1.00 c	0.92 ± 0.96 b	1.01 ± 1.01 d
Reeder	39.53 ± 8.22 b	49.87 ± 8.83 b	42.63 ± 8.29 b	58.30 ± 9.31 c	55.00 ± 4.98 b	92.06 ± 2.81 a	88.10 ± 3.45 a	99.00 ± 1.00 a	10.70 ± 3.70 a	5.94 ± 2.48 bc	1.84 ± 1.41 b	12.00 ± 3.25 b
SteeleND	70.83 ± 7.29 a	81.03 ± 5.92 a	73.84 ± 6.84 a	87.21 ± 4.87 a	49.00 ± 5.00 b	81.10 ± 4.25 b	80.12 ± 4.39 ab	92.00 ± 2.72 b	13.15 ± 4.23 a	18.82 ± 4.53 a	13.95 ± 5.09 a	29.47 ± 4.68 a
Vida	14.15 ± 4.79 cd	19.98 ± 6.09 c	18.12 ± 5.54 c	21.70 ± 6.84 d	48.00 ± 5.00 b	74.10 ± 4.85 b	82.12 ± 4.19 a	85.00 ± 3.59 bc	1.92 ± 1.41 b	5.94 ± 2.48 bc	4.63 ± 2.44 b	12.00 ± 3.25 b
F-value	***24.04***	***28.14***	***23.8***	***30.55***	***11.86***	***15.94***	***15.4***	***10.2***	***3.91***	***3.77***	***5.8***	***6.94***
df	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 684***	***6, 684***	***6, 684***	***6, 684***
P-value	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***0.0007***	***0.0011***	***<0.0001***	***<0.0001***

Infestation Rates within a column followed by the same letters are not significantly different (P ≤ 0.05, LSD).

Table 35. Mean percentage (± S.E.) of damaged stems at each internode and across all internodes at Scranton in 2009, 2010, and 2011.

Variety	2009				2010				2011			
	Internode			Across all Internodes	Internode			Across all Internodes	Internode			Across all Internodes
	1	2	3		1	2	3		1	2	3	
AC Lillian	32.00 ± 4.67 b	32.00 ± 4.67 b	27.00 ± 4.44 b	44.98 ± 5.56 b	27.94 ± 4.89 bc	57.00 ± 4.98 b	48.98 ± 6.67 b	77.18 ± 4.82 ab	31.00 ± 4.67 c	56.13 ± 6.67 b	49.97 ± 6.45 b	77.31 ± 5.15 bc
Choteau	23.00 ± 4.21 b	34.00 ± 4.74 b	25.00 ± 4.33 bc	41.97 ± 5.50 b	14.94 ± 3.76 de	26.00 ± 4.40 d	43.89 ± 6.60 b	56.05 ± 5.97 c	60.00 ± 4.96 a	51.03 ± 6.74 bc	28.72 ± 5.61 c	70.26 ± 5.81 c
Glenn	56.00 ± 4.96 a	70.00 ± 4.58 a	61.00 ± 4.88 a	74.08 ± 4.78 a	22.93 ± 4.53 cd	50.00 ± 5.03 bc	41.85 ± 6.55 b	69.15 ± 5.44 bc	44.00 ± 5.02 bc	73.36 ± 5.65 a	64.18 ± 6.09 a	87.29 ± 3.82 ab
Mott	10.00 ±3.00 c	14.00 ± 3.47 c	15.00 ± 3.57 c	15.92 ± 3.89 c	14.94 ± 3.76 de	41.00 ± 4.94 c	37.79 ± 6.38 b	57.06 ± 5.95 c	9.99 ± 3.01 d	18.63 ± 4.74 d	26.71 ± 5.44 c	35.76 ± 6.20 d
Reeder	53.00 ± 4.99 a	70.00 ± 4.58 a	64.00 ± 4.80 a	76.08 ± 4.63 a	48.99 ± 5.55 a	60.00 ± 4.92 ab	45.93 ± 6.64 b	82.18 ± 4.30 a	50.00 ± 5.51 ab	72.35 ± 5.74 a	59.11 ± 6.30 ab	83.31 ± 4.41 ab
SteeleND	51.00 ± 5.00 a	60.00 ± 4.90 a	57.00 ± 4.95 a	65.06 ± 5.28 a	35.95 ± 5.29 ab	73.00 ± 4.46 a	64.25 ± 6.28 a	84.17 ± 4.06 a	49.99 ± 5.21 ab	73.94 ± 5.70 a	64.29 ± 6.12 a	88.67 ± 3.67 a
Vida	27.00 ± 4.44 b	40.00 ± 4.90 b	35.00 ± 4.77 b	46.99 ± 5.58 b	6.961 ± 2.61 e	26.00 ± 4.40 d	23.64 ± 5.30 c	32.85 ± 5.56 d	14.00 ± 3.49 d	37.79 ± 6.45 c	54.03 ± 6.42 ab	66.21 ± 6.09 c
F-value	***11.89***	***16.31***	***14.87***	***15.53***	***9.71***	***11.61***	***5.64***	***13.13***	***13.43***	***15.15***	***9.24***	***14.04***
df	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 690***	***6, 684***	***6, 684***	***6, 684***	***6, 684***
P-value	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***<0.0001***	***0.0007***	***0.0011***	***<0.0001***	***<0.0001***

Infestation Rates within a column followed by the same letters are not significantly different (P ≤ 0.05, LSD).

Verification of Solidity Rating

A strong interaction was observed between visual solidity rating and measured solidity ($R^2 = 0.9251$; df = 2, 5092; and $P < 0.0001$). Visual solidity rating was a strong predictor of measured solidity (Fig. 8). Mean measured solidity ratings were significantly different for each visual solidity ratings ($F = 15779.5$; df = 4, 5090; $P < 0.0001$) (Table 36). The visual rating of "1" had a mean measured solidity score of 0.471591 (Table 34). The solidity rating of "2" had a mean measured solidity score of 0.674408 (Table 36). The visual solidity rating of "3" and "4" had a mean score of 0.842864 and 0.945514, respectfully (Table 36). The visual solidity rating of "5" had a mean measured solidity score of 1.0, which denotes a completely solid stem (Table 36).

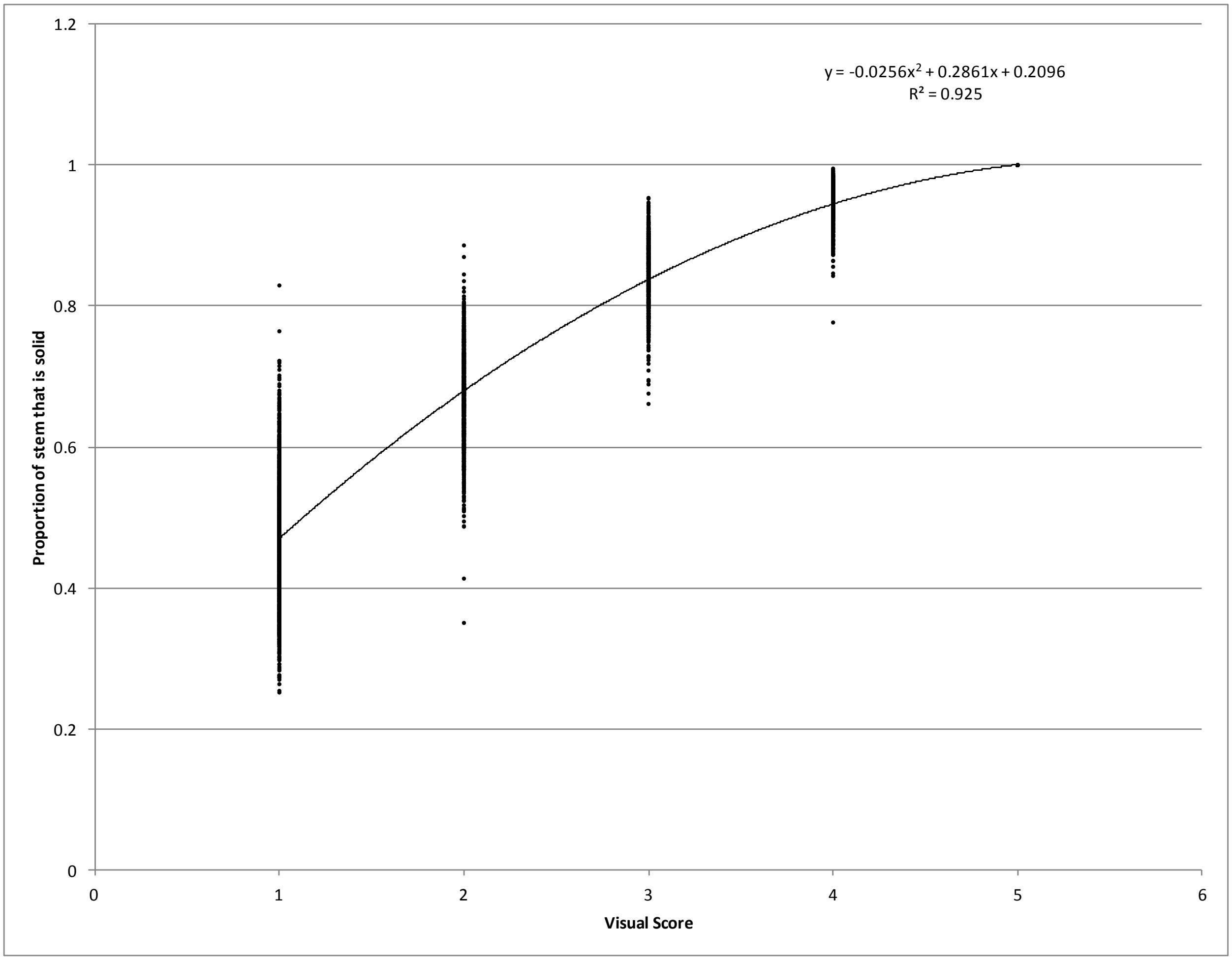

Figure 8. Correlation between visual solidity rating and measured solidity.

Table 36. Means of measured solidity (± S.E) for each visual solidity rating.

Visual Solidity Rating	Mean Measured Solidity
5	1.000 ± 0.000 a
4	0.946 ± 0.002 b
3	0.843 ± 0.003 c
2	0.674 ± 0.003 d
1	0.470 ± 0.003 e

Solidity ratings followed by the same letters are not significanlty different ($P \leq 0.05$, LSD).

Discussion

The solid-stemmed hard red spring wheat varieties, Mott and Choteau, had the highest stem solidity rating and also the lowest levels of wheat stem sawfly damaged stems. Wheat variety research on stem solidity found that solidity deters wheat stem sawfly damage (Wallace and McNeal 1966, Sherman et al. 2010). Varieties with higher solidity are also known to reduce stem cutting and reduce female fecundity (Carcamo et al. 2005, Weaver et al. 2009). AC Lillian and Vida had solidity ratings that were intermediate among the tested wheat varieties. As expected, these semi solid-stemmed also had intermediate values for the percentage of wheat stem sawfly damaged stems. DePauw et al. (2005) determined that AC Lillian was the first solid-stemmed hard red spring variety that was comparable in yield and protein to hollow-stemmed varieties with similar maturity in Canada. The tested hollow-stemmed wheat varieties, Glenn, Reeder and Steele ND, had the lowest solidity ratings and the highest infestation levels.

Female wheat stem sawfly uses a combination of olfactory, visual, and contact stimuli for host plant selection (Bruce et al. 2005, Weaver et al. 2009, Buteler and Weaver 2012). Weaver et al. (2009) found that female wheat stem sawfly preferred the variety Reeder as opposed to the variety Conan due to different plant volatiles. In this study, Reeder was also highly preferred as opposed to other wheat varieties. Sherman et al. (2010) also found that hard red spring wheat varied in the degree of attractiveness to wheat stem sawfly females. Recent research has explored the role that plant volatiles plays on female wheat stem sawfly preference (Piesik et al. 2008, Weaver et al. 2009, Buteler and Weaver 2012).

Our study showed that solid-stemmed wheat varieties reduced wheat stem sawfly damaged stems. Depauw et al. (1994) estimated that 50% less damage is seen in varieties with solid pith compared to varieties with no pith. However, some producers are reluctant to utilize solid-stemmed wheat varieties due to lower yields (Beres et al. 2009). Beres et al. (2007, 2009) found that solid-stemmed wheat performed better under moderate to high levels of wheat stem sawfly populations. More recent varieties with higher levels of solidity have been improved in yield and quality under absence of wheat stem sawflies (DePauw et al. 2005). For example, at Regent in 2010 when the percentage of wheat stem sawfly damaged stems was high in hollow-stemmed varieties, yield was much higher solid-stemmed varieties. Solid-stemmed wheat varieties averaged 3,191 kg per ha compared to 3,007 kg per ha for hollow-stemmed wheat varieties. In contrast, under low wheat stem sawfly infestation the hollow-stemmed wheat varieties typically had higher yield than the solid-stemmed varieties. Overall, the solid-stemmed variety, Mott, that was developed by the North Dakota Agricultural Experiment Station tended to yield significantly higher with or without the pressure of wheat stem sawfly and appeared to be well-adapted to growing conditions in western North Dakota.

Wallace et al. (1973) found that a mean solidity rating of 3.75 was needed to have consistent wheat stem sawfly resistance. The variety Mott had a mean solidity rating of 3.51 and ranged from 2.77 to 4.09 depending on the location and year. Another solid-stemmed variety Choteau had a mean solidity rating of 3.34 ranged from 2.22 to 4.25 across all site years. Solidity expression in wheat is governed by the interaction between genotype and environmental conditions (Beres et al. 2012). However, Beres et al. (2011) stated that the variation in solidity should not discourage producers from utilizing solid-stemmed wheat varieties in areas that are prone to high populations of wheat stem sawfly. The visual solidity scale of 1-5 was positively correlated to the measured solidity (R^2= 0.9251), and thus a good predictor of the measured solidity of wheat stems. This research provide validity to the wheat breeders who use the visual solidity rating scale to estimate the degree of solidity as an indicator of resistance against wheat stem sawfly.

Agronomical traits of varieties differed considerably from location to location. Numerous factors, such as genetics and environment can impact yield, test weight and protein. The highest test weight was predominantly held by the variety Glenn. Glenn is a hollow-stemmed hard red spring wheat that boasts high test weight (MAES 2006). Highest protein content among varieties was usually held by AC Lillian with an overall mean of percentage of 16.2 protein content across all site years. AC Lillian is documented as a wheat stem sawfly resistant variety that boosts high protein content (DePauw et al. 2005, McCallum and DePauw 2008).

Yields varied more among site years then test weight or protein content. Yield varied among solid-stemmed and hollow-stemmed wheat varieties across site years. In 2010 at Makoti when the wheat stem sawfly populations were high, the solid-stemmed variety Mott yielded significantly higher (3794 kg per ha) than the hollow-stemmed varieties Glenn (2386 kg per ha), Reeder (3098 ka per ha), and Steele (2892 kg per ha). For percentage of damaged stems by wheat stem sawfly at Makoti in 2010, Mott had a significantly lower percentage of damaged stems (13 %) then Glenn (99 %), Reeder (90 %), and Steele ND (88 %). However, the reverse correlation was observed at locations where wheat stem sawfly populations were low. In general, solid-stemmed varieties, Mott and Choteau, performed better than hollow-stemmed varieties under wheat stem sawfly pressure. The solid pith of varieties, such as Mott and Choteau, are known to deter damage from wheat stem sawfly (Beres et al. 2007). Holmes and Peterson (1962) determined that this is due to increased mortality of larvae, as they travel down the solid stem.

Infestation predominantly occurred in the lower internodes (1 and 2) near the base of the wheat plant. Hollow-stemmed varieties showed a drop in infestation from the second internode to the first internode. While the solid-stemmed varieties showed a gradual decline with each lower internode as solidity increased. The difference in internode solidity between solid- and hollow-stemmed varieties accounted for variability in wheat stem sawfly damaged stems. Solid-stemmed varieties have higher solidity in the lower internodes, which would deter tunneling by wheat stem sawfly larvae. Hollow-stemmed varieties did not vary in solidity between internodes; however, a drop of infestation was seen between the second and first internodes. This drop in infestation for hollow-stemmed varieties can be contributed to the act of parasitism from *B. cephi*.

Solid-stemmed hard red spring wheat varieties provide a crucial pest management strategy in mitigating wheat stem sawfly damage. Weaver et al. (2009) found that solid-stemmed wheat varieties could be planted on field edges as trap crops and more susceptible spring wheat varieties could be planted in the middle to reduce stem cutting by wheat stem sawfly. Solid-stemmed spring wheat varieties also provided an environmental and economical way to manage wheat stem sawfly damage without pesticides or losing grain quality.

GENERAL CONCLUSIONS

The wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae), is regarded as a major pest of wheat and other cereals in the Upper Great Plains (Runyon et al. 2002). Wheat stem sawfly exhibits a unique life cycle that limits the methods of management that can be utilized by growers. Common pest management strategies for control of agricultural pests, such as insecticide application are not efficacious or recommended (Knodel et al. 2009), which has focused wheat stem sawfly research to cultural control, biological control and host plant resistance. For Julian Date, June 20 and June 29 was the average date for first and peak emergence of adult wheat stem sawfly, and June 25 and July 4 for first and peak emergence of adult *B. cephi*. For comparison of degree day bases, the air temperature was slightly better than soil temperature for predicting first and peak emergence of wheat stem sawfly and *B. cephi*. The lowest degree day base of 0 C also was generally the best predictor of first and peak emergence of wheat stem sawfly and *B. cephi*. The solid-stemmed varieties, Mott and Choteau, had the lowest levels of wheat stem sawfly damage, highest levels of stem solidity and yields were comparable to hollow-stemmed varieties, Glenn, Reeder and Steele ND. This research demonstrated that newly released solid-stemmed wheat varieties can compete with hollow-stemmed varieties for agronomical traits (yield, protein), while still providing protection against wheat stem sawfly through host plant resistance.

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