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Soybean Planting Date, Row Width, and Seeding Rate Response in Three Tillage Systems

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Soybean [*Glycine max* (L.) Merr.] and corn (*Zea mays* L.) are commonly grown in rotation, but information regarding soybean production in conservation-tillage systems has lagged behind corn. This study was conducted to determine the influence of planting date, row width, and seeding rate on soybean grain yields, plant stands, and other agronomic characteristics, as affected by tillage intensity. Two field studies were conducted at Arlington, WI, with no-tillage (NT), reduced tillage (RT), and complete tillage (CT) systems, using 'Hodgson 78' (Group I) and 'Corsoy 79' (Group II) varieties. In one 4-yr study, soybeans were seeded in 8- and 30-in. rows in mid-May, late May, and mid-June. Yields in NT were 5.3 and in RT 2.8 bu/acre lower than in CT. Solid-seeded soybeans (8 in.) yielded 3.1 bu/acre more than wide rows (30 in.). This yield advantage for solid-seeding, however, reversed at the latest planting dates in CT and RT. Early and late plant populations, plant height, and lodging were also lower in NT and RT than in CT. In a second study, soybeans were seeded in 8-in. rows at 50 000 to 300 000 viable seeds/acre in three tillage systems for 3 yr. Plant emergence was 13 and 15% greater in CT than either RT or NT, respectively, when averaged across seedling rates. Late-season stands did not differ among tillages at the lower seeding rates (50 000 and 100 000 viable seeds/acre). At the higher seeding rates (150 000 to 300 000), however, the NT and RT systems required an additional 50 000 seeds/acre to achieve harvestable plant stands equivalent to CT culture. When averaged across all seeding rates, CT outyielded NT and RT by an average of 4.5 bu/acre. When yields at equivalent final stands were compared, however, yields in CT were less than 3 bu/acre higher than RT or NT. Soybean seeding rates in NT and RT systems must be approximately 15% to 32% higher than those normally used in CT if equivalent yields are to be expected.

Although corn production in conservation tillage, including NT, is increasing, use of reduced-tillage systems for soybean has lagged because of problems such as weed control (4, 5, 13) and reduced plant stands (5, 15, 19). Since soybean is commonly grown in rotation with corn, however, solutions to

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Abbreviations: CT, complete tillage; GS, growth stages: NT, no-tillage; RM, relative maturity; RT, reduced tillage

soybean production problems in conservation tillage systems must keep pace with similar technology in corn.

Yield advantages for solid-seeding soybean (2, 7, 8, 17, 18), and for timely planting (2, 17, 18), have been documented in studies conducted using CT. Soybean yields in conservation tillage systems, however, are often lower than yields with complete tillage (4, 11, 15, 16, 19, 20). Reduced emergence and final plant stands from comparable seeding rates may account for part of the yield reductions (11, 12, 15, 19). Burnside et al. (5) increased seeding rates each year in a weed control study involving conservation tillage systems in order to obtain adequate plant stands. Cooler and moister soil environments, which frequently occur in conservation-tillage systems- particularly early in the growing season (14, 19), may be primarily responsible for reduced soybean emergence.

Suggested seeding rates for solid-seeded soybean in CT systems are between 150 000 and 180 000 viable seeds/acre (2, 3, 6, 7, 21). Speed of canopy closure affects moisture conservation (10) and weed suppression (4, 12, 16), which are advantageous for stand establishment in both conservation and CT systems. Soybean plants compensate in yield over a broad range of plant densities, providing the stands do not fall below 50 000 to 70 000 plant/acre (3, 16). Compensation is achieved through adjustments in pods per plant, seeds per pod, seed weight, and branching (8, 16, 21). Natural plant thinning of stands generally occurs when plants are above optimum densities (2, 16).

Freed (12) found that final plant densities for NT and mulch tillage were 24 and 9% less than CT, respectively. He reported canopy cover was greater in CT than in NT 4 wk after planting. Lodging was lower in NT than in other tillage systems, due to lower actual plant densities. Seeding rate increases of 10 and 15% over CT rate were recommended for mulch-till and NT, respectively.

Optimum planting dates, row widths, and seeding rates for establishing adequate plant stands and obtaining optimum yields in conservation tillage systems, as opposed to complete tillage, have not been determined. Objectives of these studies were (i) to determine effects of soybean planting date, row spacings, and tillage systems and measure interactions among these management practices; and (ii) to determine the optimum seeding rate necessary to establish adequate final plant populations for maximum yields in conservation tillage systems.

MATERIAL AND METHODS

Two field studies (planting date x row spacing, and seeding rate) were conducted on adjacent fields from 1983 through 1986 at the University of Wisconsin Arlington Research Station. The soil was a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll) consisting of loess on silty sediments 3.2 to 5.0 ft thick over medium textured outwash, well to moderately well drained with a 2% slope. Average soil test indicated a pH of 6.1, 4.0% organic matter, 128 lb P/acre, and 320 lb K/acre. Fertilizer was broadcast prior to planting in accordance with soil test recommendations.

General Practices

Planting was done using a Tye No-till drill[1] equipped with 16-in. diameter rippled coulters on 8-in. centers in front of double-disk openers and dual press wheels, with a light spring tine drag mounted

[1]Mention of vendor or proprietary product does not constitute a guarantee or warranty of the vendor or the product by the University of Wisconsin, and does not imply its approval to the exclusion of vendors or products that may also be suitable.

behind to level ridges, and a John Deere 7000 Maxemerge consisting of four 30-in. rows. Seeds were planted at a depth of 1.5 in. each year except 1986, when seeds were placed 2.3-in. deep due to dry soil at planting. The previous crop in all years was corn. Plot length was trimmed to 30 ft between growth stages (GS) V1 and V3. In narrow-row plots, eight 8-in. rows were planted and the center six rows mechanically harvested; in the wide-row plots, four 30-in. rows were planted and the center two rows were mechanically harvested with a plot combine.

Weed-free plots were maintained with herbicides and hand weeding to more accurately evaluate yield responses. Herbicides applied included post-emergence applications of bentazon at 1 lb/acre plus acifluorfen at 0.15 lb/acre plus sethoxydim at 0.3 lb/acre plus 1 qt/acre of crop oil concentrate. In all years, postemergence treatments were applied between 15 and 33 d after planting when the soybeans were between GS V2 and V5.

Experimental Variables

Study 1. Tillage, planting date, and row width. Research was conducted each year from 1983 to 1986 using a split-split-split-plot design with three replications. **Tillage systems** were the main plots and consisted of:

NT - Soybean seed was placed directly into the soil through undisturbed corn residue which left an 85% crop-residue cover on the soil surface.

RT - Treatments were established with a para plow in the fall, operated to a depth of 18 in., with no secondary tillage in the spring, which left 66% residue cover.

CT - Complete tillage included fall moldboard plowing followed by cultivation and cultimulching in the spring, which left 7% residue cover.

Similar tillage strips were established in an adjacent area which permitted soybean to be planted following corn in each year of the studies. Corn was produced using the same tillage variables as for soybean**.** **Planting dates** were the subplot treatments. Soybeans were planted each year on 15 May ± 4d, 30 May ± 4 d, and 13 June ± 2 d. **Row widths** of 8 and 30 in. were sub-subplots. Untreated seeds were planted at 200 000 and 148 000 viable seeds/acre in 8 and 30-in. rows, respectively. These seeding rates corresponded to the recommended optimum seeding rates for soybean in narrow- and wide-row culture using CT. **Varieties** were sub-sub-subplots and consisted of 'Hodgson 78', an early Maturity Group I 100-d relative maturity (RM) and 'Corsoy 79' a Group II variety of 110-d RM.

Study 2. Seeding rate and tillage. Research in this study was conducted each year from 1984 to 1986 using a split-split-plot design with four replications. **Tillage** systems were the main plots, and **varieties** were the subplots, both of which were the same as described for Study 1. **Seeding rates** (x 1000) of 50, 100, 150, 200, 250, and 300 viable untreated seeds/acre were the sub-subplots. Planting was 18 May ± 4 d in 8-in. rows.

Plant and Growth Measurements

Plant stands were measured in a 20-sq-ft area early (between GS VC and V3), and late (just prior to harvest at GS R8). At harvest, plant height, lodging (using a visual rating system of 2 = all plants erect to 5 = all plants prostrate), and grain yields (adjusted to 13% moisture) were determined. Crop emergence was calculated as a percentage, based on the number of plants at the early stand vs. the number of viable seeds planted. Plant survival was calculated as a percentage of the late stand vs. the early stand. Crop residue cover was determined prior to planting using the photographic technique at a height of 9 ft similar to that described by Williams (22). All data were subjected to the analysis of variance and comparisons were made using Fisher's protected LSD test (FLSD) or single degree of freedom contrasts. Orthogonal polynomials were determined for the seeding rate study and appropriate regression analysis performed.

RESULTS AND DISCUSSION

Study 1. Planting Date x Row Width Interactions with Tillage

Tillage, planting date, row width, and variety each significantly affected yield (Fig. 1) and agronomic characteristics (Table 1) in this 4-yr study. Soybean yields were lower with reduced intensity of tillage. Yield was 5.3 bu/acre lower in NT and 2.8 bu/acre lower in RT than CT ($P<0.05$). Early and late planting population, plant height, and lodging also were reduced with reduced intensity of tillage. While the two varieties differed for all variables except early plant population, they responded similarly to tillage, planting dates, and row spacings. Similar tillage studies conducted in Wisconsin and Nebraska, using a broad range of variety maturities and plant types, also indicated a lack of variety by tillage interaction (10, 15). Therefore our data presentation and discussion are the mean of both varieties.

Row Spacing Effects on Yield and Plant Stands. Soybeans planted in 8-in. rows had the greatest yield advantage over those planted in 30-in. rows at mid- to late-May plantings, regardless of the tillage system (Fig. 1). When

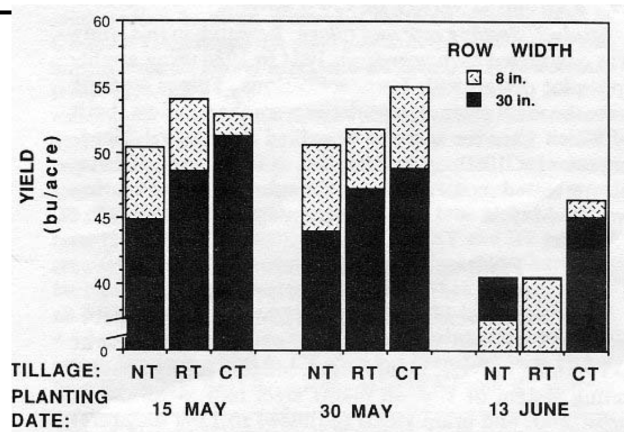

Fig. 1. Study 1, soybean grain yield in no-tillage (NT), reduced tillage (RT), and complete tillage (CT) from three planting dates and two row spacings, averaged for two varieties and 4 yr at Arlington, WI. The FLSD (0.05) for comparing row widths within tillages and planting dates = 2.5 bu/acre, tillages within planting dates and row widths = 3.0 bu/acre, and dates within tillages and widths = 2.7 bu/acre.

planting was delayed to mid-June, yields in 30-in. rows were higher than 8-in. rows under NT. Row spacing did not affect yields with RT or CT at the late planting date. This is in contrast to most reports that suggest the later soybeans were planted, the greater the advantage for planting in narrow rows (2, 16). The yield differences found in our studies may have been the result of plant population differences. At the mid- and late-May plantings, emerged and harvested plant populations were greater in 8-in. rows than in 30-in. rows (Fig. 2). Plant stand differences early in the season, were similar to the 26% seeding rate difference (200 000 vs. 148 000 seeds/acre) between row widths. For the mid-June planting, plant stands at harvest were not different between the two row widths in NT and RT and were about 10% higher for 30-in. rows in CT. When averaged over all tillages, planting dates, and varieties, emerged plant stands were only 8% greater in narrow rows (compared with 26% higher seeding rates), indicating a better emergence rate with reduced intrarow spacing of planted seeds in 30-in. rows.

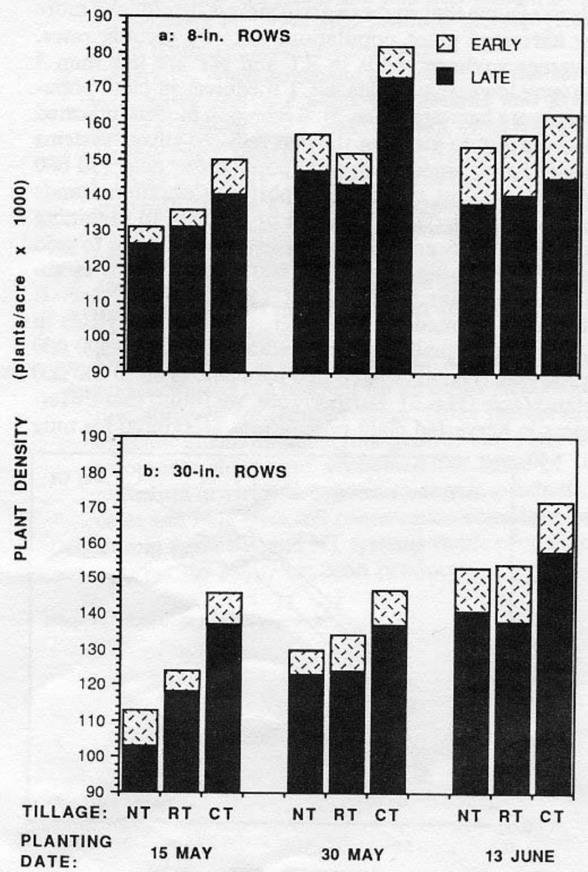

Fig. 2. Study 1, early and late soybean plant densities in no-tillage (NT), reduced tillage (RT), and complete tillage (CT) from three planting dates in two row spacings, averaged for two varieties over 4 yr at Arlington, WI. The FLSD (0.05) for comparing tillages within planting dates and row widths = 15 000 plants/acre, and dates within tillages and row widths = 14 000 plants/acre.

Table 1. Main effect of tillage system, planting date, row width, and variety (Study 1 – 1983-1986) and seeding rate (Study 2 – 1984-1986) on soybean grain yield and other agronomic characteristics. Arlington, WI.[†]

Main effect	Yield	Plant Population		Plant survival[‡]	Plant height	Lodging score[§]
		Early	Late			
	bu/acre	Plants/acre X 1000		%	In.	1-5
		Study 1				
Tillage System						
NT	44.7	139	129	93	40	2.7
RT	47.2	143	133	93	41	3.1
CT	50.0	160	148	93	42	3.3
FLSD (0.05)	2.5	6	7	NS	1	0.4
Planting Date						
15 May	50.4	133	126	95	41	3.0
31 May	49.6	150	141	94	42	3.2
13 June	41.9	159	143	90	40	3.0
FLSD (0.05)	1.6	6	7	3	1	NS
Row width (in.)						
8	48.8	153	143	93	41	3.0
30	45.7	141	131	93	41	3.1
Probability	*	*	*	NS	NS	*
Variety						
Hodgson 78	46.8	146	134	92	39	2.6
Corsoy 79	47.8	149	140	94	44	3.5
Probability	*	NS	*	*	*	*
		Study 2				
Seeding rate						
50	35.9	44	43	98	33	2.3
100	43.3	87	84	97	34	2.4
150	50.8	122	113	93	35	2.6
200	53.1	148	139	94	36	2.5
250	53.7	170	157	92	36	2.7
300	53.3	199	175	88	36	2.9
FLSD (0.05)	1.6	9	8	9	1	0.2

*Indicates that the two values are significantly different at the 5% level of probability. NS indicates nonsignificance.

[†]Tillage systems were no-tillage (NT), reduced tillage (RT), and complete tillage (CT). Seeding was at 200 000 and 148 000 viable seeds/acre in 8- and 30-in. rows, respectively, for Study 1.

[‡]Plant survival % - (plant stand early at V1 ÷ plant stand late at R8) x 100.

[§]Lodging Score – 1 = all plants erect and 5 ÷ all plants prostrate.

Plant stands at harvest of soybean from 8-in. rows at the early planting date did not differ between RT and CT (Fig. 2), and yields were similar (Fig. 1). Moisture conservation may have given a slight yield advantage to RT at the early planting date while a modest amount of tillage overcame some of the inhibitions to early growth and yield noted in other studies (12, 15, 19). Even though plant stands were similar between RT and NT at the second planting date for both row spacings, RT outyielded NT.

Planting Date Effects on Yield and Plant Stands. Although yields decreased with delayed planting (Fig. 1, and Table 1), particularly from 30 May to 13 June, the average number of emerged and harvested plants increased at each date (Table 1). Rainfall from April through June averaged 2.9 in. below normal in 3 of the 4 yr of this study. We feel that plant emergence and harvest density, between the first two planting dates, were influenced more by increasing soil temperatures than by lack of moisture in the seed zone. By the mid-June planting, however, dry soil conditions in CT caused lower plant emergence and survival in 8-in. rows with wider intrarow seed spacings (Fig. 2). Moisture conservation has been recognized as a beneficial effect in conservation tillage systems (RT and NT in this study), and may have benefitted emergence in 8-in. rows for these tillage systems by the final planting date. Yield compensation can occur across a broad range of plant populations, but it is clear that improved stands, regardless of tillage, established at later planting dates cannot compensate for the shorter growing season (2, 18).

Interactions did occur between tillage intensities and other agronomic factors, such as plant height and lodging. Deviations from the main effect (Table 1), however, such as decreased plant height and lodging with decreasing tillage, were related to differences in plant population more than to tillage differences.

Study 2. Seeding Rate Interactions with Tillage

Maximum soybean yields of 53.7 bu/acre occurred at the 250 000 viable seeds/acre planting rate, when averaged over the two varieties and three tillages (Table 1). Yields at the 200 000 and 300 000 seeding rates were not different but yields were lower at the lower seeding rate. Final plant populations at the 250 000 and 300 000 seeds/acre planting rate were 157 000 and 175 000 plants/acre (Table 1), which is within the previously reported optimum population ranges (2, 3, 7, 21). CT yielded 4.5 bu/acre more than RT and NT systems, which is similar to the yield advantage found in the planting date x row spacing study discussed earlier and in tillage studies conducted to compare variety response (15; Fig. 3).

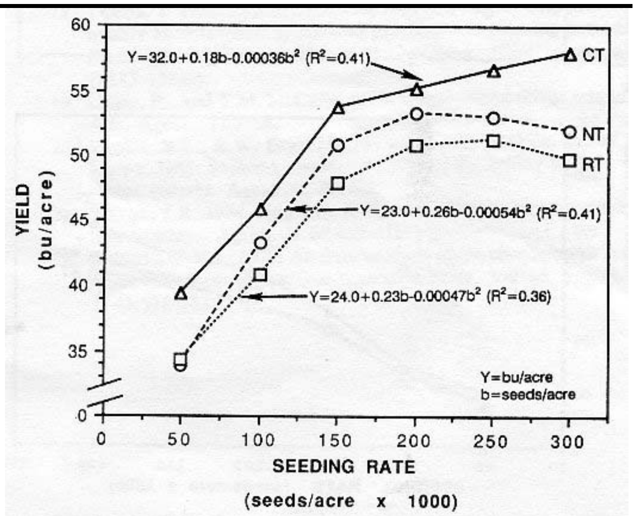

Fig. 3. Study 2, soybean yield and prediction models in response to seeding rate for no-tillage (NT), reduced tillage (RT), and complete tillage (CT) systems, averaged for two varieties over 3 yr at Arlington, WI.

Early Plant Population Effects. Early plant populations determined shortly after emergence (Fig. 4) were greater in CT than in RT and NT but interactions with seeding rate were not observed, indicating differences due to tillage were consistent across seeding rates. Using single degree of freedom contracts, we found that early stands from the 250 000 and 300 000 seeds/acre rates in RT and NT were equivalent to early plant stands at the 200 000 and 250 000 seeds/acre rates in CT, respectively.

Late Plant Population Effects. Although late plant populations differed among tillages (Fig. 4b) and years (data not shown), more plants were present at harvest in CT than in either RT or NT. Late plant populations did not differ between tillages at the 50 000 and 100 000 seeds/acre rates, however harvested plant populations were greater in CT than RT or NT at seeding rates of 150 000 or higher. Late stands in RT at 250 000 and 300 000 seed rates were equivalent, respectively, to the 200 000 and 250 000 seeding rates in CT. Late populations for NT seeded at 250 000 seeds/acre were equivalent to the 200 000-seed rate of CT, while a seeding rate of 300 000 in NT produced fewer harvested plants than the 250 000-seed rate in CT.

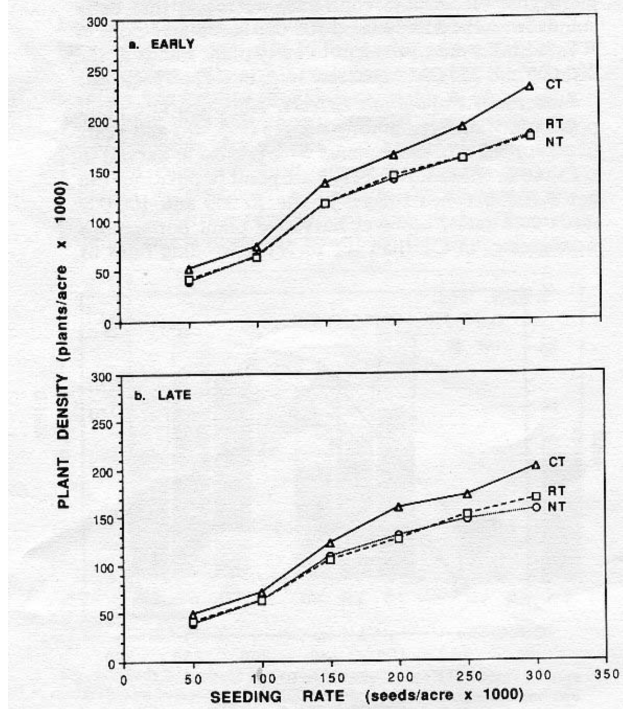

Fig. 4. Study 2, (a) early and (b) late soybean plant densities in no-tillage (NT), reduced tillage (RT), and complete tillage (CT) from six seeding rates, averaged for two varieties over 3 yr at Arlington, WI.

Problems in establishing and maintaining equitable plant populations with reduced tillage have been noted in previous work (12, 15, 19). Cooler early-season soil temperatures can reduce crop emergence in conservation tillage (6, 15, 16, 19). Higher seedling emergence has been associated with reduced plant survival, but our results indicate that plant survival is no greater with lower populations resulting from a particular seeding rate in conservation tillage than equivalent seeding rates and higher early populations in CT. Therefore, compensation for

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Abbreviations: CT, complete tillage; GS, growth stages: NT, no-tillage; RM, relative maturity; RT, reduced tillage

excessive seeding rates by natural plant thinning over the season did not equilibrate stands among tillages, somewhat contrary to previous reports from CT (2, 17). The only stands to exceed the reported range of optimum plant populations in any tillage, however, were from seeding rates of 250 000 and 300 000 seeds/acre in CT, which were between 180 000 and 225 000 plants/acre (Fig. 4b). These populations are 12 to 25% higher than the upper limits previously reported as optimum, however in this study they also corresponded to the highest grain yields in CT (Fig. 3).

Grain Yield vs. Seeding Rate. Average yields in CT were greater at all seeding rates than in either of the conservation tillage systems (Fig. 3). Yields in NT exceeded RT only at 100 000 seeds/acre, but average yield responses across seeding rates were not different between these two tillage intensities. Soybean yield in NT and RT peaked at a 250 000 seeds/acre rate as opposed to CT, which had highest yields at 300 000 seeds/acre. Yield differences in CT were not as great between seeding rate intervals above 150 000 seeds/acre. Using regression equations, the peak soybean yield in NT was predicted at a seeding rate of 232 000 viable seeds/acre. The same yield could be obtained by planting 176 000 viable seeds/acre in CT, which is within the reported optimum seeding rates for solid-seeded soybeans. Therefore, to obtain equivalent yields in NT to those of CT, a grower planting at 176,000 seeds/acre inCT must increase seeding rates by 32% in NT. If a g rower already seeds near 200 00 seeds/acre in CT, seeding rates must be increased by 16% in conservation tillage systems. These seeding rate increases for reduced tillage are considerably greater than those previously suggested in Wisconsin studies (12).

Grain Yield vs. Harvest Populations. It seems reasonable to assume that soybean grain yield is determined more by harvested plant populations than by seeding rates. Average soybean yields in RT and NT are less than 3 bu/acre lower than yields in CT if equivalent plant populations are harvested (Fig. 5). Regression models indicated that maximum yields in the two reduced tillage systems would be obtained from final populations near 150 000 plants/acre, just as has been reported as optimum stands for CT (3, 21). Therefore, one of the keys to obtaining maximum soybean yields in conservation tillage is to seed at sufficiently high rates (232 000 seeds/acre) to establish harvest stands of at least 150 000 plants/acre. It should be pointed out, however, that soybean yields in CT did not actually peak at seeding rates up to 300 000 seeds/acre (Fig. 4) or harvested populations up to 200 000 plants/acre (Fig. 5). Furthermore, we found that differences in harvested plant populations accounted for only 61% of the variation in yield among tillages and seeding rate accounted for only 39% of the variation in yield.

Other research (1, 9, 19) suggests that root growth may be inhibited in reduced tillage the first few seasons after tillage is reduced. Reduced early soybean growth and development rates under reduced tillage systems may also be contributing to the slightly lower yields (14, 15). It appears, however, that

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much of the reduction in soybean yields using reduced tillage can be overcome by adjusting seeding rates so that the number of harvested plants is equivalent to that in conventional tillage.

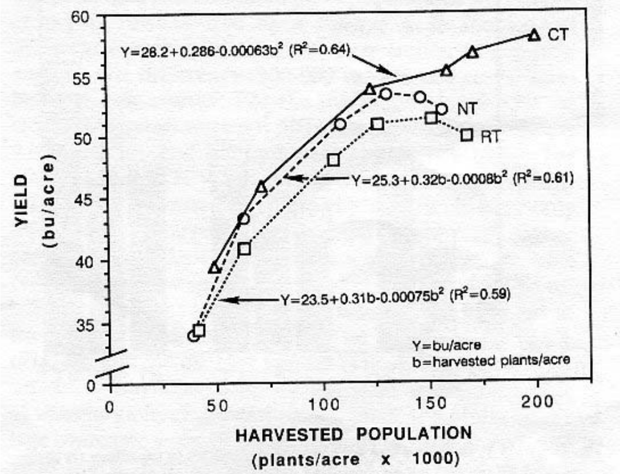

Fig. 5. Study 2, soybean yield and prediction models in response to plant populations at harvest, for three tillage systems, averaged for two varieties over 3 yr at Arlington, WI.

INTERPRETIVE SUMMARY

Results from these studies indicate several considerations can increase producer yields and net economic returns in the northern Corn Belt when planting soybean using the same reduced tillage systems in rotation with corn:

1. Soybean production practices that maximize yields in CT systems can also be used to maximize yields in RT and NT systems. Factors such as early planting, use of narrow rows, and selection of high yielding soybean cultivars also produce the top yields when using reduced tillage systems.
2. Generally, when soybeans are seeded at the same rate, early and late plant populations and grain yields are lower in RT and NT than when the same seeding rate is used in CT. Yield differences between CT and RT or NT, however, can be narrowed from approximately a 4 bu/acre difference to less than a 3 bu/acre difference if equivalent populations are harvested. Results from these studies indicate it is necessary to increase seeding rates by 32% (176 000 in CT to 232 000 in NT) in order to obtain nearly equivalent soybean yields.
3. Differences in seeding rate and harvested plant population did not account for all of the yield reduction observed for reduced tillage. Other factors such as reduced early-season root growth and plant development may have accounted for some of the reduction in yield. Economic savings in production costs and long-term soil conservation considerations should make RT and NT systems viable production options for many soybean producers.

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