better than visual estimates.

Trellis fill by itself does not adequately characterize a grapevine canopy. However, when it is combined with the point quadrat method of measuring the number of leaf layers in a canopy (Smart, 1985), objective, quantitative measurements of grapevine canopies are possible. Such measurements will often provide useful insights regarding the influence of vine manipulations on vine canopies.

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Comparing Sod Strength Parameters of Warm-season Turfgrasses Using a Hydraulically Driven Sod Strength Machine

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ADDITIONAL INDEX WORDS. sod strength, force, work, pull speed

SUMMARY. Research was conducted to evaluate the performance of a hydraulically driven turfgrass sod strength machine equipped with a force transducer to measure various strength parameters. The most commonly reported strength parameter, peak force (PF), continued to provide the quickest and easiest measurements of sod strength. Calculations of work involving the continuous measurement of sod strength over the duration of the stretch did not consistently improve the information provided by the PF measurement. Changes in sod bed pull speeds altered the calculations of work, whereas pull speed changes generally had little effect on force measurements, an important consideration for sod strength measurement devices that have limited control of

sod bed pull speed. The unit was marginally successful in distinguishing sod strength differences between St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze.] treated with various levels of pyridine herbicides. The device also provided strength parameters that distinguished the relative strengths of four warm-season turfgrass sods.

In commercial turfgrass sod production, success is achieved by rapidly growing a harvestable crop that has adequate tensile strength to facilitate handling at harvest and installation. Many machines have been designed to measure sod strength, with the most common strength measurement being the peak force required to tear a piece of harvested sod into two pieces. Rieke et al. (1968) developed the first technique in sod strength measurement by securing one end of the sod to an immobile frame and securing the other end of the sod to a movable frame that was weighted by pouring sand into an attached bucket. The weight of the sand broke the sod apart, and the weight was recorded as the force required to break the sod. Other researchers have modified Rieke's sod strength machine by installing electric motors, push-and-pull gauge scales, load sensors, and torque wrenches to measure the force required to break the sod, but all are still based on the same premise of attaching sod between an immobile and mobile frame and measuring the peak force required to tear the sod (Goatley and Schmidt, 1991; Hall et al., 1985; Jagschitz, 1980; Mitchell and Dickens, 1979; Parish, 1995; Philley et al., 1992; Troutman and Jagschitz, 1971; Turner and Dickens, 1987; Turner et al., 1990).

Burns and Futral (1980) used the Instron universal testing instrument to measure sod strength. This device offered uniform, adjustable speed, a printout of the breaking pattern, and a measurement of sod elongation before breaking; however, the Instron unit is expensive and is not designed for field use.

A hydraulically powered sod strength device was constructed at Mississippi State University, using the standard design of the stationary and mobile frames to tear a secured piece of sod into two pieces. A force transducer attached to a chart recorder was

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used to measure various sod strength parameters in addition to peak force to determine if the accuracy of sod strength measurements could be improved. This machine is the first portable unit using the combination of hydraulic power and a force transducer to measure sod strength.

The objectives of the research were to a) evaluate and calculate different variables that measure sod strength; b) evaluate the performance of a portable, hydraulically driven sod strength device; and c) determine what effect other measurable criteria associated with commercial sod harvesting (sod biomass, soil moisture, sod thickness, etc.) have on sod strength.

Materials and methods

A sod testing machine evaluated various measurements of sod strength—peak force (PF), average force (AF), pull distance (PD), total work (TW), peak work (PW), and average maximum work (AW)—as they related to sod biomass dry weight (DW) and, in one case, visual herbicide injury ratings. The machine consisted of two sod beds, each mounted on four steel wheels (Fig. 1). The wheels ran back and forth in door tracks. Metal tracks were used to minimize the rolling resistance of the wheels. The horizontal surfaces of the upper and lower parts of each sod bed were covered with 0.25-inch-thick (0.6-cm-thick) expanded metal. The upper frame was hinged to allow it to fit over varying thicknesses of sod and had nine 0.2-inch-diameter $\times$ 1-inch-long (0.5-cm-diameter $\times$ 2.5-cm-long) metal spikes located 1 inch (2.5 cm) from the leading edge that pierced the sod when the frame was lowered.

One of the two sod beds was held stationary by a 0- to 45-kg force transducer (Omega Engineering, Inc., Stamford, Conn.) attached to the bed and the frame of the sod test unit. The

other sod bed was attached to a hydraulic cylinder (model 4z194A; Dayton Elec. Mfg. Co., Chicago), which passed over the front part of the metal frame (Fig. 1). The hydraulic cylinder was powered using the hydraulic system on a conventional farm tractor. The speed at which the mobile end of the cylinder was moved was controlled by using a combination of the tractor's engine speed and mechanical stops for the hydraulic control lever. Two microswitches were mounted on the frame spaced at a distance of 12 inches (30.5 cm) apart. As the mobile bed moved past the switches, a strip chart recorder measured the time necessary to close both switches. The sod bed pull speeds available for use were 1, 2, and 3 inch/s (2.5, 5, and 7.5 cm $\cdot$ s $^{-1}$).

The signals for the force transducer were recorded on a strip chart recorder (model 595; Scientific Marketing, Georgetown, Texas) while using a chart speed of 12 inch/min (30.5 cm $\cdot$ min $^{-1}$). Calibration of the force transducer indicated that the output signal was very accurate from 0 to 220 kg. From each stripchart record we calculated values for each independent variable. PF was the maximum force recorded for a given sod type-bed speed-replication combination. AF was calculated as the average of all nonzero forces divided by the number of these forces measured over 0.2-s time intervals. The 0.2-s interval was the smallest time that could be read accurately from the strip charts. PD was defined as the sod bed travel distance over which the sod restraining force was ≥ 2.3 kg. PW was defined as the peak force multiplied by the pull speed multiplied by 0.2 s. AW was defined as the average of the three maximum force measurements multiplied by the pull speed multiplied by 0.2 s. TW was defined as the product of the average forces during each 0.2-s interval multiplied by the pull speed multiplied by 0.2 s.

Depending on the particular ex-

periment, biomass DWs, percent soil moisture (SM), and average sod thickness (AST) were also measured. Biomass DWs were taken by washing soil from the harvested sod sample and determining the weight of the biomass after drying in an oven for at least 48 h at 80 °C. Soil samples to determine percent soil moisture were collected from each sod strip harvested for measurements by removing a 2-inch-deep (5-cm) soil core from the corner of each strip. Soil wet weight was determined immediately after collection and soil DW was determined by drying at 80 °C for at least 48 h. Percent SM was calculated by subtracting soil DW from wet weight, dividing by wet weight, and multiplying by 100. AST was measured for all samples by measuring the thickness of the sod at the midpoint of the harvested sample, but in most instances the thicknesses were virtually identical and the variable was not included in the statistical analysis. The turf areas selected for this research were all located at the Plant Science Research Center on the campus of Mississippi State University.

HERBICIDE EFFICACY TRIAL. St. Augustinegrass (*Stenotaphrum secundatum*) turf grown on an unmodified Marietta fine sandy loam soil (fine-loamy, mixed, thermic, siliceous Aquic Fluventic Eutrochrepts; pH 6.5) was evaluated for sod strength in the last week of September 1990 following completion of a summer herbicide efficacy trial designed to evaluate St. Augustinegrass tolerance to foliar spray applications of pyridine herbicides. Treatments were a control, fluroxypyr (4-amino-3,5-dichloro-6-fluoro-2-pyridyl-oxacetic acid) at 2 and 4 lb acid equivalent (ae)/acre (2.3 and 4.6 kg/ae/ha), and triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid} at 1, 2, and 4 lb/ae/acre (1.1, 2.3, and 4.6 kg/ae/ha). Each treatment was replicated three times and the experiment was arranged as a randomized complete block. The turf was treated on 7 Aug. 1990 and percent turf injury ratings were made at 49 days after treatment (DAT), using a scale of 0 = no visible turf damage to 100 = dead turf. A commercial sod cutter was used

Fig. 1. Schematic of the sod strength testing device. A) Force transducer, B) mobile sod frame, C) stationary sod frame, D) hydraulic cylinder, E) wheel track.

to cut a single 12-inch-wide × 15-inch-long × 0.5-inch deep (30-cm-wide × 38-cm-long × 1.2-cm-deep) sod strip from each plot. To equate harvesting techniques with those of commercial sod producers, an attempt was made to keep sod thickness at 0.5 inch (1.2 cm) or less to minimize soil removal. Sod strength parameters measured were PF, AF, PD, and biomass DW. Differences between SM and AST measurements for sod strips were taken to be negligible and those values were not included in statistical analyses. A single sod bed pull speed of 2 inch/s was used for all samples in this trial.

BERMUDAGRASS PUTTING GREEN

TRIAL. In July 1991, a second experiment was conducted on a 'Tifgreen' bermudagrass (*Cynodon dactylon* × *transvaalensis* Burt-Davey) turf maintained as a golf putting green by mowing three times weekly at a 0.25-inch (0.6-cm) cutting height to evaluate independent variables calculated for sod strength measurements. The soil type was a Marietta fine sandy loam (as described previously) that had been modified over the past 10 years by topdressing with medium-textured sand as part of routine maintenance. Thirty-six strips of sod were harvested as previously described from the same immediate location in the 'Tifgreen' area. Sod bed pull speeds of 1, 2, and 3 inch/s were evaluated in a completely randomized design, resulting in 12 replications for each speed tested. Variables calculated following stretching of the bermudagrass sod were PF, AF, TW, PW, AW, and PD. SM and DW were taken as described previously. AST was recorded but was not included in the statistical analysis due to similarities between samples.

SPECIES TRIAL. A third research trial was conducted in Summer 1993 on 'Tifway' bermudagrass (*Cynodon* × *magensii* Hurcombe), 'Common' centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.], St. Augustinegrass, and 'Meyer' zoysiagrass (*Zoysia japonica* Steud.) turfs that were grown under minimal maintenance conditions [weekly mowing at 2 inch (5 cm), N fertility ≤40 lb/acre/yr (44 kg/ha/yr), and no supplemental irrigation] at the Plant Science Research Center. All turf areas had been established for at least 4 years. The soil type was an unmodified Marietta fine sandy loam. The turfs were harvested as described previously and data were collected for

PF, AF, TW, PW, AW, AST, PD, and biomass DW. SM was very consistent within samples because of a 0.5-inch (1.3-cm) rainfall event 2 days before sod stretching. Bed speeds of 1 or 3 inch/s were evaluated in a completely randomized design with six replications per pull speed for each species.

In the herbicide efficacy trial, the data were subjected to analysis of variance with mean separation done using Fisher's protected LSD. Linear and quadratic effects of the two herbicide rates were also investigated. In the putting green trial, analysis of covariance was used to compare treatments with DW and SM used as covariates. Where the effect of the covariates was significant, adjusted treatment means were compared. Linear and quadratic effects of speed were also investigated. In the species trial, analysis of covariance was used to compare treatments for each grass with DW and AST as covariates. Where effects of the covariates were not significant, analysis of variance and Fisher's protected LSD were used to analyze data. Regression equations are given for those variables where covariates are significant. In all hypothesis tests, the significance level used was 0.05. All statistical analyses were made with SAS (SAS Institute, 1987).

Results and discussion

HERBICIDE EFFICACY TRIAL.

Table 1. St. Augustinegrass injury ratings and sod strength parameters of peak force (PF) recorded; average force (AF), which is the average of all nonzero forces divided by the number of forces measured over 0.2-s intervals; pull distance (PD), which is the sod bed travel distance over which sod restraining force was ≥2.3 kg; and dry weight (DW) following treatments with pyridine herbicides.

Treatment	Level [†] (lb/ae/acre)	Injury [‡] (%)	PF (kg)	AF (kg)	PD (cm)	DW (g)
Triclopyr	1.0	8.0 a ^x	21.9 bc	9.4 bc	5.8	9.3 bc
	2.0	33.3 b	18.9 b	8.2 b	5.5	8.6 bc
	4.0	43.0 b	19.5 b	7.6 b	4.9	6.4 ab
Fluroxypyr	2.0	15.0 a	28.7 c	12.1 c	6.5	9.6 c
	4.0	63.0 c	9.1 a	4.4 a	3.6	4.2 a
Control	0.0	9.6 a	21.8 bc	10.3 bc	7.3	9.6 c
LSD		14.3	8.4	3.0	NS	3.1
Trend [¶]						
Triclopyr		L	NS	NS	NS	NS
Fluroxypyr		L,Q	L,Q	L,Q	L	L

[†]Herbicide levels given in pounds of acid equivalent (ae); 1.0 lb/ae/acre = 1.1 kg/ae/ha, 2.0 lb/ae/acre = 2.2 kg/ae/ha, and 4.0 lb/ae/acre = 4.5 kg/ae/ha.

[‡]Injury ratings based on 0 = no herbicide damage to 100 = completely dead turf.

^xMeans within a column followed by the same letter are not significantly different according to Fisher's protected LSD ($P \leq 0.05$).

[¶]Gradient trend analyses significant at $P \leq 0.05$; L = linear; Q = quadratic.

^{NS}Nonsignificant.

grass injury ratings at 49 DAT increased linearly for triclopyr as concentrations increased and showed linear and quadratic trends for fluroxypyr as concentrations increased (Table 1). The most injury was evident for the 4 lb/ae/acre levels of either herbicide. As expected with severe herbicide injury, DW also decreased as the concentrations of both chemicals increased, but a significant linear trend was indicated only for fluroxypyr. When comparing means across both chemical treatments, the only differences for the sod strength parameters of AF and PF were significantly lower values for fluroxypyr at 4 lb/ae/acre compared to the control (Table 1). However, significant negative linear and quadratic trends existed for AF and PF as fluroxypyr concentrations increased from 0 to 4 lb/ae/acre. Pyridine treatments caused no significant differences in PD, but there was a significant negative linear trend for the fluroxypyr-treated sod. Pull distance provides an indication of sod integrity as the pull is conducted, with a relatively strong sod having higher PD values due to interlocking of grass stems and roots.

Sod strength devices have been previously used to measure differences in sod tensile strength following chemical applications, although the devices were not always capable of distinguishing between different levels of herbicides (Goatley and Schmidt, 1991;

Table 2. Effects of sod bed pull speed (PS) on maximum peak force (PF) recorded; average force (AF), which is the average of all nonzero forces divided by the number of forces measured over 0.2-s intervals; peak work (PW), which is PF multiplied by PS multiplied by 0.2 s; total work (TW), which is product of the AF during 0.2-s intervals multiplied by PS multiplied by 0.2 s; average work (AW), which is the average of three PF measurements; and pull distance (PD), which is the sod bed travel distance over which sod restraining force was ≥ 2.3 kg, for 'Tifgreen' bermudagrass.

PS ^a (inch/s)	PF (kg)	AF (kg)	PW (J)	TW (J)	AW ^b (J)	PD (cm)
1.0	28.0	11.6	13.9 a ^c	57.6 a	15.1 a	3.8 a
2.0	28.1	12.3	27.9 b	99.6 b	23.3 a	6.2 b
3.0	29.3	11.9	44.4 c	125.9 b	36.0 b	7.1 c
LSD	NS	NS	NA ^w	NA	12.0	NA
Trend ^d						
Linear	NS	NS	L	L	L	L

^aFor PS, 1.0 inch/s = 2.5 cm·s⁻¹, 2.0 inch/s = 5 cm·s⁻¹, and 3.0 inch/s = 7.5 cm·s⁻¹.

^bCovariate not significant. Mean value listed.

^cData listed are adjusted means from analysis of covariance with DW as the covariate. Means within a column followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

^wNA = not applicable.

^dGradient trend analyses significant at $P \leq 0.05$; L = linear.

^eNonsignificant.

Troutman and Jagschitz, 1971; Turner and Dickens, 1987; Turner et al., 1990). St. Augustinegrass was more tolerant to triclopyr applications than fluroxypyr applications, particularly at 4 lb/ae/acre. The sod strength measurements were not able to distinguish between any level of triclopyr for measurements of PF, AF, PD, and DW although injury ratings differed significantly. More replications likely would have improved the detection of possible differences in sod strength between chemical levels.

BERMUDAGRASS PUTTING GREEN TRIAL. Sod bed pull speeds of 1, 2, and 3 inch/s were used for the 'Tifgreen' turf. Average force or PF did not differ based on PS, but there were significant

differences in PW, TW, and AW as PS increased and linear trends were indicated (Table 2). The differences in response between the force and work parameters indicated that a uniform and repeatable sod stretching speed is essential if work is to be used to measure sod strength. PD values increased linearly as PS increased. The significance in the increase in PD values as PS increased is not known, but the importance of maintaining a consistent speed between sod samples is indicated.

SPECIES TRIAL. For nearly all measurements, AST or DW did not differ for most analyses within the separate grass species, and these variables were removed from the model when such was the case. PF and AF were not

significantly different between PS for either zoysiagrass or bermudagrass (Table 3). However, all remaining parameters that involved time in their computation (PW, TW, AW, and PD) were all significantly lower for the PS of 1 than 3 inch/s, except for TW for bermudagrass. These results again indicate the importance of maintaining consistent pull speeds if variables other than PF or AF are measured.

For centipedegrass, the PS of 3 inch/s again resulted in higher sod strength measurements for all variables except for AF (Table 3). However, the relationship between AST and PF was different for the two pull speeds (Table 4). Average sod thickness had no significant effect on PF at the 3 inch/s PS, but PF increased as AST increased at a PS of 1 inch/s. This was expected since a thicker sod would have more soil and a more integrated root mass that would contribute to greater sod strength; hence, greater force was required to break the sod.

For St. Augustinegrass, PS again was an important factor for all variables measured, but in this case the parameters were lower for the 3 than 1 inch/s speed (Table 3). For the different PS, there also were different linear relationships between the independent variables of PD and PW and the dependent variables of AST and DW (Table 5). DW had no effect on PW for the PS of 1 inch/s, but there was a negative linear relationship between PW and DW for the PS of 3 inch/s. We do not know the significance of this observation because it was expected that PW would increase as DW increased. It seems logical that there

Table 3. Effects of sod bed pull speed (PS) on sod strength parameters of peak force (PF) recorded; average force (AF) of all nonzero forces divided by the number of these forces measured over 0.2-s intervals; total work (TW), which is product of the average forces during each 0.2-s interval multiplied by PS multiplied by 0.2 s; peak work (PW), which is PF multiplied by PS (cm) multiplied by 0.2 s; average work (AW), which is the average of the three maximum force measurements multiplied by PS (cm) multiplied by 0.2 s; and pull distance (PD), which is sod bed travel distance (cm) over which sod restraining force was ≥ 2.3 kg, of bermudagrass, zoysiagrass, centipedegrass, and St. Augustinegrass.

Strength parameter	PS (inch/s) ^a							
	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
	Bermudagrass		Zoysiagrass		Centipedegrass		St. Augustinegrass	
PF	26.0 a ^y	25.4 a	32.0 a	42.9 a	NA ^x	NA	57.8 a	35.1 b
AF	9.2 a	12.1 a	14.3 a	21.8 a	5.8 a	4.6 a	26.1 a	15.9 b
PW	12.0 a	38.6 b	14.7 a	65.0 b	4.6 a	12.5 b	NA	NA
TW	95.9 a	195.8 a	101.9 a	407.4 b	33.3 a	64.7 b	362.8 a	547.8 b
AW	4.2 a	18.4 b	6.6 a	33.3 b	2.4 a	7.0 b	12.2 a	24.2 b
PD	8.4 a	14.9 b	6.7 a	18.0 b	6.5 a	13.7 b	NA	NA

^aFor PS, 1.0 inch/s = 2.5 cm·s⁻¹ and 3.0 inch/s = 7.5 cm·s⁻¹.

^yMeans for strength parameters within a row for each grass followed by the same letter are not significantly different according to Fisher's protected LSD ($P \leq 0.05$).

^xNA = not applicable.

Table 4. Linear regression slopes and intercepts for maximum peak force (PF) recorded of centipedegrass sod strength with average sod thickness (AST), in inches, as the dependent variable based on varying sod bed pull speed (PS).

Strength parameter	PS (inch/s) ^a			
	1.0		3.0	
	Intercept	Slope	Intercept	Slope
PF	52.4 a ^y	17.3 a	0.85 b	2.1 b

^aFor PS, 1.0 inch/s = 2.5 cm·s⁻¹ and 3.0 inch/s = 7.5 cm·s⁻¹.

^yIntercepts and slopes with the same letter in a row are not significantly different at $P \leq 0.05$. Neither intercept or slope for 3.0 inch/s (7.5 cm·s⁻¹) pull speed differ from zero.

would be more lateral stems associated with a higher DW for St. Augustinegrass, resulting in a greater sod strength due to a greater chance of the stolons meshing with one another. The relationship between PW and DW might be different if more than six replications were conducted; however, the sod strips were harvested from the same immediate area at the same time to reduce sampling variation. Further research is necessary to verify this finding on St. Augustinegrass.

Correlations of DW and sod strength parameters were also made for the other species in this trial, again with the anticipation that DW would be significantly correlated with greater sod strength. All correlations between DW and sod strength parameters were positive but nonsignificant (data not shown). By its nature, DW must be a major factor in sod strength during the development of the sod, but it is apparently of limited importance in the strength of a healthy, mature sod.

Conclusions

Overall, the sod strength device performed as desired. The use of the tractor's hydraulic system for consistent speed control of the mobile sod frame and the force transducer and strip chart recorder for measuring a continuous signal during the stretch provides the opportunity to calculate values other than the standard PF. Sod strength parameters that were calculated as averages or totals had somewhat less variability than peak values; however, the differences were generally not significant (data not shown). PW and PD allowed us to examine sod strength with time; nevertheless, PW and PD did not consistently improve the information provided by the standard measurement of PF, and the time involved in collecting the data from the chart recorder sheets to calculate PW and PD is significant. Based on the

sensitivity of this machine and stretching technique, PF continues to be a valid measurement of sod strength, providing the quickest and easiest measurements to determine for this machine. Conducting as many replications or breaks of the sod as possible will reduce variations in sod strength. This was seen from the data in the herbicide damage trial that was based on only three replications due to limited plot size. Even though the visible damage to the St. Augustinegrass was quite severe for the medium and high concentrations of pyridines, the sod strength measurements did not always differentiate between the untreated control and the herbicide-treated sod. Turner and Dickens (1987) reported similar variability in sod tensile strength measurements following herbicide applications.

Pull speed is an important consideration in the use of this type of machine. Consistent pull speed must be maintained for the duration of the stretch or the strength parameters can drastically change, particularly for parameters that evaluate strength over time. PF and AF measurements were unaffected by differing PS except for the St. Augustinegrass in the species trial. The flexibility of PF and AF measurements regardless of PS is a desirable feature.

Table 5. Linear regression intercepts and slopes for peak work (PW), which is peak force multiplied by PS (cm) multiplied by 0.2 s, and pull distance (PD) measurements of St. Augustinegrass sod strength with average sod thickness (AST), in inches, and dry weight (DW), in kilograms, as the dependent variables within varying pull speeds (PS).

Strength parameter	PS (inch/s) ^a					
	1.0			3.0		
	Intercept	AST	DW	Intercept	AST	DW
PW	19.8 a ^y	---	0.02 a	175.4 b	---	-0.40 b
PD	50.2 a	-8.8 a	0.003 a	181.7 b	-25.9 b	-0.15 b

^aFor PS, 1.0 inch/s = 2.5 cm·s⁻¹ and 3.0 inch/s = 7.5 cm·s⁻¹.

^yIntercepts and slopes with the same letter in a row are not significantly different at $P \leq 0.05$. For the 1.0 inch/s (2.5 cm·s⁻¹) PS, neither slope differs significantly from zero and only the intercept for PD differs from zero.

While no statistical comparisons were made, the device apparently provides distinguishable PF and PW measurements between the different warm-season grass species (Table 3). Other work has shown that PF measurements could distinguish between cultivars within species (Jagschitz, 1980; Philley et al., 1992). Qualitative notes taken at the time of washing the harvested warm-season sods (data not reported) indicated that washed St. Augustinegrass had the best handling characteristics, followed by a grouping of zoysiagrass and bermudagrass, and finally a very poor handling centipedegrass (Tables 3-5).

The overall ease in operation and data collection, and the relatively inexpensive cost of materials in construction are advantageous. However, this measurement technique continues to be destructive by necessity, since sod must be harvested and broken. Further work to a) define the role that AST and SM play in sod strength and b) develop a nondestructive technique for field research that would permit larger numbers of replications to reduce variation in sod strength is needed.

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Rowcover-removal Timing Affects Yield of Tomatoes Planted on Fall-prepared Beds

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SUMMARY. Spring-planted 'Pilgrim' tomatoes (*Lycopersicon esculentum*) were grown under slitted clear polyethylene rowcovers on beds prepared in the fall with black plastic mulch and trickle irrigation. Fall beds allowed for earlier planting and a corresponding earlier harvest. Plastic mulch and trickle irrigation remained intact during the winter. There was no significant advantage to leaving covers on past the time of the traditional planting date for the area. It was estimated that the additional cost for this system would be about \$1000 per acre. The profitability of this system will be determined by the price growers receive for their earliest fruit. An early season price of \$0.60/lb is the approximate break-even figure. Higher early season prices will lead to much greater profits. For heat-sensitive crops like tomatoes, using rowcovers on fall beds may effectively maximize early yield and profitability.

To maximize farm profitability, vegetable growers often try to bring crops to

market earlier. Early harvests usually result in price premiums of two to three times that which is received just a few weeks or even days later. Plastic mulches have been used by growers to enhance earliness for many years (Bonanno and Lamont, 1987; Perry and Sanders, 1986). In the past decade, there has been an increase in the use of rowcovers to enhance early yield. The protected conditions under the cover have resulted in early yield increases for muskmelons (Hemphill and Mansour, 1986; Wells and Loy, 1985;) and other cucurbits (Hemphill and Crabtree, 1988) but has had a mixed effect on peppers, (Gent, 1989) and tomatoes. Perry and Sanders (1986) demonstrated early yield of tomatoes was reduced, possibly due to high temperatures under the covers. Reiners and Nitzsche (1993) found increased early yields of tomatoes using floating spunbonded covers and slitted clear plastic covers. Wolfe et al. (1988) estimated that temperatures >95 °F can have detrimental effects on tomato yield. Peterson and Taber (1991) found a correlation between early yield loss and a sustained high temperature >104 °F for ≥3 consecutive hours. Apparently, the yield loss in tomatoes grown under plastic may be related to insufficient pollination at high temperatures (Shelby et al., 1978), blossom drop (Sugiyama et al., 1966), or fruit abortion (Peterson and Taber, 1991).

For rowcovers to be effective they must be managed according to the temperature requirements or limitations of individual crops. A possible reason for the failure to increase early yield in some studies may be due to the lateness of planting. Tomato plants set near the time of traditional spring plantings for a region and covered had reduced early yield (Wolfe et al., 1989). Gent (1989) found that 16 pepper varieties planted early (21 Apr.) and covered matured 10 d earlier than unprotected plants. When planted at the more traditional time 1 month later, all varieties of protected peppers exhibited an early yield loss, with the first harvest delayed 9 d. Clearly, later plantings of tomatoes and peppers do not benefit from protection and may be damaged by high temperatures. The best advantage of rowcovers may be that they allow growers to plant several weeks earlier than traditional planting dates. The challenge encountered when trying to plant tomatoes

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