SOYBEAN GROWTH COMPONENTS AS INFLUENCED BY NO-TILL AND STRIP-TILL SYSTEMS AND DIFFERENT P AND K RATES AND PLACEMENTS

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Abstract

Reduced tillage and broadcast phosphorus (P) and potassium (K) applications can lead to accumulation of these nutrients in the soil surface. The objective of this study was to determine the impact of conservation tillage (no-till and strip-till) and rate/placement of P and K on soybean production. The experiment was arranged in a split-split-block design with three replications with tillage/placement— no-till broadcast (NTBC), no-till deep placement at 15 cm (NTDP), and strip-till deep placement at 15 cm (STDP) — as the main plot, P rate (0, 25, 50, 75 lb P_2O_5 ac^{-1} yr^{-1}) as the subplot, and K rate (0, 45, 90, 180 lb K_2O ac^{-1} yr^{-1}) as the sub-subplot in a corn (*Zea mays* L.)-soybean rotation. Tillage and fertilizer placement was conducted immediately before planting every year. Vegetative samples were collected in 2008 and 2009 eight times at nine-day intervals from V1 to R6 development stage. During the first four samplings, every plot was sampled; thereafter only plots receiving P-K rates of 0-0, 75-0, 0-180, 75-180, and 50-90 lb P_2O_5-K_2O ac^{-1} were sampled to measure leaf area index (LAI), specific leaf weight (SLW), and crop growth rate (CGR). STDP significantly increased soybean yields both years, in 2008 NTDP also increased yield compared to NTBC. A phosphorus application of 50 lb P_2O_5 ac^{-1} was sufficient to maximize yield. A significant tillage/placement by P rate interaction indicated that soybean yield in the STDP treatment was not influenced by P rate. This treatment provided a tillage effect at the check (zero P application) that increased soybean yields compared to the other tillage/placement and P rates. Application of K decreased yield slightly, likely due to salt injury. LAI was significantly influenced by tillage/placement and soybean development stage. LAI was maximized at R4/R5 and was higher for STDP compared to other tillage/placement treatments. SLW was lower for STDP at V1 likely because of rapid root expansion compared to the no-till systems. SLW continually decreased during the rapid leaf area development from late vegetative to mid-reproductive stage (R2/R4). Once leaf area expansion stopped and the rapid seed-fill period began (late reproductive stages). SLW increased likely as photosynthates accumulated in the leaves before being translocated into the developing seed. Crop growth rate followed similar pattern to that of LAI and generally increased at a constant rate from late vegetative to late reproductive stage.

Introduction

Soybean [*Gylcine max* (L.) Merr.] is one of the major crops of Illinois with more than ten million acres typically planted every year. Most of the soybeans in the state are planted under no-tillage (NT) or other conservation tillage systems. Under conservation tillage systems where minimum mixing of the soil occurs, surface application of immobile nutrients like P and K can lead to vertical stratification of these nutrients (Blevins et al., 1986; Borges and Mallarino, 2000; Holanda et al., 1998; Karathanasis and Wells, 1990; Mallarino and Borges, 2006; Yin and Vyn, 2002b). This vertical stratification can limit the availability of P and K under dry soil surface periods. For this reason, efforts have been directed at deep placement of nutrients to mitigate nutrient availability concerns by placing nutrients at soil depths that might not be as affected by drying conditions as the soil surface. Deep banding has produced inconsistent yield results. Yield increase in corn and soybean with deep placement has been shown by several authors (Bordoli and Mallarino, 1998; Buah et al. 2000; Ebelhar and Varsa 2000; Hairston et al., 1990; Howard and Tyler 1987). On the other hand, several reports exist showing no yield difference associated with deep banding of P and K fertilizers (Hudak et al., 1989; Rehm and Lamb, 2004; Vyn and Janovicek, 2001; Yin and Vyn, 2002a, 2002b). Deep banding has been found to be advantageous at increasing early P and K uptake by crops (Bordoli and Mallarino, 1998; Borges and Mallarino, 2003; Eckert and Johnson, 1985; Lauzon and Miller, 1997; Mengel et al., 1988; Yibirin et al., 1993). The band applications of fertilizers can provide a starter effect on young crops that have to be established typically in cooler and wetter soils in no-till systems than for other tillage systems. More recently, strip-tillage has emerged as an alternative that combines the benefits of no-till and conventional tillage systems. Strip-till provides narrow residue-free cultivated zones for seed placement and leaves a significant area of the field uncultivated to provide the soil conservation and biodiversity benefits of no-till (Morrison, 2002). The strip-till operation also provides an opportunity to deep-place nutrients. Relatively few studies have been conducted to compare the benefits of strip-till to no-till. The inconsistency in yield results from previous nutrient placement studies and the limited information available for strip-till warrants the present study. The impact of tillage and nutrient placement on yield is likely a reflection of how the crop responds to these management techniques during the growing season. Therefore, the objective of this study was to evaluate the effect of tillage-nutrient placement and P and K rate on the vegetative growth of soybean in order to help elucidate how these management techniques are impacting yield.

Methods and Materials

This project was initiated in spring 2007 at the Crop Sciences Research & Education Center at Champaign, Illinois. The study was conducted on a field with Flanagan silt loam soil (Fine, smectitic, mesic Aquic Argiudolls) and small portions of a Drummer silty clay loam soil (Fine-silty, mixed, superactive, mesic Typic Endoaquolls). The initial chemical properties of the field are CEC: 14 cmol (+) kg^{-1}, organic matter: 3.6 %, pH: 5.7 (1:1), Bray P_1 concentration: 16 mg kg^{-1},ammonium acetate exchangeable K concentration: 185 mg kg^{-1}, Ca concentration: 1564 mg kg^{-1}, and Mg concentration: 253 mg kg^{-1}. Soybeans were established in a rotation with corn with both crops present every year in 20 x 70 ft. plots and 30 inch row spacing. Treatments were established in a split-split-plot arrangement in a randomized complete block design with three replications. The main plots include three tillage and fertilizer placement treatments: no-till broadcast (NTBC), no-till deep placement at 15 cm (NTDP), and strip-till deep placement at 15 cm (STDP). The split plot and split-split plot treatments have four phosphorus levels (0, 25, 50, 75 lb P_2O_5 ac^{-1} yr^{-1}) and four potassium levels (0, 45, 90, and 180 lb K_2O ac^{-1} yr^{-1}), respectively. Phosphorus as triple super phosphate (0-45-0) and K as potash (0-0-62) were applied in spring prior to planting each year. In 2007, soybeans (HI – Soy2846) were planted on May 25 at a plant density of 148,000 plants ac^{-1} and machine harvested in the 2nd week of October while in 2008, planting was done on June 13 and harvested was done on October 28.

At the start of the project, soil samples were collected from the center of each plot from the 0-2, 2-4, 4-7, and 7-20 inches soil depth increment before the application of treatments. At the end of 2007 and 2008 crop harvesting, soil samples were collected from the same depth increments but from two different locations (in-row and between-row). Three composite samples were collected with tractor mounted probes. Five different fertility level plots (0-0, 75-0, 0-180, 75-180, and 50-90 lb acre^{-1} of P_2O_5 and K_2O respectively) were selected for intensive field sampling. The data were collected to measure crop growth components, root proliferation, soil-water, and yield components. However, in this paper only soybean grain yield data and growth component data are presented. Vegetative samples were collected eight times at 9-day intervals between V1 and R6 development stage. Development stages at the time of sampling in 2008 were V1, V2, V4, R1, R2, R4, R5, and R6, and in 2009 V1, V2, R1, R2, R4, R5, R5, and R6. During the first four samplings, every plot was sampled; thereafter only selected plots receiving P-K rates of 0-0, 75-0, 0-180, 75-180, and 50-90 lb P_2O_5-K_2O ac^{-1} were sampled. Leaf areas were measured using a leaf area meter and the oven-dry weight of leaf and stem samples was recorded. The data was analyzed using proc mixed and other appropriate procedures of Statistical Analysis Software (SAS Institute, 2004). Means comparison tests were performed according to Tukey (α=0.05).

Results and Discussion

Soybean yield increased in response to tillage (Fig 1). The STDP treatment produced higher yields in both year and the NTDP treatment increased yields compared to the NTBC treatment in 2008. The difference in 2008 is likely the result of a starter effect in the NTDP compared to the broadcast application when spring conditions were wet and likely limited root development and uptake of nutrients. The STDP treatment likely provided more adequate growth conditions then the no-till treatments by allowing soil conditions to be slightly drier and warmer at the time of emergence and early development. A P rate of 50 lb P_2O_5 acre^{-1} was sufficient to maximize yield ($p<0.05$). Most importantly, there was a significant ($p<0.1$) P by tillage/placement interaction. Soybean yield in the STDP treatment was not influenced by P rate. This treatment provided a tillage effect at the check (zero P application) that increased soybean yields compared to the other tillage/placement and P rates. The NTDP treatment needed 25 lb P_2O_5 acre^{-1} in order to increase yield from its corresponding check, and the NTBC treatment required 50 lb P_2O_5 acre^{-1} in order to increase yields significantly from its check plot. This finding illustrates that deep placement maybe important to increase P application rate efficiency. Further, STDP provided a tillage effect that enhanced soybean yield beyond the effect of P applications on the other tillage/placement treatments. This could be an important consideration in terms of management of P fertilizer in this system compared to a no-till system. Potassium applications had a negative effect on yield ($p<0.05$). The yield decrease with addition of K was small 1.4 to 2.0 bu acre^{-1} and it was likely the result of salt injury due to the spring application of this fertilizer. While there was not a significant tillage/placement by K rate interaction, it appears that these small yield reductions occurred more severely in the NTDP treatment whereas the STDP treatment showed very little if any yield decline at the highest K rate compared to the check (zero K applied).

Growth component analysis conducted for all the treatment plots during the first four sampling periods yielded similar result to those observed for the selected plots that were sampled during the entire growing season. For this reason, only data from the selected plots are being shown. Leaf area index, a measurement of leaf area per unit of soil surface (m^2 m^{-2}), showed no significant response to tillage/placement or fertilizer rate. However, there was a significant tillage/placement by sampling interaction (Figure 2). Differences were not observed during the early vegetative stages where energy allocation is likely higher to the root and the shoot is growing slowly. The differences due to tillage/placement were observed during the reproductive stages in which the STDP treatment had significantly higher LAI than the NTBC and the NTDP had intermediate values between the other two treatments. These findings follow a similar response to that observed for yield.

Specific leaf weight measurements correlate well with LAI measurements. During the rapid leaf development phase of soybean (steepest portion of LAI curve) SLW was constantly declining (Figure 3). This would be expected because most carbon resources are being utilized to increase leaf and root surface area to establish a crop that can later sustain rapid seed-fill. At the late reproductive stages when the physiological emphasis changed from growth to accumulation of yield, the inverse situation occurred in which LAI stopped increasing and SLW begun to increase. This increase in SLW likely indicates accumulation of photosynthates in the leaves that eventually will be transported into the seed. It is important to point out that during the V1 stage, SLW was much lower for the STDP treatment, this likely indicates that the plants growing in this system had better rooting conditions and the actively growing root system was acting as an important sink of photosynthates. On the other hand, the other two tillage/placement systems likely had less favorable root-growth due to wetter and cooler soil conditions, and the resources produced in the leaves were not at high demand until later (V2 stage).

Crop Growth rate followed similar pattern to that of LAI (Fig 4) and generally increased consistently from late vegetative to late reproductive stage. Since CGR simply stated is the product of LAI and net assimilation rate (NAR) indicates that NAR may have declined rapidly even though LAI was constant or slightly declining during the last sampling interval for the STDP treatment. Likely, this decline is the result of plants approaching senescence slightly ahead of the other treatments.

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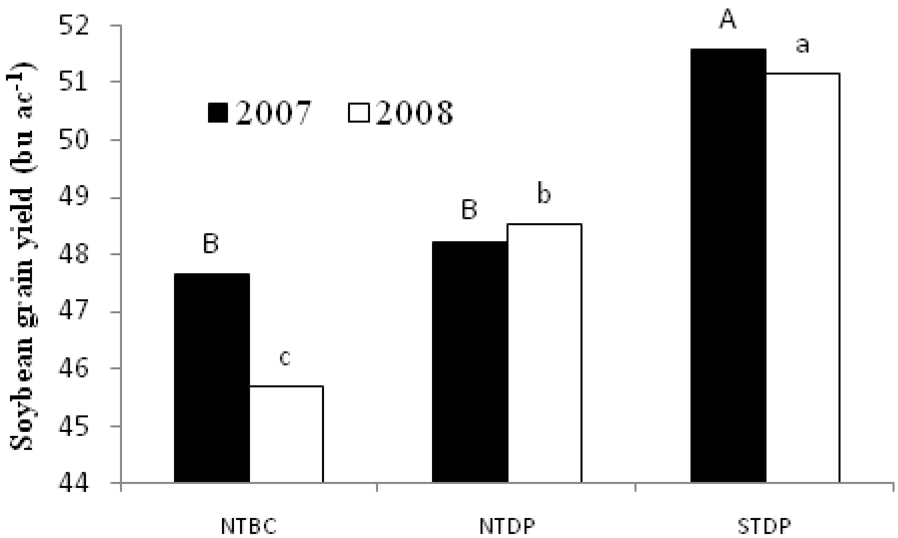

Fig 1: Soybean yield for 2007 and 2008 for the different tillage/placement treatments

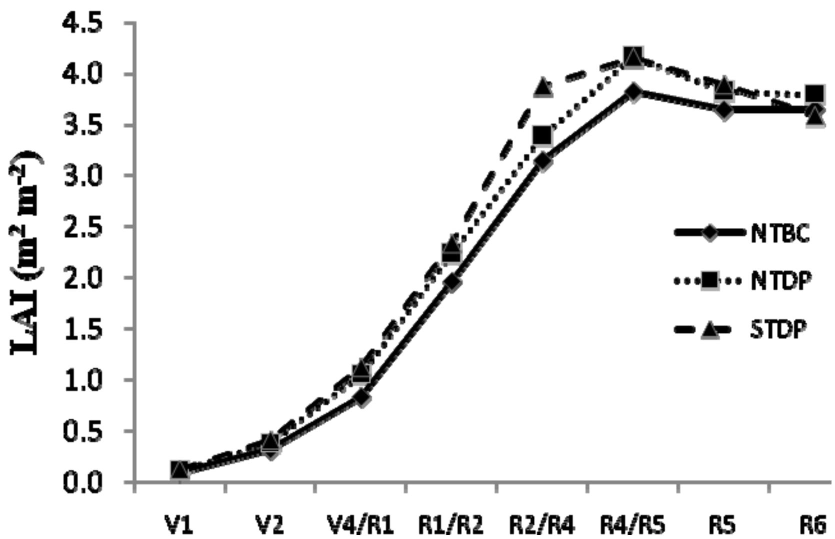

Fig 2: Effect of tillage/placement at different development stages on LAI

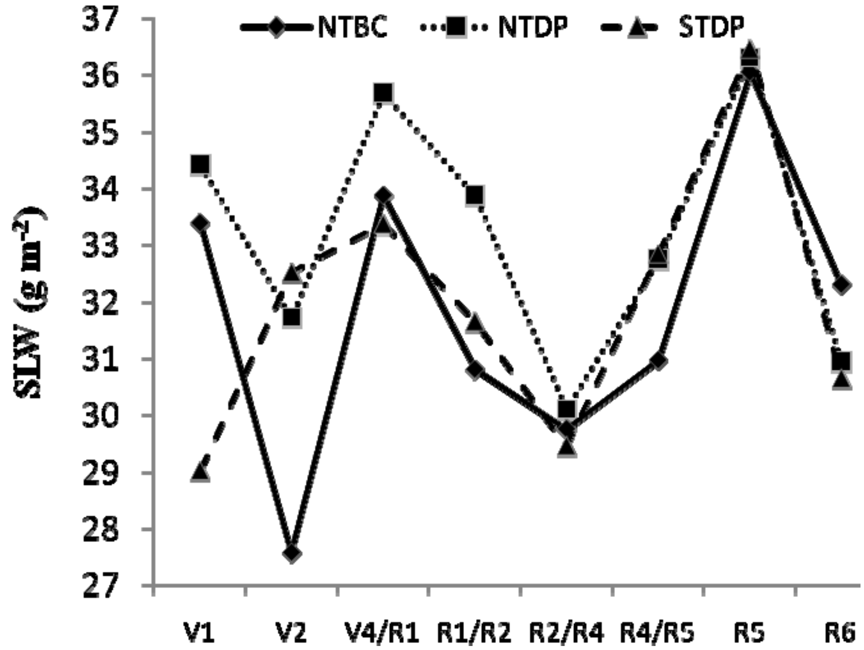

Fig 3: Effect of tillage/placement and sampling interaction on SLW for selected plots

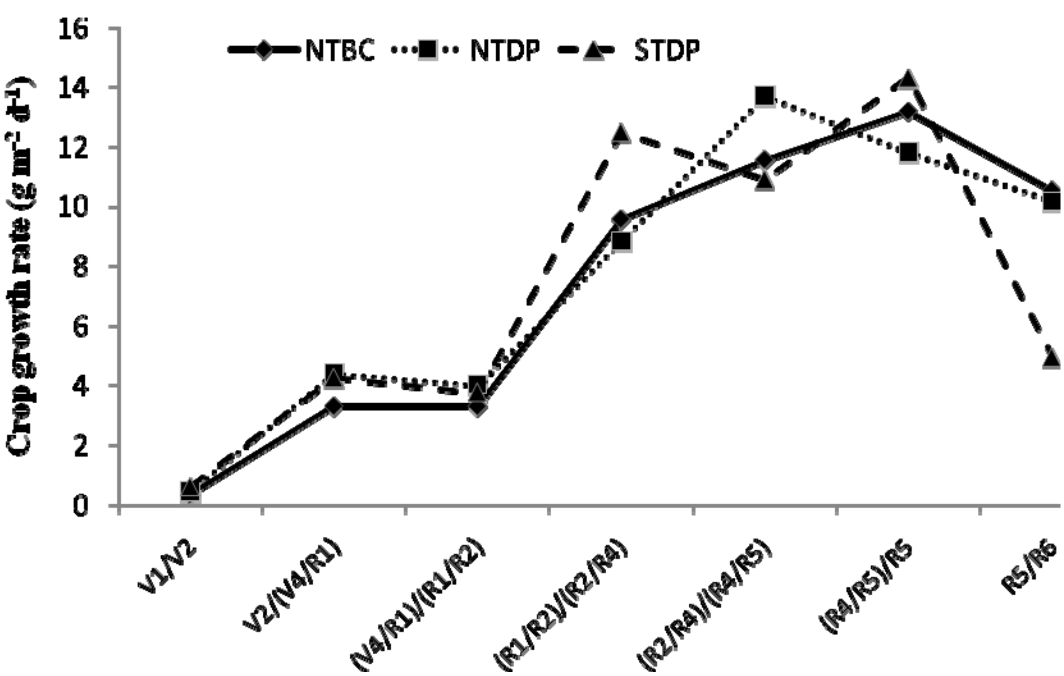

Fig 4: Effect of tillage/placement at different development stage intervals on crop growth rate

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