2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

EVALUATION OF A 15INCH SPINDLE HARVESTER IN VARIOUS ROW PATTERNS: ONE YEAR'S PROGRESS

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Abstract

A John Deere Pro 12 spindle picker row unit (In-line head) with modifications to cut one row and crowd it into a standing row located 15 inches to the left and passing directly through the picking unit was mounted on a single row picker chassis (John Deere Model 122, one row cotton harvester mounted on a JD 4020 tractor). The harvester was operated in cotton produced in eight different row configurations including 15, 30, and 38-inch row solid cotton, 15-inch row, 2 x 1 skip row, 15-inch row, 2x2 skip row, 30-inch rows with a 1 x 1 skip-row (cotton in 60-inch rows), 30-inch row, 2 x 1 skip row, and 38-inch row, 2 x 1 skip row. These row configurations were planted at the North Mississippi Research and Extension Center, Verona, MS, and at a private farm in Falkner, MS. Harvester operation was observed, yield and losses measured, samples ginned and lint sampled for AFIS and HVI quality determinations.

Wet soil condition through most of May delayed planting of the plots until 5/28/03. This resulted in unusually late and green plots with immature bolls immediately prior to defoliation. The wet spring conditions also resulted in irregular plant spacing within the row. Coupled with a cool September and early October and field moisture keeping the plants green; many of the bolls were not fully fluffed and dried at the time of harvest. The picking unit performed very well; however, the combination of these conditions and adjustments to the picking row unit resulted in the cut row stalks bunching at intervals, thus slug feeding the picking unit to a minor degree. Only one choke-up to the picking unit was noted while harvesting the plots and that occurred in the 30 inch, 2 X 1 skip row plot where no cut stalks were being harvested. That choke-up did not appear to be a result of the picking unit modifications. The picking unit handled a wider range of plant conditions that would have impeded the operation of a finger stripper.

The harvest simulation model, XLCOTSIM, was used to predict the impact of row spacing and machine performance on net revenue after harvest costs were deducted. Yield, fiber quality, harvest losses, and estimates of machinery costs were used in the model for each row pattern. The trend for both locations was for wider rows and lower yielding plots to have greater harvest losses. No statistically significant fiber quality differences were found between row patterns. Micronaire was lower at the Falkner location due to an early application of defoliation with few open bolls and was lower for wider row patterns with a greater number of immature bolls. This was the only variable in the quality measurements that impacted the value of the lint; causing a slightly lower value due to a discount for the later maturing wider row treatments. Trash and nep levels were consistent with spindle harvested seed cotton levels and would not be expected to create spinning performance difficulties for textile mills.

Introduction

Efficient cotton production for improved net returns is essential for cotton growers to maintain a competitive advantage in a global market. Ultra narrow row (UNR) cotton and skip-row cotton production systems (Parvin et al. 2000, 2002b) have been used as means for improving profitability. UNR cotton has shown equal or higher yields (Atwell 1996; Buehring et al. 2001; Nichols et al. 2002; Shurley et al. 2002) and net returns (Parvin et al. 2002a; Shurley et al. 2002) than conventional wide rows. However, the 3 to 5¢/lb discount for the fiber's negative spinning quality (mainly neps); the inability to operate the finger strippers under high humidity or dampness in the rain belt; and the increased trash content have offset these advantages. The increased trash content in the material taken to the gin reduces processing capacity (Brashears 1968; Mayfield 1999; and Anthony et al. 1999 and 2000). Although HVI fiber quality analysis have shown no differences between spindle picker and finger stripper cotton, finger stripper cotton had increased neps (Anthony et al. 1999 and 2000; Willcutt et al. 2001).

Researchers at Tempe, AZ, constructed a prototype harvester and described it as, "A method of harvesting stalk-like plants wherein the plants are retained in substantially their upright growing position comprising the steps of conveying the plants together, intertwining the tops of the plant, cutting the stalks of some of the converged intertwined plants and feeding the intertwined cut and uncut plants through a harvester" (Kappelman, et al., 1972). California researchers (Kempner, et al. 1975) modified and tested a brush stripper for harvesting twin rows. Seed cotton losses ranged from 2.7% to 8.0%; however, they experienced many of the problems associated with stripper cotton harvesters including failure to operate satisfactorily in high humidity, stalks being pulled from the soil and lack of cleaner capacity.

John Deere has recently developed, tested and introduced a prototype spindle picker unit for 15-inch row production systems (Deutsch, et al., 2001). Their row unit employs a cutting device consisting of rotary knives operating against a stationary section to shear stalks approximately 2 to 6 inches above the soil. The un-harvested plants are moved in a vertical orientation into the adjacent uncut row where both cut and uncut plants are passed through the picking unit. Rotating finger wheels are employed to move stalks into the uncut row and assist the stalks in moving between the first and second picking drums of an inline picking unit. The units have been introduced in the Australian and Brazilian markets. This design offers the potential to offset some of the limitations of the UNR system; namely, a harvester that can operate in a wider range of plant and weather conditions than a finger or brush stripper.

The objective of this study was to determine the performance of this spindle picker unit and the effect it has on lint yield and quality harvested from UNR and skip row patterns.

Materials and Methods

Studies were initiated in 2003 on a Marietta silt loam and Falaya sandy loam soil at Verona and Falkner, MS, respectively. The studies were conducted as randomized complete block designs with four replications. Plot size was 20 ft by 120 ft with row patterns (treatments) as shown in Figure 1. Deltapine DP449BG/RR cotton cultivar was planted no-till into a spring prepared stale seedbed on 5/28/03 at Falkner and replanted 5/29/03 at Verona. The cotton at Verona, first planted on 5/13/03, had to be replanted due to a stand failure. A complete description of the agronomic production practices and resulting plant characteristics may be found in a companion paper for this conference entitled “Spindle Picker 15-Inch Row Pattern Influence on Lint Yield and Plant Characteristics: One Year’s Progress” (Buehring et al, 2004).

The cotton was defoliated on 10/03/03 at Verona with Super Boll (ethephon) + Folex (phosphorotrithioate) at 1.5 + 0.75 lb ai/acre. The cotton at Falkner was defoliated on 10/02/03 with Super Boll + Folex at 1.5 + 0.75 lb ai/acre with a repeated application at 0.75 + 0.28 lb ai/acre on 10/13/03. The cotton was harvested at Verona on 10/22/03 and at Falkner on 10/29/03.

All cotton plots were harvested with a John Deere Pro 12 twin row 15-inch spindle picker unit mounted on a single row picker using a John Deere 4020 as the power unit (Deutsch et al., 2001). Figure 2 is a drawing of the header excerpted from the Deere patent. Four rows of the 15-inch solid, 15-inch 2x1 skip row, 15-inch 2x2 skip row (treatments 1, 2, and 3), 1 row of the 60-inch row (treatment 6), 2 rows of 30 and 38-inch solid (treatments 4 and 7); and 2 rows of the 30 and 38-inch 2x1 skip row (treatments 5 and 8) in each plot were harvested for yield. One choke-up of the picker row unit occurred during harvest of one replication of the 30-inch, 2 X 1 skip row treatment.

Harvest losses were determined by gleaning seed cotton from the stalks, then removing any dropped seed cotton from the ground from three 10 ft sections of the harvested rows. Large sticks, burs and leaves were removed by hand. The seed cotton from the ground and stalk were combined, weighed and dried. The dried seed cotton loss samples were then combined into one sample from each location and an average turnout determined by ginning. The seed cotton loss per treatment was then multiplied by the average turnout percent for the loss sample and expressed as a lint loss per acre. Percent harvest loss was determined as total lint loss per acre divided by the lint yield per acre at 6% moisture multiplied by 100.

The seed cotton from the harvested plots was stored until November 3, then ginned in the Mini-gin at Mississippi State University (a state of the art, 12 inch wide gin machinery, arranged in a recommended ginning sequence equivalent to a commercial gin) to determine lint yield. Lint moisture determinations were made on all samples before and after ginning and the yield was adjusted to 6% moisture for all plots before data analysis. Three sub-samples were taken from each sample and sent to Cotton Incorporated for HVI and AFIS analysis to determine fiber properties. All data were analyzed by Analysis of Variance and means were separated at the 5% significance level.

A lint value based on Memphis spot cotton prices for December 5, 2003 was determined. The average color grade used was 31-1. A seed value of $135 per ton was determined for Memphis area spot quotes for December 5, 2003, and discounted $5 per ton for average seed grade for the area or a net price of $130 per ton.

A harvest simulation model (Chen, et. al, 1992 and To and Willcutt, 2002) was used to simulate a season long harvesting operation. The simulation calculates costs, timing of the harvester and handling system machinery components while adjusting for quality and yield due to weather conditions for the Mid South. This model was used to compare projected season long harvest yield, costs and revenues from a farm sized and full season operation.

The lint yields, harvest loss, lint values from the Verona location, and variables for a John Deere four row spindle picker configured to harvest the different treatment row patterns were used as input information into the XLCOTSIM harvest simulation model. Performance rate for each treatment was determined by using a synchronized speed of 3.6 mph for the harvester multiplied by the width of the harvester swath (for a four row picker chassis) and dividing by 10 to arrive at harvested acres per hour. This equates to about 85% field efficiency for the picker. The XLCOTSIM harvest simulation accounts for harvester unloading, turning and waiting times and further reduces field efficiency appropriate to the handling system used. Adequate seed cotton handling was allotted to each system to prevent the harvester from waiting for a place to unload. Acreage for each treatment simulation was chosen so that the model indicated completion of the simulated harvest an average of 30 days and approximately 236 hours total for the harvest for each treatment when the model was run for ten replications. An average weather scenario was chosen for all runs. In the event the model did not indicate "harvest completed" within the prescribed time, acreage was adjusted until all 10 replications were completed by the model.

Harvester retail price was determined from John Deere's web site, build and price menu and reduced by 15% (Deere & Company, 2003). A JD 9970 four row 30-inch rows equipped with four-wheel drive guide axle costing $220,000 and 15-inch row modifications estimated at $25,000 (for 4 rows) -for a total of $245,000 was used for the 15-inch treatments 1, 2 and 3. The same harvester with standard John Deere Pro 12 row units was estimated at $220,000 and was used for the 30-inch solid planted, treatment 4. A wide row harvester with four-wheel drive guide axle was estimated to cost $221,000 and was used for the wide row and skip row treatments 5, 6, 7 & 8. Each harvester system included the picker, one boll buggy priced at $20,000 and one module builder priced at $24,000 with two tractors and four laborers including the harvester operator for cost comparisons. Total harvest system costs and net revenue after deducting harvest system costs from gross lint and seed revenue were computed. The model was not run for the Falkner location; however, results should follow a similar order for treatments, even though net revenue would be lower for this location.

Results and Discussion

The wet soil conditions in May delayed planting at both locations until the last days of May. Above normal rainfall throughout the growing season resulted in above average plant and fruit growth. However, late August cloudy, rainy weather resulted in the top-crop fruit shed at both locations. The cool weather in late September and early October also resulted in a loss of harvestable bolls in the upper most fruiting branches due to a lack of maturity at the time of defoliation.

Bolls were slow to open and dry, making spindle picking appear to have higher than normal losses especially for the less mature treatments. The picking unit performed very well; however, the combination of these conditions and adjustments to the picking row unit resulted in the cut row stalks bunching at intervals, thus slug feeding the picking unit to a minor degree. The compressor door tension springs were tightened to near maximum in an attempt to better clean the stalks. Only one choke-up to the picking unit was noted in harvesting the plots, which occurred in the 30-inch, 2 X 1 skip row plot where no cut stalks were being harvested and did not appear to be a result of the picking unit modifications. The picking unit handled a wider range of plant conditions that would probably have impeded the operation of a finger stripper. Some bunching of the cut stalks was noted in the 15-inch row treatments. This bunching of stalks resulted in a slugging effect to the picking unit and thus probably increased seed cotton remaining on the stalk and dropped onto the ground, particularly for the Falkner location where plants were less mature. Yields were above average for the two locations and are provided in Table 1. Yields of wider row production systems would be expected to be nearer the 15-inch production systems in years where planting during the later two weeks of April or first week of May and normal summer growing conditions occur. A discussion of statistical differences in yields and harvest losses is included in the companion paper by Buehring, et al. (2004) referenced above.

A lint value based on Memphis spot cotton prices for December 5, 2003, was determined. The average color grade used was 31-1. No premiums or discounts were found for the fiber properties for the Verona location. A seed value of $135 per ton was determined for Memphis area spot quotes for December 5, 2003, and discounted $5 per ton for average seed grade for the area or a net price of $130 per ton.

XLCOTSIM model input variables are listed in Table 2. Lint price, seed price, interest rate, permanent and temporary labor rates and diesel fuel cost were held constant for all treatments. Lint yield and percent of yield harvested in first picking (1-harvest loss) were used for each treatment respectively (Table 3). Picker parameters are also listed in Table 3 along with the model prediction of harvest system cost and net revenue after deducting harvest system costs. The 15-inch treatments ranged from $610 to $619 in net revenue with total system costs from $75 to $147 per acre. All the 15-inch row treatments produced greater net revenue than the wider row treatments with net revenues of approximately $120 per acre more than conventional row patterns and $72 more than the 30-inch solid treatment (treatment 4). Simulated acreage harvested ranged from 750 acres per machine system for the solid 15-inch row and solid 30-inch rows, 1475 acres for the 15-inch row 2x2 skip, treatment 3 up to a maximum of 1500 acres for the 30-inch 1X1 skip row (treatment 6). It should be noted that model output for the season long simulation never reached harvested yield for the plots. Figure 3 depicts a typical yield curve for XLCOTSIM. By design, the plot yields harvested were considered to be at the top of the curve or maximum yield for the treatments; thus, the season long yields will always be lower than the plot yields.

Additional years of testing are needed before adopting this system of production or harvesting. Plans for 2004 are for three locations, Verona, Falkner and Clarksdale with similar treatments and harvest methods.

Conclusions

All 15-inch row patterns produced greater yields than did wider row patterns. This was probably due in part to less than favorable planting and early spring conditions as well as cool conditions during September and early October that delayed maturity of the cotton produced in wider row patterns. Yields from all row patterns were above average for the locations. XLCOTSIM predictions of harvest system costs and net revenues suggested that 15-inch row production systems would have been more profitable than conventional systems provided that pre-harvest production costs were equal. This is a preliminary report on these production and harvesting systems; thus, additional years results are needed. Plans for 2004 are for three locations, Verona, Falkner and Clarksdale with similar treatments and harvest method.

Acknowledgement

This project's completion was possible only with close cooperation of a dedicated team of scientists, staff and sponsors. The authors gratefully acknowledge the funding support provided by Cotton Incorporated, harvester row unit provided by John Deere and Company, Harvester Engineering Group and grain drill provided by Great Plains Manufacturing. The authors also acknowledge Keith Morton Farms Incorporated in support of the research through his provision of a second location for plots, time and interest in the experiment.

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Table 1: Lint yield on a land basis and harvest losses as influenced by row pattern on a Marietta silt loam soil, Verona, MS and Falaya silt loam soil, Falkner, MS in 2003.

	Treatment **Row pattern**	**Verona Lint Yield (lb/acre)**	**Verona Harvest Loss (%)**	**Falkner Lint Yield (lb/acre)**	**Falkner Harvest Loss (%)**	**Average Yield Both Locations (lb/ac)**	**Average Harvest Loss (%)**
1	15-in solid	1196	3.3	995	10.5	1096	6.9
2	15-in 2 X 1 skip	1106	3.4	932	9.8	1019	6.6
3	15-in 2 X 2 skip	1039	4.0	885	14.1	962	9.1
4	30-in solid	1038	4.0	949	12.3	994	8.2
5	30-in 2 X 1 skip	813	4.6	801	10.8	807	7.7
6	60-in solid	902	7.0	715	15.4	809	11.2
7	38-in solid	922	4.1	907	13.0	915	8.6
8	38-in 2 X 1skip	810	4.0	751	11.7	781	7.9
	Mean	978	4.3	867	12.2	923	8.3
	LSD (0.05)	141	1.6	76	NS		
	% CV	10	25.5	6	31		

Table 2: XLCOTSIM Input Values

1196	Expected Average Lint Yield (lb/acre)
$ 0.67	Lint Price ($)/Lb
$130.00	Seed Price ($)/ ton
7.50%	Interest rate (%)
$ 10.00	Permanent labor Rate ($/hr)
$ 7.50	Temporary labor Rate ($/hr)
$ 1.00	Diesel fuel cost ($/gal.)
150	area of maturity group 1 (acres)
500	area of maturity group 2 (acres)
100	area of maturity group 3 (acres)
97%	% of yield harvested in 1st picking
0%	% of yield harvested in 2nd picking

Attributes of Pickers	**JD 4 Row**
Field capacity (ac/hr)	3.6
Basket capacity (lb)	8500
Purchase Price ($)	$245,000
Leasing cost for Leased picker ($/hr)	$ -
Fuel Consumption (gal/hr)	14
Second Harvest Field capacity (ac/hr)	0
Second Harvest Percent of Acreage Harvested	0.00%
Leased or Owned (L/O)	O
Included in Simulation (Y/N)	y

Attributes of boll Buggies	**Buggy #1**
CAPACITY (lb)	10000
Purchase Price ($)	$ 20,000
Included in Simulation (Y/N)	y

Attributes of Module Builders	**Builder #1**
Capacity (lb)	20000
Purchase Price ($)	$ 24,000
Included in Simulation (Y/N)	y

Attributes of of Trailers	**Trailer#1**
Capacity (lb)	12000
Purchase Price ($)	$ 3,600
Turnaround time (hr)	1.5
Included in Simulation (Y/N)	n

2	Weather Scenario, 1=good 2= moderate, 3=bad
10	Number of replications to run this model
9/16	Initial Harvest date (mm/dd)
Y	Preemption option , Y/N
n	Include second harvest?
9/4	The date considered day-1 of harvest season
$15.74	Tractor fixed cost for boll buggy and module builder operations ($/hr) See MSU crop budget
$ 8.92	Tractor direct cost ($/hr) for boll buggy and module builder operations See MSU crop budget

Table 3: XLCOTSIM model simulated harvest system costs, Verona, MS in 2003.

Treatments	Yield (lb/Ac)	Loss (%)	Acres/Group	Total Acres/ Machine	Performance Rate (Ac/Hr)	Hrs	Harvest Cost ($/Ac)	Net Revenue ($/Ac)
1 15-in solid	1196	3.3	150, 500, 100	750	3.6	234	$147	$618
2 15-in 2 X 1 skip	1106	3.4	200, 775, 150	1125	5.4	236	$98	$619
3 15-in 2 X 2 skip	1039	4.0	300, 975, 200	1475	7.2	237	$75	$610
4 30-in solid	1038	4.0	150, 500, 100	750	3.6	236	$137	$538
5 30-in 2 X 1 skip	813	4.6	200, 800, 125	1125	5.4	235	$92	$436
6 60-in solid	902	7.0	300, 1050, 150	1500	7.2	237	$69	$491
7 38-in solid	922	4.1	150, 688, 125	963	4.6	236	$108	$490
8 38-in 2 X 1 skip	810	4.0	250, 975, 200	1425	6.8	235	$72	$460

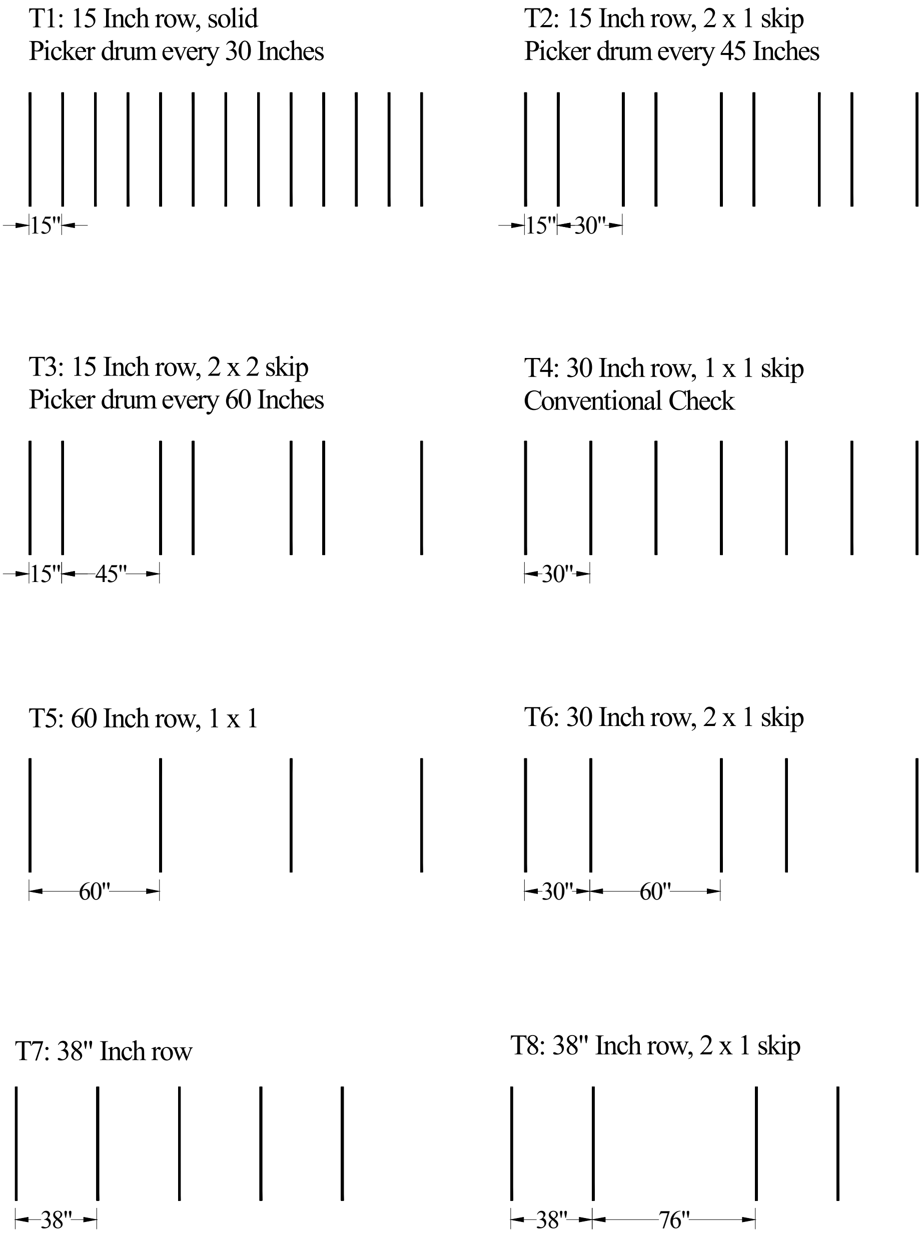

Figure 1: Row Patterns Tested.

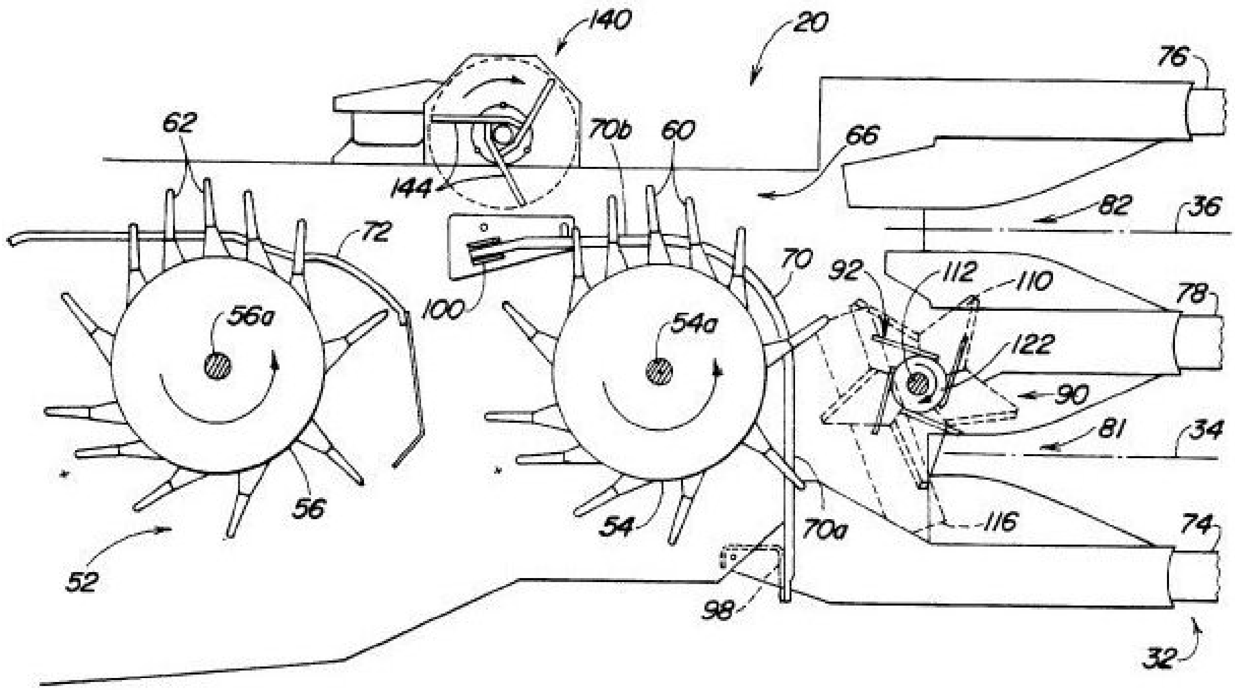

Figure 2: John Deere, Pro 12, 15-inch spindle picker row unit (Deutsch, et al., 2001,US Patent Number 6,293,078 B1).

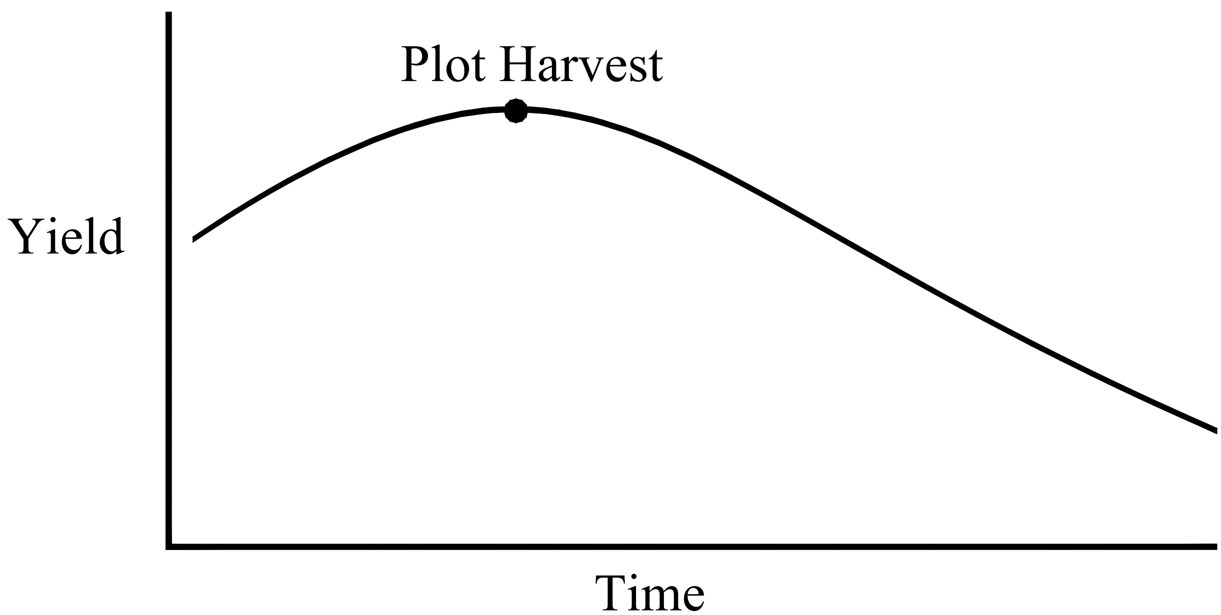

Figure 3: Typical XLCOTSIM Simulation Model Yield Curve.