WHEAT YIELD REDUCTION DUE TO EROSION FROM SIMULATED RAINFALL

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SUMMARY:

The reduction in wheat grain yield due to a heavy
rainfall directly after planting is presented.
Water was applied with a rainfall simulator. The
relationship between final stem count, fall emer-
gence, and grain yield are analyzed. Breakeven
analysis for determining whether to replant is
generated and an example given.

KEYWORDS: wheat, rainfall, rain simulator,
erosion, yields

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Wheat Yield Reduction due to Erosion from Simulated Rainfall

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Abstract

A heavy rain occurring within a few days after winter wheat planting can significantly reduce winter wheat plant emergence, stem count and grain yield. A 30 mm rainfall in 30 minutes can reduce fall wheat emergence by 50 percent, which can reduce stem count by 35 percent and grain yield by 23 percent. Linear equations were developed for stem count and grain yield as a function of fall emergence, and grain yield as a function of stem count. Decision-making criteria and a worksheet were developed to determine whether to replant the winter wheat in order to minimize financial losses. Rather than wait 10 to 14 days for complete emergence, rainfall amount within 30 minutes was used to predict emergence and subsequent wheat grain yield loss.

Introduction

Winter wheat (Triticum aestivum L.) is a major crop in the Central Great Plains of the United States. It is primarily grown using a two-year, wheat-fallow, clean-till cropping system. Reduced-tillage and chemical-fallow systems are being adopted which leave residue or stubble from the previous wheat crop on the soil surface at planting time. Winter wheat is planted primarily with grain drills that have hoe or disk-type openers at a seeding depth of 25 to 40 mm. Typical drills have V-shaped steel press wheels, flat steel press wheels, or flat rubber press wheels These drills form V-shaped furrows with seed placement below the furrow bottoms.

Rain storms occurring after wheat planting can inhibit emergence because soil from the ridge and sides of the furrow will erode or slump into the bottom of the furrows. Increasing intensity and duration of a rain storm increases the amount of soil slump in wheat furrows. High intensity storms generally pond water on the surface sooner, eliminating soil water matric potential at the surface which reduces aggregate stability. Amount of soil eroded generally increases with storm duration, with rain intensity normally declining with time for the longer duration storms. If populations of the remaining emerged wheat plants are too low, grain yields may be reduced at harvest.

The shape of the furrow can be affected by the type of press wheels. V-shaped steel press wheels generally leave a V-shaped furrow regardless of soil tillage or residue levels. Flat press wheels used with reduced tillage and increased surface residue conditions leave a flatter-bottomed furrow. Objectives of this research were to: 1) quantify any changes in winter wheat plant emergence, stem count and grain yield due to 30 minutes of uniform sprinkler-applied artificial rain applied within four days after planting, and 2) develop replanting decision criteria based on rainfall received after planting to eliminate the 10-14 day waiting period to assess emergence.

Procedures

The research was conducted from 1987 to 1989 at various locations within 10 km of the U.S. Central Great Plains Research Station near Akron, Colorado. Variables in this study were amount of applied water, residue

level and tillage. Wheat emergence, stem count and grain yield were measured. Tillage practices for this region are varied and some of the more common ones were included in this study. The soils, tillage treatments and residue levels are summarized in Table 1. The soils were described by Petersen et al (1986). Disk treatment followed the common practice of sweep-plowing during the fallow period and then disking just before planting. Clean-tilled plots were disked throughout the fallow period which left no surface residue at planting time. Residue levels were determined by picking up, drying and weighing surface residue samples from 1 m^2 areas.

Table 1. Site numbers, soils, tillage treatments and residue levels of the winter wheat emergence plots.

Year	Site	Soil Series and texture	Tillage treat. during fallow	Residue at planting(kg/ha)
1987	1.	Ascalon sandy loam	no-till	5860
			clean-tilled	0
	2.	Weld silt loam	disked	1790
1988	3.	Ascalon sandy loam	sweep-plowed	4880
			disked	2060

Check plots that received no simulated rain between planting and emergence were also included in the study. No natural precipitation occurred between planting and emergence except site 3 which received 6 mm of light rain over a 12 hour period. The plots at site 3 exhibited little or no soil movement due to this precipitation and were allowed to dry for 36 hours before the simulated rain treatments were applied.

A rainfall simulator (Hinkle, 1990), built from a design developed by Shelton et al (1985), was used to apply different simulated precipitation amounts in 30 minutes. Water application was monitored with a flow meter to attempt to maintain approximate water application levels but wind and humidity varied water application amounts somewhat between treatments. Water application amounts in the field plots were measured using four catch cans. Application amounts between 25 to 50 mm in 30 minutes were used, which correspond to 5 to 50 year annual-frequency storms, respectively (Hershfield, 1961) in the U.S. Central Great Plains region.

Winter wheat was planted at all sites with grain drills that had identical hoe furrow openers and either V-shaped steel or 75 mm flat rubber press wheels. Row spacing was 280 mm (11 in). The wheat was planted in moist soil. The seeding rate was 51 kg/ha using "Carson" variety in 1987 and "TAM 107" in 1988. Both varieties have a medium-length coleoptile. Simulated rainfall was applied to all plots within 4 days after planting and emergence started seven to ten days after planting. Land slope at all sites was less than one-half of one percent. Almost all non-infiltrated water ponded in the furrows and eroded soil did not move laterally along the furrows.

Each time the rainfall simulator was set up, water was applied to two plots. One plot was seven furrows formed with the V-shaped press wheels adjacent to another plot of seven furrows formed with the flat press wheels. The rainfall simulator was then moved a few meters to adjacent plots for the different treatment combinations of application amount and tillage. Each treatment combination was replicated four times. Fall emergence plant populations and at-harvest stem counts were counted in a 1 meter length of the 3 middle rows of each plot. The wheat grain was harvested during the summer of 1988 and 1989 with a small plot combine that cut four of the middle rows of each plot.

Results and Discussion

Winter wheat emergence, final stem count, and grain yield were all reduced due to the application of various amounts of simulated rainfall after planting. Increased crop residues on the soil surface, reduced tillage and the use of wider, flatter press wheels all helped to minimize emergence loss due to simulated rainfall (Hinkle, 1989), as shown in Fig. 1. No-till plots (which had the most surface residue), that were planted with 75 mm (3 in) flat rubber press wheels left a wide, flat-bottomed furrow as opposed to any clean-tilled plots and/or any plots that were planted with the more-traditional steel V-shaped press wheels. The latter all left a V-shaped furrow which filled-in to a greater depth with soil eroded from the tops and sides of the furrow ridges or from clods lying in the furrow which dissolved in standing water. Regression equations for fall emergence under the four different surface soil conditions are:

Clean-tilled and/or V-shaped press wheel planted wheat:

$$FE = 102 - 1.70W, \qquad\qquad R^2 = 0.810 \quad \ldots \ldots 1.$$

Wheat planted with 7.5 cm (3 in) wide press wheels:

Disk: $\qquad FE = 100 - 2.58W - 0.0228W^2, \quad R^2 = 0.975 \quad \ldots \ldots 2.$

Sweep-plow: $FE = 99 + 0.591W - 0.0270W^2, \quad R^2 = 0.980 \quad \ldots \ldots 3.$

No-till: $\qquad FE = 100 + 1.17W - 0.0296W^2, \quad R^2 = 0.961 \quad \ldots \ldots 4.$

where, $\quad$ FE = fall emergence, wheat, percent of non-watered
$\qquad\qquad$ W = water received or applied in 30 minutes, mm

Final grain yield of winter wheat decreased with increasing amounts of applied water after planting and with greater tillage (Fig. 2). All plots planted with the V-shaped press wheels and/or in clean-tilled soil had fall emergence and grain yield that were not statistically different. The averages of the grain yields for these plots are shown as the solid bars in Figure 2. Average grain yields for the dryland check plots were 2758 kg/ha (40.5 bu/ac) in 1988 and 2362 kg/ha (34.6 bu/ac) in 1989.

The no-till plots planted with the wide flat press wheels had 11 percent greater grain yield at the lower range of water application and the same grain yield at the higher range of water application than the dryland check plots. Fall emergence exhibited similar results as shown in figure 1. Evidently, the additional water increased emergence and grain yield more than furrow slumping decreased emergence and yield.

Since the two growing seasons were dissimilar due to different precipitation patterns and amounts, the results for fall emergence (FE), final stem count (SC), and grain yield (GY) were normalized to their respective non-watered dryland results. At site 2, SC and GY results were not included due to poor second-year growth due to low soil water before planting (non-fallowed). Growing season precipitation and average FE, SC, and GY for the non-watered, dryland check plots are shown in Table 2.

Table 2. Growing season precipitation, and average fall emergence, stem count and grain yield for the non-watered check plots.

Year	Growing Season Precip. (mm)	Fall Emergence (pl/m2)		Stem Count (pl/m2)		Grain Yield (kg/ha)	
		Ave.	S.D.	Ave.	S.D.	Ave.	S.D.
1987-88	321	147	10.5	773	38.9	2758	171
1988-89	190	147	4.8	374	30.4	2362	153

Stem count at harvest was reduced as a consequence of the reduced winter wheat plant emergence in the fall (Fig. 3). These results show an increasing relationship of percent SC to percent FE. A linear regression was done and resulted in,

$$SC = 39.3 + 0.522(FE), \quad r = 0.756 \quad \ldots \ldots \ldots \ldots \ldots 5.$$

where, SC = percent stem count, at harvest
FE = percent fall emergence

The no-till flat wheel plots tended to have a lower percent SC than the other plots because these plots had 100 percent or greater FE. Since the seeding rate was relatively high (51 kg/ha, 45 lb/ac), the no-till, flat-wheel plots had less tillering and subsequent less percent SC. No direct explanation can be found for why the disk, flat-wheel plots had greater than expected percent SC as a function of percent FE.

When percent GY is analyzed as a function of percent FE, a linear increasing relationship is also evident, although more poorly correlated (Fig. 4) with the linear equation defined as,

$$GY = 56.2 + 0.421(FE), \quad r = 0.578 \quad \ldots \ldots \ldots \ldots \ldots 6.$$

where, GY = percent grain yield
FE = percent fall emergence

The flat-wheel, disked, sweep and no-till plots that had greater percent FE also had a greater percent GY. The poor correlation in this relationship is due to: 1) the large variation of GY among the V-shaped and/or clean-tilled plots, and 2) the general poor correlation of percent GY to percent SC (Fig. 5) and defined as,

$$GY = 31.7 + 0.715(SC), \quad r = 0.677 \quad \ldots \ldots \ldots \ldots \ldots 7.$$

where, GY = percent grain yield
SC = percent stem count, at harvest

Black and Bauer (1990) showed similarly sloped regression equations at similar ranges of plant population, spike (stem) population and grain yield. However, they showed a nearly constant yield response between 110 and 170 plants per square meter with an increasing yield response above and below this range of plant populations.

Replanting Decision Criteria

If a heavy rain occurs between planting and emergence, and subsequently reduces FE and GY, then replanting the wheat crop may be necessary. Financial losses may be minimized by replanting. However, time could be saved if the replanting decision could be based on rainfall received rather than actual emergence which would require waiting 10-14 days for complete emergence. The criteria for deciding whether or not to replant will depend upon the following input factors:

1. the cost of the field operation of replanting the wheat
2. the cost of the wheat seed
3. the amount of soil water that is evaporated due to replanting
4. the amount of wheat yield that is lost due to late replanting
5. the amount of wheat that is produced per amount of available water
6. the potential wheat yield that is expected at harvest
7. the value of the future harvested wheat grain.

Using these seven factors and the relationships in Figure 1 (Eq. 1, 2, 3 and 4) and Figure 4 (Eq. 6), the value of any lost wheat yield and the total cost of replanting can be compared and a decision can be made about replanting.

A worksheet was developed to be a guide to make the necessary calculations for determining if replanting is justified. The worksheet is shown in Table 3 with a set of example input factors and calculations. In part A of the worksheet, the monetary value of any wheat yield loss due to an intense rain after planting is determined. In part B, the total cost of the replanting operation is determined, including the cost of seed and the replanting operation and the value of: 1.) soil water lost to evaporation due to replanting, and 2.) wheat yield loss due to replanting late in the fall season.

Since the replanting operation would likely occur as soon as possible after the rainfall event, soil water evaporation loss can be significant. Nielsen and Halvorson (1990) determined that 13 to 16 kg/ha-mm (5 to 6.5 bu/ac-in) of yield is produced per volume of available water. For dryland

wheat in high rainfall areas in which soil water is not a yield-limiting factor, then the steps to calculate the value of lost soil water are skipped over. For irrigated wheat, the irrigation cost to replace the lost soil water is used for the value of the soil water loss.

Potential winter wheat yield is lost if wheat is planted too late in the fall season because a greater percentage of the wheat plants will not have sufficient fall growth to survive the winter. Halvorson (1990) states that September 20 in the Northern Great Plains and October 1 in the Central Great Plains are typically used as deadline planting dates, after which potential winter wheat yields are reduced approximately 68 kg/ha (1 bu/ac) for each successive day after these dates. These deadline dates are only approximate because they vary with location due to climate and elevation.

The cost of the replanting operation, the cost of seed, and the value of any soil water loss and/or yield loss due to late replanting are summed to determine the total cost to replant the wheat crop. If the total cost of replanting is less than the value of the present existing yield loss, then financial losses may be minimized by replanting. A final concern is to not replant too soon after the rainfall and cause yield-limiting compaction. If this concern is great and the cost of replanting is not much less than the value of the yield loss, then the best decision may be to not replant.

Summary

Heavy rainfalls occurring within a few days after winter wheat planting can significantly reduce winter wheat plant emergence, stem count and grain yield. A 30 mm rainfall in 30 minutes can reduce fall wheat emergence by 50 percent, which can reduce stem count by 35 percent and grain yield by 23 percent. The use of surface residue, reduced tillage, and wider flatter press wheels helped reduce wheat emergence loss and subsequent yield loss.

Application of 15 to 30 cm of water after wheat planting actually increased wheat yields on non-tilled soil planted with 3 cm (10 in) wide, flat press wheels that leave wider, flat-bottomed furrows than the V-shaped steel press wheels. The additional water improved fall emergence and subsequent grain yield more than the detrimental effect that soil eroded into the furrow bottoms decreased emergence and yield. Linear equations were developed for stem count and grain yield as a function of fall emergence, and grain yield as a function of stem count.

Decision-making criteria and a worksheet were developed for deciding whether to replant the winter wheat in order to minimize financial losses. Rather than wait 10 to 14 days for complete emergence, rainfall amount within 30 minutes was used to predict emergence and subsequent wheat grain yield loss. The monetary value of the yield loss is determined from percent yield loss, the expected yield, and the expected wheat selling price. Replanting cost is determined from the cost of seed, the cost of the planting operation, and the value of any soil water loss due to the planting operation and/or the value of potential yield loss due to late replanting. Replanting may minimize financial losses if the total cost of replanting is less than the value of the present wheat yield loss. A final concern is to not replant too soon after the rainfall because yield-limiting compaction may occur if the soil is too wet.

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Table 3. Worksheet for determining the value of lost wheat yield due to a heavy rain after planting and the total cost of replanting.

Part A. CALCULATION OF THE VALUE OF THE PRESENT WHEAT YIELD LOSS.

1. From the fall emergence vs. water application amount graph, interpret percent Fall Emergence (PFE) for the tillage system, type of press wheels, and rainfall received.   PFE = _50 %_ ____ ____

2. Calculate Percent Grain Yield (PGY) expected at harvest, PGY = 56.2 + 0.421*PFE   PGY = _77 %_ ____ ____

3. What is the Expected Wheat Yield (EWY) (kilograms per hectare, (or bu/ac))   EWY = _40 bu/ac_ ____ ____

4. Calculate the Present Wheat Yield Loss (WYL) (kilograms per hectare, (or bu/ac))
   WYL = (100 - PGY) * EWY * 0.01   WYL = _9.2 bu/ac_ ____ ____

5. Expected selling price of the wheat (monetary value per kilogram, (or $/bu))   _$3/bu_ ____ ____

6. Value of the present yield loss, per area (monetary value per hectare (or $/acre)) [item 4 multiplied by item 5] $27.60/ac ____ ____

Part B. CALCULATION OF THE TOTAL COSTS OF REPLANTING THE WHEAT CROP.

7. Cost of the field replanting operation, per area (monetary value per hectare, (or $/acre)) $7.50/ac ____ $7.50/ac

8. Cost of the wheat seed for replanting, per area (monetary value per hectare, (or $/acre)) $6.00/ac ____ $7.00/ac

Note: Steps 9 through 12 calculate the value of grain yield or soil water lost due to extra soil water evaporation due to the replanting.

9. Estimate the depth of extra soil water evaporated due to replanting,   (mm, or (inches))   0.35" ____ 0.35"

Note: For non-irrigated wheat, skip item 10 and go to item 11.

10. For irrigated wheat, estimate the cost per area to apply the water depth in item 9, and skip items 11 and 12. (monetary value per hectare, (or $/acre))   — ____ $1/ac

11. Estimate wheat grain produced per volume of water (kg/ha-mm, or (bu/acre-inch))   5 bu/ac-in ____ —

12. Yield loss from soil water evap. after replanting (kg/hectare, or (bu/acre)) [item 9 multiplied by item 11]   1.75 bu/ac ____ —

13. Yield loss due to late replanting (>winterkill) (kg/hectare, or (bu/acre))   0 ____ 0

14. Total yield loss due to the replanting operation (kg/hectare, or (bu/acre)) [sum of items 12 and 13]   1.75 bu/ac ____ 0

15. Value of the total yield loss due to replanting (monetary value per hectare (or $/acre)) [item 14 multiplied by item 5] $5.25/ac ____ 0

16. Total cost to replant the wheat crop. (monetary value per hectare (or $/acre)) [sum of items 7, 8, 10 and 15] $18.75/ac DRYLAND $15.50/ac IRRIGATED

If item 16 is greater than item 6, then total replanting costs are greater than the value of the present yield losses, and financial losses are minimized by NOT replanting.

If item 16 is less than item 6, financial losses are minimized by REPLANTING
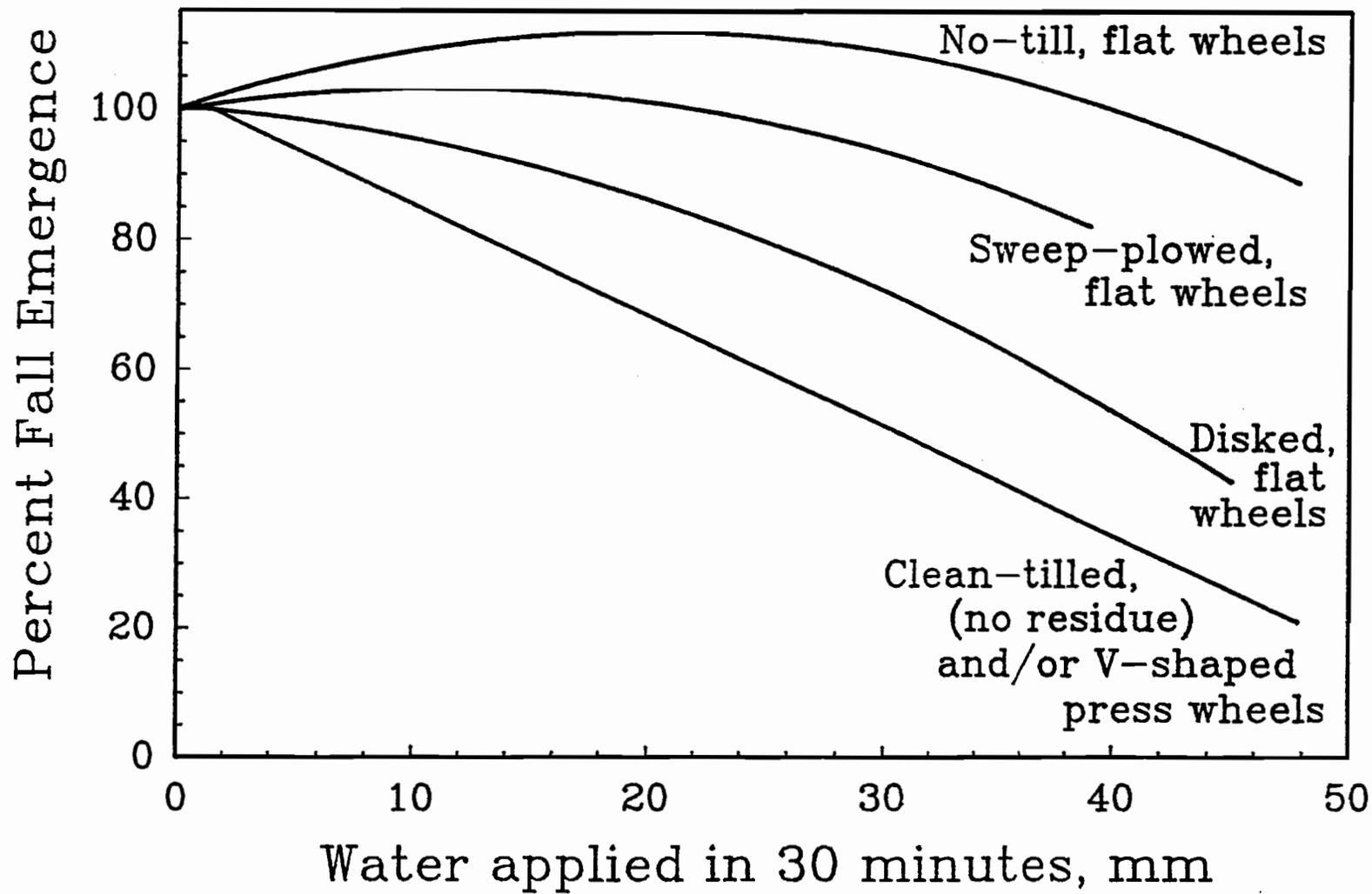
- 8 -

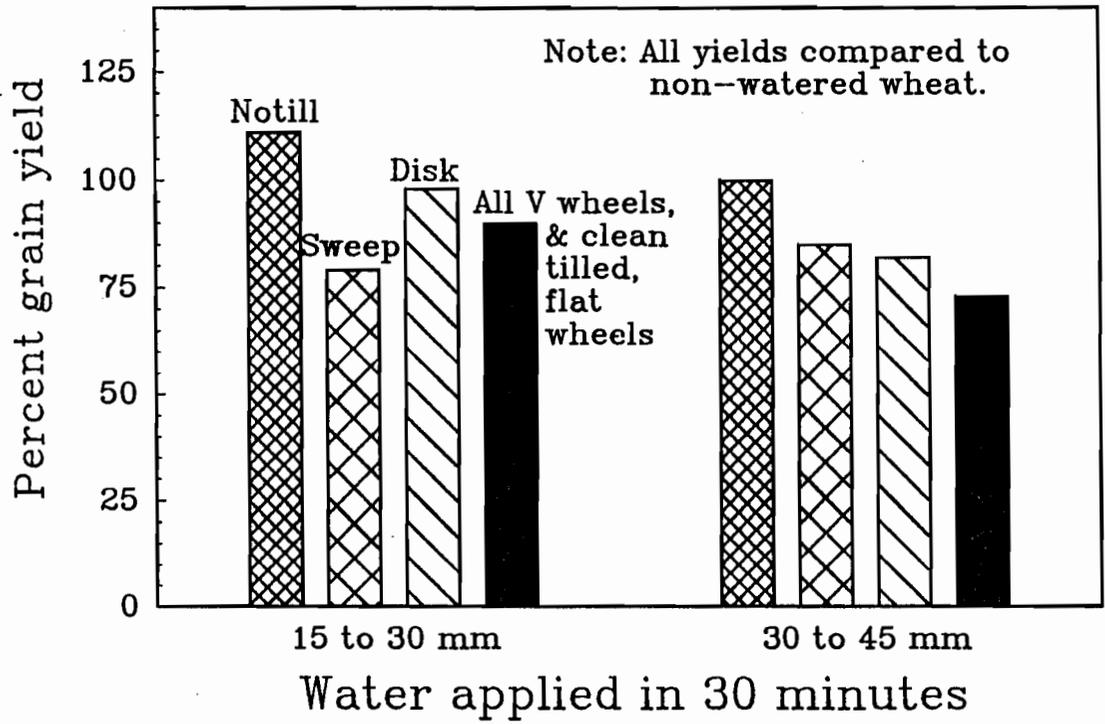Figure 1.   Percent fall wheat emergence versus water applied in 30 minutes

Figure 2. Percent wheat grain yield versus water applied in 30 minutes.
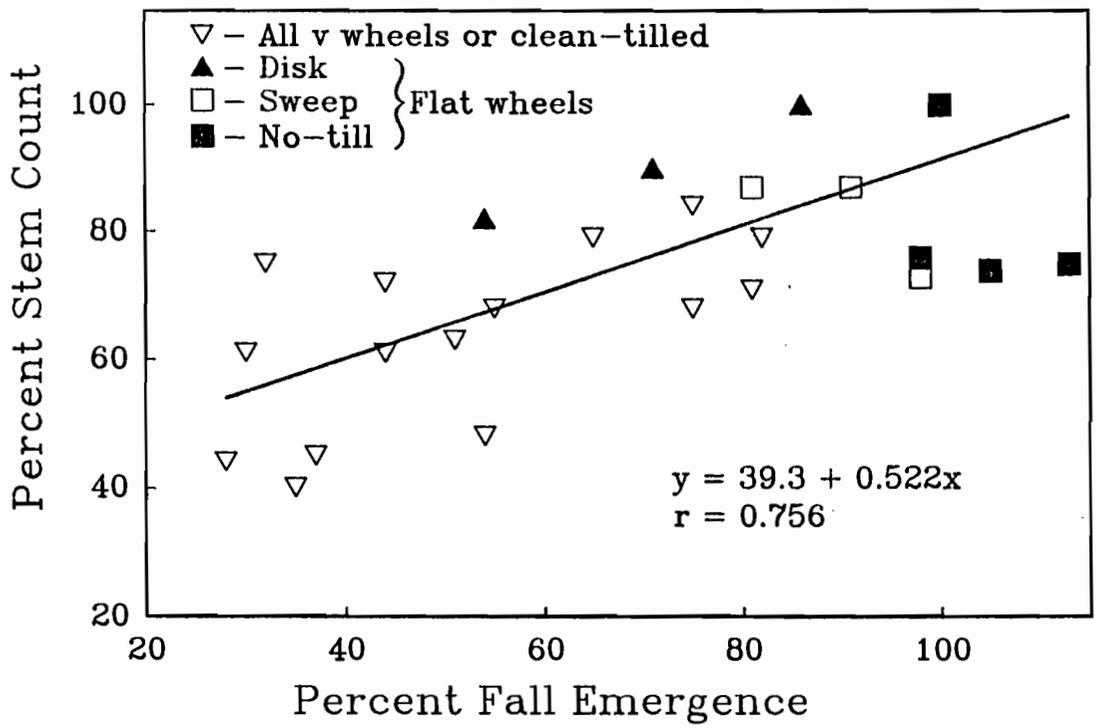

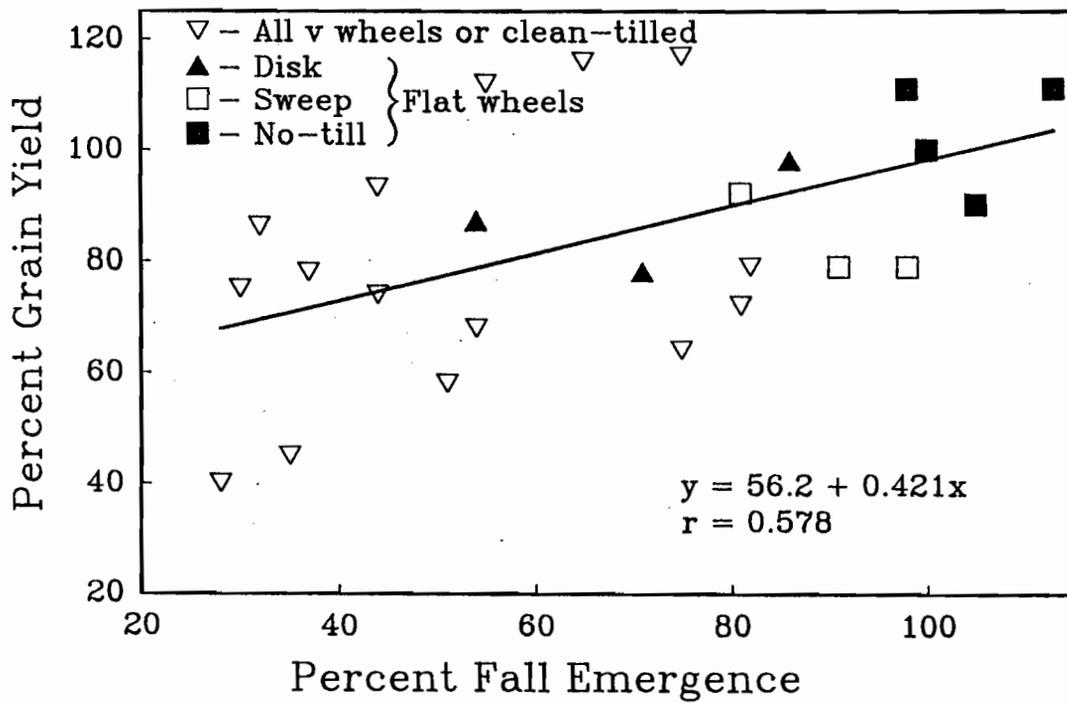Figure 3. Percent wheat stem count as a function of percent fall emergence.

Figure 4. Percent wheat grain yield as a function of percent fall emergence.
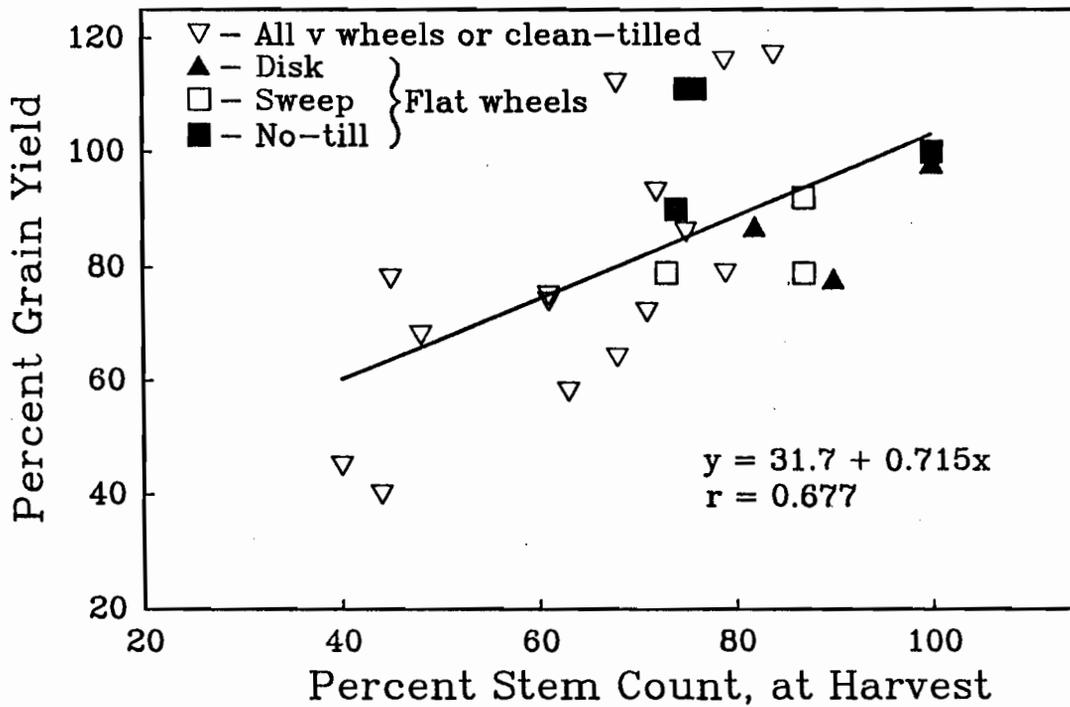
$$y = 56.2 + 0.421x$$
$$r = 0.578$$

Figure 5. Percent wheat grain yield as a function of percent stem count.

$$y = 31.7 + 0.715x$$
$$r = 0.677$$