EVALUATION OF SOYBEAN INOCULANT PRODUCTS AND TECHNIQUES TO ADDRESS SOYBEAN NODULATION PROBLEMS IN KANSAS

by

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Abstract

Nitrogen fixation by *Bradyrhizobium japonicum* in soybean [*Glycine max*] is highly beneficial in soybean crop production. Nodulation issues have been encountered on fields new to growing soybeans in recent years in Kansas. The purpose of this research was to evaluate soybean nodulation performance under various situations and seed handling practices in order to educate producers on how to achieve reliable nodulation consistency in the field. The objectives of the study were to: 1) compare inoculant products using single and double rates and in combination with one another on fields with varying soybean history; 2) determine if there was a negative interaction between inoculant products and common seed treatments; and 3) discover the influence of inoculated seed storage conditions before planting on the rhizobia's ability to successfully nodulate soybean roots. Field experiments were conducted on diverse Kansas sites in 2011 and 2012. Inoculant treatment and seed treatment interaction trials had ten and seven experimental sites respectively. Inoculated seed storage conditions were evaluated in a greenhouse experiment during the spring of 2013. All studies used a randomized complete block design with four replications. The Novozymes inoculant products generally provided superior nodulation performance over other company products in the study where soybean had not been in recent rotation with an average increase of 167% in nodule number verses the control. The combination of dry and liquid inoculant products provided a significant increase in root nodule number at five of the environments out of recent rotation with a 76% increase over single inoculant rates. Although there were early season nodulation differences between treatments in new soybean ground, these did not carry through to seed yield differences in the majority of research sites. Hot and dry summer conditions reduced yields, making detection of treatment differences difficult. There were no negative effects on nodulation performance with any of the seed treatments. Although soybean seed yield was 634 kg ha^{-1} greater for the Novozyme combination treatment compared to the check at one location in 2011, the control yielded as well or better than all other treatment/inoculant combinations, implying that yield differences were likely not related to inoculant treatments. At other sites, yield was not influenced by seed treatment and inoculant combinations. Results indicate that seed treatment formulations did not significantly impact bacterial inoculant product performance, soybean nodulation, or yield. Storage conditions had no effect on nodulation performance in the greenhouse study, likely due to survival of *Bradyrhizobium japonicum* in the heat-treated growth medium.

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Chapter 1 - Literature Review

Symbiotic N_2 Fixation of *Bradyrhizobium japonicum* with Soybean

Biological nitrogen fixation is the process of fixing atmospheric N_2 to NH_3 and occurs in the symbiotic relationship between soybean plants and *Bradyrhizobium japonicum*. Bacteria involved in the symbiosis go through a process of infecting the roots of the soybean host plant and forming nodules where fixation takes place (Lie, 1981).The resulting symbiosis provides usable nitrogen for the plant and carbohydrates for the bacteria. Nodules can immediately form on roots upon germination, but will not begin fixing nitrogen until the V3-V4 soybean growth stage (Pedersen, 2004). The number and weight of nodules increases through the growing season until the end of flowering (de Mooy and Pesek, 1966). Pods and seeds require great amounts of nitrogen respective to the rest of the plant, containing around 75% of the total nitrogen in the plant (Zapata et al., 1987). Therefore it is not surprising that the greatest demand for nitrogen is in the R3 to R5 soybean growth stages. This corresponds to the period of greatest nitrogen fixation by nodules (Zapata et al., 1987). Others report maximum soybean nitrate utilization peaks at full bloom, before nitrogen fixation peaks approximately three weeks later at pod fill (Harper, 1974). In the vegetative stages, nitrogen uptake by the plant cycles up and down in intervals corresponding to leaf emergence (Henry and Raper, 1989).

Nodulation and nodule growth are indicators of nitrogen fixation rates (Serraj and Sinclair, 1998). As the growing season progresses, nodule number and size increase. Plants with successful symbiosis with *B. japonicum* possess greater plant nitrogen concentration and total plant nitrogen compared to those with poor nodulation (Ruiz-Diaz et al., 2009). Consequently, soybean plant size is positively correlated with nodule number per plant (Larson and Siemann, 1998). For bacteria to nodulate soybean roots, *B. japonicum* must be introduced to the soil as it does not natively occur in U.S. soils. Once introduction takes place through inoculation at the time of seed planting, populations will naturalize in the soil. It is usually recommended to inoculate seed if soybeans have not been in a field for the previous three to five years, or if there have been extreme environmental conditions that would affect soil bacterial survival (Pedersen, 2004; Albareda et al., 2009).

Soybean Inoculant Strains and Carriers

The bacterial inoculant strain and its carrier formulation influence the field performance and survivability of the bacteria (Albareda et al., 2008). Inoculants are available in different forms including powder (usually in peat carrier), granule, and liquid. Rhizobial cells contained in the inoculant are living organisms and continue to grow and multiply (Xavier et al., 2004). The formulation of the inoculant must be such that the rhizobia survive in sufficient quantities to ensure the minimum quantity of living cells required for successful nodulation at planting (Xavier et al., 2004). In a study comparing liquid and peat based inoculants, both were shown to adequately nodulate soybeans in the field (Tittabutr et al., 2007).

Most current inoculant products are supported in a liquid carrier due to the simplicity of production and application (Xavier et al., 2004). Bacterial survival in liquid carriers has been greatly improved with new formulations. Without the protection of peat or related carriers, liquid carriers have been less consistent in maintaining high bacterial cell counts in the inoculant in the past. Rhizobial cells in liquid inoculants tend to experience starvation stress or nutrient depletion at a greater degree in comparison to those in peat (Tittabutr et al., 2007). However, quality liquid formulations currently available will maintain adequate population densities for soybean inoculation for at least three months of storage (Albareda, et al., 2008). Liquid additives in these inoculant product formulations improve performance and can be customized to the individual bacterial strain (Tittabutr et al., 2007). Additives also are able to protect *B. japonicum* on the seed when exposed to high temperatures (Tittabutr, et al., 2007). Even with recent improvements to liquid formulations, peat carriers have proven to better protect rhizobia (Tittabutr et al., 2007).

Companies have developed inoculants with superior bacterial strains for vigorous nodulation. However, if planting into a field with current rhizobial populations, the introduced bacteria must be competitive against the resident bacterial in the soil (Berg et al., 1988). The number of root nodules per plant is directly correlated with the years since the last soybean crop. The more years since the last soybean crop results in fewer numbers of root nodules per plant (Larson and Siemann, 1998). Despite new inoculants on the market that boast improved bacterial strains, many times the naturalized rhizobia in the soil out competes the newer strains for infection of soybean roots. For improved competiveness with resident bacterial populations, in-furrow inoculants have proven to be superior (Lopez-Garcia et al., 2009). The competiveness of naturalized rhizobia may be the reason for lack of separation in the performance of inoculant products in a study by Furseth, et al. (2012). In their study, soybean yield or oil and protein content did not differ between inoculant products or the non-inoculated controls in ground with persisting *B. japonicum* populations. Therefore, if the inoculant cannot compete with the naturalized populations, there is no benefit of inoculating the seed with superior rhizobia strains.

The minimum bacterial density for achieving adequate nodulation is 10^3 rhizobia per seed (Hiltbold et al., 1980). Nodulation in soil free of *B. japonicum* is directly related to the number of bacteria applied per seed. Lopez-Garcia et al. (2009) found that certain formulations or carriers out-perform others. In-furrow inoculants yielded slightly more than seed-applied inoculant on ground new to soybean in one study. On the other hand, Schulz and Thelen (2008) reported that liquid inoculants provided a significant yield advantage over other products in areas new to soybean production. Finally, inoculant product brand did not affect yields in a 2008 study that compared several products (Schulz and Thelen, 2008). With ongoing inconsistencies in research results, inoculant product development will continue to be an area of activity.

Conditions Influencing the Survivability of *B. japonicum*

Nodulation of soybean through inoculation of the bacteria in *B. japonicum* -free soil has a significant role in establishing naturalized bacterial populations in the soil for subsequent years (Kuykendall et al., 1982). These populations can persist in the soil for decades under good soil environment conditions. Several environmental factors may limit *B. japonicum* symbiosis, including drought stress, water logging, extreme temperatures, and carbohydrate supply from the plant (Lie, 1981). The ability of rhizobia to persist in the soil also is affected by the bacterial strain and the soil type (Albareda et al., 2009). It is prudent to inoculate soybeans if there is a concern bacteria are not present in adequate numbers. Therefore, it is recommended that soybeans are inoculated to ensure sufficient rhizobial populations if three years have passed since the introduction of soybeans to a field (Albareda et al., 2009). Soybeans are able to obtain adequate bacterial infection and nodulation when kept in rotation after initial rhizobium establishment without re-inoculating in subsequent years. There was no effect on yield from inoculant products in fields where there was soybean history in a 73 location study in the years 2000 to 2008 (De Bruin et al., 2010). In Illinois soils, Elkins et al. (1976) found that sufficient populations of bacteria persist for at least 10 or 11 years.

Soils that had never been cropped to soybean also have been shown to nodulate well. This was found in fields that had been continuous sod and in fields that had been cropped to species other than soybeans (Elkins et al., 1976). However, the bacteria do not tend to move independently. It has been suggested that rhizobia are transferred by wind, equipment, and livestock (Elkins et al., 1976; Lowther and Patrick, 1993). Larson and Siemann (1998) estimated that half of the *B. japonicum* population in the soil directly after being planted to soybean will survive after 30-40 years without soybean in rotation. Therefore, although the number of soybean-compatible rhizobia is greatly reduced, a population can persist for decades. *Bradyrhizobium* are able to multiply in the soil without a host plant and can also spread in the soil. Lowther and Patrick (1993) suggested that rhizobia will spread up to 4 m yr^{-1} downslope. Even with such persistence of bacterial populations, it may still prove economically beneficial to inoculate fields with soybean history as increased yields have been obtained (Schulz and Thelen, 2008).

Effects of Heat and Water Stress on Nodule N_2 Fixing Activity

B. japonicum tend to be sensitive to unfavorable or extreme conditions. Elevated temperatures have a depressive effect on nodulation. Few bacterial strains survive at temperatures past 40°C (Favre and Eaglesham, 1986). The development and function of root nodules have been affected at soil temperatures around 30-35°C (Munevar and Wollum, 1982). Drought stress also has a depressive effect on nodulation (Serraj and Sinclair, 1998). Drought stress can reduce 75% of nitrogen fixation by the nodules (Pankhurst and Sprent, 1975). Under severe drought stress, the nitrogen fixing capability of nodules is completely hindered (Pankhurst and Sprent, 1975). However, once drought stress is relieved, nodules tend to recover activity (Sinclair et al., 1988).

Soybean Nitrogen Fertilizer Application

Nitrogen fertilizer has been shown to decrease nodule number, weight, and mean nodule size (Chen et al., 1992). There is a negative relationship between N fixation and applied N (Bhangoo and Albritton, 1975; Wu and Harper, 1990). When N rates exceed 224 kg ha^{-1}, N fixation does not take place (Bhangoo and Albritton, 1975). Rhizobia require carbohydrates from the plant in the symbiotic relationship between the two, and when the plant does not require the nitrogen provided by the bacteria, it stops supplying carbohydrates.

Nitrogen fertilizer applications can be beneficial, although the response is not consistent and varies with environment. A marked increase in yield is obtained when plants receive nitrogen from soil or applied sources in comparison to receiving all the nitrogen requirements from nitrogen fixation (Bhangoo and Albritton, 1975). When applying nitrogen, the rates must be such that they do not inhibit N fixation. For best utilization and efficiency the applied N rate should be between 56 and 112 kg N ha^{-1} according to one study (Bhangoo and Albritton, 1975). Others recommend lower rates (Wesley et al., 1998).

Plants relying solely on atmospheric nitrogen achieved less than half the yield of plants that utilized soil nitrate and atmospheric nitrogen (Harper, 1974). Conversely, those plants grown solely reliant on nitrate had less yield compared to those that received both nitrate and atmospheric nitrogen (Harper, 1974). Un-inoculated soybeans with a 200 kg N ha^{-1} fertilizer rate produced seed yields less than un-fertilized inoculated soybeans (Albareda et al., 2009). Plants grown on low nitrate levels had higher nitrogen fixation rates (Harper, 1974). Under high yielding environments where the yield potential exceeds 3700 kg ha^{-1}, nitrogen fertilization is beneficial (Wesley et al., 1998). The demand for nitrogen increases beyond the capacity of biological nitrogen fixation in these environments (Salvagiotti et al., 2008; Wesley et al., 1998). A good approach in these situations is a pre-plant field application of deep banded slow-release urea to insure nodulation is not inhibited (Salvagiotti et al., 2009). Another suggestion by Wesley et al., (1998) is supplemental nitrogen application at a rate of 22 kg N ha^{-1} at the R3 growth stage.

Later-season applications of nitrogen fertilizer are most likely to generate a yield response if applied when the plant requires greater amounts of nitrogen for growth and seed formation. Nitrogen application before flowering did not prove beneficial over simply inoculating seed (Ruiz-Diaz et al., 2009). Inoculated soybean planted into long-term pasture with no soybean history increased yield by 130 kg ha^{-1} compared to non-inoculated plots with nitrogen fertilizer rates of 0-280 kg N ha^{-1} (Ruiz-Diaz et al., 2009). Lack of response from nitrogen fertilization was confirmed by Albareda et al. (2009) who applied a rate of 100 kg N ha^{-1} at 30 and 60 days after planting that did not improve yield over inoculated soybeans.

Soybean Inoculants with Pesticide Seed Treatments

Seed applied pesticide treatments protecting the newly germinating soybean plant against fungal, insect, and nematode pests are a production practice of many producers. Several studies have found a negative yield response of bacteria to seed applied fungicide treatments (Schulz and Thelen, 2008; Hiltbold et al., 1980; Campo et al., 2009). Schulz and Thelen (2008) experienced a 130 and 500 kg ha^{-1}decrease in yield due to inoculant and fungicide interactions. Hiltbold et al. (1980) recorded poor inoculant performance when a fungicide treatment was added to the seed. Toxic effects of the fungicides were more pronounced in sandy soils without soybean history (Campo et al., 2009). Peat-based inoculants have proven to mitigate fungicide-bacteria interactions better than liquid inoculants (Schulz and Thelen, 2008). A study by Mallik and Tesfai (1984) found no negative effects of three fungicides on nodulation where peat-based inoculant was added to treated seed before planting. The amount of viable *B. japonicum* on treated seeds decreases with time but also varies with fungicide product (Revellin et al., 1993). The effects of the reduction of bacteria viability carries through to nodulation, resulting in reduced nodule numbers and dry weight (Revellin et al., 1993). The degree of reduction in viable bacteria and nodulation is impacted heavily by the fungicide product used (Revellin et al., 1993; Mallik and Tesfai, 1984). Revellin et al. (1993) found after 24 hours of inoculant contact on treated seed, bacteria viability was reduced by less than a factor of 10 in the majority of fungicides tested. Inoculant labels included a listing of compatible seed treatments that the inoculant can be added to after seed treatment. This provides options for fungicides, insecticides, and nematicides that should not reduce nodulation performance or harm the viability of the living bacteria to the extent that nodulation is hindered.

Kansas Soybean Production

Soybean acreage has increased significantly in the last eighty years (Figure 1.1). In 1924 the state soybean production was approximately 600 metric tons. The 2012 data shows the state production is at 1,915,000 metric tons. Production peaked in 2009 with 4,371,000 metric tons of soybeans produced. The value of soybean has also increased, likely a driver in the increasing production. In year 2000, the average price of soybeans sold in Kansas was \$0.13 L^{-1}, in 2012 it was \$0.41 L^{-1}. With the increase of soybean production in the state, there has been a resulting expansion of soybean acreage into fields that has been out of soybean production for a number of years or that has never been in soybean production. This expansion can be clearly seen by the comparison of the two distribution maps presented in Figures 1.2 and 1.3. (United States Department of Agriculture, 2012).

Research Question and Justification

Recently there has been an increase in reports of poor nodulation in fields new to soybean production (K.L. Roozeboom, personal communication, 2011). The symbiotic relationship between soybean and *B. japonicum* is greatly beneficial to the producer by supplying much of the high nitrogen demand required by soybeans. This has placed attention on consistently obtaining well nodulated soybean in fields new to soybean production to prevent yield and profit losses due to inadequate nitrogen supply. Several soybean bacterial inoculants are available on the market that boast superior formulations, high performing bacteria, or beneficial additives. In situations with no naturalized *B. japonicum,* increased rates or inoculant product combinations are recommended to assure adequate populations in the soil. Additional research is needed to identify how to assure good nodulation in various soybean production situations.

The goal of this research was to improve consistency of soybean production, especially on "new" soybean ground by addressing nodulation problems observed in recent years.

Specific research objectives were to:

1. compare inoculant products using single and double rates and in combination with one another on fields with varying soybean history,
2. determine if there was a negative interaction between inoculant products and common seed treatments, and
3. discover the influence of inoculated seed storage conditions before planting on the rhizobia’s ability to successfully nodulate soybean roots.

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Figures and Tables

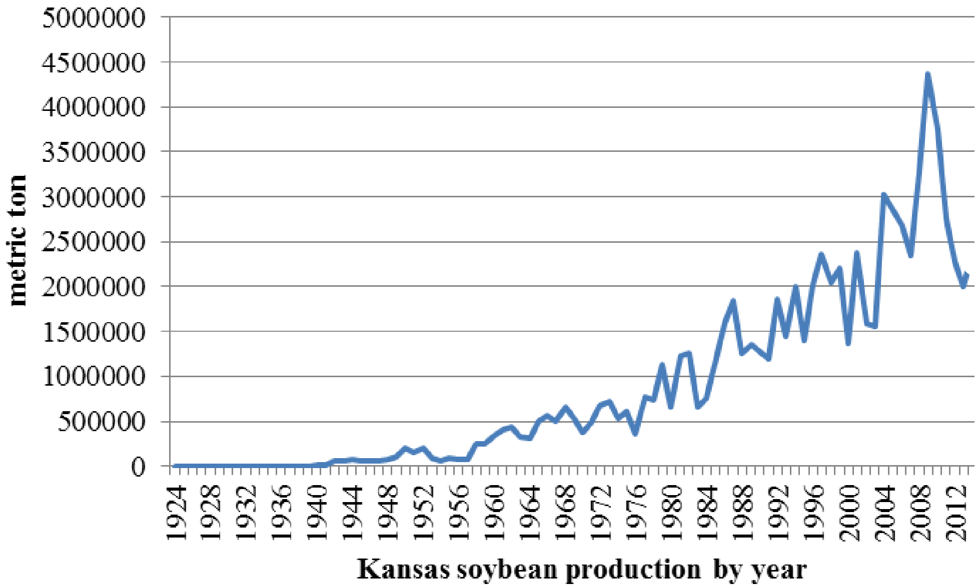

Figure 1.1 Kansas soybean production by year from 1924 to 2012.

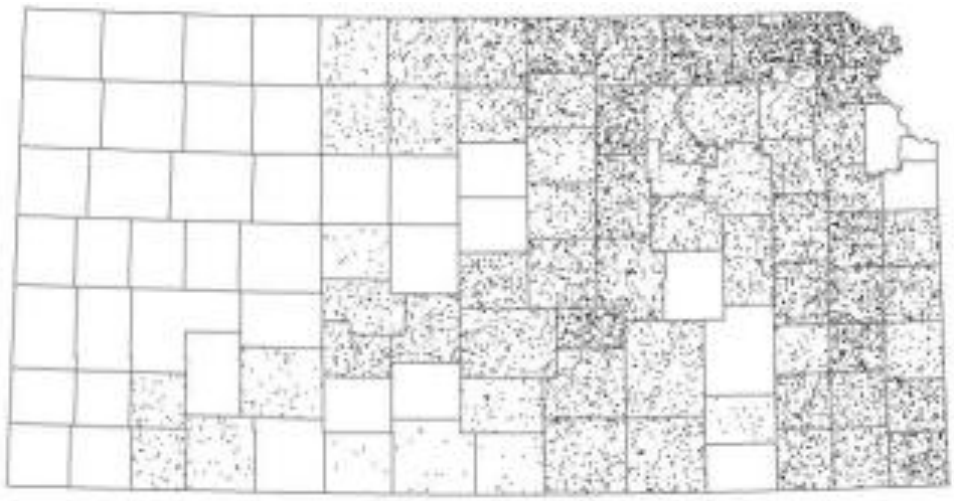

Figure 1.2 Kansas soybean production distribution in 2009, provided by USDA agriculture statistics.

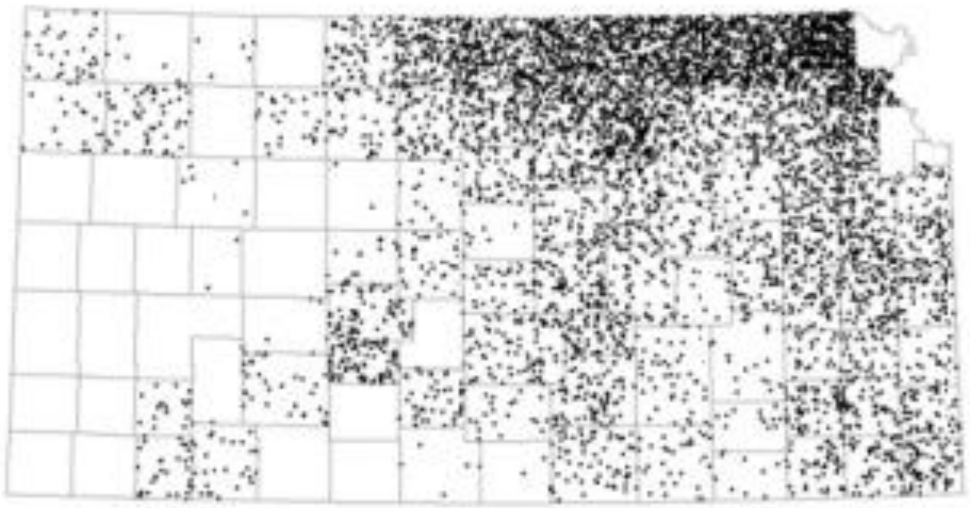

Figure 1.3 Kansas soybean production distribution in 2011, provided by USDA agriculture statistics. One dot is equivalent to 408,300 kg.

Chapter 2 - A Comparison of Inoculant Product Treatments in Various Soybean Production Scenarios

Abstract

Bradyrhizobium japonicum performs biological nitrogen fixation in its symbiotic relationship with soybean [*Glycine max*]. Survival of bacterial inoculants is critical in situations where adequate populations of *B. japonicum* do not already exist in the soil to nodulate soybean and provide nitrogen for uptake by the plant. Nodulation issues have been encountered on fields new to growing soybeans in recent years in Kansas. The research objective was to evaluate inoculant products, product rates, and product combinations on soybean nodulation and growth performance on fields with varying soybean history. Doubling inoculant rates or using product combinations are often recommended for land not previously planted to soybean. Ten field experiments were conducted at five Kansas sites in 2011 and 2012. The Novozymes inoculant products generally provided superior nodulation performance over the other company products in the study. The combination of dry and liquid inoculant products provided a significant increase in root nodule number at three of five sites in 2012. There was not a consistent response to double rates or inoculant combinations over single rates in 2011. Although there were early season nodulation differences between treatments in new soybean fields, these did not carry through to seed yield differences in the majority of research sites. Hot and dry summer conditions likely reduced yields, making detection of treatment differences difficult.

Introduction

Biological nitrogen fixation is the process of fixing atmospheric N_2 to NH_3 and occurs in the symbiotic relationship between soybean plants and *Bradyrhizobium japonicum* within nodules on the soybean root (Lie, 1981). Nodulation and nodule growth are indicators of nitrogen fixation rates (Serraj and Sinclair, 1998). Plants with successful symbiosis with *B. japonicum* possess greater plant nitrogen concentration and total plant nitrogen compared to plants that nodulate poorly (Ruiz-Diaz et al., 2009). *B. japonicum* does not natively occur in U.S. soils, so *B. japonicum* must be introduced to the soil by inoculation. Bacterial populations will naturalize in the soil once seed is inoculated at the time of planting. It is usually recommended to inoculate the seed if soybeans have not been in a field for the previous three to five years, or if there have been extreme environmental conditions that would affect soil bacterial survival (Pedersen, 2004; Albareda et al., 2009).

The bacterial inoculant strain and its carrier formulation influence the field performance and survivability of the bacteria (Albareda et al., 2008). Inoculants are available in different forms. These include powder (usually in peat carrier), granule, and liquid. The formulation of the inoculant must be such that the rhizobia can survive for an extended period in order to ensure the required quantity of living cells are present for successful nodulation at the time of seed application (Xavier et al., 2004). In a study comparing liquid and peat based inoculants, both were shown to adequately nodulate soybeans in the field (Tittabutr et al., 2007). Companies have developed inoculants with superior bacterial strains for vigorous nodulation. However, if planting into a field with current rhizobial populations, the introduced bacteria must be competitive against the resident bacterial in the soil (Berg et al., 1988).

Conditions Influencing the Survivability of B. japonicum

Nodulation of soybean through inoculation of the bacteria in *B. japonicum* -free soil has a significant role in establishing naturalized bacterial populations in the soil for subsequent years (Kuykendall, et al., 1982). These populations can persist in the soil for decades under good soil environment conditions. Several environmental factors may limit *B. japonicum* symbiosis including drought stress, water logging, extreme temperatures, and carbohydrate supply from the plant (Lie, 1981). The ability of rhizobia to persist in the soil also is affected by the bacterial strain and the soil type (Albareda et al., 2009). It is prudent to inoculate soybeans if there is a concern bacteria are not present in adequate numbers. Soybean are able to obtain good bacterial infection and nodulation when kept in rotation after initial rhizobium establishment without re-inoculating in subsequent years. There was no effect on yield from inoculant products in fields where there was a soybean history in a 73 location study in the years 2000 to 2008 (Bruin et al., 2010). In Illinois, Elkins et al. (1976) found that sufficient populations of bacteria persist in soil for at least 10 or 11 years.

Soils that had never been cropped to soybean also have been shown to nodulate well. This was found in ground that had been continuous sod and in fields that had been cropped to species other than soybeans (Elkins et al., 1976). However, the bacteria do not tend to move independently. It has been suggested that rhizobia are transferred by wind, equipment, and livestock (Elkins et al., 1976; Lowther and Patrick, 1993). Larson and Siemann (1998) estimated that half of the *B. japonicum* population in the soil directly after being planted to soybeans will survive after 30-40 years without soybean in rotation. Even with such persistence of bacterial populations, it may still prove economically beneficial to inoculate fields with soybean history as increased yields have been obtained (Schulz and Thelen, 2008). This may be due to a loss of the N fixation effectiveness of the infecting bacteria present in the soil (Wadisirisuk et al., 1989).

Soybean Nitrogen Fertilizer Application

Nitrogen fertilizer has been shown to decrease nodule number, weight, and mean nodule size (Chen et al, 1992). There is a negative relationship between nitrogen fixation and applied nitrogen fertilizer (Bhangoo and Albritton, 1975; Wu and Harper, 1990). When nitrogen fertilizer rates exceed 224 kg N ha^{-1}, nitrogen fixation does not take place (Bhangoo and Albritton, 1975).

Nitrogen fertilizer applications can be beneficial, although response is not consistent and varies with environment. A marked increase in yield is obtained when plants receive some nitrogen from soil or applied sources in comparison to receiving all the nitrogen requirements from nitrogen fixation (Bhangoo and Albritton, 1975). Plants grown on low nitrate levels had higher nitrogen fixation rates (Harper, 1974). When applying nitrogen, the rates must be such that they do not inhibit N fixation. For best utilization and efficiency the applied N rate should be between 56 and 112 kg N ha^{-1} according to one study (Bhangoo and Albritton, 1975). Others recommend lower rates (Wesley et al., 1998). Under high yielding environments where the yield potential exceeds 3700 kg N ha^{-1}, nitrogen fertilization was beneficial as demand for nitrogen increases beyond the capacity of biological nitrogen fixation (Wesley et al., 1998).

However, inoculating is a better option than solely relying on soil applied nitrogen. Un-inoculated soybeans with a 200 kg N ha^{-1} nitrogen fertilizer rate produced seed yields less than un-fertilized inoculated soybeans (Albareda et al., 2009). Inoculated soybean planted into long-term pasture with no soybean history increased yield by 130 kg ha^{-1} compared to non-inoculated plots with nitrogen fertilizer rates of 0-280 kg N ha^{-1} (Ruiz-Diaz et al., 2009).

Kansas Soybean Production

Soybean acreage has significantly increased in the last 80 years. In 1924 the state soybean production was approximately 600 metric tons. The 2012 data shows the state production is at 1,915,000 metric tons. Production peaked in 2009 at 4,371,000 metric tons of soybeans produced. With the increase of soybean production in the state, there has been a resulting expansion of soybean acreage into fields that has been out of soybean production for a number of years or that has never been in soybean production (United States Department of Agriculture, 2012).

Research Question and Justification

Recently there has been an increase in reports of poor nodulation in fields new to soybean production (K.L. Roozeboom, personal communication, 2011). The symbiotic relationship between soybean and *B. japonicum* is greatly beneficial to the producer by supplying much of the high nitrogen demand required by soybeans. This has placed attention on consistently obtaining well nodulated soybean in fields new to soybean production to prevent yield and profit losses due to inadequate nitrogen supply. Several soybean bacterial inoculants are available on the market that boast superior formulations, high performing bacteria, or beneficial additives. In situations with no naturalized *B. japonicum,* increased rates or inoculant product combinations are recommended to assure adequate populations in the soil. The goals of this research were to improve consistency of soybean production, especially on "new" soybean ground by comparing inoculant products using single and double rates and in combination with one another on fields with varying soybean history.

Materials and Methods

Ten field experiments were conducted over years 2011 and 2012 at Kansas State University research fields and cooperator fields in Kansas. The locations were selected to achieve a range of histories of soybean production from never before grown to being in recent rotation. The locations also represented a range of yield environments across Kansas. Descriptions of each location are presented in Tables 2.1, 2.2, and 2.3. Soil samples were taken at each location when the soybeans were between the V3-V5 stage at 15 and 60 cm depths.

Treatments included soybean inoculant products from four companies using single rates, double rates, and dry/liquid inoculant combinations (Table 2.4). Single rates of common inoculant products represented typical inoculant applications whereas double rates and combinations represented product label recommendations for land which had not previously grown soybean. Inoculant treatments were applied to raw soybean seed according to supplier protocols within seven days of planting and kept in cold storage (4° C) until planting. Inoculants were added to seed and manually mixed in a sterile glass jar for three minutes to uniformly distribute inoculant over the seed. The single exception was the in-furrow inoculant, which was added to individual seed packets at the labeled rate on a mass area^{-1} basis. Seed inoculated with liquid products was spread on blotting paper to dry before packaging into envelopes for plot planting. Seed was transported to the field in a cooler to ensure viability of inoculants. Equipment used for seed processing was sterilized using 950 g kg^{-1} concentration ethyl alcohol.

Two N fertilizer treatments of urea [46-0-0 (N-P-K)] were applied to non-inoculated plots in the vegetative stage (V3-V5) at rates of 67 and 134.4 kg N ha^{-1}. Nitrogen treatments represented potential rescue applications for situations where fields experience failed or poor nodulation (Mengel and Ruiz-Diaz, 2012). Fertilizer was hand broadcast. SuperU (AGROTAIN International; St. Louis, Missouri) was used in year 2011 whereas urea was used in 2012.

A two row planter with John Deere (Deere & Company; Moline, Illinois) row units and a precision cone planter attachment was used to plant plots. Planter surfaces that came in contact with the seed were cleaned with 950 g kg^{-1} concentration ethyl alcohol before planting each location. The order of planting was the untreated raw check seed followed by liquid inoculated seed and finally seed with dry inoculant treatments to minimize cross contamination. Glyphosate (N-[phosphonomethyl] glycine, in the form of its potassium salt) at the recommended rate of 0.63 to 1.48 kg ae ha^{-1} was applied for weed control at all locations as needed to maintain weed-free conditions.

Characterization of soybean response to inoculation and fertilizer treatments included plant density, nodule evaluations, and seed yield and quality. Plant density was determined at the VE to V1 stage by counting plants in 6.096 m of row in the two center rows of each plot. Soybeans were harvested using a modified two row Gleaner (model EIII; AGCO Corporation, Duluth, GA) combine at or below target seed moisture of 13%. Yield was determined by obtaining the weight of the harvested seed from the center two rows of each plot. A subsample was retained for determination of moisture content, test weight, seed size, and nitrogen content.

Nodule evaluations took place at approximately the V3 growth stage. Ten plants were dug from the outer two rows of the four row plots using hand spades. Roots were washed using a rotary root washer constructed by researchers at Colorado State University (Benjamin and

Nielsen, 2004). Following washing, roots were placed in plastic bags and stored in cold storage until analyzed for nodulation. Nodulation was visually rated on individual roots. Visual ratings were based on nodule distribution, quantity, and size. The rating scale was 0 to 5 with 0 possessing no nodules and five possessing several large nodules located along the taproot. This was similar to the rating procedure conducted by Hiltbold et al. (1980). Each plant was separately rated by three individuals and ratings were averaged. Nodules were removed and counted from each root and were randomly split to ensure the nodules were pink on the inside, demonstrating active nitrogen fixation (Sadowsky et al., 1988). Nodules from the ten plants were then collected for dry mass measurements. Plant samples were dried at 60°C in a forced-air oven to determine dry mass of plant tops, roots, and nodules. Plant tops were ground and submitted to the Kansas State University Soil Testing Lab for determining tissue N content.

The experimental design was a randomized complete block with 14 treatments and four replications. Individual plot dimensions were 1.5 m wide (four rows) by 7.62 to 9.144 m long. Statistical analysis was completed using the MIXED procedure in SAS 9.2 (SAS, 2009) statistical analysis software with block as a random factor. The distribution of data for each response variable was checked for normality using QQ-plots. Data with exponential distributions were subjected to log transformations.

Analysis was completed by environment as well as across environments within environment groupings based on soybean history. Albareda et al. (2009) suggested inoculating after soybean has been absent from a field for greater than three years to maintain good nodulation and high seed yield. Based on this recommendation, environments were separated into two groups: less than three years since soybean was grown, and greater than 15 years. There were no locations with soybean production history between three and 15 years. Multi-location analyses within environment groupings included environment as a random factor. Multi-group analyses included environment grouping based on soybean history as a fixed effect to test for treatment by soybean history interactions. Preplanned comparisons of treatment subsets were tested using contrasts. Treatment subsets included double verses single inoculant rates, inoculant combinations verses single rates, un-inoculated check verses single inoculant rates, and nitrogen-fertilized un-inoculated treatments verses single inoculant rates.

Results and Discussion

Multi-location Analysis

Analysis of variance for treatments and environment groupings based on soybean history (environments with soybeans in recent rotation verses those that had been out of soybean for an extended period) resulted in a significant ($\alpha = 0.05$) treatment by soybean history interaction for several variables (Table 2.7). Response of nodule count, nodule rating, whole plant nitrogen content, yield, and seed nitrogen content differed between locations that had soybean in recent rotation and those that had been out of soybean for 15 or more years. Based on these findings, analysis of variance was conducted separately for each environment as well as for each history grouping with environment within each soybean history group considered as random.

Nodulation

Nodulation performance in response to inoculant treatment varied between history groupings in the multi-location analysis. There was no significant differences ($\alpha = 0.05$) in any of the nodulation performance variables for the environments that had been in recent soybean rotation with environment within soybean history considered as a random effect (Table 2.8). In the environments that had been out of soybean for a minimum of 15 years, significant treatment differences existed for all three nodulation performance variables (Table 2.9). In these environments, inoculant product proved to be a more important factor in achieving better nodulation than doubling rates or using product combinations. Inoculant treatments tended to separate out by company for nodule counts and ratings (Table 2.9). Nodulation performance measured by nodule counts, dry mass, and visual ratings proved to be the greatest for the Novozyme (NZ) products regardless of the rate or product combination. Two of the inoculant company products were no different from the check, ranking in the lowest grouping (Table 2.9). There was much less separation between products, product combinations, and rates for nodule dry mass, with the check ranking in the highest grouping along with several inoculant treatments (Table 2.9).

Analysis of treatment effects at individual environments revealed no significant treatment differences for any of the nodulation performance indicators (nodule counts, nodule dry mass, nodule ratings) at the two Riley sites, which had been in recent soybean rotation (Tables 2.10 and

2.11). Check plots with no inoculant applied were not significantly different in nodule counts than those with inoculant at these sites (Tables 2.10 and 2.11).

Nodule counts differed due to inoculant treatment in six of the seven environments that had been out of soybean production for an extended period (Tables 2.10 and 2.11). The liquid and in-furrow NZ inoculant combination had a significant separation from the other inoculant treatments at the Phillips-C site with a nearly four-fold increase compared to the average of the remaining inoculant treatments (Table 2.11). There were no nodules on the check plot at this site. At both the Phillips sites and the Morris site, which were out of soybean for >40 years, the liquid and in-furrow inoculant product combination increased nodule numbers (Tables 2.10 and 2.11). However, these values were not significantly different than the other treatments using the same company products in most cases (Tables 2.10 and 2.11). The product combinations increased nodule counts over single-rate inoculant treatments at five of the seven sites that had been out of recent soybean rotation (Tables 2.10 and 2.11). There was an increase in nodule number with double (2X) rates only at the Phillips-S and 2012 Republic sites (Table 2.11).

Nodule dry mass displayed significant treatment differences at four of the seven environments that had not had soybeans for at least 15 years (Tables 2.12 and 2.13). The Osage 2011 site showed a negative response of combinations over the check in both counts and dry mass, which conflicts with the findings found at the majority of sites with treatment differences (Tables 2.10 and 2.12). Phillips-C was the only site where contrasts showed a significant benefit of inoculant product combinations over single rates for nodule dry mass (Table 2.13). At five of the seven environments that had not been in recent soybean rotation, the check ranked in the highest grouping for nodule dry mass (Tables 2.12 and 2.13), indicating that there was a sufficient bacterial population in the soil for nodulating the check plots. None of the environments had significant nodule dry mass response of single inoculant rates over the check (Tables 2.12 and 2.13).

Visual nodule ratings had treatment differences in four of the seven environments out of recent soybean rotation (Tables 2.14 and 2.15). In these environments, product combinations rated significantly higher, and the check lower, than the single rates (Tables 2.14 and 2.15). The check always ranked in the bottom grouping. However, the Advanced Biological Marketing and TerraMax products were not significantly different from the check for all but the Maximize 2X treatment at the Phillips-S site (Tables 2.14 and 2.15).

The Osage 2011 site that had been out of soybean production for >40 years did not have any significant treatment differences for nodule count or rating, and the nodule dry mass of the check placed in the top grouping where there were differences (Tables 2.10, 2.12, 2.14). Although unexpected, this matches similar occurrences reported by Elkins et al. (1976) where nodulation occurred on ground never before cropped to soybean. This again occurred in the 2012 site at Osage that had been out of soybean >30 years and was immediately adjacent to the 2011 site. Out of the seven environments that had not been in recent soybean rotation, only two (2011 Morris and 2012 Phillips-C) had no nodules present in the check plots (Tables 2.10 and 2.11). In both cases, soybeans had not been grown on the experimental sites or in the adjacent fields for at least 40 years, if ever.

There was no benefit of inoculant treatments on nodule performance on soybean in recent soybean rotation (Tables 2.10-2.15). Fields that had been out of soybean for an extended period of time generally had a positive nodulation response to inoculant treatments (Tables 2.10-2.15). However, inoculant product performance was influenced by the company formulation (Table 2.8). Generally, the company formulation was more important than increased rates or combinations of the products. The liquid and in-furrow product combination from the highest performing company had improved nodulation performance at five out of ten environments (Tables 2.10-2.15). Doubling inoculant rates rarely had a significant beneficial effect on nodulation performance compared to the recommended rates (Tables 2.10-2.15).

Vegetative Characteristics

Vegetative plant growth at the V4 growth stage was not greatly affected by inoculant treatments. Only two of the nine sites displayed significant ($\alpha = 0.05$) treatment differences (Tables 2.16 and 2.17). However, these treatment differences were not consistent. Contrasts revealed no significant differences in vegetative growth between the various treatment groupings (Tables 2.16 and 2.17).

In the multi-location grouping analysis where soybean had not been grown for a minimum of 15 years, the single rate Maximize product was the only treatment was significantly less than the other treatments in whole plant nitrogen content (Table 2.9) Plant nitrogen content was analyzed over locations rather than by location because there was not a significant treatment by location interaction ($\alpha = 0.05$). In this analysis the Maximize single and 2X treatments and the

Vault 2X treatment had significantly less plant nitrogen content than the other treatments (Table 2.18). The ABM products ranked in the top grouping, and the check appeared in the middle grouping with the remaining treatments (Table 2.18). Although contrast analysis showed a reduction in nitrogen content with the 2X rates, this may be a result of all the ABM products appearing only in the single rates (Table 2.18).

Seed Characteristics

Seed nitrogen content displayed significant treatment effects for the multi-location history group analysis. In environments with recent soybean rotation, treatment separation lacked consistency as the single rate Maximize treatment placed in the highest grouping whereas the double rate of that same product ranked in the lowest group (Table 2.8). Where soybeans had not been planted for a minimum of 15 years, single inoculant rates and un-inoculated checks tended to produce seed with lower nitrogen content. The exception was the un-inoculated treatment with the highest nitrogen fertilizer rate, which ranked in the highest group for seed nitrogen content (Table 2.9).

Seed size, nitrogen content, and test weight had few significant responses to inoculant treatments in a by-environment analysis. Seed size was affected by inoculant treatment only at the Phillips-S site (Table 2.19 and 2.20). The check, low nitrogen fertilizer rate, Maximize and Vault were in the lowest grouping (Table 2.20). There was little separation between treatments in several of the seed size responses (Table 2.20). There was a positive response to the highest nitrogen fertilizer rate in seed size when compared to the non-inoculated check and low nitrogen fertilizer rate treatments (Table 2.20).There was a positive response to the higher rate of nitrogen fertilizer for seed nitrogen content at both the Phillips-C and Morris sites over the check (Table 2.21 and 2.22). Test weight had treatment differences at three of the ten sites. All of the significant differences showed up on 2012 sites (Table 2.24). Due to an error in seed packaging in 2012, soybean varieties differed in the un-inoculated plots. Therefore, un-inoculated treatments cannot be compared to inoculated treatments in any of the seed characteristics in results from 2012 (Tables 2.20, 2.22, and 2.24).

Yield

When analyzing yield data according to the environment groupings, the fields in recent soybean rotation had treatment differences, although separation between treatments was minimal

(Table 2.8). All inoculated treatments placed in the top grouping, however, there was rarely any significant difference from the un-inoculated treatments (Table 2.8). Most of the inoculation treatment group placements overlapped with the lower un-inoculated treatments groupings (Table 2.8). In the sites out of soybean for at least 15 years, the greatest yield was associated with the highest nitrogen application rate. However, this was not significantly different from the check (Table 2.9).

Although there was separation in nodulation performance at some locations as discussed previously, these treatment differences did not translate into yield. Only four of the ten experimental locations showed significant differences in yield between treatments (Tables 2.25 and 2.26). The 2012 Riley and Osage sites did not display differences between treatments in the nodulation analysis but did show significant differences in yield (Table 2.26). Both the 2011 and 2012 growing seasons were hot and dry, resulting in below-average yields at many of the sites (Tables 2.5 and 2.6). The 2011/2012 growing season state-wide average yield was 907 kg ha^{-1} less than the state-wide average yields of the three previous years (United States Department of Agriculture, 2012). The only site with treatment differences for yield in 2011 was the Republic site, however, the check was in the middle of the groupings (Table 2.25). Schultz and Thelen (2008) have suggested a potential negative yield response from inoculation under extreme drought conditions occurring during pod fill due to an increased vegetative sink. The liquid and in-furrow inoculant combination had the greatest yield, but the other products from that company were not significantly different from the check (Table 2.25). In the 2012 sites where significant differences existed, there was little to no significant separation between inoculant treatments for yield (Table 2.26). Nitrogen fertilizer applications during vegetative growth did not yield differently than the check (Tables 2.25 and 2.26).

The lower yielding treatments were not consistently associated with rate, combination, or company products. This may suggest that inoculant treatment was not the driving factor for differences in yield. The yield at the end of the season may have been supported in large part by the residual soil nitrogen as it requires approximately 55.6 g N kg^{-1} seed (Table 2.3) (Mengel and Ruiz-Diaz, 2012). Most of the environments had around 20 kg N ha^{-1} present in the soil at sampling (Table 2.3). Lack of response was similar to results Hiltbold et al. (1980) where nitrogen deficiency from lack of inoculation was not expressed due to drought.

Conclusions

The impact of inoculant treatments was expressed up in early season nodulation analysis. Only environments that had been out of soybean production for a minimum of 15 years displayed a treatment difference for nodulation. Inoculated plots at locations in recent soybean rotation were not different from the check. The inoculant source company rather than increased rates or product combinations had a greater impact on nodulation performance. On an individual site basis, there was a significant positive response at five of the ten environments to the highest performing company's liquid and in-furrow inoculant combination treatment. Treatment differences in nodulation did not transfer to end of season yield or seed characteristics. This may be due to the growing season that produced below-average yields in both years. Nitrogen fertilizer at the high rate generally performed similar to the lower performing inoculation treatments.

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Figures and Tables

Table 2.1 Location descriptions and soil classification for ten experiments comparing inoculant products, product combinations, and rescue fertilizer treatments in Kansas in 2011 and 2012.

Year	County	Coordinates	Soil Series	Soil Classification
2011	Republic	39.8153, -97.6745	Crete silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll
2012	Republic	39.813198, -97.672305	Crete silt loam; Butler silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll; fine, smectitic, mesic Vertic Argiaquoll
2011	Riley	39.21756, -96.58958	Kahola silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludoll
2012	Riley	39.21778, -96.59139	Kahola silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludoll
2011	Osage	38.72256, -95.69450	Kenoma silt loam; Aliceville silty clay loam in SE corner	fine-silty, mixed, superactive, mesic Cumulic Hapludoll; fine, mixed, active, thermic Oxyaquic Vertic Argiudoll
2012	Osage	38.72345, -95.69502	Kenoma silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludoll
2012	Phillips	39.713228, -99.320644	Harney silt loam	fine, smectitic, mesic Typic Argiustoll
2012	Phillips	39.69852, -99.25797	Holdrege silt loam	fine-silty, mixed, superactive, mesic Typic Argiustoll
2011	Republic-I†	39.831814, -97.838931	Crete silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll
2011	Morris	38.863092, -96.753181	Irwin silty clay loam; Konza silty clay loam	fine, mixed, superactive, mesic Pachic Argiustoll; fine, smectitic, mesic Udertic Paleustoll

† I, Irrigated location.

Table 2.2 Location descriptions and management for ten experiments comparing inoculant products, product combinations, and rescue fertilizer treatments in Kansas in 2011 and 2012.

Year	County	Soybean Variety	Yr out of soybean	Previous Crop	Tillage System	Planting Date
2011	Republic	KS3406RR	15	sorghum	NT	13-Jun-2011
2012	Republic	KS3406RR	17	corn	NT	17-May-2012
2011	Riley	OHLDE 0-451	2	sorghum	NT	7-Jun-2011
2012	Riley	OHLDE 0-452	2	corn	NT	22-May-2012
2011	Osage	OHLDE 0-451	≥ 40	brome	NT	8-Jun-2011
2012	Osage	OHLDE 0-451	≥30	native grass	NT	2-Jun-2012
2012	Phillips	KS3406RR	no soybean history	corn	NT	16-May-2012
2012	Phillips	KS3406RR	no soybean history	sorghum	NT	16-May-2012
2011	Republic-I†	KS3406RR	2	corn	CT	13-Jun-2011
2011	Morris	KS3406RR	≥ 40	brome	NT	11-Jun-2011

† I, Irrigated location.

Table 2.3 Soil test values for research locations taken at approximately the V3-V5 soybean growth stage at 15 cm depth.

		Soil Test					
Year	County	pH	Mehlich P	K	$N0_3$-N†	Ca	OM
				mg kg^{-1}			g kg^{-1}
2011	Republic	5.1	39.2	351	7.6	1825	25
2012	Republic	5.0	38.5	330	26.4	1846	21
2011	Riley	5.5	33.3	161	18.9	2902	30
2012	Riley	7.4	18.8	311	16.8	5494	35
2011	Osage	6.0	10.2	264	32.4	2878	46
2012	Osage	6.1	11.6	173	22.1	2875	40
2012	Phillips-C†	5.7	46.1	553	14.2	1981	22
2012	Phillips-S‡	5.9	32.6	517	7.4	2573	20
2011	Republic-I¶	6.5	16.1	492	8.2	1990	25
2011	Morris	5.9	25.4	163	12.3	2100	32

† Profile 0-60 cm sample.
‡ C, following corn.
§ S, following sorghum.
¶ I, irrigated location.

Table 2.4 Inoculant product descriptions and rates used in the study.

Company	Product name	Rates	Carrier	Rate	Bacteria concentration
				product kg^{-1} seed	
Novozymes (Franklinton, NC)	Optimize	Single, double, combination	Liquid	1.8 ml	$5x10^9$ cell/ g
Novozymes (Franklinton, NC)	Soil Implant+	Combination	Peat-based	170 g m^{-1} row	$1x10^8$ cell/ g
Becker Underwood (Ames, IA)	Rhizo-Stick	Double, combination	Peat	3.37 g	$3x10^8$ cell/ g
Becker Underwood (Ames, IA)	Vault HP	Double, single, combination	Liquid	1.3 ml	$3x10^9$ cell/ ml
Advanced Biological Marketing (Van Wert, OH)	Excalibre SA	Single	Encapsulated	0.07 ml	$5.5x10^{10}$ cell/g
Advanced Biological Marketing (Van Wert, OH)	Excalibre	Single	Encapsulated	0.13 ml	$5.5x10^{10}$ cell/g
TerraMaxx (Bloomington, MN)	Maximize	Single, double	Liquid	1.3 ml	$4x10^9$ cell/ ml

Table 2.5 Weather data during the growing season, displaying monthly single day maximum temperature deviation from the 30 year average maximum temperature.

Year	County	May	June	July	August	September	October
					°C		
2011	Riley	13	7	10	9	14	12
2011	Republic	13	7	9	10	14	13
2011	Osage	10	7	9	13	14	11
2011	Republic-I†	14	7	8	9	13	13
2011	Morris	13	6	11	10	14	10
2012	Riley	11	11	9	7	10	10
2012	Republic	12	13	9	6	11	9
2012	Osage	8	12	11	8	12	9
2012	Phillips	14	15	8	5	12	8

† I, irrigated site.

Table 2.6 Weather data during the growing season, displaying deviation from the 30 year average precipitation.

Year	County	May	June	July	August	September	October
					mm		
2011	Riley	9.9	-12.7	-56.9	-33.5	-52.3	-0.8
2011	Republic	-8.1	16.8	16.5	7.1	-68.1	-52.6
2011	Osage	45.2	-67.3	-54.6	-27.4	-65.8	-66.5
2011	Republic-I†	52.6	7.4	73.9	49.5	-53.1	-37.3
2011	Morris	-67.8	-67.3	-52.8	-11.2	-70.4	-62.7
2012	Riley	-95.0	-39.4	-94.7	4.8	-15.2	-52.6
2012	Republic	-103.6	26.9	-19.8	-21.8	-39.6	-15.5
2012	Osage	-73.2	-128.0	-52.6	-41.9	-22.1	-53.8
2012	Phillips	-100.6	-48.5	-64.5	-36.3	-28.7	-30.7

† I, irrigated site.

Table 2.7 Main effects and interaction effects of two soybean history groups, >15 years since soybeans grown and recent soybean rotation, with the experiment variables.

Variable	Treatment	SB history	Treatment*history
	p-Value		
Nodule count	<0.0001	0.0564	<0.0001
Nodule dry mass	0.5149	0.5536	0.8164
Visual nodule rating	<0.0001	0.0970	<0.0001
Whole plant dry mass	0.4359	0.6403	0.2802
Whole plant nitrogen content	<0.0001	0.3786	0.0005
Yield	0.4407	0.0234	0.0088
Test weight	0.9723	0.8397	0.9593
Seed nitrogen content	0.4276	0.8029	0.0534
300 seed weight	0.9832	0.6640	0.8782

Table 2.8 Soybean response to inoculant treatments in environments with recent soybean rotation.

Inoculant treatment	Nodule count		Nodule dry mass		Nodule rating		Plant dry mass		Plant nitrogen		Yield		Seed nitrogen	
	nodule plant^{-1}		g (10 plants)$^{-1}$				g		g kg^{-1}		kg ha^{-1}		g kg^{-1}	
Check	14	a†	0.219	a	2.6	a	27.8	cd	39	a	-	-§	55.5	abc
67 kg ha^{-1} N	-	-	-	-	-	-	-	-	-	-	-	-	54.8	de
134.4 kg ha^{-1} N	-	-	-	-	-	-	-	-	-	-	-	-	54.6	de
ABM- Excalibre	12.7	a	0.218	a	2.3	a	30.3	bcd	41.1	a	3766	a	54.9	bcde
ABM- ExcalibreSA	14.2	a	0.212	a	2.3	a	38.6	a	39.8	a	3649	a	55.3	abcd
BU- Vault	12.2	a	0.183	a	2.2	a	32.5	abcd	39.7	a	3793	a	55.1	bcde
NZ- Optimize	12.6	a	0.172	a	2.2	a	32.5	abc	39.6	a	3791	a	55.0	bcde
TM- Maximize	13.7	a	0.243	a	2.7	a	36.4	ab	28.5	b	3824	a	56.1	a
BU- Vault 2X‡	11.3	a	0.175	a	2.7	a	31	abcd	40.5	a	3913	a	54.8	bcde
BU- Rhizo Stick 2X	14.3	a	0.234	a	2.8	a	33.7	ab	38.7	a	3576	a	54.9	cde
NZ- Optimize 2X	14.4	a	0.306	a	2.8	a	33.9	ab	39.9	a	3711	a	55.5	abc
TM- Maximize 2X	20.1	a	0.309	a	2.9	a	32.3	abcd	39.6	a	3374	a	54.2	e
BU- Vault/Rhizo Stick	14.3	a	0.245	a	2.8	a	27.5	d	39.9	a	3749	a	55.4	abc
NZ- Optimize/Cell Tech Granular	16.3	a	0.287	a	2.5	a	32.1	abcd	38.4	a	3513	a	55.6	ab

†Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

‡ Product label rates doubled.

§ A different variety was planted in check and fertilizer plots in 2012, confounding comparisons with inoculant treatments.

Table 2.9 Soybean response to inoculant treatments in environments where soybean had not been planted for at least 15 years.

Inoculant treatment	Nodule count		Nodule dry mass		Nodule rating		Yield		Seed nitrogen	
	nodule plant^{-1}		g (10 plants)$^{-1}$				kg ha^{-1}		g kg^{-1}	
Check	2.0	fg†	0.236	abc	1.0	f	-	-§	53.9	d
67 kg ha^{-1} N	-	-	-	-	-	-	-	-	54.4	cd
134.4 kg ha^{-1} N	-	-	-	-	-	-	-	-	55.2	abc
ABM- Excalibre	1.2	g	0.150	abcde	0.7	f	2029	abc	53.6	d
ABM- ExcalibreSA	1.2	g	0.085	e	0.8	f	2080	abc	54.5	abcd
BU- Vault	4.8	de	0.169	abcde	1.7	d	1805	c	54.3	cd
NZ- Optimize	7.6	abc	0.164	abcde	2.1	abc	1961	abc	55.5	ab
TM- Maximize	1.8	fg	0.103	de	1.2	ef	1741	c	53.6	d
BU- Rhizo Stick 2X‡	5.9	bcd	0.233	abcd	1.8	cd	1812	c	55.8	a
BU- Vault 2X	5.4	cd	0.150	bcde	1.9	bcd	1998	abc	55.0	abc
NZ- Optimize 2X	8.5	ab	0.297	a	2.3	ab	1896	bc	54.7	abcd
TM- Maximize 2X	3.0	ef	0.122	cde	1.6	de	1746	c	54.4	bcd
BU- Vault/Rhizo Stick	4.3	de	0.132	cde	1.6	d	1816	c	54.7	abcd
NZ- Optimize/Cell Tech Granular	11.5	a	0.268	ab	2.4	a	2141	ab	55.2	abc

†Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
‡ Product label rates doubled.
§ A different variety was planted in check and fertilizer plots in 2012, confounding comparisons with inoculant treatments.

Table 2.10 Nodule count response to inoculant treatments, 2011.

	Experimental Locations							
	2011		2011		2011		2011	
Inoculant treatment	Republic		Riley†		Osage		Morris	
	nodules plant^{-1} ‡							
Check	3.6	bc§	14.7	a	5.7	bc	0.0	d
ABM- Excalibre	2.8	c	12.8	a	2.8	c	3.4	ab
ABM- ExcalibreSA	3.1	bc	14.3	a	6.3	ab	-	-
BU- Vault	10.4	a	12.2	a	12.2	a	1.5	bc
NZ- Optimize	15.3	a	12.1	a	9.3	ab	5.4	a
TM- Maximize	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	14.2	a	16.8	a	6.9	ab	2.6	b
BU- VaultHP 2X	-	-	-	-	-	-	-	-
NZ- Optimize 2X	17.1	a	15.2	a	7.1	ab	6.6	a
TM- Maximize 2X	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	7.5	abc	14.6	a	10.3	ab	1.0	c
NZ- Optimize/Cell Tech Granular	14.8	a	16.8	a	10.7	ab	6.7	a
Contrasts								
Single rates	7.9	a	12.9	a	7.7	a	3.4	a
2X rates	15.7	a	16	a	7	a	4.6	a
Single rates	7.9	b	12.9	a	7.7	a	3.4	b
Product combinations	11.2	a	15.7	a	10.5	a	3.9	a
Check	3.6	b	14.7	a	5.7	a	0.0	b
Single rates	7.9	a	12.9	a	7.7	a	3.4	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.11 Nodule count response to inoculant treatments, 2012

	Experimental Locations									
	2012		2012		2012		2012		2012	
Inoculant treatment	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	nodules plant^{-1} ¶									
Check	6.8	de#	13.2	a	7.2	a	0.0	c	0.0	c
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	9.6	cd	12.1	a	5.0	a	1.4	b	4.7	b
NZ- Optimize	15.7	abc	13.3	a	7.6	a	3.3	b	7.1	ab
TM- Maximize	5.4	e	13.6	a	9.5	a	1.0	b	1.4	c
BU- Rhizo Stick 2X††	12.9	bc	12.1	a	6.5	a	1.9	b	5.8	b
BU- VaultHP 2X	13.6	abc	11.3	a	5.9	a	1.8	b	5.1	b
NZ- Optimize 2X	18.6	ab	13.7	a	8.1	a	2.2	b	8.3	ab
TM- Maximize 2X	9.5	cd	20.0	a	6.4	a	1.3	b	1.7	c
BU- Vault/Rhizo Stick	13.5	bc	13.9	a	7.4	a	1.6	b	6.2	b
NZ- Optimize/Cell Tech Granular	23.5	a	15.8	a	8.0	a	8.7	a	14.1	a
Contrasts										
Single rates	10.2	b	13.0	a	7.4	a	1.9	a	4.4	b
2X rates	13.7	a	14.3	a	6.7	a	1.8	a	5.2	a
Single rates	10.2	b	13.0	a	7.4	a	1.9	b	4.4	b
Product combinations	18.5	a	14.9	a	7.7	a	5.2	a	10.2	a
Check	6.8	a	13.2	a	7.2	a	0.0	a	0.0	b
Single rates	10.2	a	13	a	7.4	a	1.9	a	4.4	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.
# Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
†† Product label rates doubled.

Table 2.12 Nodule dry mass response to inoculant treatments, 2011.

	Experimental locations							
	2011		2011		2011		2011	
Inoculant treatment	Republic		Riley†		Osage		Morris	
	g (10 plants)$^{-1}$‡							
Check	0.160	abc§	0.168	a	0.224	a	0.000	de
ABM- Excalibre	0.106	bc	0.178	a	0.141	abc	0.011	d
ABM- ExcalibreSA	0.059	c	0.173	a	0.120	abc	0.001	e
BU- Vault	0.390	ab	0.121	a	0.203	a	0.024	cd
NZ- Optimize	0.599	a	0.133	a	0.144	abc	0.056	abc
TM- Maximize	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	0.490	ab	0.222	a	0.083	c	0.032	bcd
BU- Vault 2X	-	-	-	-	-	-	-	-
NZ- Optimize 2X	0.632	a	0.241	a	0.173	ab	0.114	ab
TM- Maximize 2X	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	0.221	abc	0.220	a	0.083	c	0.015	d
NZ- Optimize/Cell Tech Granular	0.505	a	0.237	a	0.099	bc	0.118	a
Contrasts								
Single rates	0.289	a	0.151	a	0.152	a	0.023	a
2X rates	0.561	a	0.232	a	0.128	a	0.073	a
Single rates	0.289	a	0.151	a	0.152	a	0.023	a
Product combinations	0.363	a	0.229	a	0.091	a	0.067	a
Check	0.160	a	0.168	a	0.224	a	0.000	a
Single rates	0.289	a	0.151	a	0.152	a	0.023	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table .
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.13 Nodule dry mass response to inoculant treatments, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatment	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	g (10 plants)$^{-1}$¶									
Check	0.176	a#	0.286	a	0.119	a	0.000	d	0.855	a
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	0.247	a	0.294	a	0.067	a	0.160	bc	0.801	a
NZ- Optimize	0.362	a	0.225	a	0.136	a	0.111	bc	0.134	a
TM- Maximize	0.193	a	0.298	a	0.135	a	0.017	d	0.395	a
BU- Rhizo Stick 2X††	0.369	a	0.246	a	0.112	a	0.099	bc	0.310	a
BU- Vault 2X	0.513	a	0.215	a	0.104	a	0.121	bc	1.155	a
NZ- Optimize 2X	0.466	a	0.389	a	0.191	a	0.220	ab	0.843	a
TM- Maximize 2X	0.268	a	0.379	a	0.103	a	0.063	c	0.285	a
BU- Vault/Rhizo Stick	0.316	a	0.272	a	0.124	a	0.132	bc	0.517	a
NZ- Optimize/Cell Tech Granular	0.269	a	0.360	a	0.165	a	0.524	a	0.660	a
Contrasts										
Single rates	0.267	a	0.272	a	0.113	a	0.065	a	0.443	a
2X rates	0.404	a	0.307	a	0.128	a	0.126	a	0.648	a
Single rates	0.267	a	0.272	a	0.113	a	0.065	b	0.443	a
Product combinations	0.293	a	0.316	a	0.145	a	0.328	a	0.589	a
Check	0.176	a	0.286	a	0.119	a	0.009	a	0.855	a
Single rates	0.267	a	0.272	a	0.113	a	0.065	a	0.443	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table .
# Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
†† Product label rates doubled.

Table 2.14 Visual rating of nodulation based on a 0-10 scale with 0 indicating no nodules and 10 indicating several large nodules located along the main taproot, 2011.

	Experimental locations							
	2011		2011		2011		2011	
Inoculant treatments	Republic		Riley†		Osage		Morris	
	average numerical rating treatment^{-1}							
Check	1.8	cd‡	3.0	a	2.0	a	0.0	d
ABM- Excalibre	1.0	d	2.8	a	1.5	a	0.3	cd
ABM- ExcalibreSA	1.0	d	2.8	a	2.3	a	0.0	d
BU- Vault	2.8	abc	2.3	a	2.5	a	0.8	cd
NZ- Optimize	3.5	a	2.8	a	2.3	a	1.8	ab
TM- Maximize	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X§	3.3	ab	3.3	a	2.3	a	1.0	bc
BU- Vault 2X	-	-	-	-	-	-	-	-
NZ- Optimize 2X	3.8	a	3.3	a	2.0	a	2.5	a
TM- Maximize 2X	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	2.3	bc	3.3	a	2.5	a	0.3	cd
NZ- Optimize/Cell Tech Granular	3.3	ab	3.0	a	2.5	a	2.3	a
Contrasts								
Single rates	2.1	a	2.7	a	2.2	a	0.7	a
2X rates	3.6	a	3.3	a	2.2	a	1.8	a
Single rates	2.1	b	2.7	a	2.2	a	0.7	b
Product combinations	2.8	a	3.2	a	2.5	a	1.3	a
Check	1.8	b	3.0	a	2.0	a	0.0	b
Single rates	2.1	a	2.7	a	2.2	a	0.7	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
§ Product label rates doubled.

Table 2.15 Visual rating of nodulation based on a 0-10 scale with 0 indicating no nodules and 10 indicating several large nodules located along the main taproot, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatments	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	average numerical rating treatment^{-1}									
Check	1.5	a¶	2.3	a	2.0	a	0.0	c	0.3	d
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	1.8	a	2.3	a	1.8	a	0.8	bc	1.8	bc
NZ- Optimize	2.0	a	1.6	a	1.8	a	1.3	ab	2.3	b
TM- Maximize	1.8	a	2.3	a	2.0	a	0.2	c	0.3	d
BU- Rhizo Stick 2X#	2.0	a	2.3	a	2.0	a	1.0	ab	2.0	b
BU- Vault 2X	1.8	a	2.3	a	1.8	a	1.0	ab	1.8	bc
NZ- Optimize 2X	2.0	a	2.3	a	2.0	a	1.3	ab	2.3	b
TM- Maximize 2X	2.0	a	2.5	a	1.8	a	0.5	bc	1.3	c
BU- Vault/Rhizo Stick	2.0	a	2.3	a	1.8	a	0.8	bc	2.0	b
NZ- Optimize/Cell Tech Granular	2.3	a	2.0	a	1.8	a	1.8	a	3.3	a
Contrasts										
Single rates	1.9	a	2.1	a	1.9	a	0.8	a	1.5	a
2X rates	2.0	a	2.4	a	1.9	a	1.0	a	1.6	a
Single rates	1.9	a	2.1	a	1.9	a	0.8	b	1.5	b
Product combinations	2.2	a	2.2	a	1.8	a	1.3	a	5.3	a
Check	1.5	a	2.3	a	2.0	a	0.0	b	0.3	b
Single rates	1.9	a	2.1	a	1.9	a	0.8	a	1.5	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
# Product label rates doubled.

Table 2.16 Total plant dry mass at approximately the V4 soybean growth stage, 2011.

	Experimental locations							
	2011		2011		2011		2011	
Inoculant treatments	Republic		Riley†		Osage		Morris	
	g‡							
Check	40.1	bc§	18.9	a	19.7	a	19.8	a
ABM- Excalibre	48.1	ab	18.2	a	25.2	a	21.2	a
ABM- ExcalibreSA	38.6	c	23.2	a	23.2	a	20.4	a
BU- Vault	48.9	ab	17.6	a	19.3	a	22.2	a
NZ- Optimize	48.3	ab	20.5	a	22.4	a	19.9	a
TM- Maximize	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	38.8	c	19.8	a	21.1	a	19.6	a
BU- Vault 2X	-	-	-	-	-	-	-	-
NZ- Optimize 2X	50.5	a	20.2	a	22.5	a	20.0	a
TM- Maximize 2X	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	49.6	a	16.2	a	20.5	a	23.0	a
NZ- Optimize/Cell Tech Granular	42.8	abc	19.0	a	21.0	a	22.5	a
Contrasts								
Single rates	46.0	a	19.9	a	22.5	a	20.9	a
2X rates	44.7	a	20.0	a	21.8	a	19.8	a
Single rates	46.0	a	19.9	a	22.5	a	20.9	a
Product combinations	46.2	a	17.6	a	20.8	a	22.8	a
Check	40.1	a	18.9	a	19.7	a	19.8	a
Single rates	46.0	a	19.9	a	22.5	a	20.9	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.17 Total plant dry mass at approximately the V4 soybean growth stage, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatments	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	g¶									
Check	52.4	a#	41.1	a	22.6	abcd	180.8	a	108.8	a
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	34.8	a	67.4	a	24.7	abc	135.0	a	89.0	a
NZ- Optimize	46.9	a	51.6	a	22.0	bcd	134.6	a	113.1	a
TM- Maximize	56.4	a	60.6	a	23.9	abc	137.6	a	79.3	a
BU- Rhizo Stick 2X††	41.5	a	58.7	a	20.6	cd	128.5	a	98.2	a
BU- Vault 2X	40.3	a	51.3	a	28.0	a	140.1	a	90.3	a
NZ- Optimize 2X	51.2	a	56.8	a	24.3	abc	121.5	a	103.1	a
TM- Maximize 2X	41.7	a	53.5	a	22.1	bcd	125.8	a	110.6	a
BU- Vault/Rhizo Stick	39.2	a	46.7	a	25.8	ab	92.6	a	88.9	a
NZ- Optimize/Cell Tech Granular	45.0	a	54.2	a	18.6	d	157.8	a	103.0	a
Contrasts										
Single rates	46.0	a	59.9	a	23.5	a	135.7	a	93.8	a
2X rates	43.7	a	55.1	a	23.8	a	129.0	a	100.6	a
Single rates	46.0	a	59.9	a	23.5	a	135.7	a	93.8	a
Product combinations	42.1	a	50.5	a	22.2	a	125.2	a	96.0	a
Check	52.4	a	41.1	a	22.6	a	180.8	a	108.8	a
Single rates	46.0	a	59.9	a	23.5	a	135.7	a	93.8	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.
# Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
†† Product label rates doubled.

Table 2.18 Above ground V-4 whole plant nitrogen content inoculant treatment response over environments.

Inoculant treatment	Plant N content	
	g kg^{-1}	
Check	32.7	b†
ABM- Excalibre	41.1	a
ABM- ExcalibreSA	40.5	a
BU- Vault	34.1	b
NZ- Optimize	32.8	b
TM- Maximize	23.7	c
BU- Rhizo Stick 2X‡	33.0	b
BU- Vault 2X	27.1	c
NZ- Optimize 2X	33.3	b
TM- Maximize 2X	25.5	c
BU- Vault/Rhizo Stick	33.5	b
NZ- Optimize/Cell Tech Granular	32.9	b
Contrasts		
Single rates	34.4	a
2X rates	29.7	b
Single rates	34.4	a
Product combinations	33.2	a
Check	32.7	a
Single rates	34.4	a

† Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
‡ Product label rates doubled.

Table 2.19 Seed size response to inoculant and nitrogen fertilizer treatments, 2011.

	Experimental locations									
	2011		2011		2011		2011		2011	
Inoculant treatment	Republic		Riley†		Osage		Republic-I†‡		Morris	
	g (300 seeds)$^{-1}$									
Check	36.85	a§	42.08	a	36.01	a	42.17	a	21.61	a
67 kg ha^{-1} N	36.81	a	41.46	a	35.65	a	43.79	a	22.68	a
134.4 kg ha^{-1} N	37.52	a	41.99	a	35.80	a	43.59	a	22.10	a
ABM- Excalibre	34.50	a	42.45	a	34.69	a	42.38	a	21.68	a
ABM- ExcalibreSA	39.51	a	42.66	a	36.27	a	42.79	a	21.54	a
BU- Vault	36.51	a	42.69	a	35.52	a	43.35	a	22.91	a
NZ- Optimize	35.17	a	42.58	a	35.43	a	42.50	a	22.77	a
TM- Maximize	-	-	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	40.63	a	42.16	a	36.30	a	42.94	a	21.30	a
BU- Vault 2X	-	-	-	-	-	-	-	-	-	-
NZ- Optimize 2X	36.63	a	42.79	a	35.58	a	42.32	a	22.44	a
TM- Maximize 2X	-	-	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	38.29	a	42.28	a	35.31	a	42.88	a	22.11	a
NZ- Optimize/Cell Tech Granular	37.21	a	42.03	a	35.94	a	42.49	a	21.15	a
Contrasts										
Single rates	34.42	a	42.60	a	35.47	a	42.76	a	22.23	a
2X rates	38.63	a	42.48	a	35.94	a	42.63	a	21.87	a
Single rates	34.42	a	42.60	a	35.47	a	42.76	a	22.23	a
Product combinations	37.75	a	84.31	a	35.63	a	42.69	a	21.63	a
Check	36.85	a	42.08	a	36.01	a	42.17	a	21.61	a
Single rates	34.42	a	42.60	a	35.47	a	42.76	a	22.23	a
N fertilizer	37.17	a	41.73	a	35.73	a	43.69	a	22.39	a
Single rates	34.42	a	42.60	a	35.47	a	42.76	a	22.23	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ I, irrigated field.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.20 Seed size response to inoculant and nitrogen fertilizer treatments, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatment	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	g (300 seeds)$^{-1}$									
Check	1094	A¶	1116	A	1215	A	877	A	758	DE
67 kg ha^{-1} N	1114	A	1101	A	1220	A	894	A	763	CDE
134.4 kg ha^{-1} N	1096	A	1129	A	1185	A	902	A	822	AB
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	1058	a	1165	a	1239	a	816	a	775	bcde
NZ- Optimize	1055	a	1119	a	1297	a	795	a	838	a
TM- Maximize	1043	a	1114	a	1254	a	824	a	750	e
BU- Rhizo Stick 2X#	1030	a	1141	a	1280	a	837	a	838	a
BU- Vault 2X	1073	a	1106	a	1312	a	854	a	814	abc
NZ- Optimize 2X	1030	a	1107	a	1287	a	790	a	794	abcde
TM- Maximize 2X	1019	a	1155	a	1259	a	823	a	794	abcde
BU- Vault/Rhizo Stick	1042	a	1116	a	1251	a	645	a	844	a
NZ- Optimize/Cell Tech Granular	1072	a	1103	a	1238	a	810	a	809	abcd
Contrasts										
Single rates	1052	a	1133	a	1263	a	812	a	788	a
2X rates	1038	a	1127	a	1284	a	826	a	810	a
Single rates	1052	a	1133	a	1263	a	812	a	788	b
Product combinations	1057	a	1109	a	1245	a	728	a	827	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$. A different variety was planted in check and fertilizer plots in 2012, confounding comparisons with inoculant treatments. Therefore, treatment comparisons can be compared only within capital or lower case letters.
# Product label rates doubled.

Table 2.21 Seed nitrogen content at harvest in response to inoculant and nitrogen fertilizer treatments, 2011.

	Experimental locations									
	2011		2011		2011		2011		2011	
Inoculant treatment	Republic		Riley†		Osage		Republic-I†‡		Morris	
	g kg^{-1}									
Check	54.8	a§	55.4	a	57.4	a	56.0	a	53.1	ef
67 kg ha^{-1} N	53.8	a	54.0	c	57.7	a	55.5	a	57.5	ab
134.4 kg ha^{-1} N	53.6	a	54.4	bc	59.7	a	55.3	a	58.4	a
ABM- Excalibre	54.1	a	55.1	ab	57.9	a	55.4	a	51.5	f
ABM- ExcalibreSA	54.7	a	55.2	a	57.9	a	56.0	a	53.9	de
BU- Vault	54.4	a	55.2	a	57.5	a	56.0	a	52.2	ef
NZ- Optimize	53.8	a	55.0	ab	57.6	a	55.8	a	56.9	abc
TM- Maximize	-	-	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	54.9	a	55.6	a	58.3	a	56.1	a	55.4	cd
BU- Vault 2X	-	-	-	-	-	-	-	-	-	-
NZ- Optimize 2X	53.9	a	55.5	a	58.0	a	56.0	a	56.4	bc
TM- Maximize 2X	-	-	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	53.8	a	55.4	a	57.4	a	56.2	a	52.9	ef
NZ- Optimize/Cell Tech Granular	55.2	a	55.6	a	57.5	a	55.8	a	55.7	bcd
Contrasts										
Single rates	54.3	a	55.1	a	57.7	a	55.8	a	53.6	a
2X rates	54.4	a	55.6	a	58.2	a	56.1	a	55.9	a
Single rates	54.3	a	55.1	a	57.7	a	55.8	a	53.6	b
Product combinations	54.5	a	55.5	a	57.5	a	56.0	a	54.3	a
Check	54.8	a	55.4		57.4	a	56.0	a	53.1	b
Single rates	53.7	a	54.2		58.7	a	55.4	a	58.0	a
N fertilizer	53.7	a	54.2	b	58.7	a	55.4	a	58.0	a
Single rates	54.3	a	55.1	a	57.7	a	55.8	a	53.6	b

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ I, irrigated field.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.22 Seed nitrogen content at harvest in response to inoculant and nitrogen fertilizer treatments, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatment	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	g kg^{-1}									
Check	54.9	A¶	55.1	A	59.4	A	49.7	CDE	47.7	E
67 kg ha^{-1} N	53.9	A	54.8	A	59.2	A	51.0	B	48.1	DE
134.4 kg ha^{-1} N	54.2	A	54.1	A	59.4	A	53.1	A	48.9	DE
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	54.8	a	54.3	a	59.0	a	49.4	de	52.1	bc
NZ- Optimize	55.1	a	54.2	a	59.8	a	50.7	bc	55.1	a
TM- Maximize	54.7	a	55.5	a	59.3	a	50.0	bcde	47.8	e
BU- Rhizo Stick 2X#	54.7	a	53.1	a	59.0	a	50.2	bcde	52.9	ab
BU- Vault 2X	58.6	a	54.2	a	59.1	a	50.3	bcd	52.1	bc
NZ- Optimize 2X	55.0	a	55.2	a	58.6	a	49.1	e	52.5	bc
TM- Maximize 2X	54.9	a	53.6	a	59.2	a	50.3	bcde	50.3	cd
BU- Vault/Rhizo Stick	54.9	a	54.7	a	59.5	a	50.4	bcd	53.6	ab
NZ- Optimize/Cell Tech Granular	54.7	a	55.3	a	58.4	a	50.8	bc	54.4	ab
Contrasts										
Single rates	54.9	a	54.7	a	59.4	a	50.0	a	51.7	a
2X rates	55.8	a	54.0	a	59.0	a	50.0	a	52.0	a
Single rates	54.9	a	54.7	a	59.4	a	50.0	a	51.7	b
Product combinations	54.8	a	55.0	a	59.0	a	50.6	a	54.0	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
A different variety was planted in check and fertilizer plots in 2012,
confounding comparisons with inoculant treatments.
Therefore, treatment comparisons can be compared
only within capital or lower case letters.
Product label rates doubled.

Table 2.23 Soybean grain test weight response to inoculant and nitrogen fertilizer treatments, 2011.

	Experimental locations									
	2011		2011		2011		2011		2011	
Inoculant treatment	Republic		Riley†		Osage		Republic-I†‡		Morris	
	kg m^{-3}									
Check	750	a§	768	a	744	a	731	a	773	a
67 kg ha^{-1} N	747	a	764	a	755	a	728	a	764	a
134.4 kg ha^{-1} N	752	a	766	a	748	a	730	a	779	a
ABM- Excalibre	751	a	770	a	749	a	727	a	770	a
ABM- ExcalibreSA	747	a	768	a	753	a	733	a	730	a
BU- Vault	748	a	768	a	749	a	731	a	771	a
NZ- Optimize	748	a	770	a	745	a	725	a	774	a
TM- Maximize	-	-	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	750	a	770	a	759	a	729	a	773	a
BU- Vault 2X	-	-	-	-	-	-	-	-	-	-
NZ- Optimize 2X	750	a	770	a	734	a	728	a	768	a
TM- Maximize 2X	-	-	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	750	a	766	a	758	a	732	a	769	a
NZ- Optimize/Cell Tech Granular	754	a	766	a	732	a	728	a	775	a
Contrasts										
Single rates	749	a	769	a	749	a	729	a	761	a
2X rates	750	a	770	a	747	a	729	a	770	a
Single rates	749	a	769	a	749	a	729	a	761	a
Product combinations	752	a	766	a	745	a	730	a	772	a
Check	750	a	768	a	744	a	731	a	773	a
Single rates	749	a	769	a	749	a	729	a	761	a
N fertilizer	750	a	765	a	752	a	729	a	772	a
Single rates	749	a	769	a	749	a	729	a	761	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ I, irrigated field.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.24 Soybean grain test weight response to inoculant and nitrogen fertilizer treatments, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatment	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
	kg m^{-3}									
Check	767	A¶	742	A	762	B	744	E	738	A
67 kg ha^{-1} N	769	A	746	A	759	B	759	ABC	746	A
134.4 kg ha^{-1} N	760	B	748	A	758	B	752	BCDE	743	A
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	756	bcd	765	a	772	a	766	a	759	a
NZ- Optimize	755	bcd	770	a	773	a	749	cde	757	a
TM- Maximize	755	bcd	750	a	771	a	750	bcde	756	a
BU- Rhizo Stick 2X#	759	bc	756	a	775	a	757	abc	759	a
BU- Vault 2X	751	d	755	a	772	a	746	de	603	a
NZ- Optimize 2X	759	bc	755	a	771	a	762	ab	757	a
TM- Maximize 2X	752	cd	754	a	775	a	753	bcde	752	a
BU- Vault/Rhizo Stick	760	b	748	a	777	a	755	abcde	756	a
NZ- Optimize/Cell Tech Granular	758	bcd	757	a	772	a	753	bcde	600	a
Contrasts										
Single rates	755	a	762	a	772	a	755	a	757	a
2X rates	755	a	755	a	77.3	a	755	a	718	a
Single rates	755	a	762	a	772	a	755	a	757	a
Product combinations	759	a	753	a	775	a	754	a	678	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$. A different variety was planted in check and fertilizer plots in 2012, confounding comparisons with inoculant treatments. Therefore, treatment comparisons can be compared only within capital or lower case letters.
# Product label rates doubled.

Table 2.25 Yield response to inoculant and nitrogen fertilizer treatments, 2011.

	Experimental locations									
Inoculant treatment	2011 Republic		2011 Riley†		2011 Osage		2011 Republic-I†‡		2011 Morris	
					kg ha^{-1}					
Check	3631	bc§	2515	a	2099	a	4119	a	637	a
67 kg ha^{-1} N	3313	c	2512	a	2140	a	4013	a	580	a
134.4 kg ha^{-1} N	3655	bc	2724	a	2424	a	4205	a	550	a
ABM- Excalibre	3754	abc	2867	a	2312	a	4339	a	681	a
ABM- ExcalibreSA	3908	ab	2725	a	2459	a	4246	a	467	a
BU- Vault	3270	c	2692	a	2263	a	4332	a	781	a
NZ- Optimize	3579	bc	3102	a	2380	a	4081	a	619	a
TM- Maximize	-	-	-	-	-	-	-	-	-	-
BU- Rhizo Stick 2X¶	4109	ab	2805	a	2421	a	3939	a	584	a
BU- Vault 2X	-	-	-	-	-	-	-	-	-	-
NZ- Optimize 2X	3672	bc	2945	a	2292	a	3909	a	613	a
TM- Maximize 2X	-	-	-	-	-	-	-	-	-	-
BU- Vault/Rhizo Stick	3307	c	2675	a	2179	a	4356	a	584	a
NZ- Optimize/Cell Tech Granular	4265	a	2614	a	2286	a	3817	a	724	a
Contrasts										
Single rates	3628	a	2847	a	2354	a	4250	a	632	a
2X rates	8891	a	2875	a	1924	a	3924	a	599	a
Single rates	3628	a	2847	a	2354	a	4250	a	632	a
Product combinations	3786	a	2645	a	2233	a	4087	a	654	a
Check	3631	a	2515	a	2099	a	4119	a	637	a
Single rates	3628	a	2847	a	2354	a	4250	a	632	a
N fertilizer	3484	a	2620	a	2282	a	4109	a	565	a
Single rates	3628	a	2847	a	2354	a	4250	a	632	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ I, irrigated field.
§ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.
¶ Product label rates doubled.

Table 2.26 Yield response to inoculant and nitrogen fertilizer treatments, 2012.

	Experimental locations									
	2012		2012		2012		2012		2012	
Inoculant treatments	Republic		Riley†		Osage		Phillips-C‡		Phillips-S§	
					kg ha^{-1}					
Check	1692	A¶	3240	C	1401	E	2751	A	1185	A
67 kg ha^{-1} N	1829	A	3518	BC	1507	DE	2667	A	1619	A
134.4 kg ha^{-1} N	1913	A	3251	C	1524	CDE	3219	A	1711	A
ABM- Excalibre	-	-	-	-	-	-	-	-	-	-
ABM- ExcalibreSA	-	-	-	-	-	-	-	-	-	-
BU- Vault	1792	a	4356	a	2187	ab	1038	c	1354	a
NZ- Optimize	1804	a	4189	ab	1946	abc	1679	bc	1692	a
TM- Maximize	1909	a	4151	ab	1800	bcde	1468	bc	1098	a
BU- Rhizo Stick 2X#	1636	a	3983	ab	1993	ab	1609	bc	1591	a
BU- Vault 2X	1656	a	4241	ab	1958	ab	1683	bc	1259	a
NZ- Optimize 2X	1713	a	4278	a	1938	abc	1242	bc	1800	a
TM- Maximize 2X	1926	a	3701	abc	1805	bcde	1160	bc	1403	a
BU- Vault/Rhizo Stick	1741	a	4217	ab	1856	bcd	1446	bc	1600	a
NZ- Optimize/Cell Tech Granular	1914	a	4109	ab	2313	a	1888	b	1553	a
Contrasts										
Single rates	1835	a	4232	a	1978	a	1395	b	1381	a
2X rates	1733	a	4051	a	1924	a	1424	a	1513	a
Single rates	1835	a	4232	a	1978	a	1395	a	1381	a
Product combinations	1828	a	4163	a	2085	a	1667	a	1577	a

† Environment that had been rotated to soybean in the past three years. All other environments had been out of soybean rotation for a minimum of 15 years.
‡ C, following corn.
§ S, following sorghum.
¶ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$. A different variety was planted in check and fertilizer plots in 2012, confounding comparisons with inoculant treatments. Therefore, treatment comparisons can be compared only within capital or lower case letters.
# Product label rates doubled.

Chapter 3 - Soybean Inoculant and Seed Treatment Interactions in Various Soybean Production Scenarios

Abstract

Soybean seed treatments provide protection against various seedling pests and diseases. Potential interactions of seed treatment formulations with seed applied *Bradyrhizobium japonicum* bacterial inoculants are of interest. Survival of seed-applied bacterial inoculants is critical in situations where there is no *B. japonicum* present in the soil in order to achieve adequate nodulation and nitrogen fixation. The objective of this study was to investigate possible interactions of various seed treatment formulations with soybean bacterial inoculants. A factorial experimental design with seed treatments and inoculant products was employed. Seed treatments included fungicides, insecticides, and nematicides applied as ApronMaxx® RFC; ApronMaxx® RFC, Cruiser®; ApronMaxx® RFC, Cruiser®, Avicta®; and ApronMaxx® RFC, Poncho®/VOTiVO™. Inoculant products applied in conjunction with these seed treatments included Advanced Biological Marketing, ExcalibreSA™; Becker Underwood, Vault® HP; Novozymes, Optimize® 400, and Terramax Maximize. Seven field experiments were set up in a randomized complete block design with four replications each of at five locations. There were no negative effects on nodulation performance with any of the seed treatments. There were significant differences in yield between inoculant treatments at one location in 2011. However, differences were small and the untreated seed yielded as well or better than all treatment/inoculant combinations. At the other sites, yield was not significantly influenced by seed treatment and inoculant combinations. The results indicate that seed treatment formulations did not significantly affect bacterial inoculant product performance, soybean nodulation, or yield.

Introduction

Biological nitrogen fixation is the process of fixing atmospheric N_2 to NH_3 and occurs in the symbiotic relationship between soybean plants and *Bradyrhizobium japonicum* within nodules on the soybean root (Lie, 1981). Nodulation and nodule growth are indicators of nitrogen fixation rates (Serraj and Sinclair, 1998). As the growing season progresses, nodule number and size increase. Plants with successful symbiosis with *B. japonicum* possess greater plant nitrogen concentration and total plant nitrogen compared to those with poor nodulation (Ruiz-Diaz et al., 2009). For bacteria to nodulate soybean roots, *B. japonicum* must be introduced to the soil as it does not natively occur in U.S. soils. Once this takes place through inoculation of the seed at the time of planting, populations will naturalize in the soil. The bacterial inoculant strain and its carrier formulation influence the field performance and survivability of the bacteria (Albareda et al., 2008). Most current inoculant products are supported in a liquid carrier due to the simplicity of production and application (Xavier et al., 2004).

Seed applied pesticide treatments protecting the newly germinating soybean plant against fungal, insect, and nematode pests are used by many producers. Several studies have found a negative yield response do to loss of bacteria viability when seed applied fungicide treatments are used (Schulz and Thelen, 2008; Hiltbold et al., 1980; Campo et al., 2009). Schulz and Thelen (2008) reported a 130 and 500 kg ha^{-1}decrease in yield due to inoculant and fungicide interactions. Hiltbold et al. (1980) recorded poor inoculant performance when a fungicide treatment was added. Toxic effects of the fungicides were more pronounced in sandy soils without soybean history (Campo et al., 2009).

Peat-based inoculants have proven to mitigate fungicide-bacteria interactions better than liquid inoculants (Schulz and Thelen, 2008). A study by Mallik and Tesfai (1984) found no negative effects of three fungicides on nodulation where peat-based inoculant was added to treated seed before planting. The amount of viable *B. japonicum* on treated seeds decreases with time but also varies with fungicide product (Revellin et al., 1993). The effects of the reduction of bacteria viability carries through to nodulation, resulting in reduced nodule numbers and dry weight (Revellin et al., 1993).

The degree of reduction in viable bacteria and nodulation is impacted heavily by the fungicide product used (Revellin et al., 1993; Mallik and Tesfai, 1984). Revellin et al. (1993) found after 24 hours of inoculant contact on treated seed, bacteria viability was reduced by less than a factor of 10 in the majority of fungicides tested. Inoculant labels included a listing of compatible seed treatments that the inoculant can be added to after seed treatment. This provides options for fungicides, insecticides, and nematicides that should not reduce nodulation performance or harm the viability of the living bacteria to the extent that nodulation is hindered.

Research Question and Justification

Recently there has been an increase in reports of poor nodulation in fields new to soybean production (K.L. Roozeboom, personal communication, 2011) in the state of Kansas. The symbiotic relationship between soybean and *B. japonicum* is greatly beneficial to the producer by supplying much of the high nitrogen demand required by soybeans. This has placed attention on consistently obtaining well nodulated soybeans in fields new to soybean production to prevent yield and profit losses due to inadequate nitrogen supply. The goal of this research was to determine if a negative interaction exists between inoculant products and common seed treatments

Material and Methods

Seven field experiments were conducted over years 2011 and 2012 at Kansas State University research fields and cooperator fields in Kansas. The locations were selected to achieve a range of histories of soybean production from never before grown to being in recent rotation. The locations also represented a range of yield environments across Kansas. Descriptions of each location are presented in Tables 3.1, 3.2, and 3.3. Soil samples were taken at 15 and 60 cm depths at each location when soybean was at the V3-V5 stage.

Treatments included four soybean inoculant products applied to seed with one of five seed treatment combinations including fungicide, insecticides, and/or nematicides in addition to untreated seed (Table 3.4). All seed treatments are labeled as compatible with bacterial inoculants. Untreated soybean seed was sent to Syngenta in Stanton, MN for pesticide seed treatments (Table 3.5). Liquid inoculants were applied to treated soybean seed according to supplier protocols within seven days of planting and kept in cold storage (4° C) until planting. Inoculants were added to seed and manually mixed in a sterile glass jar for three minutes to uniformly distribute inoculant over the seed. Seed inoculated with liquid formulations was spread on blotting paper to dry before packaging into envelopes for plot planting. Seed was transported to the field in a cooler to ensure viability of inoculants. Equipment used for seed processing was sterilized using 950 g kg^{-1} concentration ethyl alcohol.

A two row planter with John Deere (Deere & Company; Moline, Illinois) row units and a precision cone planter attachment was used to plant plots. Planter surfaces that came in contact with the seed were cleaned with 950 g kg^{-1} concentration ethyl alcohol before planting each location. The order of planting was the untreated raw check seed followed by treated seed to minimize cross contamination. Glyphosate (N-[phosphonomethyl] glycine, in the form of its potassium salt) at the recommended rate of 0.63 to 1.48 kg ae ha^{-1} was applied for weed control at all locations as needed to maintain weed-free conditions.

Characterization of soybean response to inoculation and seed treatments included plant density, nodule evaluations, and seed yield. Plant density was determined at the VE to V1 stage by counting plants in 6.096 m of row in the two center rows of each plot. Soybeans were harvested using a modified two row Gleaner (model EIII; AGCO Corporation, Duluth, GA) combine at or below a target seed moisture of 13%. Yield was determined by obtaining the weight of the harvested seed from the center two rows of each plot. A subsample was retained for determination of moisture content, test weight, seed size, and nitrogen content.

Nodule evaluations took place at approximately the V3 growth stage. Ten plants were dug from the outer two rows of the four row plots using hand spades. Only the plots that contained Novozymes Optimize (Franklinton, NC) inoculant with all the seed treatments were dug to reduce the volume of plants for processing. Roots were washed using a rotary root washer constructed by researchers at Colorado State University (Benjamin and Nielsen, 2004). Following washing, roots were placed in plastic bags and stored in cold storage (4° C) until analyzed for nodulation. Nodulation was visually rated on individual roots. Visual ratings were based on nodule distribution, quantity, and size. The rating scale was 0 to 5 with 0 possessing no nodules and five possessing several large nodules located along the taproot. Each plant was separately rated by three individuals and ratings averaged. Nodules were removed and counted from each root and were randomly split to ensure the nodules were pink on the inside, demonstrating active nitrogen fixation (Sadowsky et al., 1988). Nodules from the ten plants were then collected for dry mass measurements. Plant samples were dried at 60°C in a forced-air oven to determine dry mass of plant tops, roots, and nodules. Plant tops were ground and submitted to the Kansas State University Soil Testing Lab for determining tissue N content.

The experimental design was a randomized complete block factorial structure with 16 treatments and four replications. Individual plot dimensions were 1.5 m wide (four rows) by 7.62 to 9.14 m long. Statistical analysis was completed using the MIXED procedure in SAS 9.2 (SAS, 2009) statistical analysis software with block as a random factor. The distribution of data for each response variable was checked for normality using QQ-plots. Data with exponential distributions were subjected to log transformations. Analysis was completed by environment when there was interaction between environment and treatment. Otherwise, the data was analyzed across locations.

Results and Discussion

Nodulation

Seed treatments did not affect nodule counts or visual ratings ($\alpha = 0.05$) of Optimize inoculated plots compared to the check. The only significant main effect was due to environment. The highest counts where at the Republic and Riley sites where there had been soybean planted ≤17 years ago (Table 3.6). The lowest nodule counts were at the Phillips location that had no previous soybean history (Table 3.6). Nodule dry mass had significant treatment differences at only one of the six locations (Table 3.7). In the Phillips 2012 location, the ApronMaxx Cruiser seed treatment had a greater positive effect on dry mass in comparison to the other seed treatments (Table 3.7). Untreated and non-inoculated seed had the lowest nodule dry mass at this location (Table 3.7). Visual ratings followed a similar pattern as counts. Exceptions were the 2012 Republic and Riley environments that had lower ratings than 2011 environments, making them no different than the Morris environment that had not had soybeans planted for >40 years (Table 3.8). Overall, seed treatment did not negatively impact nodulation. The field environment had a greater effect on nodulation than any seed treatment combination.

Vegetative

Plant dry mass and whole above ground plant nitrogen also were unaffected by seed treatment and inoculant ($\alpha = 0.05$). The environment had the greatest effect on these variables. The 2011 Republic site had the smallest values for plant dry mass and above ground whole plant nitrogen content (Tables 3.9 and 3.10). The highest plant dry mass was obtained at the Phillips location (Table 3.9). Plant nitrogen content was highest at the 2011 Riley and Morris environments (Table 3.10). The variation in plant dry mass and plant nitrogen likely was influenced by the developmental stage of the soybean when samples were taken at each site (Table 3.3).

Seed Characteristics

There was little consistency in response of seed characteristics. Test weight was significantly affected by treatment only in 2012 at the Riley site (Table 3.11). The other locations did not display any treatment differences ($\alpha = 0.05$). At the 2012 Riley site, seed treatments tended to improve test weight (Table 3.11). Seed size and seed nitrogen content were not affected by seed treatment ($\alpha = 0.05$). Inoculant product influenced seed size at two of the four environments. Grain nitrogen content had inoculant treatment differences at three of the four sites that had been out of soybean for at least 15 years. These environments included the 2011 and 2012 Republic environments, the Phillips location, and the Morris location (Tables 3.12 and 3.13). Un-inoculated plots fell in the lower groupings in seed nitrogen content (Table 3.13). The 2012 Republic and 2011 Morris sites had treatment differences in seed size (Table 3.12). Un-inoculated plots at the Republic site had an average 7.8% change increase in seed size from the inoculant treatments (Table 3.12). At the Morris site, seed size of the check was not significantly different from any of the other inoculant products (Table 3.12).

Yield

There was no effect of seed treatment on yield ($\alpha = 0.05$). The 2012 Republic environment was the only site where inoculant product affected yield. Optimize inoculant treated plots yielded significantly more than VaultHP inoculated plots (Table 3.14). Due to a confounding of check treatments with soybean variety in 2012, the un-treated check could not be compared to the other treatments (Table 3.14).

Conclusions

Seed treatment did not negatively affect nodulation or yield. This demonstrates that these seed treatments are compatible with seed applied *B. japonicum* inoculation. Site and/or inoculant product proved to have a greater impact on nodulation and yield performance than fungicide, insecticide, or nematicide seed treatments. Seed treatment did not improve yield in these environments as none of the environments had conditions likely to lead to disease or insect problems at establishment. Dry conditions were experienced in the growing seasons of both years. Therefore, the environment was not likely to be conducive to promoting to spread of seedling diseases. Insect pests were also minimal at all locations. In addition, there was no evidence of nematode populations being an issue at any of the locations. Therefore, it was not unexpected to find a positive response or benefit of seed treatments in these conditions.

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Figures and Tables

Table 3.1 Location soil descriptions for ten experiments investigating the interaction of inoculants and soybean seed treatments in Kansas in 2011 and 2012.

Year	County	Coordinates	Soil Series	Soil Classification
2011	Republic	39.8153, -97.6745	Crete silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll
2012	Republic	39.813198, -97.672305	Crete silt loam Butler silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll fine, smectitic, mesic Vertic Argiaquoll
2011	Riley	39.21756, -96.58958	Kahola silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludoll
2012	Riley	39.21778, -96.59139	Kahola silt loam	fine-silty, mixed, superactive, mesic Cumulic Hapludoll
2012	Phillips	39.713228, -99.320644	Harney silt loam	fine, smectitic, mesic Typic Argiustoll
2011	Republic-I†	39.831814, -97.838931	Crete silt loam	fine, smectitic, mesic Pachic Udertic Argiustoll
2011	Morris	38.863092, -96.753181	Irwin silty clay loam Konza silty clay loam	fine, mixed, superactive, mesic Pachic Argiustoll fine, smectitic, mesic Udertic Paleustoll

† I, Irrigated location.

Table 3.2 Location soil descriptions for ten experiments investigating the interaction of inoculants and soybean seed treatments in Kansas in 2011 and 2012.

Year	County	Soybean Variety	Years out of soybean	Previous Crop	Tillage System	Planting Date	Growth Stage at Nodulation Analysis
2011	Republic	KS3406RR	15	sorghum	NT	13-Jun-2011	R1
2012	Republic	KS3406RR	17	corn	NT	17-May-2012	V4
2011	Riley	OHLDE 0-451	2	sorghum	NT	7-Jun-2011	V4
2012	Riley	OHLDE 0-452	2	corn	NT	22-May-2012	V4-R1
2012	Phillips	KS3406RR	no soybean history	corn	NT	16-May-2012	R2
2011	Republic-I†	KS3406RR	2	corn	CT	13-Jun-2011	R1
2011	Morris	KS3406RR	≥ 40	brome	NT	11-Jun-2011	V4

† I, Irrigated location.

Table 3.3 Soil test values for research locations taken at approximately the V3-V5 soybean growth stage at 15 cm depth.

Year	County	Soil Test pH	Mehlich P	K	$N0_3$-N†	Ca	OM
				mg kg^{-1}			g kg^{-1}
2011	Republic	5.1	39.2	351	7.6	1825	25
2012	Republic	5.0	38.5	330	26.4	1846	21
2011	Riley	5.5	33.3	161	18.9	2902	30
2012	Riley	7.4	18.8	311	16.8	5494	35
2012	Phillips-C‡	5.7	46.1	553	14.2	1981	22
2011	Republic-I§	6.5	16.1	492	8.2	1990	25
2011	Morris	5.9	25.4	163	12.3	2100	32

† Profile 0-60 cm sample.

‡ C, following corn.

§ I, Irrigated location.

Table 3.4 Inoculant product descriptions and rates used in the study.

Company	Product name	Carrier	Rate	Bacteria concentration
			product kg^{-1} seed	
Novozymes (Franklinton, NC)	Optimize	Liquid	1.8 ml	$5x10^{9}$ cell g^{-1}
Becker Underwood (Ames, IA)	Vault HP	Liquid	1.3 ml	$3x10^{9}$ cell ml^{-1}
Advanced Biological Marketing (Van Wert, OH)	Excalibre SA	Encapsulated	0.07 ml	$5.5x10^{10}$ cell g^{-1}
TerraMaxx (Bloomington, MN)	Maximize	Liquid	1.3 ml	$4x10^{9}$ cell ml^{-1}

Table 3.5 Pesticide components and rates for seed treatments.

Seed Treatment	Seed treatment components			Respective rate
	Fungicide	Insecticide	Nematicide	Mg ai seed^{-1}
1	None	None	None	
2	ApronMaxx RFC Syngenta, Stanton, MN (fludioxonil/ mefenoxam)	None	None	0.0092
3	ApronMaxx RFC	Cruiser Syngenta, Stanton, MN (thiamethoxam)	None	0.0092; 0.0756
4	ApronMaxx RFC	Cruiser	Avicta Syngenta, Stanton, MN (abamectin)	0.0092; 0.0756; 0.1500
5	ApronMaxx RFC	Poncho/Votivo Bayer CropScience, RTP, NC (clothianidin; *Bacillus firmus*)		0.0092; 0.0616

Table 3.6 Nodule count per plant averages with Optimize inoculant at each location over all seed treatments.

Year	Experimental location County	Nodule count† nodules plant^{-1}	
2011	Republic	13.2	a‡
2012	Republic	11.7	a
2011	Riley	12.7	a
2012	Riley	13.6	a
2012	Phillips	2.6	c
2011	Morris	4.4	b

† Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.7 Nodule dry mass of ten plants response to seed treatment with Optimize inoculant.

		Experimental locations											
		2011 Republic		2012 Republic		2011 Riley		2012 Riley		2012 Phillips		2011 Morris	
		g (10 plants)$^{-1}$ †											
Un-inoculated	None	-	-	0.237	a	-	-	0.258	a	0.004	c	-	-
NZ- Optimize	None	0.408	a‡	0.315	a	0.159	a	0.096	a	0.258	ab	0.049	a
NZ- Optimize	ApronMaxxRFC	0.380	a	0.264	a	0.172	a	0.131	a	0.234	ab	0.149	a
NZ- Optimize	ApronMaxx Cruiser	0.590	a	0.361	a	0.182	a	0.336	a	0.396	a	0.112	a
NZ- Optimize	ApronMaxx Cruiser Avicta	0.324	a	0.358	a	0.176	a	0.348	a	0.159	b	0.093	a
NZ- Optimize	ApronMaxx Poncho Votivo	0.534	a	0.369	a	0.151	a	0.236	a	0.202	b	0.104	a

† Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table.
‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.8 Nodule visual rating at each environment averaged over all seed treatments with Optimize inoculant based on a 0-10 scale with 0 indicating no nodules and 10 indicating several large nodules located along the main taproot.

	Experimental location		
Year	County	Nodule visual rating	
2011	Republic	2.9	a†
2012	Republic	2.0	b
2011	Riley	2.7	a
2012	Riley	2.1	b
2012	Phillips	1.1	c
2011	Morris	1.9	b

† Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.9 Whole plant dry mass at V4 at each environment average over all seed treatments with Optimize inoculant.

Year	Experimental location County	Nodule dry mass† g (10 plants)$^{-1}$	
2011	Republic	47.20	c‡
2012	Republic	57.63	b
2011	Riley	21.86	d
2012	Riley	53.59	bc
2012	Phillips	127.15	a
2011	Morris	20.74	d

† Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table .

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.10 Above ground V4 whole plant nitrogen content at each environment averaged over all seed treatments with Optimize inoculant.

Experimental location		Nodule dry mass†	
Year	County	g kg^{-1}	
2011	Republic	2.90	c‡
2012	Republic	3.46	b
2011	Riley	3.91	a
2012	Riley	3.32	b
2012	Phillips	2.04	d
2011	Morris	3.86	a

† Natural log transformation was performed before analysis to achieve normal distribution and values were back transformed for reporting in the table .

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.11 Harvested grain test weight response to seed treatments and inoculants.

		Experimental locations						
		2011	2012	2011	2012	2012	2011	2011
Inoculant	Seed Treatment	Republic	Republic	Riley	Riley	Phillips	Republic-I†	Morris
		kg m^{-1}						
Un-inoculated	None	757 a‡	761 a	764 a	744 e	750 a	721 a	759 a
ABM- ExcalibreSA	None	762 a	- -	765 a	- -	- -	719 a	764 a
BU- VaultHP	None	757 a	757 a	768 a	753 cde	752 a	- -	758 a
NZ- Optimize	None	762 a	758 a	770 a	757 bcd	751 a	712 a	738 a
TM- Maximize	None	- -	756 a	- -	750 de	750 a	- -	- -
ABM- ExcalibreSA	ApronMaxxRFC	759 a	- -	771 a	- -	- -	712 a	754 a
BU- VaultHP	ApronMaxxRFC	759 a	758 a	765 a	755 bcd	767 a	- -	755 a
NZ- Optimize	ApronMaxxRFC	760 a	755 a	773 a	762 abc	752 a	714 a	749 a
TM- Maximize	ApronMaxxRFC	- -	751 a	- -	760 abcd	751 a	- -	- -
ABM- ExcalibreSA	ApronMaxx Cruiser	757 a	- -	770 a	- -	- -	713 a	754 a
BU- VaultHP	ApronMaxx Cruiser	763 a	750 a	767 a	750 de	751 a	- -	767 a
NZ- Optimize	ApronMaxx Cruiser	755 a	756 a	766 a	764 ab	751 a	719 a	757 a
TM- Maximize	ApronMaxx Cruiser	- -	751 a	- -	769 a	744 a	- -	- -
ABM- ExcalibreSA	ApronMaxx Cruiser Avicta	759 a	- -	772 a	- -	- -	719 a	766 a
BU- VaultHP	ApronMaxx Cruiser Avicta	766 a	753 a	770 a	761 abcd	749 a	718 a	765 a
NZ- Optimize	ApronMaxx Cruiser Avicta	760 a	755 a	765 a	762 abc	746 a	716 a	768 a
TM- Maximize	ApronMaxx Cruiser Avicta	- -	751 a	- -	761 abcd	750 a	- -	- -
ABM- ExcalibreSA	ApronMaxx Poncho Votivo	749 a	- -	772 a	- -	- -	720 a	759 a
BU- VaultHP	ApronMaxx Poncho Votivo	763 a	755 a	766 a	755 bcd	750 a	- -	758 a
NZ- Optimize	ApronMaxx Poncho Votivo	760 a	755 a	773 a	758 abcd	747 a	715 a	750 a
TM- Maximize	ApronMaxx Poncho Votivo	- -	755 a	- -	761 abc	754 a	- -	- -

† I, irrigated location.
‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 3.12 Seed size response to inoculant treatments.

	Experimental locations													
	2011		2012		2011		2012		2012		2011		2011	
Inoculant	Republic		Republic		Riley		Riley		Phillips		Republic-I†		Morris	
	g (300 seed)$^{-1}$													
Un-inoculated	33.00	a‡	1119.10	-§	43.28	a	1121.01	-	866.29	-	41.70	a	22.39	ab
ABM- ExcalibreSA	35.21	a	-	-	43.64	a	-	-	-	-	43.17	a	21.67	b
BU- Vault	34.88	a	1029.94	b	43.81	a	1149.93	a	828.84	a	41.95	a	23.32	a
NZ- Optimize	34.93	a	1050.49	b	43.55	a	1138.80	a	818.62	a	42.33	a	23.00	a
TM- Maximize	-	-	1034.47	b	-	-	157.07	a	831.15	a	-	-	-	-

† I, irrigated location.

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

§ Due to a confounding of check treatments with soybean variety, 2012 site values cannot be compared to the remaining treatments.

Table 3.13 Grain nitrogen content response to inoculant treatment.

	Experimental locations													
	2011		2012		2011		2012		2012		2011		2011	
Inoculant	Republic		Republic		Riley		Riley		Phillips		Republic-I†		Morris	
	g kg^{-1}													
Un-inoculated	52.5	b‡	54.5	-§	55.4	a	54.9	-	50.7	-	55.1	a	53.1	bc
ABM- ExcalibreSA	53.8	b	-	-	55.3	a	-	-	-	-	55.0	a	53.1	c
NZ- Optimize	54.7	a	54.6	a	55.3	a	55.1	a	51.5	b	54.9	a	53.8	b
BU- VaultHP	53.9	ab	54.7	a	55.2	a	54.9	a	51.7	ab	54.9	a	55.4	a
TM- Maximize	-	-	54.6	a	-	-	54.8	a	52.2	a	-	-	-	-

† I, irrigated location.

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

§ Due to a confounding of check treatments with soybean variety, 2012 site values cannot be compared to the remaining treatments.

Table 3.14 Yield response to inoculant treatment over all seed treatment formulations.

	Experimental locations													
	2011		2012		2011		2012		2012		2011		2011	
Inoculant	Republic		Republic		Riley		Riley		Phillips		Republic-I†		Morris	
	kg ha^{-1}													
Un-inoculated	3582	a‡	1874	-§	3258	a	2744	-	2346	-	3966	a	387	a
ABM-ExcalibreSA	3280	a	-	-	3227	a	-	-	-	-	4231	a	472	a
BU-VaultHP	3308	a	1646	b	3151	a	3660	a	1802	a	3936	a	467	a
NZ-Optimize	3401	a	1771	a	3165	a	3791	a	1562	a	4188	a	496	a
TM-Maximize	-	-	1677	ab	-	-	3697	a	1657	a	-	-	-	-

† I, irrigated location.

‡ Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

§Due to a confounding of check treatments with soybean variety, 2012 site values cannot be compared to the remaining treatments.

Chapter 4 - Inoculated Seed Storage Effect on Soybean Nodulation

Abstract

Biological nitrogen fixation by *Bradyrhizobium japonicum* in symbiotic association with soybean [*Glycine max*] is an important relationship in the production of soybean. Nodulation issues have been encountered on fields new to growing soybeans in recent years in Kansas where naturalized bacteria populations do not exist. Field studies have been completed to investigate inoculant products and rates and possible interactions with various seed treatments. This inoculated seed storage greenhouse study was performed to complement these studies and investigate a different area that also impacts rhizobial performance. The research objective was to evaluate soybean nodulation performance after lengths of storage in different conditions, post seed inoculation. These storage treatments were set up to mimic possible conditions inoculated seed may encounter before planting. The experiment was set up as a randomized complete block design with four replications in a factorial structure. Four temperatures, six storage lengths, and two humidity conditions were imposed on batches of inoculated seed. Nodulation performance was analyzed after six weeks of growth. Nodules were counted and weighed and SPAD readings and dry mass of the plant were recorded. Non-inoculated soybeans were found to possess nodules. This suggested the soil was not sterile of bacteria when the seed was planted. Little to no separation of nodulation analysis between treatments confirmed that this study needs to be repeated in sterile soil to obtain reliable results.

Introduction

Biological nitrogen fixation is the process of fixing atmospheric N_2 to NH_3 and occurs in the symbiotic relationship between soybean plants and *Bradyrhizobium japonicum*. Bacteria involved in the symbiosis go through a process of infecting the roots of the soybean host plant and forming nodules where fixation takes place (Lie, 1981).The resulting symbiosis provides usable nitrogen for the plant and carbohydrates for the bacteria. Nodules can immediately form on roots upon germination, but will not begin fixing nitrogen until the V3-V4 soybean growth stage (Pedersen, 2004). The number and weight of nodules increases through the growing season until the end of flowering (de Mooy and Pesek, 1966).

Plants with successful symbiosis with *B. japonicum* possess greater plant nitrogen concentration and total plant nitrogen compared to those with poor nodulation (Ruiz-Diaz et al., 2009). Consequently, soybean plant size is positively correlated with nodule number per plant (Larson and Siemann, 1998). For bacteria to nodulate soybean roots, *B. japonicum* must be introduced to the soil as it does not natively occur in U.S. soils. Once this takes place through inoculation at the time of seed planting, populations will naturalize in the soil. It is usually recommended to inoculate the seed if soybeans have not been in a field for the previous three to five years, or if there have been extreme environmental conditions that would affect soil bacterial survival (Pedersen, 2004; Albareda et al., 2009).

Soybean Inoculant Strains and Carriers

The bacterial inoculant strain and its carrier formulation influence the field performance and survivability of the bacteria (Albareda et al., 2008). The formulation of the inoculant must be such that the rhizobia survive in sufficient quantities to ensure the minimum quantity of living cells required for successful nodulation can be applied to the seed at planting (Xavier et al., 2004). The minimum bacterial density for achieving adequate nodulation is 10^3 rhizobia per seed (Hiltbold et al., 1980). Most current inoculant products are supported in a liquid carrier due to the simplicity of production and application (Xavier et al., 2004). Bacterial survival in liquid carriers has been greatly improved with new formulations. Quality liquid formulations currently available will maintain adequate population densities for soybean inoculation for at least three months of storage (Albareda et al., 2008). Liquid additives in these inoculant product formulations improve performance and can be customized to the individual bacterial strain (Tittabutr et al., 2007). These additives also are able to protect *B. japonicum* on the seed when exposed to high temperatures (Tittabutr et al., 2007).

Conditions Influencing the Survivability of B. japonicum

Nodulation of soybean through inoculation of the bacteria in *B. japonicum* -free soil has a significant role in establishing naturalized bacterial populations in the soil for subsequent years (Kuykendall et al., 1982). Several environmental factors may limit *B. japonicum* symbiosis, including drought stress, water logging, extreme temperatures, and carbohydrate supply from the plant (Lie, 1981). Elevated temperatures have a depressive effect on nodulation. Few bacterial strains survive at temperatures past 40°C (Favre and Eaglesham, 1986). The development and function of root nodules has been reported to be affected at soil temperatures around 30-35°C (Munevar and Wollum, 1982). Drought stress also has a depressive effect on nodulation (Serraj and Sinclair, 1998). Nodule number is reduced under drought stress (Serraj and Sinclair, 1998). Drought stress can reduce 75% of nitrogen fixing activity by the nodules (Pankhurst and Sprent, 1975). Under severe drought stress, the nitrogen fixing capability of nodules is completely hindered (Pankhurst and Sprent, 1975). However, once drought stress is relieved, nodules tend to recover activity (Sinclair et al., 1988).

Inoculant Storage

Bacteria viability can be maintained for a long period of time, even up to a year at 25°C in inoculant formulations (Albareda et al., 2008). The viability of bradyrhizobium on the seed decreases with time and increasing temperature (Penna et al., 2011). Inoculated seed storage should preferably be below 20°C (Penna et al., 2011). The number of viable bacteria that are retained on the seed after inoculation decreases rapidly within 30 days of seed storage when stored at 25°C (Albareda et al., 2008). Heat and lack of water causes desiccation of rhizobial cells, resulting in cell death. Cell death caused by these circumstances has been shown to follow a negative linear relationship over time (Mary et al.,1985). The speed and severity of drying also will affect bacterial survival. Inoculant formulation can affect viability after storage on seed due to formulation, the number of viable *B. japonicum* per unit volume, dosage, and the possible inclusion of an osmoprotectant (Penna et al., 2011).

Research Question and Justification

Recently there has been an increase in reports of poor nodulation in fields new to soybean production (K.L. Roozeboom, personal communication, 2011). The symbiotic relationship between soybean and *B. japonicum* is greatly beneficial to the producer by supplying much of the high nitrogen demand required by soybeans. This has placed attention on consistently obtaining well nodulated soybeans in fields new to soybean production to prevent yield and profit losses due to inadequate nitrogen supply. *B. japonicum* is highly sensitive to heat and desiccation. Although studies have explored inoculant storage effect on viability, little has been done to determine the effects of inoculated seed storage before planting. The goals of this research were to improve consistency of soybean production, especially on "new" soybean fields through discovering the influence of inoculated seed storage conditions before planting on the rhizobia's ability to successfully nodulate soybean roots.

Materials and Methods

A greenhouse experiment was conducted at Kansas State University in spring of 2013. Growing conditions were set with a day and night temperature of 23/15°C. Supplemental lighting came from 1000 watt S52 overhead lights (P.L. Light Systems, Beamsville, ON, Canada) set on a 12 hour day. Plants were bottom watered with city water containing a low nitrogen content of 0.03 ppm NO^{3-} and 0.5 ppm NH_4^+ with no added fertilizer. The soil was a 1:1 mixture of top soil and sand from the standard greenhouse supply. Soil nutrient test values are listed in Table 4.1. All soil was steamed at 72°C for 1.75 hours to pasteurize the growing media. Plants were grown in 656 ml volume cone-tainers (Stuewe and Sons, Tangent, OR) with a diameter of 6.4 m and depth of 25 cm. Racks holding 20 cone-tainers and were set against each other and borders were planted with non-treatment plants to avoid a border effect on plant growth.

The experiment was set up to evaluate the effect of inoculated seed storage on subsequent nodulation. Treatments were set up in a split-plot factorial design with four replications. There were three treatment factors: storage temperature with four levels, storage time after inoculation with six levels, and storage humidity condition with two levels. The control was immediately planted with no storage. Storage temperatures were 15, 25, 35, and 49 °C. Storage lengths were 4, 12, 24, 48, 168, and 336 hours. The two conditions were humid and desiccant. Soybean seed variety was the KS3406RR with ApronMaxxRFC seed treatment (Syngenta, Stanton, MN [ai: fludioxonil/ mefenoxam]). Optimize (Novozymes, Franklinton, NC) was used to inoculate the seed. Inoculant was applied according to the manufacturer protocol and rate. Inoculant was added to seed and manually mixed in a sterile glass jar for three minutes to uniformly distribute inoculant over the seed. Equipment used for seed processing was sterilized using 950 g kg^{-1} concentration ethyl alcohol.

Preliminary testing was done to monitor and control humidity at the four set temperatures of the head space of enclosed jars to understand the storage conditions that inoculated seed would experience. A CS215 temperature and relative humidity probe (Campbell Scientific, Logan, UT) was used to log data for three hours. Collected data was analyzed and plotted to set up storage treatments. Humidity levels plateaued within one hour and stayed relatively consistent throughout the entirety of the study. Relative humidity at respective temperatures in desiccant and wet conditions are listed in Table 4.2. To achieve moist air conditions, 140 ml of water was added to the bottom of the jar. Dry air conditions were achieved by placing 60 ml of silica gel ([SiO2] 6-12 Mesh, Certified ACS, Fisher Chemical, Hampton, NH) in the base of the jar.

All seed was inoculated at the same time and placed into small, plastic, open containers within sealed jars containing free water or desiccant. Jars were then placed in incubators set at the appropriate temperature. Approximately four seeds hand planted into cone-tainers after storage from each treatment. Plants were later thinned to one plant per cone-tainer upon germination. Plants were harvested six weeks after planting. At harvest, SPAD meter readings were taken from the uppermost fully extended trifoliate leaf and growth stage was recorded. All plants were at the V3 to V4 developmental growth stage. Plants were then removed from the pots and roots were washed. Tops and nodules were dried after processing to obtain dry mass. Nodules were counted on each root, and five nodules were split to ensure active nitrogen fixation.

Statistical analysis was completed using the MIXED procedure in SAS 9.2 (SAS, 2009) statistical analysis software with block as a random factor. Each variable was evaluated by one of the three main effects: storage time, storage temperature, and storage environment. The remaining two main effects were included as random in each analysis.

Results and Discussion

Results from this study were not considered to reliably portray the effects of the inoculated seed storage treatments. Non-inoculated seed grown in the pasteurized soil possessed good nodulation. In this study, there should have been no nodules on non-inoculated plants. This would imply that there was bacterial contamination in the procedure. The single pasteurization of the soil most likely was not sufficient for terminating populations in the soil.

The response of nodule count, nodule weight, above ground plant dry mass, and SPAD leaf readings were analyzed according to storage time, temperature, and condition. The storage time displayed the most impact on causing significant differences ($\alpha = 0.05$) in variable response (Table 4.3). The control plants that were subjected to no storage after inoculation placed in the bottom grouping in both the nodule counts and weights. These were the plants that would be expected to obtain the best nodulation performance. Instead, the seeds that were stored for two weeks (336 hours) had both superior counts and weights to all the shortest stored seeds (Table 4.3). The longest storage time also possessed the highest above ground plant dry mass. This was not significantly different from the one week storage time and the control (Table 4.3). In the SPAD meter readings, the lowest reading was associated with the longest storage times. These again were no different from the check (Table 4.3).

Nodule counts were the only variable affected by storage temperature and storage condition. In each case, the control was again in the lowest grouping (Tables 4.4 and 4.5). The other treatments were not significantly ($\alpha = 0.05$) different from each other (Tables 4.4 and 4.5).

Conclusions

Nodulation performance did not line up with the expected outcome of storage treatment effect on inoculated soybean seeds. Based on the knowledge we have concerning the bacteria's ability to survive, the higher temperatures, longer storage, and desiccant conditions should have resulted in reduced cell viability. However, these storage treatments did not negatively affect nodulation in any way. In fact, the control plants that had no storage between inoculation and planting had lower nodule counts in every case. Due to the fact that there was good nodulation on plants that were not inoculated, the results were likely not influenced by storage treatment. As there were adequate bacterial populations, introduced by the soil or some other method, to nodulate non-inoculated plants, all plants would nodulate regardless of if there were viable cells on the seed or not at planting. Therefore, this study must be repeated using care that there is no outside bacterial contamination that could affect the results before any conclusions based on treatment are made.

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Figures and Tables

Table 4.1 Soil test results of 1:1 top soil, sand greenhouse soil after pasteurization.

Soil test					
pH	Mehlich P	K	Mn	NH_4-N	$N0_3$-N
	mg kg^{-1}				
8.0	34.4	160	4.5	5.3	9.1

Table 4.2 Equilirium humidity of conditions in storage treatments.

Storage conditions†	Average humidity
	g kg^{-1}
15°C W	997.6
15°C D	35.1
25°C W	910.8
25°C D	87.2
35°C W	873.2
35°C D	84.0
40°C W	838.7
40°C D	59.8

† W- Wet conditions; D- desiccant conditions

Table 4.3 Response of variables to storage time.

Storage time	Nodule count		Nodule weight		Plant top weight		SPAD readings	
hours	nodules $plant^{-1}$		g		g			
Control	54.5	c†	0.117	bc	1.35	abc	28.6	abc
4	90.0	ab	0.138	b	1.14	cd	30.2	a
12	81.7	b	0.133	bc	1.09	d	30.3	a
24	88.7	ab	0.124	c	1.19	cd	30.2	a
48	84.4	ab	0.122	c	1.22	bc	28.5	b
168	85.3	ab	0.146	ab	1.31	ab	27.5	bc
336	96.0	a	0.158	a	1.34	a	27.2	c

† Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 4.4 Response of variables to storage temperature.

Storage temp	Nodule count		Nodule weight		Plant top weight		SPAD readings	
°C	nodules plant^{-1}		g		g			
Control	54.5	b†	0.117	a	1.35	a	28.6	a
15	84.4	a	0.136	a	1.23	a	29.4	a
25	90.2	a	0.139	a	1.23	a	28.8	a
35	91.6	a	0.135	a	1.22	a	28.5	a
40	83.4	a	0.136	a	1.18	a	29.1	a

† Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Table 4.5 Response of variables to storage environmental condition.

Storage condition	Nodule count		Nodule weight		Plant top weight		SPAD readings	
	nodules plant^{-1}		g		g			
Control	54.5	b†	0.117	a	1.35	a	28.6	a
Dry	85.6	a	0.138	a	1.22	a	29.0	a
Wet	89.4	a	0.135	a	1.21	a	28.9	a

† Values within columns followed by different letters represent statistically significant differences at $\alpha \leq 0.05$.

Chapter 5 - Research Conclusions and Impacts

Achieving adequate nodulation is crucial in soybean production. Many factors may impact the success of inoculation and maintaining adequate *Bradyrhizobium japonicum* populations in the soil. The purpose of this research was to evaluate soybean nodulation performance under various situations and seed handling practices in order to educate producers on how to achieve reliable nodulation consistency in the field. The objectives of the study were to: compare inoculant products using single and double rates and in combination with one another on fields with varying soybean history; determine if there was a negative interaction between inoculant products and common seed treatments; and discover the influence of inoculated seed storage conditions before planting on the rhizobia's ability to successfully nodulate soybean roots.

The impact of inoculant product treatments, product combinations, and double rates showed up in early season nodulation analysis. However, only environments that had been out of soybean production for a minimum of 15 years displayed a treatment difference on nodulation. Those in recent rotation were not different from the non-inoculated check. The inoculant source company had a greater impact on nodulation performance rather than increased rates or product combinations. On an individual site basis, there was a significant positive response at five of the ten research environments to the highest performing company's liquid and in-furrow inoculant combination treatment. Treatment differences in nodulation did not transfer to end of season yield or seed characteristics. This may be due to the growing season conditions that produced below-average yields in both years. Nitrogen fertilizer at the high rate generally performed similar to the lower performing inoculation treatments.

Pesticide seed treatments did not negatively affect nodulation or yield. This demonstrates that the seed treatments used in this study were compatible with seed applied *B. japonicum* inoculation. Site and/or inoculant product proved to have a greater impact on nodulation and yield performance than fungicide, insecticide, or nematicide seed treatments. Seed treatment did not improve yield in these environments as none of the environments had conditions likely to lead to disease or insect problems at establishment. Dry conditions were experienced in the growing seasons of both years. Therefore, the environment was not likely to be conducive to seedling diseases. Insect pests were also minimal at all locations. In addition, there was no evidence of nematode populations being an issue at any of the locations. Therefore, it was not unexpected to find a positive response or benefit of seed treatments in these conditions.

Nodulation performance did not line up with the expected outcome of storage treatment effect on inoculated soybean seeds. Based on the knowledge we have concerning the bacteria's ability to survive, the higher temperatures, longer storage, and desiccant conditions should have resulted in reduced cell viability. However, these storage treatments did not negatively affect nodulation in any way. In fact, the control plants that had no storage between inoculation and planting had lower nodule counts in every case. Due to the fact that there was good nodulation on plants that were not inoculated, the results were likely not influenced by storage treatment. As there was adequate bacterial populations, introduced by the soil or some other method, to nodulate non-inoculated plants, all plants would nodulate regardless of if there was viable cells on the seed or not at planting. Therefore, this study must be repeated using care that there is no outside bacterial contamination that could affect the results before any conclusions based on treatment are made.

In conclusion, inoculation according to company protocol and cool storage of inoculated seed before planting achieves successful nodulation regardless of the environment and soybean history. In situations where there was no soybean history, expect fewer numbers of nodules per plant verses environments where there had been soybean grown in the past. Also, the inoculant product applied impacts the nodulation performance. Therefore, the quality of the company product will determine, to some extent, the nodulation performance. Seed treatments that are listed as compatible with bacterial inoculants, applied to the seed before inoculation, do not have negative impacts on achieving successful nodulation. Compatible seed treatments and inoculant products can be seed applied without causing negative effects on nodulation performance.

Appendix A - Raw Data: "A Comparison of Inoculant Product Treatments in Various Soybean Production Scenarios"

YR	LOC	REP	TREATMENT	POP (plant ha^{-1})	PLANT N (g kg^{-1})	TOP DM (g)	ROOT DM (g)	DM TOTAL (g)	NOD CT $PLANT^{-1}$	NOD WT (g 10 $PLANT^{-1}$)	RATING	TEST WT (kg m^{-3})	Yield (kg ha^{-1})	Seed N (g kg^{-1})	300 SEED WT (g)
2011	MORRIS	1	134.4 kg N ha-1	38782								0.0	0.0	0.0	20.4
2011	MORRIS	2	134.4 kg N ha-1	40545								792.8	276.2	57.6	19.8
2011	MORRIS	3	134.4 kg N ha-1	40192								768.3	838.5	59.4	24.0
2011	MORRIS	4	134.4 kg N ha-1	40897								774.8	536.0	58.2	24.2
2011	MORRIS	1	67 kg N ha-1	34199								0.0	0.0	0.0	22.1
2011	MORRIS	2	67 kg N ha-1	46186								773.5	513.3	58.2	24.3
2011	MORRIS	3	67 kg N ha-1	37724								773.5	505.4	57.4	21.8
2011	MORRIS	4	67 kg N ha-1	37372								745.2	722.6	57.0	22.5
2011	MORRIS	1	ABM-Excalibre	38782		17.8	3.2	21.0				0.0	0.0	0.0	20.2
2011	MORRIS	2	ABM-Excalibre	31731	39.5	15.2	2.9	18.1	0.1	0.002	0.1	776.1	494.2	53.0	22.7
2011	MORRIS	3	ABM-Excalibre	37019	45.5	23.2	4.0	27.2	0.2	0.000	0.1	765.8	842.4	51.5	20.5
2011	MORRIS	4	ABM-Excalibre	33141	45.7	16.2	3.3	19.5	3.4	0.058	1.4	768.3	706.0	49.9	23.3
2011	MORRIS	1	ABM-ExcalibreSA	32788		12.6	2.5	15.1				0.0	0.0	0.0	0.0
2011	MORRIS	2	ABM-ExcalibreSA	31731	46.2	23.0	3.9	26.9				785.1	398.2	54.9	22.1
2011	MORRIS	3	ABM-ExcalibreSA	34551	38.6	17.0	3.1	20.1	0.1	0.002	0.1	761.9	413.8	52.6	22.3
2011	MORRIS	4	ABM-ExcalibreSA	37372	42.5	17.8	3.2	21.0	0.1	0.001	0.1	643.5	589.1	54.1	21.8
2011	MORRIS	1	BU- Vault HP	22564	42.0	19.1	3.1	22.2	5.4	0.091	1.4	0.0	0.0	0.0	18.6
2011	MORRIS	2	BU- Vault HP	26442	41.5	18.1	3.2	21.3	0.9	0.020	0.6	781.2	889.5	52.3	26.3
2011	MORRIS	3	BU- Vault HP	21859	36.0	15.7	2.9	18.6	0.7	0.010	0.5	759.3	728.7	51.5	23.6
2011	MORRIS	4	BU- Vault HP	27500	42.9	23.3	4.2	27.5	0.7	0.017	0.6	773.5	726.3	52.8	23.1
2011	MORRIS	1	BU-Rhizo-Stick 2X	28910	43.6	14.5	2.6	17.1	4.8	0.068	1.9	0.0	0.0	0.0	18.2

2011	MORRIS	2	BU-Rhizo-Stick 2X	31731	40.5	17.5	3.4	20.9	2.2	0.038	1.2	781.2	451.7	55.4	22.3
2011	MORRIS	3	BU-Rhizo-Stick 2X	37372	38.7	16.3	3.4	19.7	2.2	0.081	1.2	767.1	647.4	56.5	20.0
2011	MORRIS	4	BU-Rhizo-Stick 2X	31026	40.4	17.3	3.5	20.8	0.2	0.005	0.2	769.6	652.4	54.4	24.7
2011	MORRIS	1	BU-Rhizo-Stick+BU Vault HP	23974	32.2	22.1	3.7	25.8	0.9	0.015	0.5	0.0	0.0	0.0	22.2
2011	MORRIS	2	BU-Rhizo-Stick+BU Vault HP	25032	37.5	16.1	2.9	19.0	0.6	0.014	0.4	785.1	602.4	53.8	24.2
2011	MORRIS	3	BU-Rhizo-Stick+BU Vault HP	25385	46.1	19.6	3.5	23.1	0.4	0.010	0.4	769.6	568.6	52.5	20.8
2011	MORRIS	4	BU-Rhizo-Stick+BU Vault HP	25385	42.0	21.1	3.7	24.8	1.0	0.022	0.6	751.6	579.9	52.5	21.3
2011	MORRIS	1	Check	30320		16.6	3.1	19.7				0.0	0.0	0.0	18.4
2011	MORRIS	2	Check	37019	42.4	16.4	2.9	19.3	0.1	0.005	0.1	788.9	434.9	54.9	21.3
2011	MORRIS	3	Check	28205		14.4	3.0	17.4				761.9	496.3	53.8	19.9
2011	MORRIS	4	Check	33846		18.9	4.2	23.1				767.1	980.3	50.7	26.9
2011	MORRIS	1	NZ-Optimize	28205	38.5	15.5	2.5	18.0	6.4	0.036	1.3	0.0	0.0	0.0	21.8
2011	MORRIS	2	NZ-Optimize	27500	46.9	17.3	2.6	19.9	8.2	0.091	2.3	769.6	417.0	57.1	22.8
2011	MORRIS	3	NZ-Optimize	28910	44.7	14.6	2.9	17.5	6.4	0.075	2.1	776.1	836.4	55.5	23.4
2011	MORRIS	4	NZ-Optimize	26795	27.3	21.0	4.2	25.2	3.4	0.049	1.6	777.3	603.0	58.1	23.1
2011	MORRIS	1	NZ-Optimize 2X	31026	33.9	13.3	2.0	15.3	6.7	0.108	1.9	0.0	0.0	0.0	17.6
2011	MORRIS	2	NZ-Optimize 2X	36314	42.5	18.9	3.7	22.6	5.4	0.065	1.7	759.3	557.6	56.8	22.9
2011	MORRIS	3	NZ-Optimize 2X	29968	41.5	19.8	3.7	23.5	8.6	0.147	2.9	773.5	736.8	56.5	26.1
2011	MORRIS	4	NZ-Optimize 2X	32436	46.8	16.7	3.0	19.7	6.4	0.164	2.6	770.9	545.9	55.8	23.3
2011	MORRIS	1	Soil Implant+ +Optimize	28558	44.3	17.7	3.4	21.1	8.0	0.142	3.0	0.0	0.0	0.0	21.8
2011	MORRIS	2	Soil Implant+ +Optimize	29263	45.6	21.2	4.3	25.5	4.8	0.066	1.3	782.5	584.5	55.0	20.1
2011	MORRIS	3	Soil Implant+ +Optimize	32083	43.6	18.6	3.4	22.0	7.1	0.127	2.3	763.2	635.5	55.0	20.6
2011	MORRIS	4	Soil Implant+ +Optimize	36667	45.1	18.5	3.1	21.6	7.2	0.164	2.5	779.9	951.1	57.0	22.1
2011	OSA	1	134.4 kg N ha-1	32788								765.8	3154.7	55.7	41.7
2011	OSA	2	134.4 kg N ha-1	35961								731.0	2072.8	62.7	33.8
2011	OSA	3	134.4 kg N ha-1	31731								743.9	2147.2	59.4	33.2

2011	OSA	4	134.4 kg N ha-1	27500								751.6	2321.7	61.0	34.5
2011	OSA	1	67 kg N ha-1	38782								750.3	2055.2	57.6	35.1
2011	OSA	2	67 kg N ha-1	27500								752.9	1959.2	58.1	34.8
2011	OSA	3	67 kg N ha-1	33846								770.9	2372.9	58.1	36.2
2011	OSA	4	67 kg N ha-1	32436								747.7	2170.9	57.1	36.4
2011	OSA	1	ABM-Excalibre	33493	45.4	17.1	4.2	21.3	8.3	0.097	2.2	749.0	2348.2	58.2	35.8
2011	OSA	2	ABM-Excalibre	21506	36.3	18.8	3.9	22.7	4.0	0.091	1.8	737.5	2488.6	57.6	34.4
2011	OSA	3	ABM-Excalibre	27500	44.7	24.6	4.6	29.2	1.5	0.361	0.8	760.6	2032.9	58.7	33.0
2011	OSA	4	ABM-Excalibre	25385	41.8	23.3	5.4	28.7	1.4	0.125	0.8	747.7	2378.4	57.1	35.6
2011	OSA	1	ABM-ExcalibreSA	31378	42.3	14.3	3.7	18.0	8.3	0.126	2.5	764.5	2710.5	57.0	41.2
2011	OSA	2	ABM-ExcalibreSA	38782	33.9	17.7	4.5	22.2	4.8	0.134	1.7	752.9	2284.0	59.5	34.6
2011	OSA	3	ABM-ExcalibreSA	34551	44.8	22.0	3.7	25.7	19.7	0.168	3.0	764.5	2457.1	57.9	34.3
2011	OSA	4	ABM-ExcalibreSA	25032	44.7	23.9	4.3	28.2	1.6	0.073	0.8	729.7	2383.0	57.1	35.1
2011	OSA	1	BU- Vault HP	31026	42.7	12.7	3.1	15.8	14.6	0.188	3.0	763.2	2793.1	56.8	39.5
2011	OSA	2	BU- Vault HP	33141	41.2	13.4	3.2	16.6	10.3	0.255	1.9	752.9	1915.0	59.0	34.3
2011	OSA	3	BU- Vault HP	31378	46.7	19.0	3.7	22.7	10.4	0.214	2.3	747.7	2106.8	59.5	34.4
2011	OSA	4	BU- Vault HP	27852	42.1	19.5	3.9	23.4	15.0	0.164	2.9	733.6	2237.6	54.7	34.0
2011	OSA	1	BU-Rhizo-Stick 2X	31731	39.8	10.0	2.6	12.6	9.7	0.186	2.5	765.8	2795.3	56.0	40.4
2011	OSA	2	BU-Rhizo-Stick 2X	40545	30.8	16.7	3.2	19.9	8.6	0.043	2.1	755.5	1700.6	60.2	34.0
2011	OSA	3	BU-Rhizo-Stick 2X	37019	34.1	21.1	5.4	26.5	4.7	0.194	1.9	763.2	2664.1	58.9	36.5
2011	OSA	4	BU-Rhizo-Stick 2X	35256	41.7	24.6	5.0	29.6	4.7	0.031	1.8	751.6	2523.5	57.9	34.3
2011	OSA	1	BU-Rhizo-Stick+BU Vault HP	39840	50.6	16.0	4.0	20.0	14.1	0.036	2.9	767.1	2730.1	55.5	39.8
2011	OSA	2	BU-Rhizo-Stick+BU Vault HP	38077	44.3	18.3	4.0	22.3	9.7	0.085	1.7	747.7	1527.6	58.2	33.5
2011	OSA	3	BU-Rhizo-Stick+BU Vault HP	33846	45.9	14.1	4.1	18.2	8.0	0.188	2.5	746.5	2236.2	57.8	33.9
2011	OSA	4	BU-Rhizo-Stick+BU Vault HP	31378	40.7	18.4	3.5	21.9	10.2	0.084	2.6	772.2	2220.9	58.2	34.1
2011	OSA	1	Check	34551	36.2	16.6	3.0	19.6	11.2	0.203	2.5	738.7	1981.7	55.8	41.6
2011	OSA	2	Check	29615	43.8	11.7	2.6	14.3	4.1	0.288	1.3	746.5	2077.5	57.6	35.2
2011	OSA	3	Check	35256	42.3	17.5	4.1	21.6	3.8	0.227	1.5	741.3	2152.0	57.4	32.9

2011	OSA	4	Check	33846	45.2	20.7	4.0	24.7	5.7	0.189	1.9	749.0	2186.5	58.9	34.3
2011	OSA	1	NZ-Optimize	35256	32.7	17.2	4.5	21.7	14.3	0.238	2.2	732.3	2755.1	54.9	38.0
2011	OSA	2	NZ-Optimize	32083	31.8	14.6	3.0	17.6	10.3	0.099	2.5	760.6	1957.1	59.5	34.8
2011	OSA	3	NZ-Optimize	30320	44.4	22.3	3.9	26.2	9.1	0.186	2.0	747.7	2256.5	59.4	33.9
2011	OSA	4	NZ-Optimize	28205	32.3	21.4	3.7	25.1	5.9	0.098	2.0	738.7	2551.7	56.5	35.0
2011	OSA	1	NZ-Optimize 2X	35609	36.4	14.6	3.6	18.2	15.0	0.155	2.7	742.6	2073.4	59.2	34.6
2011	OSA	2	NZ-Optimize 2X	32436	47.2	14.3	3.7	18.0	7.0	0.227	1.7	767.1	2238.4	58.2	37.3
2011	OSA	3	NZ-Optimize 2X	38077	46.6	25.6	5.2	30.8	12.2	0.215	2.2	697.6	2505.3	57.8	34.4
2011	OSA	4	NZ-Optimize 2X	23269	42.4	21.5	4.1	25.6	1.8	0.118	0.8	727.2	2350.2	56.6	36.0
2011	OSA	1	Soil Implant+ +Optimize	31378	30.9	12.7	3.5	16.2	12.7	0.051	2.4	761.9	2655.1	56.6	38.5
2011	OSA	2	Soil Implant+ +Optimize	30320	41.5	15.0	3.3	18.3	9.6	0.076	2.5	731.0	1915.8	59.7	33.9
2011	OSA	3	Soil Implant+ +Optimize	28205	44.5	18.3	3.7	22.0	10.5	0.167	2.8	740.0	2353.4	57.4	35.3
2011	OSA	4	Soil Implant+ +Optimize	28205	45.2	25.2	4.8	30.0	8.7	0.150	2.3	696.3	2218.4	56.3	36.1
2011	REP	1	134.4 kg N ha-1	41250								752.9	4460.1	54.4	40.7
2011	REP	2	134.4 kg N ha-1	37724								745.2	3512.0	52.6	41.2
2011	REP	3	134.4 kg N ha-1	34904								747.7	3203.2	53.8	34.5
2011	REP	4	134.4 kg N ha-1	35961								763.2	3443.4	53.6	33.6
2011	REP	1	67 kg N ha-1	40192								749.0	3424.7	53.1	36.7
2011	REP	2	67 kg N ha-1	43013								737.5	3356.0	53.3	39.3
2011	REP	3	67 kg N ha-1	35609								749.0	2956.5	54.6	38.1
2011	REP	4	67 kg N ha-1	34199								751.6	3515.8	54.1	33.2
2011	REP	1	ABM-Excalibre	38782	38.0	42.1	9.1	51.2	3.6	0.151	1.3	746.5	4549.7	52.2	34.4
2011	REP	2	ABM-Excalibre	39487	42.4	31.8	7.4	39.2	3.8	0.148	1.4	756.8	3432.2	53.8	32.1
2011	REP	3	ABM-Excalibre	34551	41.6	36.2	8.2	44.4	2.1	0.125	1.2	751.6	3995.3	55.8	40.6
2011	REP	4	ABM-Excalibre	44423	31.5	50.8	9.1	59.9	1.6	0.046	0.8	747.7	3039.7	54.4	30.9
2011	REP	1	ABM-ExcalibreSA	37724	44.0	28.7	6.4	35.1	5.6	0.366	1.9	732.3	4699.1	54.4	39.5
2011	REP	2	ABM-ExcalibreSA	35961	42.4	36.6	8.3	44.9	4.4	0.402	2.4	752.9	3990.9	53.9	40.9
2011	REP	3	ABM-ExcalibreSA	44775	42.6	34.7	8.2	42.9	0.2	0.002	0.2	754.2	3827.1	54.2	39.8

2011	REP	4	ABM-ExcalibreSA	38782	42.1	26.8	6.0	32.8	0.6	0.042	0.3	747.7	3116.3	56.3	37.9
2011	REP	1	BU- Vault HP	30673	37.4	37.0	8.1	45.1	7.3	0.231	2.3	754.2	4141.5	55.2	42.4
2011	REP	2	BU- Vault HP	28910	41.2	34.9	7.5	42.4	13.5	0.482	3.4	740.0	2950.1	53.3	36.7
2011	REP	3	BU- Vault HP	31026	44.6	51.5	9.6	61.1	17.2	0.720	3.7	750.3	3196.2	54.6	36.9
2011	REP	4	BU- Vault HP	24679	44.6	40.4	8.4	48.8	7.1	0.290	2.0	747.7	2793.7	54.6	30.1
2011	REP	1	BU-Rhizo-Stick 2X	41250	43.0	28.2	5.9	34.1	11.7	0.458	3.0	745.2	4549.7	56.0	44.2
2011	REP	2	BU-Rhizo-Stick 2X	35256	44.3	30.9	6.5	37.4	14.9	0.561	3.8	743.9	4469.8	53.4	41.8
2011	REP	3	BU-Rhizo-Stick 2X	39840	45.2	35.5	7.5	43.0	15.6	0.426	3.3	751.6	4216.6	55.8	38.8
2011	REP	4	BU-Rhizo-Stick 2X	44070	42.6	34.5	6.8	41.3	14.0	0.526	3.4	758.0	3199.7	54.4	37.7
2011	REP	1	BU-Rhizo-Stick+BU Vault HP	32436	32.3	44.2	9.2	53.4	8.8	0.333	2.2	749.0	3898.4	53.6	39.8
2011	REP	2	BU-Rhizo-Stick+BU Vault HP	22917	39.7	35.4	7.3	42.7	9.8	0.202	2.5	743.9	3424.7	55.8	44.0
2011	REP	3	BU-Rhizo-Stick+BU Vault HP	34551	46.2	37.9	8.0	45.9	11.5	0.429	3.1	751.6	3341.5	55.7	39.8
2011	REP	4	BU-Rhizo-Stick+BU Vault HP	28910	30.8	49.1	8.8	57.9	3.3	0.082	1.2	756.8	2562.5	50.2	29.7
2011	REP	1	Check	39487	35.1	36.8	8.1	44.9	5.1	0.239	1.8	754.2	4549.7	53.9	37.9
2011	REP	2	Check	43718	43.4	27.7	6.5	34.2	0.8	0.031	0.6	741.3	2943.7	55.5	42.4
2011	REP	3	Check	39840	42.4	38.4	7.8	46.2	15.9	0.619	3.4	750.3	4235.0	54.9	36.3
2011	REP	4	Check	35256	41.9	29.8	6.8	36.6	1.9	0.143	1.2	752.9	2796.7	54.7	30.8
2011	REP	1	NZ-Optimize	24679	43.9	32.5	6.6	39.1	19.3	0.606	3.7	740.0	4075.2	50.7	36.1
2011	REP	2	NZ-Optimize	30673	42.8	46.8	9.6	56.4	16.6	0.540	3.7	759.3	4164.1	55.5	37.0
2011	REP	3	NZ-Optimize	31378	35.6	36.6	8.0	44.6	8.3	0.580	2.0	754.2	3196.2	54.7	33.6
2011	REP	4	NZ-Optimize	27500	38.9	46.1	9.3	55.4	21.1	0.679	3.8	740.0	2879.7	54.1	34.0
2011	REP	1	NZ-Optimize 2X	34551	41.6	33.6	7.2	40.8	24.0	0.853	4.4	747.7	4629.5	55.0	37.8
2011	REP	2	NZ-Optimize 2X	31731	37.7	40.1	8.2	48.3	26.1	0.728	4.0	751.6	3902.6	53.1	35.4
2011	REP	3	NZ-Optimize 2X	28205	40.4	53.6	9.3	62.9	17.0	0.819	3.8	747.7	3755.6	53.8	39.1
2011	REP	4	NZ-Optimize 2X	25737	44.4	44.6	7.8	52.4	8.3	0.313	2.6	751.6	2399.8	53.6	34.3
2011	REP	1	Soil Implant+ +Optimize	34904	44.7	30.3	6.1	36.4	17.3	0.764	4.0	750.3	5410.0	55.2	37.1
2011	REP	2	Soil Implant+ +Optimize	38077	42.1	33.0	6.9	39.9	26.3	0.744	4.2	754.2	4221.2	55.2	39.2

2011	REP	3	Soil Implant+ +Optimize	35609	43.8	38.5	8.4	46.9	21.6	0.864	4.3	751.6	3667.7	55.2	34.9
2011	REP	4	Soil Implant+ +Optimize	32436	41.3	40.8	8.4	49.2	5.1	0.132	1.2	759.3	3759.6	55.2	37.6
2011	REP I	1	134.4 kg N ha-1	33846								728.4	3765.2	54.7	43.7
2011	REP I	2	134.4 kg N ha-1	45833								729.7	4289.5	55.2	43.9
2011	REP I	3	134.4 kg N ha-1	40192								725.9	4114.9	55.4	42.9
2011	REP I	4	134.4 kg N ha-1	45481								734.9	4650.8	56.0	43.9
2011	REP I	1	67 kg N ha-1	40192								713.0	4034.7	55.2	42.6
2011	REP I	2	67 kg N ha-1	40897								727.2	3861.2	55.7	45.0
2011	REP I	3	67 kg N ha-1	33141								731.0	4044.2	55.4	43.6
2011	REP I	4	67 kg N ha-1	45833								740.0	4112.9	55.8	44.0
2011	REP I	1	ABM-Excalibre	49359								734.9	4216.0	53.9	40.3
2011	REP I	2	ABM-Excalibre	30673								716.9	4448.4	55.5	44.9
2011	REP I	3	ABM-Excalibre	42660								728.4	4145.0	56.0	43.1
2011	REP I	4	ABM-Excalibre	45128								727.2	4544.7	56.3	41.2
2011	REP I	1	ABM-ExcalibreSA	35609								733.6	3522.2	56.0	41.7
2011	REP I	2	ABM-ExcalibreSA	38077								731.0	4660.5	56.2	42.7
2011	REP I	3	ABM-ExcalibreSA	39840								737.5	4271.5	56.3	44.5
2011	REP I	4	ABM-ExcalibreSA	36667								731.0	4528.3	55.4	42.4
2011	REP I	1	BU- Vault HP	22564								734.9	4339.5	55.4	44.6
2011	REP I	2	BU- Vault HP	34199								728.4	4380.0	56.0	44.0
2011	REP I	3	BU- Vault HP	18333								731.0	4186.3	56.6	44.2
2011	REP I	4	BU- Vault HP	27852								728.4	4421.3	56.0	40.6
2011	REP I	1	BU-Rhizo-Stick 2X	44070								740.0	3808.5	56.2	42.8
2011	REP I	2	BU-Rhizo-Stick 2X	39134								718.1	4088.0	55.8	42.0
2011	REP I	3	BU-Rhizo-Stick 2X	47596								731.0	4452.6	56.2	44.0
2011	REP I	4	BU-Rhizo-Stick 2X	37372								728.4	3408.5	56.2	42.9
2011	REP I	1	BU-Rhizo-Stick+BU Vault HP	25385								733.6	3596.7	55.5	42.6
2011	REP I	2	BU-Rhizo-Stick+BU Vault HP	26795								732.3	4499.5	56.6	42.8

2011	REP I	3	BU-Rhizo-Stick+BU Vault HP	22564								733.6	4960.0	56.5	43.5
2011	REP I	4	BU-Rhizo-Stick+BU Vault HP	32788								729.7	4368.2	56.3	42.6
2011	REP I	1	Check	42308								724.6	4124.5	55.4	39.7
2011	REP I	2	Check	40897								732.3	4193.5	56.0	42.7
2011	REP I	3	Check	48301								738.7	3874.6	56.5	44.1
2011	REP I	4	Check	44423								731.0	4281.5	56.0	42.3
2011	REP I	1	NZ-Optimize	29615								714.3	3924.2	55.5	40.4
2011	REP I	2	NZ-Optimize	31026								737.5	4712.6	56.0	43.7
2011	REP I	3	NZ-Optimize	31378								725.9	3911.4	56.3	43.1
2011	REP I	4	NZ-Optimize	27500								723.3	3775.9	55.2	42.9
2011	REP I	1	NZ-Optimize 2X	33846								722.0	4065.7	55.5	41.1
2011	REP I	2	NZ-Optimize 2X	38429								728.4	3402.2	56.0	41.0
2011	REP I	3	NZ-Optimize 2X	40545								729.7	4524.9	56.3	43.0
2011	REP I	4	NZ-Optimize 2X	31026								733.6	3643.0	56.0	44.3
2011	REP I	1	Soil Implant+ +Optimize	33493								734.9	3620.1	55.5	42.6
2011	REP I	2	Soil Implant+ +Optimize	46538								725.9	3691.5	55.7	42.9
2011	REP I	3	Soil Implant+ +Optimize	32788								728.4	4389.6	56.2	42.5
2011	REP I	4	Soil Implant+ +Optimize	30320								723.3	3568.1	55.7	42.0
2011	RILEY	1	134.4 kg N ha-1	29968								765.8	2911.8	54.4	42.2
2011	RILEY	2	134.4 kg N ha-1	23093								767.1	2873.3	54.2	41.0
2011	RILEY	3	134.4 kg N ha-1	33846								760.6	2576.5	54.9	42.4
2011	RILEY	4	134.4 kg N ha-1	28381								769.6	2534.8	54.2	42.3
2011	RILEY	1	67 kg N ha-1	27324								767.1	2263.8	53.9	40.5
2011	RILEY	2	67 kg N ha-1	30673								758.0	2429.9	55.2	41.7
2011	RILEY	3	67 kg N ha-1	36667								765.8	2942.5	53.6	43.4
2011	RILEY	4	67 kg N ha-1	20801								763.2	2410.7	53.3	40.2
2011	RILEY	1	ABM-Excalibre	32612	42.9	14.7	2.8	17.5	11.4	0.136	2.0	773.5	2567.4	54.6	42.1

2011	RILEY	2	ABM-Excalibre	31378	34.7	16.7	3.1	19.8	16.3	0.315	3.9	768.3	2576.5	55.2	43.2
2011	RILEY	3	ABM-Excalibre	37372	45.0	14.9	2.9	17.8	11.0	0.108	2.1	767.1	3580.6	55.7	42.8
2011	RILEY	4	ABM-Excalibre	30320	46.6	15.1	2.8	17.9	14.1	0.215	3.2	770.9	2744.4	54.7	41.7
2011	RILEY	1	ABM-ExcalibreSA	36667	44.5	20.9	3.5	24.4	11.0	0.082	1.9	768.3	1754.9	54.9	41.6
2011	RILEY	2	ABM-ExcalibreSA	36314	44.0	16.1	3.3	19.4	14.4	0.226	3.1	768.3	2911.8	55.7	43.1
2011	RILEY	3	ABM-ExcalibreSA	37372	43.2	24.2	4.1	28.3	17.6	0.220	2.9	769.6	3126.6	54.9	43.8
2011	RILEY	4	ABM-ExcalibreSA	36490	44.1	18.6	3.1	21.7	15.4	0.220	2.7	767.1	3105.4	55.2	42.2
2011	RILEY	1	BU- Vault HP	29615	44.8	12.9	2.5	15.4	8.2	0.078	2.4	770.9	1702.2	55.4	41.2
2011	RILEY	2	BU- Vault HP	41955	37.6	13.9	2.5	16.4	18.3	0.228	3.4	763.2	2306.6	55.4	42.3
2011	RILEY	3	BU- Vault HP	37372	34.5	15.8	2.9	18.7	17.4	0.188	2.3	776.1	3691.0	55.7	43.4
2011	RILEY	4	BU- Vault HP	40192	44.0	17.6	2.8	20.4	9.1	0.064	1.8	761.9	3066.5	54.2	43.9
2011	RILEY	1	BU-Rhizo-Stick 2X	34904	42.9	13.6	2.7	16.3	13.8	0.135	2.8	765.8	2203.4	56.0	39.7
2011	RILEY	2	BU-Rhizo-Stick 2X	32083	40.1	18.9	3.2	22.1	21.2	0.336	3.6	772.2	2989.0	54.9	43.4
2011	RILEY	3	BU-Rhizo-Stick 2X	35256	40.1	17.5	2.7	20.2	15.3	0.236	3.0	768.3	2815.3	55.5	43.0
2011	RILEY	4	BU-Rhizo-Stick 2X	39487	33.5	18.2	2.9	21.1	17.5	0.228	3.3	773.5	3211.9	56.0	42.6
2011	RILEY	1	BU-Rhizo-Stick+BU Vault HP	39487	45.7	13.0	2.4	15.4	15.1	0.244	3.3	767.1	2377.0	55.4	43.8
2011	RILEY	2	BU-Rhizo-Stick+BU Vault HP	32260	43.3	14.5	2.6	17.1	16.8	0.290	4.1	760.6	2359.4	55.7	41.0
2011	RILEY	3	BU-Rhizo-Stick+BU Vault HP	39487	44.5	12.3	2.1	14.4	12.3	0.151	2.5	765.8	2987.8	55.7	41.7
2011	RILEY	4	BU-Rhizo-Stick+BU Vault HP	34199	42.8	15.4	2.8	18.2	15.2	0.220	3.1	772.2	2974.6	54.9	42.6
2011	RILEY	1	Check	30497	42.2	11.5	2.3	13.8	15.9	0.235	3.7	767.1	2477.1	54.9	41.2
2011	RILEY	2	Check	29615	35.8	14.1	2.8	16.9	21.2	0.338	3.8	767.1	2374.4	56.2	41.6
2011	RILEY	3	Check	26795	39.3	18.1	3.1	21.2	14.4	0.208	2.2	773.5	2727.1	55.7	42.8
2011	RILEY	4	Check	24503	46.2	22.5	3.1	25.6	10.0	0.048	1.8	763.2	2481.6	54.6	42.7
2011	RILEY	1	NZ-Optimize	28558	48.1	13.8	2.4	16.2	11.5	0.126	2.6	758.0	2201.0	54.1	41.5
2011	RILEY	2	NZ-Optimize	40721	35.5	20.2	3.6	23.8	16.8	0.197	3.4	772.2	2990.0	55.0	42.2
2011	RILEY	3	NZ-Optimize	34551	33.7	17.8	2.9	20.7	13.0	0.158	2.6	776.1	3815.2	55.8	44.0
2011	RILEY	4	NZ-Optimize	30144	43.2	19.0	3.0	22.0	8.0	0.080	1.8	772.2	3403.3	55.0	42.7
2011	RILEY	1	NZ-Optimize 2X	26442	44.9	14.6	2.7	17.3	10.8	0.200	2.6	773.5	2128.1	55.7	41.6

2011	RILEY	2	NZ-Optimize 2X	31026	34.5	17.5	3.2	20.7	16.1	0.264	4.2	768.3	3137.7	55.5	42.9
2011	RILEY	3	NZ-Optimize 2X	32083	37.6	18.0	3.3	21.3	20.2	0.299	3.0	765.8	3211.7	55.2	43.2
2011	RILEY	4	NZ-Optimize 2X	43365	45.5	19.5	2.4	21.9	15.0	0.213	3.2	773.5	3300.6	55.5	43.5
2011	RILEY	1	Soil Implant+ +Optimize	29792	40.6	15.3	2.6	17.9	14.5	0.215	3.0	772.2	2844.3	55.5	42.4
2011	RILEY	2	Soil Implant+ +Optimize	38429	37.0	19.5	4.0	23.5	24.2	0.353	3.7	763.2	2236.2	55.4	41.1
2011	RILEY	3	Soil Implant+ +Optimize	42131	42.2	16.5	2.9	19.4	13.2	0.197	2.3	758.0	2180.3	56.3	41.7
2011	RILEY	4	Soil Implant+ +Optimize	38782	45.0	13.5	2.5	16.0	16.7	0.210	2.9	769.6	3194.2	55.2	42.9
2012	OSA	1	134.4 kg N ha-1	38782								765.8	843.3	59.7	38.6
2012	OSA	2	134.4 kg N ha-1	31026								745.2	2165.0	59.8	42.2
2012	OSA	3	134.4 kg N ha-1	29615								764.5	1222.6	59.5	42.6
2012	OSA	4	134.4 kg N ha-1	38782								755.5	1866.0	58.7	43.9
2012	OSA	1	67 kg N ha-1	41250								765.8	1282.4	59.0	41.3
2012	OSA	2	67 kg N ha-1	42308								754.2	1808.2	59.2	44.1
2012	OSA	3	67 kg N ha-1	35609								755.5	1555.9	59.0	43.3
2012	OSA	4	67 kg N ha-1	40192								760.6	1381.5	59.5	43.5
2012	OSA	1	BU - Vault HP	36667	3.0	15.7	4.6	20.3	5.1	0.071	1.7	764.5	2042.2	58.4	40.8
2012	OSA	2	BU - Vault HP	34904	3.2	22.3	4.3	26.6	6.9	0.149	1.8	778.6	2208.9	58.9	42.2
2012	OSA	3	BU - Vault HP	31731	3.2	21.3	3.8	25.1	8.8	0.234	1.9	772.2	2000.5	59.7	46.5
2012	OSA	4	BU - Vault HP	39487	2.8	25.5	1.8	27.3	1.7	0.008	0.8	773.5	2497.9	59.0	45.4
2012	OSA	1	BU-Rhizo Stick 2X	35256	3.1	15.9	4.0	19.9	5.4	0.105	1.8	777.3	1877.6	59.0	44.1
2012	OSA	2	BU-Rhizo Stick 2X	32083	2.8	18.3	3.8	22.1	10.5	0.106	1.8	772.2	2037.6	58.4	48.0
2012	OSA	3	BU-Rhizo Stick 2X	27500	3.1	13.9	3.3	17.2	3.5	0.071	1.5	777.3	2177.5	59.5	42.3
2012	OSA	4	BU-Rhizo Stick 2X	28910	3.1	19.9	4.1	24.0	7.7	0.201	2.1	774.8	1877.6	59.2	46.3
2012	OSA	1	BU-Rhizo Stick+VaultHP	25737	3.2	19.3	3.9	23.2	9.0	0.147	1.6	777.3	1712.6	60.0	40.5
2012	OSA	2	BU-Rhizo Stick+VaultHP	32788	3.0	19.9	3.9	23.8	5.9	0.097	1.2	779.9	1998.3	59.7	41.9
2012	OSA	3	BU-Rhizo Stick+VaultHP	31026	2.9	20.6	3.9	24.5	8.2	0.146	2.1	772.2	1667.1	59.2	46.5
2012	OSA	4	BU-Rhizo	29615	3.2	26.8	6.0	32.8	7.3	0.112	1.8	779.9	2046.8	59.0	47.7

			Stick+VaultHP												
2012	OSA	1	BU-Vault HP 2X	27852	3.0	17.0	3.7	20.7	7.0	0.059	1.5	781.2	2007.3	59.4	45.6
2012	OSA	2	BU-Vault HP 2X	33141	3.2	26.2	6.6	32.8	4.9	0.168	1.6	768.3	2000.5	59.4	43.7
2012	OSA	3	BU-Vault HP 2X	33493	2.9	24.9	5.2	30.1	7.0	0.231	2.2	770.9	1659.6	58.1	48.8
2012	OSA	4	BU-Vault HP 2X	35256		25.3	4.9	30.2	5.1	0.051	1.3	767.1	2164.8	59.4	47.1
2012	OSA	1	Check	25385	2.9	20.3	4.2	24.5	7.2	0.100	1.8	768.3	1099.8	58.9	43.5
2012	OSA	2	Check	38077	2.9	17.9	3.0	20.9	5.6	0.114	1.5	750.3	1359.5	58.6	37.0
2012	OSA	3	Check	44423	3.0	16.4	3.2	19.6	9.1	0.152	1.9	761.9	1176.1	59.0	40.7
2012	OSA	4	Check	44423								767.1	1967.6	61.0	50.2
2012	OSA	1	NZ-Cell Tech Granular + Optimize	29263	2.7	9.9	1.8	11.7	6.8	0.056	1.3	776.1	2771.9	58.4	41.8
2012	OSA	2	NZ-Cell Tech Granular + Optimize	26442	2.9	18.6	2.9	21.5	12.4	0.321	2.2	773.5	2109.3	58.1	42.2
2012	OSA	3	NZ-Cell Tech Granular + Optimize	32436	2.8	16.8	3.0	19.8	5.8	0.199	1.6	767.1	2005.0	58.9	42.9
2012	OSA	4	NZ-Cell Tech Granular + Optimize	42308	2.9	20.7	3.5	24.2	8.3	0.205	2.3	772.2	2365.0	58.2	47.8
2012	OSA	1	NZ-Optimize	37724	2.9	16.5	3.3	19.8	6.7	0.076	1.6	774.8	1881.8	59.2	44.9
2012	OSA	2	NZ-Optimize	38077	3.1	17.0	3.4	20.4	5.5	0.132	1.4	778.6	1630.9	60.2	42.4
2012	OSA	3	NZ-Optimize	35256	2.5	17.6	3.4	21.0	9.3	0.268	2.0	776.1	1956.7	59.0	49.1
2012	OSA	4	NZ-Optimize	37019	3.3	22.2	5.2	27.4	8.7	0.129	1.5	764.5	2313.6	60.6	46.6
2012	OSA	1	NZ-Optimize 2X	29615	3.2	20.3	4.7	25.0	10.6	0.228	2.1	767.1	1587.8	57.9	45.8
2012	OSA	2	NZ-Optimize 2X	41250	3.0	19.2	4.0	23.2	7.8	0.164	1.7	776.1	2422.7	60.0	47.3
2012	OSA	3	NZ-Optimize 2X	29968	3.4	18.4	4.8	23.2	6.1	0.138	1.6	773.5	1750.5	58.7	44.7
2012	OSA	4	NZ-Optimize 2X	39134	3.1	20.6	5.2	25.8	7.8	0.256	2.0	767.1	1989.3	57.8	43.7
2012	OSA	1	TM-Maximize	27147	3.3	16.7	4.1	20.8	6.9	0.075	1.6	776.1	1727.9	59.2	39.7
2012	OSA	2	TM-Maximize	35256	3.1	20.7	3.6	24.3	8.6	0.129	2.1	770.9	1474.9	57.9	43.3
2012	OSA	3	TM-Maximize	36314	3.0	18.1	3.5	21.6	12.8	0.228	2.5	769.6	1873.4	60.5	45.5
2012	OSA	4	TM-Maximize	37724	2.8	24.7	5.1	29.8	10.2	0.152	2.3	767.1	2123.2	59.4	48.5
2012	OSA	1	TM-Maximize 2X	35961	3.0	18.8	3.9	22.7	6.3	0.054	1.0	774.8	2049.1	59.5	45.6
2012	OSA	2	TM-Maximize 2X	32436	2.8	14.4	2.2	16.6	7.0	0.165	1.8	774.8	1710.9	58.2	41.6
2012	OSA	3	TM-Maximize 2X	35961	3.0	20.6	4.1	24.7	4.5	0.049	1.5	773.5	1879.7	59.8	43.0

2012	OSA	4	TM-Maximize 2X	38429	3.1	21.1	4.4	25.5	8.1	0.258	2.2	778.6	1580.2	59.2	47.5
2012	PHILC	1	134.4 kg N ha-1	32436								752.9	3235.6	53.4	33.6
2012	PHILC	2	134.4 kg N ha-1	34904								758.0	3630.2	52.3	32.8
2012	PHILC	3	134.4 kg N ha-1	34199								761.9	2647.7	52.6	34.4
2012	PHILC	4	134.4 kg N ha-1	27852								734.9	3363.8	54.1	26.5
2012	PHILC	1	67 kg N ha-1	31731								781.2	2536.4	49.1	31.5
2012	PHILC	2	67 kg N ha-1	30673								751.6	2980.6	51.0	31.2
2012	PHILC	3	67 kg N ha-1	28910								754.2	3362.2	52.5	31.5
2012	PHILC	4	67 kg N ha-1	20096								750.3	1789.8	51.5	32.0
2012	PHILC	1	BU - Vault HP	29968	1.8	97.8	14.0	111.8	2.2	0.200	1.1	770.9	1357.6	49.4	30.8
2012	PHILC	2	BU - Vault HP	40545	1.9	121.0	21.9	142.9	0.9	0.069	0.5	770.9	1187.9	49.4	30.8
2012	PHILC	3	BU - Vault HP	25385	1.7	124.9	16.4	141.3	2.1	0.113	0.8	761.9	1064.4	49.3	26.7
2012	PHILC	4	BU - Vault HP	24679	1.8	127.1	19.9	147.0	0.5	0.421	0.2	761.9	540.7	49.3	26.7
2012	PHILC	1	BU-Rhizo Stick 2X	29968	1.8	112.2	17.2	129.4	1.2	0.084	0.6	765.8	1436.1	48.6	29.1
2012	PHILC	2	BU-Rhizo Stick 2X	32083	1.8	129.8	20.1	149.9	2.1	0.114	0.7	765.8	946.1	48.6	29.1
2012	PHILC	3	BU-Rhizo Stick 2X	34904	1.9	87.0	14.7	101.7	2.6		1.0	754.2	2272.0	52.2	29.7
2012	PHILC	4	BU-Rhizo Stick 2X	36314	2.0	13801.0	22.0	13823.0	1.5	0.100	0.7	742.6	1781.0	51.4	30.2
2012	PHILC	1	BU-Rhizo Stick+VaultHP	46538	2.0	110.4	17.9	128.3	0.8	0.057	0.2	751.6	1731.0	49.9	28.7
2012	PHILC	2	BU-Rhizo Stick+VaultHP	35256	2.1	129.3	23.2	152.5	2.5	0.296	1.0	751.6	1069.1	49.9	28.7
2012	PHILC	3	BU-Rhizo Stick+VaultHP	40897	1.9	91.1	11.9	103.0	1.2	0.159	0.8	755.5	1556.1	50.9	3.3
2012	PHILC	4	BU-Rhizo Stick+VaultHP	35961	2.2	15.1	21.3	36.4	2.1	0.112	1.0	760.6	1428.6	50.7	30.4
2012	PHILC	1	BU-Vault HP 2X	43365	2.3	97.3	17.5	114.8	0.8	0.067	0.4	749.0	1816.6	49.4	29.5
2012	PHILC	2	BU-Vault HP 2X	39840	2.3	146.4	22.2	168.6	1.7	0.176	0.7	749.0	1328.8	49.4	29.5
2012	PHILC	3	BU-Vault HP 2X	37372	1.8	124.6	18.5	143.1	1.3	0.119	0.7	745.2	2111.3	51.5	30.8

2012	PHILC	4	BU-Vault HP 2X	26090	2.0	118.4	20.6	139.0	4.8	0.155	1.6	742.6	1476.4	51.0	30.8
2012	PHILC	1	Check	26442	1.9	139.9	28.7	168.6	0.0		0.2	751.6	2420.3	48.6	30.7
2012	PHILC	2	Check	28558	1.7	139.4	27.7	167.1	0.1	0.009	0.0	751.6	1823.6	48.6	30.7
2012	PHILC	3	Check	34199		173.0	34.6	207.6			0.1	741.3	2930.9	50.7	31.8
2012	PHILC	4	Check	27500	2.4	148.5	34.1	182.6			0.3	732.3	3830.1	50.9	30.5
2012	PHILC	1	NZ-Cell Tech Granular + Optimize	21506	2.1	123.8	21.8	145.6	9.9	0.528	2.1	752.9	1518.9	50.7	28.5
2012	PHILC	2	NZ-Cell Tech Granular + Optimize	37372	1.9	124.7	21.4	146.1	7.9	0.416	1.3	752.9	1299.5	50.7	28.5
2012	PHILC	3	NZ-Cell Tech Granular + Optimize	30673	2.2	129.9	19.3	149.2	7.8	0.743	2.2	754.2	2124.1	50.9	27.5
2012	PHILC	4	NZ-Cell Tech Granular + Optimize	31378	1.7	174.5	20.6	195.1	8.5	0.461	1.9	751.6	2610.7	51.0	29.9
2012	PHILC	1	NZ-Optimize	35961	2.1	154.4	21.6	176.0	1.0	0.047	0.7	745.2	1968.5	49.6	28.6
2012	PHILC	2	NZ-Optimize	39840	1.9	105.7	12.9	118.6	0.3	0.040	0.3	745.2	1255.8	49.6	28.6
2012	PHILC	3	NZ-Optimize	32788	1.5	90.5	14.5	105.0	4.6	0.450	1.9	752.9	1101.9	51.8	27.5
2012	PHILC	4	NZ-Optimize	41250	2.0	131.5	18.0	149.5	7.2	0.178	1.9	752.9	2390.2	51.8	27.5
2012	PHILC	1	NZ-Optimize 2X	35256	2.1	102.8	18.2	121.0	4.4	0.354	1.6	778.6	1417.7	45.8	28.0
2012	PHILC	2	NZ-Optimize 2X	32436	2.4	109.5	18.4	127.9	3.4	0.258	1.2	745.2	1590.4	50.6	29.6
2012	PHILC	3	NZ-Optimize 2X	33493	1.9	75.6	13.7	89.3	2.1	0.205	1.0	763.2	1098.2	49.9	27.0
2012	PHILC	4	NZ-Optimize 2X	32788	1.6	130.9	26.6	157.5	1.4	0.124	0.6	763.2	861.7	49.9	27.0
2012	PHILC	1	TM-Maximize	29968	1.9	125.5	21.3	146.8	0.0		0.2	745.2	979.9	49.4	29.6
2012	PHILC	2	TM-Maximize	41955	2.0	144.4	19.7	164.1	0.1	0.004	0.1	745.2	1385.4	49.4	29.6
2012	PHILC	3	TM-Maximize	40545	1.9	100.6	15.6	116.2	0.3	0.028	0.2	755.5	1947.3	50.6	28.0
2012	PHILC	4	TM-Maximize	26442	1.8	111.6	16.3	127.9	1.1	0.041	0.4	755.5	1557.8	#VALUE!	.

2012	PHILC	1	TM-Maximize 2X	40545	1.8	122.5	20.2	142.7	0.6	0.044	0.5	746.5	766.2	49.6	28.7
2012	PHILC	2	TM-Maximize 2X	31026	2.0	107.8	20.0	127.8	2.0	0.200	1.0	746.5	1157.8	49.6	28.7
2012	PHILC	3	TM-Maximize 2X	28205	1.7	107.1	15.3	122.4	0.5	0.029	0.3	759.3	1974.6	50.9	29.4
2012	PHILC	4	TM-Maximize 2X	25737	1.8	94.2	18.1	112.3	0.4	0.061	0.2	759.3	742.6	50.9	29.4
2012	PHILS	1	134.4 kg N ha-1	24679								743.9	1610.0	49.3	27.0
2012	PHILS	2	134.4 kg N ha-1	28910								752.9	1313.5	51.2	30.8
2012	PHILS	3	134.4 kg N ha-1	26795								737.5	2179.6	47.7	29.3
2012	PHILS	4	134.4 kg N ha-1	22564	1.4							738.7	1739.4	47.5	28.9
2012	PHILS	1	67 kg N ha-1	22211								756.8	1445.0	48.5	24.7
2012	PHILS	2	67 kg N ha-1	19744								756.8	1881.8	49.3	27.2
2012	PHILS	3	67 kg N ha-1	26442								736.2	1510.9	47.0	27.3
2012	PHILS	4	67 kg N ha-1	29263	1.5							736.2	1639.5	47.5	28.4
2012	PHILS	1	BU - Vault HP	23622	1.4	51.5	13.5	65.0	4.0	0.604	1.6	764.5	1366.6	52.0	27.8
2012	PHILS	2	BU - Vault HP	26090	1.4	70.5	15.5	86.0	4.3	0.754	1.6	745.2	1242.9	51.8	26.6
2012	PHILS	3	BU - Vault HP	27147	1.4	61.1	14.0	75.1	9.7	1.618	2.1	768.3	1783.8	55.2	27.7
2012	PHILS	4	BU - Vault HP	22564		129.3	20.2	149.5	2.9	0.558	1.1	756.8	1022.7	49.4	27.3
2012	PHILS	1	BU-Rhizo Stick 2X	27500	1.4	84.2	20.4	104.6	4.9	0.755	2.2	772.2	1668.6	53.8	30.2
2012	PHILS	2	BU-Rhizo Stick 2X	32436	1.3	90.9	19.6	110.5	4.5	0.469	1.7	760.6	1331.0	51.4	28.7
2012	PHILS	3	BU-Rhizo Stick 2X	24327	1.5	69.1	13.2	82.3	10.7	0.031	2.1	763.2	1595.6	51.2	29.1
2012	PHILS	4	BU-Rhizo Stick 2X	31026	1.5	84.5	13.3	97.8	4.3	0.845	1.9	741.3	1767.8	55.2	30.3
2012	PHILS	1	BU-Rhizo Stick+VaultHP	33141	1.4	66.8	15.3	82.1	2.8	0.442	1.8	759.3	1663.4	56.0	30.3
2012	PHILS	2	BU-Rhizo Stick+VaultHP	33846	1.5	90.1	22.6	112.7	10.9	0.642	2.4	758.0	1695.2	55.8	27.9
2012	PHILS	3	BU-Rhizo Stick+VaultHP	26442	1.5	55.0	12.3	67.3	9.0	0.142	2.3	760.6	1405.4	50.7	29.5
2012	PHILS	4	BU-Rhizo Stick+VaultHP	27500	1.4	88.2	12.3	100.5	4.6	1.770	1.9	747.7	1637.5	51.8	31.4
2012	PHILS	1	BU-Vault HP 2X	24679	1.5	77.0	19.4	96.4	11.3	1.018	2.4	765.8	1751.9	53.1	27.8
2012	PHILS	2	BU-Vault HP 2X	18333	1.4	63.6	13.4	77.0	7.2	2.122	2.2	760.6	1177.4	52.3	30.7

2012	PHILS	3	BU-Vault HP 2X	27852	1.5	60.3	12.3	72.6	3.1	0.802	1.7	759.3	1255.8	49.9	28.7
2012	PHILS	4	BU-Vault HP 2X	34199	1.4	106.7	16.6	123.3	2.6	1.028	1.4	127.4	852.0	53.0	27.6
2012	PHILS	1	Check	22564	1.4	88.0	23.7	111.7				737.5	1219.8	48.2	28.4
2012	PHILS	2	Check	26090	1.4	101.8	25.3	127.1			0.5	737.5	1203.4	48.0	28.4
2012	PHILS	3	Check	23974	1.3	54.8	17.2	72.0	0.1	0.943	0.1	738.7	1208.4	46.9	23.5
2012	PHILS	4	Check	29263		114.4	22.9	137.3	0.0	0.776	0.1	738.7	1107.7	47.8	26.7
2012	PHILS	1	NZ-Cell Tech Granular + Optimize	26442	1.6	87.2	18.6	105.8	16.3	1.893	3.1	761.9	1676.4	53.3	28.0
2012	PHILS	2	NZ-Cell Tech Granular + Optimize	31378	1.3	110.1	20.7	130.8	15.7	0.978	3.6	749.0	1858.5	54.9	29.1
2012	PHILS	3	NZ-Cell Tech Granular + Optimize	32083	1.5	62.5	14.8	77.3	11.2	1.043	2.8	772.2	1868.8	56.8	28.9
2012	PHILS	4	NZ-Cell Tech Granular + Optimize	26442	1.7	88.0	17.2	105.2	13.8	0.098	2.8	115.8	807.9	52.5	28.2
2012	PHILS	1	NZ-Optimize	31731	1.4	84.0	18.0	102.0	9.4	0.889	2.0	756.8	1653.9	55.4	29.0
2012	PHILS	2	NZ-Optimize	29615	1.4	100.6	24.0	124.6	4.4	0.767	2.1	761.9	1783.8	56.8	29.6
2012	PHILS	3	NZ-Optimize	26795	1.5	82.6	17.5	100.1	9.4	0.001	3.2	755.5	1764.2	55.2	29.9
2012	PHILS	4	NZ-Optimize	25032	1.6	108.2	20.6	128.8	8.4	0.474	1.8	754.2	1566.1	52.8	29.7
2012	PHILS	1	NZ-Optimize 2X	23974	1.4	75.8	19.1	94.9	6.7	0.887	2.3	751.6	1655.8	51.4	27.3
2012	PHILS	2	NZ-Optimize 2X	25737	1.3	93.8	20.2	114.0	6.0	0.631	1.7	760.6	1575.9	52.2	27.0
2012	PHILS	3	NZ-Optimize 2X	33493	1.4	74.4	13.4	87.8	14.1	1.178	2.6	761.9	2349.7	53.4	29.9
2012	PHILS	4	NZ-Optimize 2X	29615	1.5	99.5	19.5	119.0	7.5	0.765	2.0	755.5	1574.1	53.0	27.8
2012	PHILS	1	TM-Maximize	24679	1.4	104.1	20.5	124.6	0.4	0.056	0.3	761.9	822.6	47.5	26.4
2012	PHILS	2	TM-Maximize	22211	1.4	37.7	16.6	54.3	1.8	0.832	1.4	761.9	771.2	48.2	26.5
2012	PHILS	3	TM-Maximize	22564	1.3	42.4	10.6	53.0	0.1	1.480	0.2	749.0	1309.6	49.0	27.5
2012	PHILS	4	TM-Maximize	21506	1.4	95.3	15.2	110.5	0.5	0.354	0.3	750.3	1488.4	46.6	25.4
2012	PHILS	1	TM-Maximize 2X	29615	1.4	88.3	22.6	110.9	1.2	0.148	0.5	760.6	1961.5	49.6	26.0
2012	PHILS	2	TM-Maximize 2X	21154	1.5	75.5	17.7	93.2	3.4	0.348	1.5	751.6	754.1	49.9	27.4
2012	PHILS	3	TM-Maximize 2X	23974	1.5	86.2	20.8	107.0	1.1	0.329	1.0	755.5	1109.1	49.8	28.1

2012	PHILS	4	TM-Maximize 2X	35609	1.5	113.7	21.4	135.1	2.6	0.389	1.3	738.7	1788.6	51.7	30.5
2012	REP	1	134.4 kg N ha-1	33141								760.6	2063.5	53.8	35.9
2012	REP	2	134.4 kg N ha-1	37019								759.3	1695.2	54.9	38.8
2012	REP	3	134.4 kg N ha-1	25737								759.3	1879.4	54.6	37.4
2012	REP	4	134.4 kg N ha-1	17981	3.7							760.6	2014.0	53.3	42.6
2012	REP	1	67 kg N ha-1	20801								767.1	1689.5	52.8	40.0
2012	REP	2	67 kg N ha-1	31026								769.6	2068.1	54.6	40.2
2012	REP	3	67 kg N ha-1	35961								763.2	1896.5	54.1	38.2
2012	REP	4	67 kg N ha-1	39134								777.3	1663.1	54.2	38.8
2012	REP	1	BU - Vault HP	40192	3.7	26.4	6.0	32.4	9.7	0.274	1.0	760.6	1885.6	54.7	38.3
2012	REP	2	BU - Vault HP	43365	3.4	44.7	9.4	54.1	8.0	0.195	1.5	749.0	1674.1	54.2	36.7
2012	REP	3	BU - Vault HP	35609	3.5	28.4	7.2	35.6	13.0	0.307	1.9	759.3	1495.0	54.7	39.1
2012	REP	4	BU - Vault HP	32083	3.0	19.2	4.2	23.4	7.8	0.226	1.6	754.2	2113.8	55.5	35.2
2012	REP	1	BU-Rhizo Stick 2X	39134	3.3	37.9	7.6	45.5	15.5	0.304	1.8	754.2	1530.7	54.4	38.3
2012	REP	2	BU-Rhizo Stick 2X	38077	3.8	37.0	8.5	45.5	9.4	0.241	1.8	755.5	1802.8	55.2	33.7
2012	REP	3	BU-Rhizo Stick 2X	25032	3.3	29.3	6.5	35.8	12.0	0.484	2.0	763.2	1712.5	54.9	35.0
2012	REP	4	BU-Rhizo Stick 2X	26795	3.5	33.9	6.0	39.9	15.6	0.522	2.4	761.9	1500.0	54.1	38.3
2012	REP	1	BU-Rhizo Stick+VaultHP	38077	3.2	37.2	7.1	44.3	9.9	0.198	1.3	760.6	1598.7	54.4	37.5
2012	REP	2	BU-Rhizo Stick+VaultHP	44070	3.4	37.0	6.1	43.1	11.0	0.220	1.7	759.3	1875.6	55.2	36.9
2012	REP	3	BU-Rhizo Stick+VaultHP	29263	3.4	29.7	6.5	36.2	19.5	0.434	2.7	764.5	1809.0	55.4	34.8
2012	REP	4	BU-Rhizo Stick+VaultHP	37019	3.6	25.7	8.5	34.2	14.6	0.529	2.0	755.5	1682.1	54.6	37.8
2012	REP	1	BU-Vault HP 2X	27500	3.3	28.1	7.0	35.1	17.4	0.521	1.9	741.3	1291.2	69.1	39.3
2012	REP	2	BU-Vault HP 2X	46186	4.2	57.1	9.8	66.9	9.9	0.632	1.7	751.6	1822.2	54.7	37.8
2012	REP	3	BU-Vault HP 2X	24679	3.5	38.2	7.6	45.8	14.0	0.342	2.0	751.6	1911.3	54.6	38.2
2012	REP	4	BU-Vault HP 2X	28910	3.7	19.3	5.1	24.4			1.4	760.6	1598.7	56.0	36.1
2012	REP	1	Check	17981		51.8	9.1	60.9	3.5	0.071	0.8	765.8	1549.2	54.1	40.8
2012	REP	2	Check	27852	3.2	34.7	6.7	41.4	3.6	0.088	1.0	769.6	1691.4	54.2	39.7
2012	REP	3	Check	38077	3.5	59.2	12.4	71.6	12.4	0.471	1.8	763.2	1727.2	55.7	37.9

2012	REP	4	Check	29615	3.4	36.7	5.0	41.7	11.2	0.329	2.1	770.9	1798.8	55.5	36.0
2012	REP	1	NZ-Cell Tech Granular + Optimize	22564	3.7	42.8	7.2	50.0	20.4	0.386	2.0	749.0	2384.9	54.1	39.5
2012	REP	2	NZ-Cell Tech Granular + Optimize	29615	3.6	38.8	7.2	46.0	22.0	0.082	2.8	755.5	1600.1	55.0	37.3
2012	REP	3	NZ-Cell Tech Granular + Optimize	38077	3.5	34.3	8.8	43.1			2.4	763.2	1506.8	54.9	36.9
2012	REP	4	NZ-Cell Tech Granular + Optimize	10577	3.6	34.7	6.8	41.5	26.9	0.552	2.3	763.2	2163.3	54.7	37.5
2012	REP	1	NZ-Optimize	27147	2.9	36.9	6.0	42.9	17.2	0.456	2.2	751.6	1714.4	55.0	36.3
2012	REP	2	NZ-Optimize	29968	3.4	47.4	8.8	56.2	15.1	0.299	2.2	760.6	1751.3	55.2	36.9
2012	REP	3	NZ-Optimize	21506	3.8	33.5	6.3	39.8			2.4	752.9	2081.1	55.2	37.5
2012	REP	4	NZ-Optimize	36667	3.4	40.6	10.0	50.6	13.6	0.310	1.8	756.8	1668.6	55.0	38.1
2012	REP	1	NZ-Optimize 2X	22211	3.3	28.4	5.3	33.7	18.9	0.363	1.9	754.2	2031.9	54.2	37.9
2012	REP	2	NZ-Optimize 2X	33141	3.3	60.9	10.5	71.4	18.0	0.522	2.4	759.3	1489.8	55.2	37.7
2012	REP	3	NZ-Optimize 2X	43365	3.7	38.0	7.3	45.3	13.9	0.337	2.0	760.6	1731.0	55.2	34.2
2012	REP	4	NZ-Optimize 2X	35256	3.4	54.5	8.4	62.9	24.5	0.737	2.0	761.9	1598.7	55.5	35.5
2012	REP	1	TM-Maximize	40192	2.9	65.2	13.8	79.0	9.4	0.399	2.0	754.2	1500.0	53.4	37.0
2012	REP	2	TM-Maximize	40545	3.0	45.5	8.1	53.6	1.6	0.048	0.9	750.3	1798.8	54.7	38.8
2012	REP	3	TM-Maximize	33493	3.2	53.7	11.5	65.2	8.2	0.295	1.5	755.5	2169.2	55.0	36.6
2012	REP	4	TM-Maximize	28558	3.2	29.1	7.5	36.6	5.7	0.248	1.9	761.9	2168.1	55.5	34.7
2012	REP	1	TM-Maximize 2X	32788	3.5	30.3	6.3	36.6	15.6	0.317	1.7	746.5	2038.7	54.4	35.9
2012	REP	2	TM-Maximize 2X	43365	3.6	42.8	7.1	49.9	9.4	0.297	1.7	742.6	1961.0	55.4	35.0
2012	REP	3	TM-Maximize 2X	40545	2.9	24.2	5.5	29.7	8.3	0.253	1.9	759.3	1798.8	55.0	37.4
2012	REP	4	TM-Maximize 2X	31026	3.3	47.3	8.2	55.5	6.5	0.216	1.6	760.6	1905.7	54.6	35.5
2012	RILEY	1	134.4 kg N ha-1	37724	3.3							751.6	3484.8	55.7	39.8
2012	RILEY	2	134.4 kg N ha-1	30673								759.3	3788.2	52.8	40.4
2012	RILEY	3	134.4 kg N ha-1	22564								750.3	3376.0	53.0	39.1
2012	RILEY	4	134.4 kg N ha-1	22917								732.3	2353.8	54.7	40.0
2012	RILEY	1	67 kg N ha-1	22211	3.8							745.2	3762.0	53.8	38.7
2012	RILEY	2	67 kg N ha-1	23269								749.0	3770.4	55.7	36.9
2012	RILEY	3	67 kg N ha-1	31026								746.5	3537.0	54.6	39.1

2012	RILEY	4	67 kg N ha-1	26090								745.2	3000.9	55.2	40.7
2012	RILEY	1	BU - Vault HP	28910	3.3	24.6			8.1	0.187	2.1	803.1	4074.9	53.9	39.5
2012	RILEY	2	BU - Vault HP	27500	3.4	59.5	11.4	70.9	15.5	0.505	2.8	742.6	4416.3	54.9	40.8
2012	RILEY	3	BU - Vault HP	38782	3.2	30.0						754.2	4908.1	54.4	43.8
2012	RILEY	4	BU - Vault HP	31378	3.5	57.9	11.0	68.9	14.2	0.295	1.8	761.9	4023.0	53.8	40.3
2012	RILEY	1	BU-Rhizo Stick 2X	31731	3.5	35.2			12.8	0.261	2.2	747.7	4405.9	52.2	44.6
2012	RILEY	2	BU-Rhizo Stick 2X	33846	3.4	50.9	10.3	61.2	13.3	0.477	3.0	763.2	4747.5	54.2	37.8
2012	RILEY	3	BU-Rhizo Stick 2X	32436	3.5	41.0	7.5	48.5	15.7	0.136	1.6	756.8	3800.4	52.0	39.2
2012	RILEY	4	BU-Rhizo Stick 2X	33846	3.4	62.4	10.1	72.5	8.4	0.216	2.3	756.8	2977.5	53.9	39.3
2012	RILEY	1	BU-Rhizo Stick+VaultHP	27147	3.6	30.8	9.0	39.8	18.8	0.273	2.1	732.3	3298.2	53.6	38.2
2012	RILEY	2	BU-Rhizo Stick+VaultHP	29263	3.8	35.0	6.9	41.9	14.7	0.493	2.9	738.7	4445.2	55.4	40.3
2012	RILEY	3	BU-Rhizo Stick+VaultHP	34551	3.3	48.5	8.7	57.2	9.9	0.191	1.7	759.3	4481.2	54.7	39.5
2012	RILEY	4	BU-Rhizo Stick+VaultHP	31026	3.2	42.8	7.2	50.0	12.9	0.212	1.7	761.9	4644.5	55.0	39.4
2012	RILEY	1	BU-Vault HP 2X	23269	3.6	39.1	7.4	46.5	14.1	0.184	1.6	759.3	3552.5	54.2	42.2
2012	RILEY	2	BU-Vault HP 2X	27500	3.8	48.2	9.1	57.3	8.1	0.188	2.1	746.5	4248.5	52.5	35.4
2012	RILEY	3	BU-Vault HP 2X	29263	3.3	35.6			9.0	0.185	2.0	765.8	4267.4	55.4	37.5
2012	RILEY	4	BU-Vault HP 2X	28205	3.2	43.1	8.2	51.3	15.9	0.336	2.5	750.3	4893.7	54.7	41.1
2012	RILEY	1	Check	34551	3.6	27.1	7.7	34.8	11.9	0.186	2.3	747.7	2816.5	55.4	41.3
2012	RILEY	2	Check	22211		38.6	7.1	45.7	7.8	0.210	1.8	731.0	2873.6	54.7	37.5
2012	RILEY	3	Check	37724		35.4	5.9	41.3	16.1	0.381	2.1	737.5	3882.7	55.0	40.2
2012	RILEY	4	Check	28205	3.4	37.4	6.1	43.5	19.6	0.450	2.6	750.3	3387.3	55.2	38.5
2012	RILEY	1	NZ-Cell Tech Granular + Optimize	29615	3.1	28.0	6.7	34.7	20.9	0.297	2.2	751.6	3064.9	54.4	39.8
2012	RILEY	2	NZ-Cell Tech Granular + Optimize	38077	3.5	57.5	10.5	68.0	17.1	0.554	2.5	755.5	4765.2	54.2	41.9
2012	RILEY	3	NZ-Cell Tech Granular + Optimize	30673	3.3	53.6	9.7	63.3	10.9	0.272	2.2	756.8	4150.4	57.6	35.2
2012	RILEY	4	NZ-Cell Tech Granular + Optimize	36314	3.2	60.0						763.2	4456.1	55.0	38.8
2012	RILEY	1	NZ-Optimize	24679	3.5	47.0	8.3	55.3	12.4	0.175	1.4	760.6	4690.7	54.7	40.6

2012	RILEY	2	NZ-Optimize	32436	3.4	48.3	10.4	58.7	14.2	0.275	2.3	759.3	4262.6	54.2	38.3
2012	RILEY	3	NZ-Optimize	35256	3.5	28.5	5.6	34.1				761.9	4070.3	53.8	41.3
2012	RILEY	4	NZ-Optimize	34551	3.5	54.6	9.6	64.2	14.2	0.261	2.1	756.8	3733.5	53.9	37.7
2012	RILEY	1	NZ-Optimize 2X	28205	4.5	47.5	8.8	56.3	23.7	0.701	2.6	749.0	3382.6	56.3	36.8
2012	RILEY	2	NZ-Optimize 2X	38429	3.4	40.9	8.7	49.6	8.4	0.286	2.0	759.3	4436.2	55.5	41.1
2012	RILEY	3	NZ-Optimize 2X	33846	3.4	51.5	10.1	61.6	13.6	0.294	2.0	754.2	5027.3	54.4	41.2
2012	RILEY	4	NZ-Optimize 2X	33846	3.2	58.6			13.4	0.389	1.9	759.3	4266.8	54.6	37.1
2012	RILEY	1	TM-Maximize	26090	3.3	54.6	10.4	65.0	14.6	0.407	2.8	736.2	3632.3	56.8	35.3
2012	RILEY	2	TM-Maximize	42308	3.3	41.7	8.4	50.1	18.9	0.206	2.0	754.2	4819.6	54.6	38.7
2012	RILEY	3	TM-Maximize	29615	3.4	51.4	10.1	61.5	12.1	0.303	1.8	760.6	4366.7	56.6	41.9
2012	RILEY	4	TM-Maximize	29968	3.6	56.9	10.4	67.3	10.3	0.310	2.0	747.7	3785.3	53.8	41.3
2012	RILEY	1	TM-Maximize 2X	32788	3.6	37.7	7.1	44.8	15.2	0.234	1.9	764.5	3596.6	52.2	41.1
2012	RILEY	2	TM-Maximize 2X	31026	3.6	42.8	7.5	50.3	28.4	0.808	2.7	746.5	3785.1	53.9	42.1
2012	RILEY	3	TM-Maximize 2X	29615	3.5	39.2			18.6	0.281	1.9	733.6	3783.1	54.2	36.8
2012	RILEY	4	TM-Maximize 2X	28910	3.3	57.7	10.8	68.5	20.0	0.388	2.6	772.2	3641.0	54.2	43.0

Appendix B - Raw Data: "Soybean Inoculant and Seed Treatment Interactions in Various Soybean Production Scenarios"

YR	LOC	REP	TREATMENT		POP (plant ha^{-1})	PLANT N (g kg^{-1})	TOP DM (g)	ROOT DM (g)	DM TOTAL (g)	NOD CT PLANT^{-1}	NOD WT (g 10 PLANT^{-1})	RATING	TEST WT (kg m^{-3})	Yield (kg ha^{-1})	Seed N (g kg^{-1})	300 SEED WT (g)
2011	MORRIS	1	ABM-ExcalibreSA	ApronMaxx RFC	39487								770.9	346.6	55.0	20.5
2011	MORRIS	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	34551								755.5	457.9	53.3	21.7
2011	MORRIS	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	39487								767.1	311.6	55.8	19.9
2011	MORRIS	1	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	34551								782.5	405.2	54.1	23.3
2011	MORRIS	1	ABM-ExcalibreSA	None	41955								763.2	557.0	55.0	20.5
2011	MORRIS	2	ABM-ExcalibreSA	ApronMaxx RFC	32083								737.5	373.3	50.6	24.2
2011	MORRIS	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	33846								764.5	449.2	52.8	22.0
2011	MORRIS	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	36667								783.8	658.6	53.4	20.2
2011	MORRIS	2	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	33141								769.6	278.9	51.0	18.2
2011	MORRIS	2	ABM-ExcalibreSA	None	40192								782.5	541.4	51.0	22.8
2011	MORRIS	3	ABM-ExcalibreSA	ApronMaxx RFC	31026								769.6	523.5	51.7	22.0
2011	MORRIS	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	37724								754.2	607.3	54.1	25.0
2011	MORRIS	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	35961								765.8	368.2	54.9	16.4
2011	MORRIS	3	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	32436								756.8	330.9	53.6	21.3
2011	MORRIS	3	ABM-ExcalibreSA	None	36667								768.3	574.7	51.5	21.8
2011	MORRIS	4	ABM-ExcalibreSA	ApronMaxx RFC	37372								740.0	478.6	53.4	21.5
2011	MORRIS	4	ABM-ExcalibreSA	ApronMaxx RFC	33846								741.3	642.5	53.4	23.6

				Cruiser												
2011	MORRIS	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	43013								747.7	520.7	53.3	22.1
2011	MORRIS	4	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	37019								727.2	417.1	52.2	21.7
2011	MORRIS	4	ABM-ExcalibreSA	None	27852								742.6	599.4	52.8	24.9
2011	MORRIS	1	BU-Vault	ApronMaxx RFC Cruiser Avicta	40545								776.1	471.7	53.4	19.7
2011	MORRIS	1	BU-Vault	ApronMaxx RFC	45833								746.5	273.3	56.0	23.3
2011	MORRIS	1	BU-Vault	ApronMaxx RFC Cruiser	43718								778.6	436.5	55.5	21.3
2011	MORRIS	1	BU-Vault	None	20449								779.9	404.2	55.7	24.2
2011	MORRIS	1	BU-Vault	ApronMaxx RFC Poncho/Votivo	33493								763.2	344.1	55.8	24.9
2011	MORRIS	2	BU-Vault	ApronMaxx RFC Cruiser Avicta	32436								760.6	437.6	51.2	20.7
2011	MORRIS	2	BU-Vault	ApronMaxx RFC	32436								756.8	655.5	53.9	21.8
2011	MORRIS	2	BU-Vault	ApronMaxx RFC Cruiser	38077								774.8	302.1	54.2	23.5
2011	MORRIS	2	BU-Vault	None	25737								758.0	439.5	53.0	25.3
2011	MORRIS	2	BU-Vault	ApronMaxx RFC Poncho/Votivo	38077								764.5	473.9	53.8	21.0
2011	MORRIS	3	BU-Vault	ApronMaxx RFC Cruiser Avicta	35609								760.6	542.1	52.3	21.8
2011	MORRIS	3	BU-Vault	ApronMaxx RFC	33141								767.1	506.7	55.7	23.8
2011	MORRIS	3	BU-Vault	ApronMaxx RFC Cruiser	39134								759.3	466.1	53.4	24.7
2011	MORRIS	3	BU-Vault	None	19038								749.0	374.3	54.2	23.3
2011	MORRIS	3	BU-Vault	ApronMaxx RFC Poncho/Votivo	32436								754.2	452.3	54.1	22.7
2011	MORRIS	4	BU-Vault	ApronMaxx RFC Cruiser Avicta	38429								764.5	658.9	52.0	24.7
2011	MORRIS	4	BU-Vault	ApronMaxx RFC	29615								750.3	454.9	53.9	25.3
2011	MORRIS	4	BU-Vault	ApronMaxx RFC Cruiser	39840								756.8	536.3	52.5	26.7
2011	MORRIS	4	BU-Vault	None	25737								743.9	529.7	52.5	23.4
2011	MORRIS	4	BU-Vault	ApronMaxx RFC	32436								751.6	578.2	53.8	24.4

				Poncho/Votivo												
2011	MORRIS	1	NZ-Optimize	ApronMaxx RFC	33846		15.4	2.9	18.3	5.6	0.094	1.9	768.3	285.2	55.7	20.6
2011	MORRIS	1	NZ-Optimize	ApronMaxx RFC Cruiser	34551		16.9	3.4	20.3	2.7	0.114	1.2	750.3	330.8	55.0	24.4
2011	MORRIS	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	39134		27.0	4.2	31.2	2.0	0.066	0.9	778.6	353.2	56.2	23.9
2011	MORRIS	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	34199		20.6	4.0	24.6	2.0	0.195	0.8	776.1	432.9	57.1	23.2
2011	MORRIS	1	NZ-Optimize	None	29615		18.4	3.7	22.1	4.5	0.032	1.7	764.5	339.6	56.8	20.3
2011	MORRIS	2	NZ-Optimize	ApronMaxx RFC	33846		13.9	2.8	16.7	6.2	0.222	2.3	746.5	362.9	54.4	24.4
2011	MORRIS	2	NZ-Optimize	ApronMaxx RFC Cruiser	29968		17.5	3.7	21.2	5.4	0.074	2.5	770.9	640.4	55.2	22.6
2011	MORRIS	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	35961		14.9	3.1	18.0	7.1	0.169	2.3	763.2	563.6	54.2	23.7
2011	MORRIS	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	42660		17.6	3.6	21.2	3.5	0.057	1.8	711.7	428.8	54.1	23.9
2011	MORRIS	2	NZ-Optimize	None	25385		14.7	2.8	17.5	6.5	0.045	2.1	754.2	338.7	54.9	23.5
2011	MORRIS	3	NZ-Optimize	ApronMaxx RFC	32436		14.9	2.2	17.1	5.1	0.203	1.5	760.6	508.8	55.8	23.5
2011	MORRIS	3	NZ-Optimize	ApronMaxx RFC Cruiser	23974		20.3	4.0	24.3	5.9	0.052	2.4	747.7	424.8	54.7	21.2
2011	MORRIS	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	37372		18.4	3.9	22.3	3.9	0.134	2.2	759.3	523.9	56.2	20.1
2011	MORRIS	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	44070		12.6	2.8	15.4	5.1	0.212	3.1	749.0	746.7	56.0	23.5
2011	MORRIS	3	NZ-Optimize	None	28910		14.8	3.1	17.9	3.3	0.048	1.5	761.9	669.3	56.3	23.3
2011	MORRIS	4	NZ-Optimize	ApronMaxx RFC	36314		21.7	3.4	25.1	3.6	0.115	1.6	722.0	728.6	56.2	22.4
2011	MORRIS	4	NZ-Optimize	ApronMaxx RFC Cruiser	22564		21.7	4.9	26.6	3.3	0.360	1.3	759.3	652.6	53.8	24.6
2011	MORRIS	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	33493		17.2	4.4	21.6	5.0	0.051	2.0	772.2	439.0	56.3	22.8
2011	MORRIS	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	31731		15.2	3.3	18.5	7.5	0.049	2.4	764.5	549.2	54.7	24.1
2011	MORRIS	4	NZ-Optimize	None	29968		17.7	3.6	21.3	3.9	0.082	1.5	671.8	602.8	54.9	24.0
2011	MORRIS	1	Untreated	None	35961								755.5	312.4	53.9	23.5
2011	MORRIS	2	Untreated	None	44775								749.0	357.6	51.7	22.9
2011	MORRIS	3	Untreated	None	38782								763.2	361.8	53.6	22.1

2011	MORRIS	4	Untreated	None	42308								769.6	515.7	53.3	21.0
2011	REP	1	ABM-ExcalibreSA	ApronMaxx RFC	46186								755.5	3199.7	52.8	36.1
2011	REP	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	38782								747.7	3515.8	53.6	39.1
2011	REP	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	41602								752.9	3603.6	55.0	37.8
2011	REP	1	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	40545								756.8	2722.7	50.6	32.7
2011	REP	1	ABM-ExcalibreSA	None	37372								761.9	3603.6	53.1	32.8
2011	REP	2	ABM-ExcalibreSA	ApronMaxx RFC	45481								770.9	2716.8	52.8	32.1
2011	REP	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	47596								769.6	3439.7	53.3	33.1
2011	REP	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	40897								756.8	3919.6	54.6	33.1
2011	REP	2	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	38782								751.6	3439.7	55.2	38.1
2011	REP	2	ABM-ExcalibreSA	None	38429								761.9	2719.7	53.9	33.2
2011	REP	3	ABM-ExcalibreSA	ApronMaxx RFC	38782								749.0	3206.6	53.6	34.9
2011	REP	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	37019								759.3	2876.6	54.6	38.2
2011	REP	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	39840								763.2	3123.1	54.9	37.6
2011	REP	3	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	44423								743.9	2799.7	54.6	40.3
2011	REP	3	ABM-ExcalibreSA	None	38429								767.1	3755.6	53.6	35.8
2011	REP	4	ABM-ExcalibreSA	ApronMaxx RFC	33846								759.3	3435.9	54.9	34.7
2011	REP	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	39840								751.6	3519.7	54.2	31.8
2011	REP	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	39840								763.2	3839.6	55.0	34.0
2011	REP	4	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	38429								745.2	3123.1	54.4	34.7
2011	REP	4	ABM-ExcalibreSA	None	41602								758.0	3036.4	51.0	34.2
2011	REP	1	BU-Vault	ApronMaxx RFC Cruiser Avicta	40192								769.6	2559.7	53.4	34.8
2011	REP	1	BU-Vault	ApronMaxx RFC	47596								761.9	3599.6	56.6	38.0
2011	REP	1	BU-Vault	ApronMaxx RFC	45128								760.6	3839.6	52.2	30.1

				Cruiser												
2011	REP	1	BU-Vault	None	28205								752.9	3359.7	54.7	31.6
2011	REP	1	BU-Vault	ApronMaxx RFC Poncho/Votivo	36667								763.2	3839.6	54.9	33.6
2011	REP	2	BU-Vault	ApronMaxx RFC Cruiser Avicta	45128								761.9	2959.7	53.4	31.6
2011	REP	2	BU-Vault	ApronMaxx RFC	37372								760.6	3279.7	54.4	34.4
2011	REP	2	BU-Vault	ApronMaxx RFC Cruiser	41250								765.8	3356.0	53.8	36.1
2011	REP	2	BU-Vault	None	26090								763.2	3199.7	55.7	37.4
2011	REP	2	BU-Vault	ApronMaxx RFC Poncho/Votivo	34551								758.0	2799.7	52.6	37.7
2011	REP	3	BU-Vault	ApronMaxx RFC Cruiser Avicta	41955								764.5	3043.0	51.8	29.6
2011	REP	3	BU-Vault	ApronMaxx RFC	44423								760.6	3839.6	52.8	33.2
2011	REP	3	BU-Vault	ApronMaxx RFC Cruiser	35961								751.6	3599.6	54.1	36.9
2011	REP	3	BU-Vault	None	27500								745.2	3039.7	53.6	37.5
2011	REP	3	BU-Vault	ApronMaxx RFC Poncho/Votivo	35256								760.6	3443.4	54.6	37.6
2011	REP	4	BU-Vault	ApronMaxx RFC Cruiser Avicta	44423								769.6	2959.7	52.2	33.7
2011	REP	4	BU-Vault	ApronMaxx RFC	35961								754.2	3835.5	55.2	37.8
2011	REP	4	BU-Vault	ApronMaxx RFC Cruiser	44775								772.2	3119.7	54.6	34.7
2011	REP	4	BU-Vault	None	29615								765.8	3519.7	53.4	34.2
2011	REP	4	BU-Vault	ApronMaxx RFC Poncho/Votivo	37724								770.9	2962.9	54.6	37.1
2011	REP	1	NZ-Optimize	ApronMaxx RFC	41250		41.3	8.0	49.3	12.6	0.306	2.7	765.8	3203.2	55.2	32.1
2011	REP	1	NZ-Optimize	ApronMaxx RFC Cruiser	29615		49.9	11.5	61.4	29.5	0.923	4.1	750.3	2642.6	56.8	37.2
2011	REP	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	37019		31.6	5.8	37.4	2.3	0.150	1.1	755.5	3683.6	53.8	36.7
2011	REP	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	44423		30.2	6.0	36.2	20.0	0.775	3.8	751.6	3199.7	54.9	37.1
2011	REP	1	NZ-Optimize	None	30320		29.0	5.7	34.7	14.2	0.643	3.5	756.8	3599.6	54.7	35.6
2011	REP	2	NZ-Optimize	ApronMaxx RFC	40897		35.6	6.6	42.2	16.1	0.444	3.3	761.9	3759.6	53.3	35.4

2011	REP	2	NZ-Optimize	ApronMaxx RFC Cruiser	30320		38.4	8.8	47.2	17.2	0.499	2.5	764.5	3679.6	55.0	35.5
2011	REP	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	49359		48.1	9.8	57.9	9.1	0.244	2.3	761.9	3999.6	56.0	38.3
2011	REP	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	45481		39.7	8.5	48.2	17.1	0.514	3.2	760.6	3439.7	56.3	38.3
2011	REP	2	NZ-Optimize	None	34199		35.5	7.6	43.1	18.4	0.478	3.1	761.9	3435.9	53.9	33.9
2011	REP	3	NZ-Optimize	ApronMaxx RFC	37724		36.7	6.6	43.3	14.6	0.530	3.4	746.5	3527.3	53.9	38.3
2011	REP	3	NZ-Optimize	ApronMaxx RFC Cruiser	35256		42.1	7.8	49.9	13.3	0.552	3.6	750.3	3763.7	51.0	34.9
2011	REP	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	32788		44.3	8.7	53.0	20.7	0.861	3.7	751.6	3839.6	53.8	32.1
2011	REP	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	43013		41.8	8.6	50.4	11.7	0.375	2.6	764.5	3363.3	55.4	33.0
2011	REP	3	NZ-Optimize	None	39487		44.1	8.4	52.5	7.9	0.187	1.8	759.3	3039.7	54.2	33.2
2011	REP	4	NZ-Optimize	ApronMaxx RFC	36667		27.4	5.0	32.4	14.3	0.290	2.9	767.1	3759.6	55.4	34.0
2011	REP	4	NZ-Optimize	ApronMaxx RFC Cruiser	31378		49.4	9.7	59.1	14.2	0.477	3.5	754.2	2959.7	54.4	32.5
2011	REP	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	45481		42.8	8.8	51.6	11.7	0.349	3.1	772.2	3435.9	56.2	34.6
2011	REP	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	44070		43.8	9.2	53.0	13.0	0.546	2.3	764.5	3279.7	56.5	32.8
2011	REP	4	NZ-Optimize	None	32083		47.0	8.7	55.7	13.1	0.482	3.1	768.3	2402.4	52.8	33.4
2011	REP	1	Untreated	None	43013								751.6	3843.8	52.2	37.3
2011	REP	2	Untreated	None	31378								752.9	3283.2	54.7	30.5
2011	REP	3	Untreated	None	39840								760.6	3763.7	49.1	31.4
2011	REP	4	Untreated	None	36314								763.2	3435.9	54.1	32.9
2011	REP I	1	ABM-ExcalibreSA	ApronMaxx RFC	32436								716.9	4200.5	54.4	44.0
2011	REP I	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	40192								719.4	4311.9	54.2	39.8
2011	REP I	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	40897								718.1	4127.9	54.9	45.7
2011	REP I	1	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	38077								720.7	4210.4	54.9	44.1
2011	REP I	1	ABM-ExcalibreSA	None	44070								718.1	4301.0	54.4	45.5
2011	REP I	2	ABM-ExcalibreSA	ApronMaxx RFC	39840								715.6	4767.5	54.4	43.8

2011	REP I	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	38782								715.6	4157.8	54.6	42.2
2011	REP I	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	34551								713.0	4171.4	55.0	43.5
2011	REP I	2	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	38077								723.3	4372.0	55.4	39.7
2011	REP I	2	ABM-ExcalibreSA	None	37372								720.7	4555.8	55.4	43.6
2011	REP I	3	ABM-ExcalibreSA	ApronMaxx RFC	32083								711.7	3870.4	55.4	42.8
2011	REP I	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	36667								723.3	3888.0	55.5	44.9
2011	REP I	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	46186								72.5	4866.0	54.7	44.5
2011	REP I	3	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	38429								715.6	4081.1	54.9	43.7
2011	REP I	3	ABM-ExcalibreSA	None	41602								718.1	4333.5	55.4	43.5
2011	REP I	4	ABM-ExcalibreSA	ApronMaxx RFC	47243								711.7	4491.2	55.2	43.8
2011	REP I	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	40192								716.9	3912.3	55.4	42.2
2011	REP I	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	43718								723.3	4333.5	54.7	45.2
2011	REP I	4	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	44070								720.7	3895.4	54.9	41.7
2011	REP I	4	ABM-ExcalibreSA	None	33846								720.7	3781.1	55.7	39.3
2011	REP I	1	BU-Vault	None	26795								707.9	3620.5	54.2	41.6
2011	REP I	2	BU-Vault	None	24679								718.1	4418.4	55.2	44.5
2011	REP I	3	BU-Vault	None	22917								706.6	4090.3	54.9	41.0
2011	REP I	4	BU-Vault	None	22917								716.9	3613.3	55.2	40.7
2011	REP I	1	NZ-Optimize	ApronMaxx RFC	38782								707.9	4455.7	54.4	43.1
2011	REP I	1	NZ-Optimize	ApronMaxx RFC Cruiser	31026								718.1	3754.4	54.4	42.4
2011	REP I	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	38782								718.1	3013.6	53.4	41.2
2011	REP I	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	39487								719.4	4663.5	55.0	38.2
2011	REP I	1	NZ-Optimize	None	38077								715.6	4542.6	54.9	44.1
2011	REP I	2	NZ-Optimize	ApronMaxx RFC	37724								716.9	4459.0	55.2	42.0

2011	REP I	2	NZ-Optimize	ApronMaxx RFC Cruiser	32083								716.9	4833.6	55.0	44.9
2011	REP I	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	27147								719.4	3910.0	55.5	42.3
2011	REP I	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	47949								719.4	4578.0	55.5	45.9
2011	REP I	2	NZ-Optimize	None	30673								707.9	4565.5	54.2	45.1
2011	REP I	3	NZ-Optimize	ApronMaxx RFC	45481								707.9	4083.8	55.0	41.0
2011	REP I	3	NZ-Optimize	ApronMaxx RFC Cruiser	31731								715.6	4033.5	55.2	37.7
2011	REP I	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	37019								715.6	4299.2	55.0	43.7
2011	REP I	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	37019								704.0	4478.1	55.5	43.2
2011	REP I	3	NZ-Optimize	None	25385								714.3	4058.2	54.9	41.8
2011	REP I	4	NZ-Optimize	ApronMaxx RFC	36667								719.4	3976.4	55.2	41.5
2011	REP I	4	NZ-Optimize	ApronMaxx RFC Cruiser	32436								724.6	3750.6	55.2	40.1
2011	REP I	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	34199								711.7	4116.3	55.4	43.9
2011	REP I	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	31378								718.1	4363.8	54.9	43.7
2011	REP I	4	NZ-Optimize	None	31731								711.7	3820.6	55.0	40.9
2011	REP I	1	Untreated	None	31731								718.1	3762.5	54.2	38.4
2011	REP I	2	Untreated	None	38429								724.6	4262.1	55.0	42.9
2011	REP I	3	Untreated	None	42308								722.0	3983.9	55.5	44.0
2011	REP I	4	Untreated	None	45481								718.1	3856.6	55.7	41.5
2011	RILEY	1	ABM-ExcalibreSA	ApronMaxx RFC	44070								759.3	3488.1	53.9	43.6
2011	RILEY	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	35961								770.9	3137.4	55.5	44.0
2011	RILEY	1	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	34551								765.8	3063.1	55.0	44.2
2011	RILEY	1	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	37372								756.8	3580.6	54.6	44.6
2011	RILEY	1	ABM-ExcalibreSA	None	31026								755.5	2836.1	54.4	44.0
2011	RILEY	2	ABM-ExcalibreSA	ApronMaxx RFC	34199								770.9	3179.9	55.0	43.9

2011	RILEY	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	33846								776.1	3602.3	55.5	45.0
2011	RILEY	2	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	31731								768.3	2960.2	54.9	43.4
2011	RILEY	2	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	45833								776.1	3346.4	55.2	43.4
2011	RILEY	2	ABM-ExcalibreSA	None	37019								770.9	3119.7	55.8	44.1
2011	RILEY	3	ABM-ExcalibreSA	ApronMaxx RFC	33141								779.9	3240.4	54.7	44.2
2011	RILEY	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	31731								768.3	3094.5	55.7	44.1
2011	RILEY	3	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	37372								777.3	3122.6	55.5	42.4
2011	RILEY	3	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	33141								781.2	2819.3	56.2	43.3
2011	RILEY	3	ABM-ExcalibreSA	None	32083								768.3	2979.9	55.5	44.2
2011	RILEY	4	ABM-ExcalibreSA	ApronMaxx RFC	38782								774.8	2944.2	55.5	43.3
2011	RILEY	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser	30673								764.5	3123.2	55.7	43.4
2011	RILEY	4	ABM-ExcalibreSA	ApronMaxx RFC Cruiser Avicta	35961								778.6	3983.8	55.4	42.4
2011	RILEY	4	ABM-ExcalibreSA	ApronMaxx RFC Poncho/Votivo	35256								774.8	3717.0	56.2	44.0
2011	RILEY	4	ABM-ExcalibreSA	None	33493								764.5	3197.7	56.0	41.3
2011	RILEY	1	BU-Vault	ApronMaxx RFC Cruiser Avicta	33846								767.1	3300.6	54.7	43.6
2011	RILEY	1	BU-Vault	ApronMaxx RFC	41250								763.2	3257.9	54.7	44.9
2011	RILEY	1	BU-Vault	ApronMaxx RFC Cruiser	36314								761.9	3431.1	54.4	42.4
2011	RILEY	1	BU-Vault	None	37019								765.8	3417.3	54.4	42.5
2011	RILEY	1	BU-Vault	ApronMaxx RFC Poncho/Votivo	36314								764.5	3187.1	54.6	44.8
2011	RILEY	2	BU-Vault	ApronMaxx RFC Cruiser Avicta	40192								767.1	3112.3	55.2	44.4
2011	RILEY	2	BU-Vault	ApronMaxx RFC	43718								764.5	2898.9	55.5	43.8
2011	RILEY	2	BU-Vault	ApronMaxx RFC Cruiser	35256								769.6	3389.4	55.7	43.7
2011	RILEY	2	BU-Vault	None	39487								759.3	2895.7	55.0	45.1

2011	RILEY	2	BU-Vault	ApronMaxx RFC Poncho/Votivo	35256								774.8	3535.2	55.4	43.5
2011	RILEY	3	BU-Vault	ApronMaxx RFC Cruiser Avicta	38429								776.1	3258.2	55.7	45.0
2011	RILEY	3	BU-Vault	ApronMaxx RFC	35961								759.3	3361.3	55.2	45.3
2011	RILEY	3	BU-Vault	ApronMaxx RFC Cruiser	32436								772.2	3568.7	55.7	46.0
2011	RILEY	3	BU-Vault	None	24679								779.9	3304.7	55.5	44.8
2011	RILEY	3	BU-Vault	ApronMaxx RFC Poncho/Votivo	32436								768.3	3521.4	54.4	43.9
2011	RILEY	4	BU-Vault	ApronMaxx RFC Cruiser Avicta	34904								768.3	3301.1	56.0	42.6
2011	RILEY	4	BU-Vault	ApronMaxx RFC	31731								772.2	2614.4	55.8	41.2
2011	RILEY	4	BU-Vault	ApronMaxx RFC Cruiser	29615								763.2	2611.5	55.7	42.5
2011	RILEY	4	BU-Vault	None	29263								768.3	3065.7	55.8	42.8
2011	RILEY	4	BU-Vault	ApronMaxx RFC Poncho/Votivo	39134								758.0	1994.1	56.2	43.5
2011	RILEY	1	NZ-Optimize	ApronMaxx RFC	39487		20.7	3.1	23.8	12.3	0.158	2.3	765.8	2573.1	55.4	42.7
2011	RILEY	1	NZ-Optimize	ApronMaxx RFC Cruiser	32788		19.8	3.5	23.3	13.4	0.224	2.3	759.3	2982.3	53.1	43.2
2011	RILEY	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	35961		20.2	3.1	23.3	11.4	0.201	2.5	756.8	3558.9	53.9	41.5
2011	RILEY	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	39487		18.3	2.7	21.0	10.1	0.195	2.0	769.6	3435.0	54.7	44.4
2011	RILEY	1	NZ-Optimize	None	32436		19.2	2.8	22.0	12.6	0.143	2.8	760.6	2357.5	54.1	42.2
2011	RILEY	2	NZ-Optimize	ApronMaxx RFC	31378		26.4	4.1	30.5	10.2	0.290	2.0	769.6	3606.3	55.0	44.3
2011	RILEY	2	NZ-Optimize	ApronMaxx RFC Cruiser	38782		17.5	3.1	20.6	13.9	0.193	3.3	758.0	3474.2	54.6	43.0
2011	RILEY	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	29615		20.6	3.3	23.9	13.5	0.171	3.0	768.3	3123.2	54.9	44.9
2011	RILEY	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	36314		20.8	3.3	24.1	16.3	0.094	2.7	773.5	2836.1	55.4	44.5
2011	RILEY	2	NZ-Optimize	None	36667		28.4	4.0	32.4	13.1	0.179	2.7	769.6	3620.0	55.0	44.5
2011	RILEY	3	NZ-Optimize	ApronMaxx RFC	35961		17.1	2.9	20.0	8.7	0.192	2.4	778.6	3774.5	55.4	43.9
2011	RILEY	3	NZ-Optimize	ApronMaxx RFC Cruiser	36667		17.8	2.8	20.6	13.1	0.243	3.0	774.8	2923.1	55.4	44.5

2011	RILEY	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	34904		20.7	3.7	24.4	14.3	0.226	3.2	767.1	2721.1	55.8	44.7
2011	RILEY	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	44070		19.4	3.1	22.5	13.9	0.230	3.4	770.9	3012.3	55.4	44.0
2011	RILEY	3	NZ-Optimize	None	26795		12.8	2.5	15.3	16.6	0.160	3.5	774.8	2973.3	55.2	43.2
2011	RILEY	4	NZ-Optimize	ApronMaxx RFC	30320		13.1	2.6	15.7	15.1	0.100	2.6	777.3	3443.8	56.2	43.4
2011	RILEY	4	NZ-Optimize	ApronMaxx RFC Cruiser	32788		17.8	3.1	20.9	14.5	0.104	2.9	773.5	3030.1	56.0	43.3
2011	RILEY	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	36667		15.9	2.5	18.4	14.2	0.123	3.5	769.6	2923.1	55.8	42.9
2011	RILEY	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	34551		16.1	2.8	18.9	10.8	0.124	2.1	777.3	3774.5	56.2	42.6
2011	RILEY	4	NZ-Optimize	None	37724		19.6	2.9	22.5	9.6	0.158	2.3	776.1	3151.4	55.5	43.4
2011	RILEY	1	Untreated	None	34551								759.3	3403.3	54.6	43.4
2011	RILEY	2	Untreated	None	29263								763.2	2984.5	55.4	43.3
2011	RILEY	3	Untreated	None	29263								770.9	3018.9	55.7	43.2
2011	RILEY	4	Untreated	None	28205								764.5	3624.1	55.8	43.2
2012	PHILC	1	BU-Vault HP	ApronMaxx RFC	30673								754.2	1124.9	52.6	26.4
2012	PHILC	1	BU-Vault HP	ApronMaxx RFC Cruiser	29968								749.0	1721.3	49.9	32.7
2012	PHILC	1	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	40192								754.2	912.3	52.8	30.4
2012	PHILC	1	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	31378								751.6	1470.7	49.0	28.8
2012	PHILC	1	BU-Vault HP	None	25032								751.6	1053.4	51.7	28.4
2012	PHILC	2	BU-Vault HP	ApronMaxx RFC	32436								731.0	1628.6	51.0	26.7
2012	PHILC	2	BU-Vault HP	ApronMaxx RFC Cruiser	34199								749.0	1807.4	49.9	32.7
2012	PHILC	2	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	36667								754.2	1222.1	52.8	29.1
2012	PHILC	2	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	38429								751.6	991.9	49.1	28.4
2012	PHILC	2	BU-Vault HP	None	32436								751.6	1502.4	52.3	29.6
2012	PHILC	3	BU-Vault HP	ApronMaxx RFC	36667								830.1	1463.2	52.5	29.4
2012	PHILC	3	BU-Vault HP	ApronMaxx RFC Cruiser	27852								751.6	1452.2	52.8	27.6

2012	PHILC	3	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	39840								738.7	2085.1	52.0	29.2
2012	PHILC	3	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	33141								747.7	2294.3	51.2	28.3
2012	PHILC	3	BU-Vault HP	None	19744								751.6	1123.7	51.0	29.1
2012	PHILC	4	BU-Vault HP	ApronMaxx RFC	33846								751.6	2694.0	51.8	30.4
2012	PHILC	4	BU-Vault HP	ApronMaxx RFC Cruiser	29615								752.9	2960.7	52.6	29.7
2012	PHILC	4	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	32436								750.3	3446.4	52.2	30.3
2012	PHILC	4	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	27147								749.0	2397.8	52.0	28.8
2012	PHILC	4	BU-Vault HP	None	29615								751.6	2696.9	51.0	29.1
2012	PHILC	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	29263	179.4	115.9	19.8	135.7	0.5	0.102	1.1	729.7	1430.2	50.2	27.8
2012	PHILC	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	34551	203.1	141.2	25.8	167.0	1.7	0.148	0.8	747.7	1260.7	52.2	27.0
2012	PHILC	1	NZ-Optimize	ApronMaxx RFC	29615	195.0	100.4	15.6	116.0	1.8	0.195	1.2	752.9	828.9	51.8	26.7
2012	PHILC	1	NZ-Optimize	None	28558	222.8	127.4	17.5	144.9	2.4	0.241	1.1	756.8	1239.4	51.7	26.6
2012	PHILC	1	NZ-Optimize	ApronMaxx RFC Cruiser	25737	211.2	113.1	16.3	129.4	4.2	0.324	1.4	759.3	1279.3	51.2	26.9
2012	PHILC	2	NZ-Optimize	ApronMaxx RFC	37372	211.4	74.5	12.0	86.5	1.4	0.147	0.9	752.9	673.5	52.8	27.5
2012	PHILC	2	NZ-Optimize	None	25385	208.7	81.2	15.4	96.6	1.9	0.207	1.0	756.8	1170.5	52.6	28.8
2012	PHILC	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	34199	212.1	96.4	13.7	110.1	2.5	0.177	1.1	756.8	1210.2	52.8	28.8
2012	PHILC	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	31731	202.6	103.8	15.1	118.9	2.8	0.234	1.3	747.7	880.7	52.2	28.3
2012	PHILC	2	NZ-Optimize	ApronMaxx RFC Cruiser	37019	225.9	71.7	13.5	85.2	5.7	0.577	2.1	759.3	1279.3	52.3	28.4
2012	PHILC	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	41250	198.2	103.7	17.3	121.0	0.6	0.094	0.6	747.7	2309.1	50.2	31.5
2012	PHILC	3	NZ-Optimize	None	35961	183.9	67.0	13.3	80.3	2.9	0.236	1.1	740.0	1533.6	51.4	30.7
2012	PHILC	3	NZ-Optimize	ApronMaxx RFC	35256	194.0	86.3	13.3	99.6	3.1	0.334	1.5	750.3	1807.4	51.8	31.0
2012	PHILC	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	34904	203.7	123.2	21.6	144.8	3.2	0.328	1.2	741.3	828.0	52.0	28.9
2012	PHILC	3	NZ-Optimize	ApronMaxx RFC Cruiser	34199	191.6	129.5	21.3	150.8	4.6	0.311	1.4	741.3	1192.9	50.7	30.0

2012	PHILC	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	33846	212.6	106.8	18.5	125.3	1.5	0.146	1.0	752.9	2513.1	52.3	29.6
2012	PHILC	4	NZ-Optimize	ApronMaxx RFC	27147	190.8	154.9	25.8	180.7	3.1	0.312	1.6	750.3	2163.3	51.0	29.5
2012	PHILC	4	NZ-Optimize	ApronMaxx RFC Cruiser	23269	231.0	108.1	21.2	129.3	3.8	0.423	1.2	743.9	1828.6	51.2	27.2
2012	PHILC	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	28205	235.0	126.3	19.1	145.4	3.8	0.379	1.4	747.7	3222.4	52.0	32.8
2012	PHILC	4	NZ-Optimize	None	20096	209.5	170.5	28.1	198.6	4.3	0.378	1.6	751.6	2579.2	52.0	29.4
2012	PHILC	1	TM- Maximize	ApronMaxx RFC	26090								758.0	896.1	52.5	26.5
2012	PHILC	1	TM- Maximize	ApronMaxx RFC Cruiser	30673								745.2	1378.6	51.4	28.8
2012	PHILC	1	TM- Maximize	ApronMaxx RFC Cruiser Avicta	26795								743.9	830.7	53.0	28.4
2012	PHILC	1	TM- Maximize	ApronMaxx RFC Poncho/Votivo	24327								758.0	1120.1	52.8	29.8
2012	PHILC	1	TM- Maximize	None	22564								752.9	898.0	51.4	29.2
2012	PHILC	2	TM- Maximize	ApronMaxx RFC	32788								758.0	913.3	52.2	29.0
2012	PHILC	2	TM- Maximize	ApronMaxx RFC Cruiser	35256								745.2	878.8	51.4	28.8
2012	PHILC	2	TM- Maximize	ApronMaxx RFC Cruiser Avicta	33141								743.9	1073.0	53.9	29.0
2012	PHILC	2	TM- Maximize	ApronMaxx RFC Poncho/Votivo	22564								758.0	1189.0	53.0	29.0
2012	PHILC	2	TM- Maximize	None	32788								752.9	1157.0	51.7	29.7
2012	PHILC	3	TM- Maximize	ApronMaxx RFC	33846								740.0	1246.1	51.4	29.0
2012	PHILC	3	TM- Maximize	ApronMaxx RFC Cruiser	32436								745.2	1709.7	51.5	31.1
2012	PHILC	3	TM- Maximize	ApronMaxx RFC Cruiser Avicta	38782								758.0	2089.6	53.0	27.5
2012	PHILC	3	TM- Maximize	ApronMaxx RFC Poncho/Votivo	36667								747.7	2476.0	51.2	31.1
2012	PHILC	3	TM- Maximize	None	31731								755.5	1744.2	52.5	26.3
2012	PHILC	4	TM- Maximize	ApronMaxx RFC	27500								747.7	2981.1	52.2	30.0
2012	PHILC	4	TM- Maximize	ApronMaxx RFC Cruiser	28205								741.3	2630.6	51.7	29.6
2012	PHILC	4	TM- Maximize	ApronMaxx RFC Cruiser Avicta	34904								754.2	2633.6	52.3	28.9

2012	PHILC	4	TM- Maximize	ApronMaxx RFC Poncho/Votivo	35961								751.6	2754.1	52.2	32.4
2012	PHILC	4	TM- Maximize	None	18333								738.7	2544.8	52.3	32.6
2012	PHILC	1	Untreated	None	25737	176.0	122.7	23.5	146.2			0.7	749.0	2542.7	49.6	30.4
2012	PHILC	2	Untreated	None	26090	221.6	112.0	20.2	132.2	0.3	0.004	0.6	749.0	1491.7	52.3	30.7
2012	PHILC	3	Untreated	None	25737	188.5	94.0	24.9	118.9			0.5	752.9	2781.4	51.4	33.3
2012	PHILC	4	Untreated	None	21154	184.8	139.5	29.9	169.4	0.1	0.005	0.6	749.0	2568.0	49.4	27.9
2012	REP	1	BU-Vault HP	ApronMaxx RFC	38429								759.3	1874.9	55.7	38.2
2012	REP	1	BU-Vault HP	ApronMaxx RFC Cruiser	39134								764.5	1704.5	55.7	34.6
2012	REP	1	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	40897								758.0	1498.3	54.7	37.0
2012	REP	1	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	51122								755.5	1602.2	55.2	35.5
2012	REP	1	BU-Vault HP	None	37724								756.8	1632.7	55.0	35.7
2012	REP	2	BU-Vault HP	ApronMaxx RFC	34199								767.1	1498.3	55.4	36.6
2012	REP	2	BU-Vault HP	ApronMaxx RFC Cruiser	34551								738.7	1125.0	55.4	35.3
2012	REP	2	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	30673								758.0	1530.7	53.9	38.3
2012	REP	2	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	29263								759.3	1430.2	55.5	35.4
2012	REP	2	BU-Vault HP	None	41955								761.9	1856.0	55.4	33.6
2012	REP	3	BU-Vault HP	ApronMaxx RFC	42308								754.2	1604.0	53.8	35.9
2012	REP	3	BU-Vault HP	ApronMaxx RFC Cruiser	38782								745.2	1641.8	54.1	36.8
2012	REP	3	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	55352								749.0	1634.5	53.4	37.4
2012	REP	3	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	50064								750.3	1630.9	54.4	38.9
2012	REP	3	BU-Vault HP	None	28205								755.5	1462.6	53.8	36.0
2012	REP	4	BU-Vault HP	ApronMaxx RFC	43365								752.9	1943.1	54.1	35.0
2012	REP	4	BU-Vault HP	ApronMaxx RFC Cruiser	43013								752.9	1842.9	54.2	37.0
2012	REP	4	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	43365								745.2	1736.7	53.9	37.6

2012	REP	4	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	27500								755.5	1874.9	54.1	36.8
2012	REP	4	BU-Vault HP	None	40545								752.9	1804.8	54.4	35.0
2012	REP	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	44070	356.2	62.8	11.1	73.9	14.0	0.475	2.0	759.3	1768.8	55.2	36.4
2012	REP	1	NZ-Optimize	ApronMaxx RFC	38429	322.9	35.8	7.5	43.3	15.3	0.276	1.8	761.9	1498.3	55.5	36.0
2012	REP	1	NZ-Optimize	None	23974	335.8	20.4	3.9	24.3	17.9	0.277	2.1	758.0	1602.2	56.2	34.5
2012	REP	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	43718	324.4	32.7	7.7	40.4	19.5	0.616	2.3	759.3	1495.0	54.6	36.2
2012	REP	1	NZ-Optimize	ApronMaxx RFC Cruiser	30673	372.7	29.1	5.4	34.5	24.4	0.467	2.2	758.0	1666.7	55.0	36.0
2012	REP	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	37724	334.9	30.4	5.7	36.1	9.5	0.384	2.0	756.8	1972.9	55.2	36.0
2012	REP	2	NZ-Optimize	None	40897	325.5	27.0	5.6	32.6	10.6	0.320	1.9	760.6	1774.6	54.6	34.6
2012	REP	2	NZ-Optimize	ApronMaxx RFC	37372	326.6	48.0	9.0	57.0	12.8	0.405	1.9	751.6	1595.2	55.0	36.8
2012	REP	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	44775	304.0	54.7	9.9	64.6	23.9	0.574	2.4	763.2	1943.1	54.2	40.8
2012	REP	2	NZ-Optimize	ApronMaxx RFC Cruiser	44070	324.2	48.6						756.8	1632.7	55.4	34.8
2012	REP	3	NZ-Optimize	None	20801	409.4	40.8	1.7	42.5	3.3	0.231	1.1	763.2	1802.8	54.1	38.0
2012	REP	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	37372	404.2	48.4	3.3	51.7	7.3	0.250	1.7	759.3	1840.9	53.3	39.9
2012	REP	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	41250	320.1	59.7	6.0	65.7	7.7	0.474	1.8	752.9	1770.1	54.1	36.8
2012	REP	3	NZ-Optimize	ApronMaxx RFC Cruiser	38782	358.9	60.7	6.2	66.9	8.3	0.177	1.8	751.6	1906.9	54.1	39.4
2012	REP	3	NZ-Optimize	ApronMaxx RFC	44070	331.9	59.9	5.6	65.5	16.8	0.374	2.3	752.9	1431.8	54.9	34.3
2012	REP	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	46891	376.7	77.6	8.9	86.5	6.1	0.240	1.3	736.2	1906.9	53.8	37.5
2012	REP	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	31026	341.2	73.6	8.0	81.6	7.0	0.166	1.8	752.9	1950.3	53.3	36.9
2012	REP	4	NZ-Optimize	None	35609	304.7	96.7	8.8	105.5	9.4	0.482	1.8	750.3	2145.3	54.7	38.9
2012	REP	4	NZ-Optimize	ApronMaxx RFC Cruiser	31731	349.9	81.8	9.1	90.9	13.2	0.548	2.0	756.8	1938.9	54.1	37.7
2012	REP	4	NZ-Optimize	ApronMaxx RFC	52179	58.1	83.3	9.0	92.3	16.1	0.117	2.2	754.2	1772.7	54.4	39.6
2012	REP	1	TM- Maximize	ApronMaxx RFC	34199								763.2	1255.8	55.4	36.5
2012	REP	1	TM- Maximize	ApronMaxx RFC	34904								750.3	1564.7	54.9	36.3

				Cruiser												
2012	REP	1	TM- Maximize	ApronMaxx RFC Cruiser Avicta	26090								758.0	1687.7	54.7	34.9
2012	REP	1	TM- Maximize	ApronMaxx RFC Poncho/Votivo	39134								758.0	1698.9	56.3	35.1
2012	REP	1	TM- Maximize	None	33493								760.6	1451.4	55.2	37.4
2012	REP	2	TM- Maximize	ApronMaxx RFC	31378								767.1	1870.8	55.4	39.5
2012	REP	2	TM- Maximize	ApronMaxx RFC Cruiser	47596								763.2	1668.6	58.4	33.7
2012	REP	2	TM- Maximize	ApronMaxx RFC Cruiser Avicta	28910								746.5	1397.7	54.4	34.7
2012	REP	2	TM- Maximize	ApronMaxx RFC Poncho/Votivo	30673								760.6	1328.1	55.2	34.6
2012	REP	2	TM- Maximize	None	29263								755.5	1832.3	54.2	36.5
2012	REP	3	TM- Maximize	ApronMaxx RFC	36667								741.3	1602.2	54.2	36.7
2012	REP	3	TM- Maximize	ApronMaxx RFC Cruiser	29615								745.2	1423.9	54.4	38.6
2012	REP	3	TM- Maximize	ApronMaxx RFC Cruiser Avicta	23269								756.8	1802.8	53.8	36.5
2012	REP	3	TM- Maximize	ApronMaxx RFC Poncho/Votivo	28910								751.6	1634.5	53.4	37.1
2012	REP	3	TM- Maximize	None	31026								756.8	2182.5	54.7	35.5
2012	REP	4	TM- Maximize	ApronMaxx RFC	58525								731.0	2045.4	53.4	38.8
2012	REP	4	TM- Maximize	ApronMaxx RFC Cruiser	43365								745.2	1666.7	54.2	35.8
2012	REP	4	TM- Maximize	ApronMaxx RFC Cruiser Avicta	46891								742.6	1634.5	53.3	38.7
2012	REP	4	TM- Maximize	ApronMaxx RFC Poncho/Votivo	37372								750.3	1810.7	53.8	36.8
2012	REP	4	TM- Maximize	None	42660								750.3	1977.2	53.9	36.1
2012	REP	1	Untreated	None	17981	355.5	42.4	9.3	51.7	14.3	0.492	2.1	774.8	1762.3	55.8	37.0
2012	REP	2	Untreated	None	29968	369.7	75.6					2.0	758.0	1627.3	54.6	39.3
2012	REP	3	Untreated	None	15160	373.5	69.2	7.6	76.8	9.7	0.038	1.5	751.6	1839.1	54.4	40.6
2012	REP	4	Untreated	None	36667	338.4	68.9	12.4	81.3	20.4	0.688	2.6	758.0	2269.0	53.1	41.0
2012	RILEY	1	BU-Vault HP	ApronMaxx RFC	41602								750.3	4175.2	54.7	41.1
2012	RILEY	1	BU-Vault HP	ApronMaxx RFC	38782								728.4	3203.6	54.7	39.4

				Cruiser												
2012	RILEY	1	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	38077								756.8	4253.6	55.4	40.0
2012	RILEY	1	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	36314								733.6	3278.0	55.2	44.3
2012	RILEY	1	BU-Vault HP	None	39487								759.3	3300.6	54.4	40.6
2012	RILEY	2	BU-Vault HP	ApronMaxx RFC	35961								750.3	4439.4	55.4	41.4
2012	RILEY	2	BU-Vault HP	ApronMaxx RFC Cruiser	40545								756.8	3859.5	55.2	38.5
2012	RILEY	2	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	42308								755.5	3507.3	55.5	41.7
2012	RILEY	2	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	35256								764.5	3461.6	54.4	43.0
2012	RILEY	2	BU-Vault HP	None	33141								751.6	3574.8	54.4	39.9
2012	RILEY	3	BU-Vault HP	ApronMaxx RFC	43365								756.8	4140.7	55.0	38.7
2012	RILEY	3	BU-Vault HP	ApronMaxx RFC Cruiser	37724								759.3	3724.3	55.0	36.3
2012	RILEY	3	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	40897								767.1	4257.2	54.6	36.7
2012	RILEY	3	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	45128								760.6	3822.1	54.9	39.4
2012	RILEY	3	BU-Vault HP	None	33493								749.0	3328.9	55.5	42.3
2012	RILEY	4	BU-Vault HP	ApronMaxx RFC	41602								764.5	2884.5	55.4	44.3
2012	RILEY	4	BU-Vault HP	ApronMaxx RFC Cruiser	39487								754.2	3635.6	55.7	41.5
2012	RILEY	4	BU-Vault HP	ApronMaxx RFC Cruiser Avicta	35256								763.2	3541.0	56.0	40.8
2012	RILEY	4	BU-Vault HP	ApronMaxx RFC Poncho/Votivo	41602								763.2	3679.3	56.2	40.6
2012	RILEY	4	BU-Vault HP	None	39840								750.3	3137.8	54.4	40.7
2012	RILEY	1	NZ-Optimize	ApronMaxx RFC	36314	338.9	48.0	8.8	56.8	7.9	0.145	1.5	767.1	3592.6	54.4	39.8
2012	RILEY	1	NZ-Optimize	None	24679	357.4	39.0	6.9	45.9	9.1	0.037	1.4	754.2	3741.8	55.4	37.8
2012	RILEY	1	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	36667	359.3	38.6	6.8	45.4	13.6	0.114	1.8	754.2	3418.3	55.5	42.8
2012	RILEY	1	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	36667	304.9	51.1	9.3	60.4	20.9	0.390	2.6	763.2	3615.8	55.7	35.1
2012	RILEY	1	NZ-Optimize	ApronMaxx RFC	41250	329.3	50.3	8.8	59.1	24.5	0.417	2.5	770.9	4834.1	54.9	40.1

				Cruiser												
2012	RILEY	2	NZ-Optimize	None	33493	373.0	30.1	5.4	35.5	14.4	0.063	1.4	764.5	3861.7	54.2	38.8
2012	RILEY	2	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	40545	332.9	43.5	8.2	51.7	17.9	0.353	2.6	759.3	3673.9	55.0	42.9
2012	RILEY	2	NZ-Optimize	ApronMaxx RFC	43013	446.9	48.9	9.2	58.1	19.0	0.243	2.2	758.0	3714.6	54.6	38.8
2012	RILEY	2	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	44070	318.2	53.3	10.8	64.1	20.9	0.464	3.0	764.5	4076.1	53.8	43.2
2012	RILEY	2	NZ-Optimize	ApronMaxx RFC Cruiser	34551	334.0	62.5	12.0	74.5	22.2	0.428	2.4	761.9	3841.9	53.9	40.9
2012	RILEY	3	NZ-Optimize	ApronMaxx RFC	43365	336.2	25.9	3.8	29.7	6.7	0.034	1.2	755.5	3519.5	55.7	36.3
2012	RILEY	3	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	45833	301.3	53.3	9.5	62.8	11.2	0.352	2.3	758.0	3473.5	54.7	41.0
2012	RILEY	3	NZ-Optimize	ApronMaxx RFC Cruiser	38077	278.7	37.4	7.5	44.9	12.3	0.205	2.0	763.2	3666.8	54.7	41.6
2012	RILEY	3	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	36314	319.5	33.6	6.8	40.4	14.8	0.281	1.7	756.8	4102.8	54.1	39.4
2012	RILEY	3	NZ-Optimize	None	31731	332.6	27.9	5.6	33.5	15.0	0.119	1.8	752.9	3798.0	55.8	39.5
2012	RILEY	4	NZ-Optimize	ApronMaxx RFC	36667	325.8	61.0	9.8	70.8	9.6	0.249	2.2	764.5	3497.3	55.7	42.0
2012	RILEY	4	NZ-Optimize	ApronMaxx RFC Cruiser	37372	331.9	63.0	10.8	73.8	11.5	0.349	2.6	759.3	4400.3	54.4	39.9
2012	RILEY	4	NZ-Optimize	ApronMaxx RFC Cruiser Avicta	37724	326.0	59.8	11.3	71.1	13.9	0.231	2.1	761.9	4104.0	55.0	38.2
2012	RILEY	4	NZ-Optimize	None	40545	314.1	57.2	10.5	67.7	14.4	0.309	2.3	758.0	2789.1	55.4	41.8
2012	RILEY	4	NZ-Optimize	ApronMaxx RFC Poncho/Votivo	44423	326.9	59.4	10.6	70.0	14.5	0.275	2.4	760.6	4107.3	54.4	43.6
2012	RILEY	1	TM- Maximize	ApronMaxx RFC	42308								755.5	4331.8	54.2	38.2
2012	RILEY	1	TM- Maximize	ApronMaxx RFC Cruiser	37372								759.3	3291.1	54.2	44.5
2012	RILEY	1	TM- Maximize	ApronMaxx RFC Cruiser Avicta	39840								758.0	4041.3	54.9	39.7
2012	RILEY	1	TM- Maximize	ApronMaxx RFC Poncho/Votivo	37019								760.6	3497.3	55.5	39.6
2012	RILEY	1	TM- Maximize	None	43365								749.0	3863.9	53.3	42.3
2012	RILEY	2	TM- Maximize	ApronMaxx RFC	38782								761.9	3867.8	53.9	40.2
2012	RILEY	2	TM- Maximize	ApronMaxx RFC Cruiser	39840								759.3	3892.5	57.3	34.6
2012	RILEY	2	TM- Maximize	ApronMaxx RFC	39487								763.2	3686.5	53.9	41.9

				Cruiser Avicta												
2012	RILEY	2	TM- Maximize	ApronMaxx RFC Poncho/Votivo	43718								761.9	3116.7	53.8	36.7
2012	RILEY	2	TM- Maximize	None	32788								750.3	3463.7	53.4	45.2
2012	RILEY	3	TM- Maximize	ApronMaxx RFC	43718								760.6	4012.5	55.0	44.0
2012	RILEY	3	TM- Maximize	ApronMaxx RFC Cruiser	38429								787.6	3658.4	56.0	39.2
2012	RILEY	3	TM- Maximize	ApronMaxx RFC Cruiser Avicta	45833								758.0	3461.7	55.2	39.4
2012	RILEY	3	TM- Maximize	ApronMaxx RFC Poncho/Votivo	41955								764.5	3766.9	55.2	42.1
2012	RILEY	3	TM- Maximize	None	32083								736.2	2920.1	54.9	39.3
2012	RILEY	4	TM- Maximize	ApronMaxx RFC	37019								763.2	3043.7	54.7	45.0
2012	RILEY	4	TM- Maximize	ApronMaxx RFC Cruiser	48654								768.3	4030.8	54.1	41.2
2012	RILEY	4	TM- Maximize	ApronMaxx RFC Cruiser Avicta	42308								763.2	4337.0	55.7	36.6
2012	RILEY	4	TM- Maximize	ApronMaxx RFC Poncho/Votivo	34551								758.0	4017.0	55.5	45.9
2012	RILEY	4	TM- Maximize	None	31378								764.5	3631.5	55.8	40.7
2012	RILEY	1	Untreated	None	34551	305.9	39.6	7.3	46.9	12.8	0.543	2.7	750.3	2614.1	55.7	34.9
2012	RILEY	2	Untreated	None	33493	345.8	37.0	7.3	44.3	11.3	0.193	1.9	738.7	3489.2	54.7	40.9
2012	RILEY	3	Untreated	None	24679	305.3	39.6	6.5	46.1	15.4	0.228	2.3	742.6	2934.2	54.2	42.3
2012	RILEY	4	Untreated	None	23974	318.4	64.4	12.0	76.4	9.1	0.185	2.4	743.9	1938.4	55.0	40.0

Appendix C - Raw Data: "Inoculated Seed Storage Effect on Soybean Nodulation"

TREAT	TIME	TEMP	ENVIRON	REP	NOD COUNT	NOD WT (g 4 plants^{-1})	TOP WT (g 4 plant^{-1})	SPAD READING
1	0	0	.	1	61	0.082	1.239	24.9
1	0	0	.	2	36	0.089	1.200	31.9
1	0	0	.	3	69	0.127	1.603	29.4
1	0	0	.	4	52	0.170	.	28.2
2	4	40	D	1	52	0.121	1.342	31
2	4	40	D	2	79	0.113	1.211	31.6
2	4	40	D	3	60	0.139	1.320	34.6
2	4	40	D	4	97	0.119	0.926	32.8
3	4	40	W	1	128	0.221	1.173	27.5
3	4	40	W	2	101	0.173	1.339	31.2
3	4	40	W	3	95	0.118	1.011	27.1
3	4	40	W	4	66	0.095	0.869	29.4
4	4	35	D	1	39	0.085	0.507	23.6
4	4	35	D	2	46	0.156	1.522	35.1
4	4	35	D	3	81	0.137	1.186	28.4
4	4	35	D	4	102	0.109	1.067	28.3
5	4	35	W	1	111	0.166	1.363	28.4
5	4	35	W	2	67	0.131	1.205	31.2
5	4	35	W	3	116	0.160	1.063	31.6

5	4	35	W	4	167	0.187	1.428	34.2
6	4	25	D	1	170	0.127	0.994	27.3
6	4	25	D	2	59	0.096	0.921	32.1
6	4	25	D	3	110	0.133	1.211	31.5
6	4	25	D	4	98	0.177	1.172	29.8
7	4	25	W	1	152	0.195	1.342	34.4
7	4	25	W	2	90	0.148	1.066	31.4
7	4	25	W	3	80	0.152	1.242	30
7	4	25	W	4	60	0.108	0.927	32.1
8	4	15	D	1	78	0.187	1.221	27.5
8	4	15	D	2	89	0.131	1.059	31
8	4	15	D	3	82	0.111	1.060	29
8	4	15	D	4	65	0.108	0.908	27.8
9	4	15	W	1	88	0.131	1.296	30.4
9	4	15	W	2	55	0.113	1.152	22.8
9	4	15	W	3	100	0.137	1.150	30.5
9	4	15	W	4	97	0.125	1.173	33.2
10	12	40	D	1	45	0.099	0.692	27.5
10	12	40	D	2	85	0.133	1.010	32.8
10	12	40	D	3	84	0.098	0.785	34.2
10	12	40	D	4	63	0.137	1.402	32.5
11	12	40	W	1	50	0.092	0.743	28.1

11	12	40	W	2	98	0.138	1.003	29.6
11	12	40	W	3	107	0.199	1.072	33.9
11	12	40	W	4	79	0.145	1.038	29.8
12	12	35	D	1	91	0.120	0.904	27.8
12	12	35	D	2	95	0.194	1.251	29.2
12	12	35	D	3	103	0.153	1.396	31.9
12	12	35	D	4	41	0.107	0.995	27.7
13	12	35	W	1	61	0.079	0.734	28.1
13	12	35	W	2	82	0.121	1.170	28
13	12	35	W	3	87	0.149	1.395	29.6
13	12	35	W	4	89	0.141	1.125	30
14	12	25	D	1	86	0.138	1.073	29.6
14	12	25	D	2	94	0.187	1.412	31.4
14	12	25	D	3	67	0.111	0.837	31.4
14	12	25	D	4	62	0.135	1.080	29.4
15	12	25	W	1	100	0.145	1.449	29.8
15	12	25	W	2	96	0.126	1.091	30.2
15	12	25	W	3	135	0.123	1.030	32.3
15	12	25	W	4	56	0.116	1.096	28.9
16	12	15	D	1	125	0.191	1.153	28.5
16	12	15	D	2	64	0.111	0.899	29.2
16	12	15	D	3	102	0.143	1.261	33.1

16	12	15	D	4	71	0.200	1.360	29.8
17	12	15	W	1	65	0.105	1.202	30.1
17	12	15	W	2	51	0.096	0.924	35
17	12	15	W	3	83	0.126	1.152	31
17	12	15	W	4	98	0.101	1.297	29.4
18	24	40	D	1	91	0.114	1.225	27.5
18	24	40	D	2	82	0.123	1.243	28.1
18	24	40	D	3	139	0.151	1.292	28.7
18	24	40	D	4	60	0.084	0.997	29.3
19	24	40	W	1	98	0.119	1.372	30.9
19	24	40	W	2	93	0.104	0.958	29.3
19	24	40	W	3	109	0.150	1.220	35.1
19	24	40	W	4	77	0.134	1.433	30.2
20	24	35	D	1	105	0.109	1.144	28.9
20	24	35	D	2	107	0.130	1.152	32
20	24	35	D	3	79	0.111	1.145	28.1
20	24	35	D	4	57	0.137	1.257	30
21	24	35	W	1	93	0.150	1.335	28.7
21	24	35	W	2	91	0.137	1.315	32.9
21	24	35	W	3	87	0.123	1.179	31
21	24	35	W	4	98	0.136	1.288	31.8
22	24	25	D	1	52	0.106	1.408	30

22	24	25	D	2	92	0.098	0.927	31.5
22	24	25	D	3	113	0.155	1.185	28.9
22	24	25	D	4	99	0.137	1.243	30.4
23	24	25	W	1	77	0.105	0.889	24.1
23	24	25	W	2	74	0.109	.	34.6
23	24	25	W	3	58	0.111	1.031	29.9
23	24	25	W	4	138	0.168	1.282	29.2
24	24	15	D	1	87	0.153	1.368	34.4
24	24	15	D	2	66	0.116	1.107	25.8
24	24	15	D	3	69	0.113	1.073	30.4
24	24	15	D	4	70	0.110	1.306	30.2
25	24	15	W	1	79	0.121	1.170	29.7
25	24	15	W	2	72	0.103	1.069	33.9
25	24	15	W	3	120	0.124	1.258	29.5
25	24	15	W	4	105	0.122	1.098	30.9
26	48	40	D	1	103	0.124	1.255	28.2
26	48	40	D	2	91	0.149	1.257	32.4
26	48	40	D	3	92	0.127	1.408	29.4
26	48	40	D	4	95	0.116	1.233	30.9
27	48	40	W	1	77	0.125	1.239	26.8
27	48	40	W	2	80	0.148	1.303	30.5
27	48	40	W	3	65	0.080	0.751	28.1

27	48	40	W	4	52	0.122	1.105	27.6
28	48	35	D	1	111	0.127	1.354	28.1
28	48	35	D	2	118	0.134	1.284	28.8
28	48	35	D	3	102	0.101	1.006	29
28	48	35	D	4	89	0.116	1.270	24.4
29	48	35	W	1	123	0.139	1.347	25.2
29	48	35	W	2	113	0.130	1.366	35.7
29	48	35	W	3	93	0.116	1.214	27.2
29	48	35	W	4	79	0.091	0.945	24.8
30	48	25	D	1	90	0.119	1.148	27.2
30	48	25	D	2	87	0.135	1.436	28.8
30	48	25	D	3	51	0.090	1.062	31.6
30	48	25	D	4	66	0.133	1.437	28.3
31	48	25	W	1	94	0.110	1.102	25.2
31	48	25	W	2	79	0.126	1.143	26.9
31	48	25	W	3	68	0.098	1.017	26.4
31	48	25	W	4	82	0.126	1.223	27.6
32	48	15	D	1	76	0.163	1.420	30.6
32	48	15	D	2	61	0.106	1.083	25.6
32	48	15	D	3	75	0.132	1.439	30.4
32	48	15	D	4	86	0.129	1.348	27.3
33	48	15	W	1	97	0.131	1.351	30.1

33	48	15	W	2	60	0.130	1.333	29.5
33	48	15	W	3	92	0.142	1.343	30.1
33	48	15	W	4	54	0.077	0.831	28.7
34	168	40	D	1	78	0.179	1.463	28
34	168	40	D	2	56	0.126	1.276	30.8
34	168	40	D	3	85	0.186	1.257	26.7
34	168	40	D	4	145	0.182	1.390	30.5
36	168	40	D	1	80	0.138	1.362	25.9
36	168	40	D	2	97	0.141	1.286	28.6
36	168	40	D	3	79	0.135	1.367	26
36	168	40	D	4	41	0.151	1.474	29.1
37	168	35	W	1	99	0.168	1.572	22.9
37	168	35	W	2	79	0.117	1.134	26.1
37	168	35	W	3	42	0.038	0.498	22.2
37	168	35	W	4	116	0.146	1.199	28.7
38	168	25	D	1	71	0.135	1.343	27.4
38	168	25	D	2	114	0.181	1.693	28.8
38	168	25	D	3	76	0.148	1.432	29.6
38	168	25	D	4	101	0.191	1.564	30.1
39	168	25	W	1	122	0.168	1.471	23.8
39	168	25	W	2	74	0.162	1.305	25.6
39	168	25	W	3	79	0.132	1.022	25.7

39	168	25	W	4	96	0.151	1.249	28
40	168	15	D	1	64	0.145	1.144	28.8
40	168	15	D	2	103	0.161	1.554	23.3
40	168	15	D	3	84	0.147	1.248	28.5
40	168	15	D	4	72	0.134	1.338	28.9
41	168	15	W	1	95	0.150	1.306	29.7
41	168	15	W	2	68	0.094	0.926	24.3
41	168	15	W	3	65	0.149	1.498	31.3
41	168	15	W	4	101	0.135	1.230	30.2
42	336	40	D	1	48	0.161	0.712	24.8
42	336	40	D	2	73	0.138	0.990	23.7
42	336	40	D	3	90	0.112	1.125	21.3
42	336	40	D	4	103	0.161	1.458	23.4
44	336	35	D	1	93	0.162	1.424	26.3
44	336	35	D	2	73	0.166	1.490	27.2
44	336	35	D	3	112	0.157	1.348	29.8
44	336	35	D	3	129	0.170	1.451	27.9
44	336	35	D	4	87	0.131	1.326	29
46	336	25	D	1	97	0.177	1.318	28
46	336	25	D	2	88	0.116	0.968	27.8
46	336	25	D	3	89	0.130	1.097	27.4
46	336	25	D	4	125	0.147	1.436	23.6

47	336	25	W	1	106	0.170	1.647	26.8
47	336	25	W	2	100	0.186	1.549	25.5
47	336	25	W	3	100	0.147	1.444	29.2
47	336	25	W	4	56	0.176	1.597	25.1
48	336	15	D	1	111	0.174	.	34.1
48	336	15	D	2	79	0.200	.	31
48	336	15	D	4	123	0.163	1.463	29.1
49	336	15	W	1	85	0.153	1.340	27.1
49	336	15	W	2	143	0.236	1.857	28.4
49	336	15	W	3	100	0.138	1.299	28.4
49	336	15	W	4	89	0.116	1.159	26.9