

No-tillage Snap Bean Growth in Wheat Stubble of Varied Height

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Abstract. Bush-type snap beans (Phaseolus vulgaris L.) were seeded by a no-tillage method into standing wheat (Triticum aestivum L.) stubble of 8, 15, 23, 30, and 38 cm in height to evaluate the effects of stubble height on pod mechanical harvest efficiency, plant morphology, and shoot component yield. Basal internode elongation, stem plus leaf yields, pod yields, efficiency of mechanical pod harvest (MH), and height of basal pod set were related in a positive linear or curvilinear fashion to wheat stubble height. Quantity of pods missed during MH was related negatively to height of basal pod set. Harvest efficiency was maximized with 15–30-cm stubble heights, and these no-tillage systems yielded MH pod levels that equaled or exceeded those of a conventional tillage (plow, disk 2 times) system. Superior MH efficiency was attributed to increased basal internode length and mechanical support of the shoots by the wheat stubble.

A wide variety of vegetable crops has been cultured using no-tillage techniques (2, 3, 9, 10, 12). Problems associated with the mechanics of no-tillage vegetable seedling or transplant establishment (9, 12) and weed control (2, 3, 9, 10) have been documented and addressed. The quality and the architecture of crop residues in no-tillage systems are known to affect water relationships (18), allelopathy (13), and early-season growth (11) of agronomic crops, but less is understood about crop residue effects in no-tillage vegetable crop systems.

Fall-seeded winter wheat followed by no-tillage soybeans [Glycine max (L.) Merr.] is a double-crop (2 crops per 12 months) rotation that is used widely in the southern United States. The substitution of no-tillage snap beans for soybeans in this double-crop rotation has been shown to offer certain management advantages over conventional tillage, summer-planted snap beans (3). Our research was conducted to understand the effects of tillage and wheat residue architecture on double-crop snap bean growth, harvest efficiency, and morphology.

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Materials and Methods

The study was conducted in the Summer 1982 and 1983 at the Virginia Truck and Ornamentals Research Station, Painter. The following cultural practices were used prior to the seeding of 'Provider' bush-type snap beans each year. The experimental area (State sandy loam; Typic Hapludults) was moldboard plowed, amended with P and K as recommended (5), and disked twice just before grain seeding in October. Wheat ('Coker 747') seed was drilled (25-cm rows) at the rate of 112 kg·ha⁻¹. Wheat was topdressed with N at 70 kg·ha⁻¹ in March. Standing wheat stubble height variables (8, 15, 23, 30, and 38 cm) were established by the appropriate adjustment of the grain combine cutterbar height at grain harvest in early July. Unattached straw residues were removed from the area by hand after grain harvest because the combine did not provide for uniform distribution of the threshed straw. Remaining stubble was oriented in a vertical position with respect to the soil surface. An application of 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat) at 0.4 kg a.i·ha⁻¹ plus 0.25% (v/v, H₂O) X-77 surfactant (Chevron Chemical, San Francisco) was made one month following wheat harvest to control emerging weeds and grasses in the fallow seed bed (July 1983 only).

Conventional tillage (CT) snap bean plots were plowed and disked twice. The CT plots were split in 1982 to assess the effects of cultivation (at 20 days after planting) on snap bean growth. The plus-cultivation treatment produced increased (P
per ha in a 0.9-m row spacing was established. Rows were oriented north-south and parallel to wheat rows. All plots were topdressed prior to snap bean emergence with N at 90 kg ha⁻¹. Excellent weed control was attained with a preemergence application of 1.7 kg a.i. ha⁻¹ of 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide (metolachlor) to all plots and 0.4 kg a.i. ha⁻¹ paraquat plus 0.25% (v/v, H₂O) X-77 surfactant (zero tillage plots only). Insects were controlled by cyano(3-phenoxyphenyl)methyl 4-chloro-a (1-methylethyl) benzeneacetate (fenvalerate) applications at the rate of 0.2 kg a.i. ha⁻¹ to all plots in 1982 and 1983.

Rainfall plus irrigation water received by the experimental sites during the cropping season was 196 + 0 mm, respectively, in 1982, and 28 + 125 mm in 1983. Rainfall during this time at the research site averages 194 mm.

Temperatures within microclimate strata (30, 15, 5, and 0 cm above and 3, 5, 10, and 15 cm below the soil surface) of each tillage system were measured 2 times during the 1982 and 1983 growing seasons. Measurements were made using copper-constantan thermocouples assembled and operated according to appropriate procedures (1, 4).

Wheat stubble height and CT treatments were replicated 3 times using a randomized complete block design. Plot area and harvest dimensions were 13 × 5.5 m and 12 × 1.8 m. Harvest occurred when 75% ± 5% of the pods attained a length of 9 to 15 cm (on or about 9 Oct.). The harvester used was a Pull Pix (Pix All Corp., Clear Lake, Wis.) single-row model operated at 3.2 km hr⁻¹, a power takeoff speed of 1400 r min⁻¹, and a harvest brush speed of 140 r min⁻¹. Whole pods not harvested from the plants or dropped within 30 cm to either side of the harvest row during mechanical harvest (missed pods) were collected subsequently by hand. Total pod yields represent the sum of the mechanical harvest (MH) plus the missed pods. Pods that were destroyed and expelled from the harvester along with the foliage trash were estimated to be <5% and were not accounted for in yield calculations. We define marketable pod harvest efficiency (hereafter referred to as harvest efficiency) to be MH yield : total harvest pod yield (expressed as a percentage) and assume the pod fraction destroyed and expelled by the harvester to be nonmarketable. Data were analyzed by methods of polynomial regression and single degree-of-freedom comparison (17).

Effects of the tillage treatments on snap bean plant morphology and yield components were monitored. Measurements of stem internode length were collected in 1982. Determinations were based on a random sample (17) of 10 stems collected from each harvest area following pod removal.

Heights from stem base to terminal and basal pod peduncles, leaf plus stem fresh weights, pod fresh weights, total shoot fresh weights, and total dry weights were measured in 1983. Intact shoots of 10 plants were removed from each plot for measurement of these variables just prior to harvest in a fashion similar to the 1982 stem sampling.

An additional study compared the basal internode elongation attained under CT culture and a NT wheat stubble system (stubble height of 23 cm) during Summer 1983. Cultivar, seed bed preparation, planting, pesticide program, soil, row spacing, and plant population were identical to those used during the 1983 stubble height study. The plots were seeded on 15 Aug. and heights from the seedbed surface to the first node were recorded (25 plants per plot) 11 days later. All plots received 2.5 cm irrigation on 22 Aug., and N at 73 kg ha⁻¹ (28 kg N preplant + 45 kg N sidedress per ha).

**Results**

Mechanical harvest pod yields were greatest in no-tillage plots with 15- to 30-cm wheat stubble heights (Fig. 1). A quadratic response to stubble height was evident in both years, but predicted optimum stubble height varied from 18 cm in 1983 to 26 cm in 1982. Yields of MH pods were lower under CT than those attained with optimum stubble treatments. The quantity of pods missed by the mechanical harvester decreased in proportion to the height of the wheat stubble. Visual examination of plots during the collection of missed pods indicated that almost all unharvested pods were attached to the basal portions of the plants. Minimum MH efficiency (MH pods per total pods) occurred under CT each year. No-tillage total pod yield trends paralleled those of the MH treatments. Total pod yields were higher within the optimum stubble treatments than CT in 1983 and similar in 1982.

Changes in snap bean plant morphology were induced under varied wheat stubble height (Fig. 2). Length of internodes 1 to 6 (from the stem base) increased in a linear fashion as wheat stubble height increased. Length of internodes 7 to 9 were unaffected by stubble height. All affected internodes were located.

...
STUBBLE HEIGHT (cm)

Fig. 2. Snap bean internode length in conventional (0-cm) and no-tillage (8- to 38-cm) wheat stubble systems in 1982. Internodes are numbered in ascending order of development from the stem base. Linear regressions of internode length vs. stubble height were significant (0.05 level) and positive for internodes 1–6.

on stem portions below a 38-cm height. Elongation of each internode was contingent on a vertical location at or below the corresponding stubble limit. Internode characteristics of the CT and 8-cm stubble treatment were very similar, except for that of internode 1.

Analysis of the 1982 yield and morphologic data suggested that elongation of plant internodes had increased the height from the stem base to the locus of lower pod development (set). We proposed that a net result of higher pod set would be increased exposure of the basal pods to the tines of the mechanical harvester and a potentially improved harvest efficiency. We tested this hypothesis in 1983 by measuring the effects of stubble height on distance of pod set from the stem base (Table 1). It was determined that height of basal pod peduncles was increased by wheat stubble in a manner consistent to that observed for basal internode elongation in 1982. Snap beans were cultured in CT and NT (23-cm wheat stubble height) systems in an additional study during 1983. Average base internode length in the CT and NT systems was 6.3 and 9.8 cm, respectively (significant at the 0.05 level). This elongation occurred within 11 days of seeding. The height from stem base to upper pod peduncle also was found to be increased by taller stubble treatments (Table 1), affirming our 1982 finding that total plant height is enhanced by wheat stubble in a fashion proportional to the upper stubble limit.

It was observed in 1982 and 1983 that little lodging occurred in the tall stubble plots (>15 cm), despite the increase in total plant height. This lack of lodging was attributed to a mechanical support of the snap beans provided by the wheat stubble throughout the season (Fig. 3).

Changes in shoot yield components were studied in 1983 (Table 1). Leaf plus stem fresh weight, total shoot fresh weight, and total shoot dry weight yields were greatest within the 15- to 38-cm stubble treatments. Total shoot and leaf plus stem fresh weight yields were suppressed under CT vs. average NT, but were similar for CT and the 8-cm stubble treatment. Leaf plus stem : pod ratios increased in a linear fashion with stubble height. This yield component ratio shift had little effect on total leaf plus stem yields but was related negatively to pod yields, shoot dry weight, and percentage of shoot dry matter attained in the 23- to 38-cm stubble treatments.

Air and soil temperatures in each treatment were at a maximum near the soil surface and at a minimum at or near the outer boundaries of measurement (Table 2). Air, soil surface, and soil temperatures averaged across NT stubble height and strata vs. CT averaged over strata were 25.2° vs. 23.7°C, 25.5° vs. 26.2°, and 21.8° vs. 21.7°, respectively, with these differences being nonsignificant (0.05 level). Data are presented as values pooled across sample date within each stratum because sample date by tillage treatment interactions were nonsignificant (0.05 level).

Discussion

Our results demonstrate the importance of stubble height in attaining efficient MH of snap beans planted following wheat. The range of stubble heights that we evaluated is representative of those existing in harvested wheat fields. Snap bean harvest efficiency within our CT plots averaged 76% and increased un-

Table 1. Snap bean yield component response to conventional tillage (CT), no-tillage (NT), and wheat stubble height in 1983.

<table>
<thead>
<tr>
<th>Tillage and stubble ht (cm)</th>
<th>Shoot fresh wt (t·ha⁻¹)</th>
<th>Shoot dry wt (t·ha⁻¹)</th>
<th>Leaf + stem : pod ratio</th>
<th>Peduncle ht (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaves</td>
<td>Pods</td>
<td>Total</td>
<td>Lower</td>
</tr>
<tr>
<td>CT 0</td>
<td>9.9</td>
<td>6.1</td>
<td>15.9</td>
<td>2.2</td>
</tr>
<tr>
<td>NT 8</td>
<td>9.9</td>
<td>6.9</td>
<td>16.8</td>
<td>2.0</td>
</tr>
<tr>
<td>15</td>
<td>13.3</td>
<td>7.5</td>
<td>20.8</td>
<td>2.6</td>
</tr>
<tr>
<td>23</td>
<td>12.4</td>
<td>7.4</td>
<td>19.8</td>
<td>2.6</td>
</tr>
<tr>
<td>30</td>
<td>13.4</td>
<td>6.5</td>
<td>19.9</td>
<td>2.5</td>
</tr>
<tr>
<td>38</td>
<td>12.5</td>
<td>6.8</td>
<td>19.4</td>
<td>2.4</td>
</tr>
<tr>
<td>NT x</td>
<td>12.1</td>
<td>6.3</td>
<td>19.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Components</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT vs. average NT</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CT vs. 8 cm NT</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>NT stubble height Linear</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>NT stubble height Quadratic</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
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<td></td>
<td>**</td>
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</tr>
</tbody>
</table>
| *NS: Significant at the 0.01 and 0.05 levels and not significant, respectively.

Previous experience to be low (<5%), and we used a cultivar that demonstrates a high mechanical harvest efficiency compared to cultivars that are prone to lodging. We found that stubble treatment-induced differences in snap bean morphology did not relate strongly to the thermal radiation regimes of our systems. Microclimate temperatures from 15 cm below to 30 cm above the soil surface were found to be relatively constant across tillage and stubble treatments. This lack of a temperature-by-tillage interaction is in contrast to that reported for spring-seeded crops (10, 11) and is likely a phenomenon related to season. Temperature differences between CT and NT systems are usually more pronounced during the early spring and often dissipate over time (11).

Total yields were increased in a quadratic fashion each year as stubble height was increased from 8 to 23 cm and declined in the 30- and 38-cm stubble treatments. This trend suggests that shading of the crop by tall wheat stubble may have a detrimental effect on snap bean yield potential, although we did not test this hypothesis in the field.

Total pod yield was, on average, greater with NT vs. CT in 1983 but similar in 1982. Trends with respect to stubble height were similar for both years. Average seasonal water requirements (evaporation plus transpiration) of snap bean cultivars seeded during the summer under optimum irrigation are about 180 mm (16). We reasoned that total water (rainfall plus irrigation) supplied during the cropping season in our studies was optimal (196 mm) in 1982 and suboptimal (153 mm) in 1983. Water storage and use-efficiency by plants have been shown to be greater in stubble-mulch than in tilled croplands (18). Snap bean dry matter percentages—one bioassay of moisture availability—were significantly greater under CT vs. NT during 1983. These factors led us to form the opinion that snap bean growth in favorable stubble height systems can produce pod yields similar to CT systems under conditions of adequate moisture and might outproduce CT systems under conditions of suboptimum moisture.

Reductions of weed and soybean yields in double-crop systems have been attributed to allelopathic effects of wheat stubble (13). We removed all unattached stubble residues from the no-tillage plots prior to seeding snap beans. The remaining wheat stubble mass was proportional to the stubble height, but no linear, negative relationship between total pod yield and stubble height was observed. Our results, therefore, benefit speculation that this allelopathy is not an outstanding limit to wheat-snap bean double-crop production. Intereme elongation in bush-type snap beans is modified through culture in standing wheat stubble. Increases in internode length are induced in proportion to wheat stubble height and dry matter percentage (8, 14), thus reducing potential for broken pod and cluster losses via expulsion with vegetative trash.

The stubble height effect on harvest efficiency was 2-fold. Increases in basal internode length adjusted the height of basal peduncles upward. This response was documented consistently in our studies and has been related to increases in harvest efficiency by others (15). We did not study incoming solar radiation levels, but we speculate that light intensity was reduced near the soil surface with the tall stubble treatments, resulting in etiolation of plant internodes. It is well-documented that etiolation is enhanced by low light intensity (6). The tall stubble treatments also provided mechanical support of the shoots. Frequency of lodging was observed to be low in tall stubble systems compared to the shortest stubble and CT treatments. Smitte et al. (15) have shown previously that upright snap bean cultivars demonstrate a high mechanical harvest efficiency compared to cultivars that are prone to lodging.

Table 2. Microclimate temperatures as influenced by tillage and wheat stubble height.

<table>
<thead>
<tr>
<th>Strata disk (cm)</th>
<th>Plow 8</th>
<th>8</th>
<th>15</th>
<th>23</th>
<th>0</th>
<th>30</th>
<th>38</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>20.5</td>
<td>22.8</td>
<td>24.2</td>
<td>25.5</td>
<td>26.5</td>
<td>27.9</td>
<td>29.4</td>
<td>30.0</td>
</tr>
</tbody>
</table>

this elongation adjusts the height of lower pod clusters upward. Lodging is also reduced through mechanical support of the beam plants by the stubble. These combined effects relate to a decrease in pod losses during mechanical harvest. Under the conditions of our study, stubble heights of 15 to 30 cm enhanced harvest efficiency without affecting total yield in an adverse manner. This research demonstrates that residue characteristics must be considered in establishing successful NT snap bean production systems.

**Literature Cited**