COTTON YIELD AND LOSSES AS A FUNCTION OF HARVESTING GROUND SPEED

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Abstract

Harvesting ground speed has been investigated across many crops in an effort to maximize yield or quality, but few such studies have been evaluated in cotton harvesting. This study investigated the picking loss effects of cotton picker speed across three varieties and two harvest timings. Differences in picking loss as a function of speed were significant in some caparisons, with picking losses generally increasing as a function of harvest speed. Significance was dependent on variety and harvest timing. Across all three varieties and both harvest timings, seed cotton picking losses were observed to be 209, 212, 240, and 250 kg ha^{-1} (186, 189, 214, and 223 lb ac^{-1}) for picking speeds of 3, 5, 6, and 8 kph (2, 3, 4, and 5 mph), demonstrating increased seed cotton losses of 11.9 kg ha^{-1} per kph above 4.8 kph (17.0 lb ac^{-1} per mph above 3.0 mph). Effect of harvest timing on seed cotton losses was significant, demonstrating increased seed cotton losses of 4.3 kg ha^{-1} day^{-1} (3.8 lb ac^{-1} day^{-1}).

Introduction

Harvesting ground speed has been investigated across many crops in an effort to maximize yield or quality, but few such studies have been evaluated in cotton harvesting. Quick and Buchele (1974) reported 1-1.5% increase in total soybean header loss per mile per hour increase in combine ground speed. Pishgar-Komleh et al. (2013) reported significant increases in corn gathering losses as a function of ground speed. In wheat, SheikhDavoodi and Houshyar (2010) found that increases in travel speed led to increases in threshing losses. Kirk et al. (2017) reported significant increase in peanut digging losses as a function of increasing ground speed.

In cotton, a 2018 Clemson University study used naturally occurring, in-field variability across a wide range of variables to model yield in Deltapine 1646; the models from this study showed harvester speed to be significant for prediction of cotton yield, accounting for a predicted range of 172 kg ha^{-1} (153 lb ac^{-1}) of observed lint yield differences in the test. A Brazilian study (Kazama et al., 2018) demonstrated an almost linear relationship between harvest speed and percent total picking losses, picking losses increasing by about 1.2% total losses per each mile per hour increase. However, they reported no significant differences between speed treatments from 5.0 to 9.0 kph (3.1 mph to 5.6 mph) and 1 kph (0.6 mph) increments.

This study sought to better understand relationships between cotton yield as a function of harvester speed. The objectives of this test were to: assess the effect of harvester speed across varieties and crop condition on seed cotton yield, on-ground losses, and on-plant losses; and to seek to determine optimum harvester speeds to maximize economic returns.

Materials and Methods

To evaluate effects of cotton picker speed on yield, quality, and picking losses, three sites were established at Edisto REC to evaluate four different picker speeds: 3, 5, 6, and 8 kph (2, 3, 4, and 5 mph). Each site was planted in a different variety of cotton to look at effects within three different Deltapine varieties: 1646, 1835, and 1851. The test at field D3A in Deltapine 1835 was established as a randomized block design with the four picker speed treatments, five replications, and only one harvest timing. The tests at field E8A and E8B were established as split plot designs with ground speed as the main plot factor, harvest timing as the subplot factor, and five replications. Field E8A was planted in Deltapine 1851 and field E8B was planted in Deltapine 1646. Harvest timing was established as "on-time" (9 days after defoliation) or "late" (25 days after defoliation), to seek to establish whether or not extended weather and cotton string-out changed the effects of cotton picker speed.

All tests were picked with a John Deere 9986 cotton picker in second gear; the picker was equipped with Pro 16 heads and John Deere cotton mass flow sensors for yield monitoring. Cotton was planted on 97 cm (38 in.) row centers.

Plots were 51.8 m long and 5.8 m wide (170 ft long and 19 ft wide); yield data was extracted from the center 26 m (85 ft) of each plot and picking losses were independently measured as on-plant and on-ground losses from 4-row wide by 2.4 m (8.0 ft) long (9.38 m^2, 101 ft^2) sampling areas positioned at the center of each plot. The yield data showed that the average achieved speeds for the 3, 5, 6, and 8 kph (2, 3, 4, and 5 mph) treatments across all three test sites were 3.2, 4.8, 6.3, and 7.7 kph (2.0, 3.0, 3.9, and 4.8 mph).

Results and Discussion

Results are presented here based on sampled seed cotton picking losses and are ignorant of yield monitor-indicated yield because the mass flow sensor response as a function of mass flow rate across harvest speeds was thought to be inconsistent. Within each replication and within each test, if the yield monitor calibration was consistently accurate across harvesting speeds, then there should have been no differences in total cotton production between speed treatments, with total cotton production being calculated as indicated yield plus collected losses. Because there were observed differences in total cotton production (indicated yield plus collected losses) between the speed treatments, the accuracy of the yield monitor was thought to be inconsistent across harvesting speeds and was therefore rejected for use in analysis.

Figure 1 shows total picking losses (on-ground and on-plant, combined) as a function of speed treatment, independent of harvest timing. There was no apparent relationship between picking speed and losses in Deltapine 1835 (Figure 1a, field D3A), although positive relationships between picking speed and picking losses were observed in Deltapine 1851 (Figure 1b, field E8A), Deltapine 1646 (Figure 1c, field E8B), and the merged dataset (Figure 1d). These relationships showed increases of 24.5 kg ha^{-1} or 1.04 % of production, 8.25 kg ha^{-1} or 0.35% of production, and 11.9 kg ha^{-1} or 0.49% of production of seed cotton lost, respectively, per each kilometer per hour above 4.8 kph (35.0, 11.8, and 17.0 lb ac^{-1} or 1.67%, 0.56%, and 0.78% of production per each mile per hour above 3 mph). Relationships were assessed here only for speeds greater than or equal to 3 mph because differences in losses between 3.2 and 4.8 kph (2.0 and 3.0 mph) were generally negligible. Although trends were apparent, significant differences (α=0.05) in picking losses as a function of picking speed were only observed in Deltapine 1851.

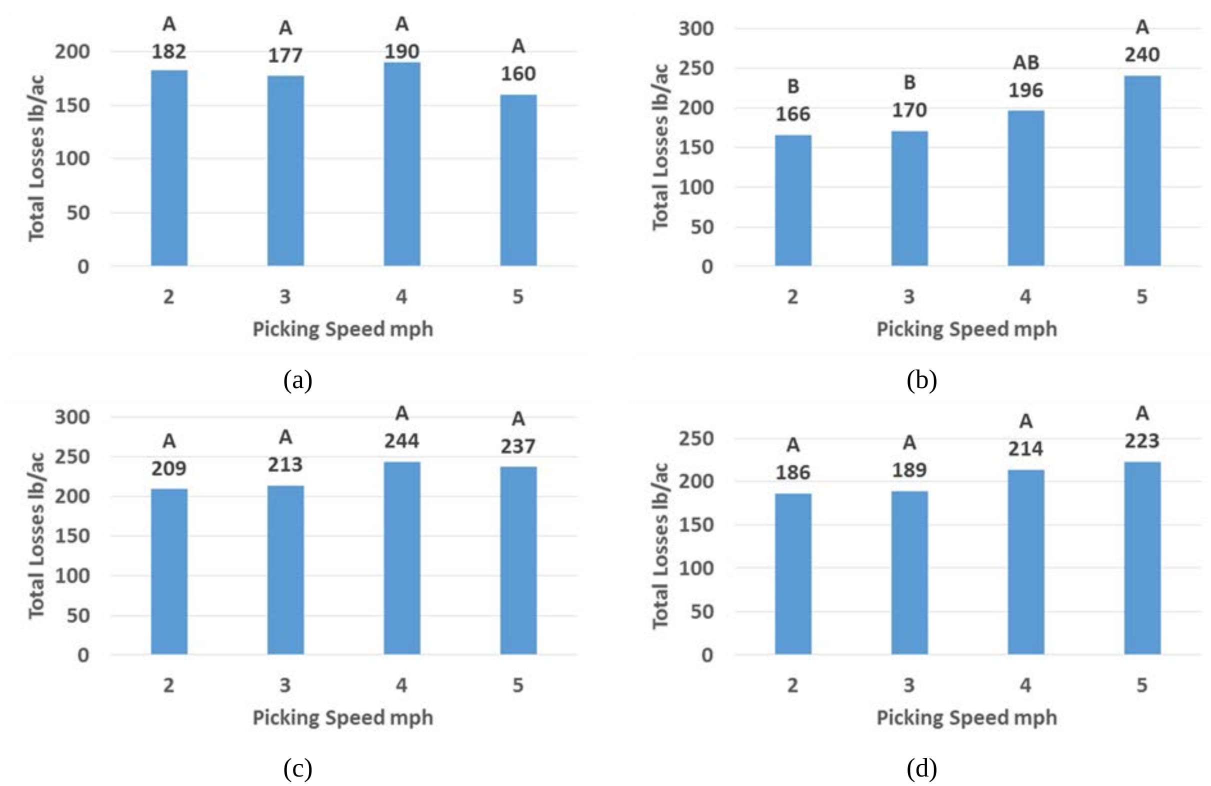
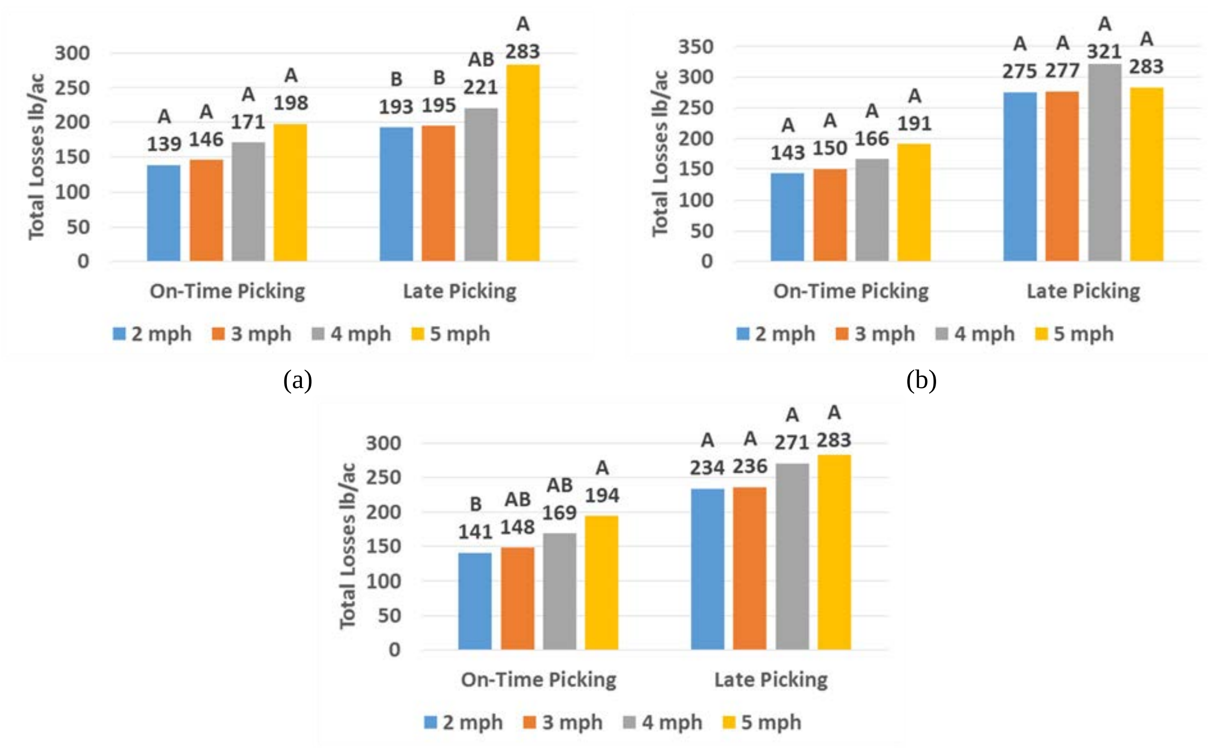


Figure 1. Total (on-ground and on-plant) seed cotton picking losses as a function of speed treatment, independent of harvest timing for Deltapine 1835 (a, field D3A), Deltapine 1851 (b, field E8A), Deltapine 1646 (c, field E8B), and the merged dataset of all three varieties (d).

Only one harvest timing (on-time) was conducted in Deltapine 1835, so assessment as a function of harvest timing could not be conducted for this variety. Significant differences in yield were observed in Deltapine 1851 at the late picking and across Deltapine 1851 and 1646 at the early picking (Figure 2). As shown in Table 1, in Deltapine 1851 there were strong relationships between total losses and picker speed at speeds greater than or equal to 4.8 kph (3.0 mph) for both the on-time picking (R^2=0.9997) and the late picking (R^2=0.9445). These relationships showed seed cotton loss increases of 18.2 kg ha^{-1} (for the on-time picking) and 30.8 kg ha^{-1} (for the late picking) per each kilometer per hour above 4.8 kph (26.0 and 44.0 lb ac^{-1} per each mile per hour above 3.0 mph). These values translate to increased losses of 0.57% (on-time picking) and 1.51% (late picking) of production per each kilometer per hour above 4.8 kph (0.91% and 2.42% per each mile per hour above 3.0 mph). When considering only speeds greater than or equal to 4.8 kph (3.0 mph) in Deltapine 1646, there was a relationship between picking losses and speed for the on-time picking (R^2=0.9864) but no relationship for the late picking (R^2=0.0181). For the on-time picking in Deltapine 1646, picking losses increased by 14.3 kg ha^{-1} (0.59%) of seed cotton production per each kilometer per hour above 4.8 kph (20.4 lb ac^{-1} or 0.94% of production per each mile per hour above 3.0 mph). Additional results showing trends in picking losses as functions of variety, picking speed, and harvest timing can be seen in Table 1. Across all varieties and both harvest timings, on-plant losses represented 42% of the total losses, were proportionately lowest (39% of the total losses) at 5 kph (3 mph), and highest (44% of the total losses) at 8 kph (5 mph). On-plant losses represented a greater percentage of total losses at the late picking (44%) than at the on-time picking (39%).



(a) (b) (c)

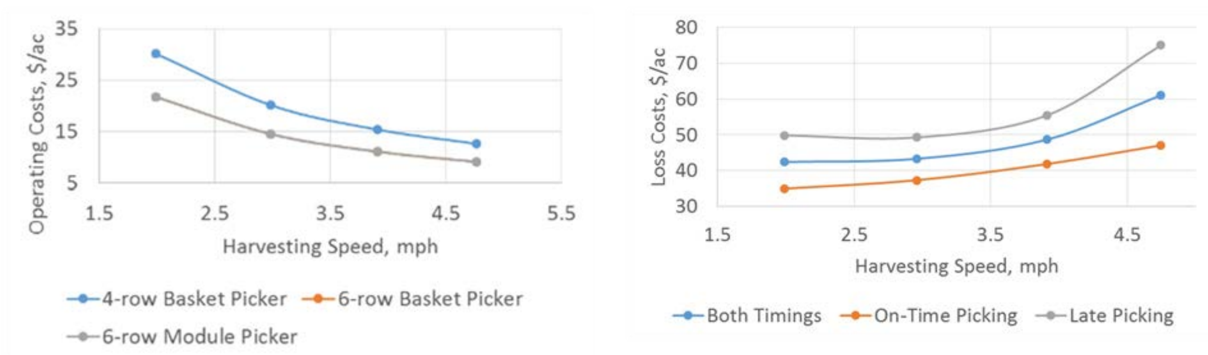
Figure 2. Total seed cotton picking losses (on-ground and on-plant) as a function of picking speed by harvest timing for Deltapine 1851 (a, E8A), Deltapine 1646 (b, E8B), and the merged data from Deltapine 1851 and 1646 (c).

Table 1. Increases in seed cotton picking losses as a function of picker speed for on-time and late picking of Deltapine 1851 and 1646.

	On-time Harvest		**Late Harvest**		**Both Harvest Timings**	
Variety	**kg ha^{-1} per kph[a] (R^2)**	**% per kph[b] (R^2)**	**kg ha^{-1} per kph[a] (R^2)**	**% per kph[b] (R^2)**	**kg ha^{-1} per kph[a] (R^2)**	**% per kph[b] (R^2)**
DP 1646	14.3 (0.9864)	0.59 (0.9776)	n/a[c] (0.0181)	n/a[c] (0.0207)	8.25 (0.5529)	0.35 (0.4972)
DP 1835	n/a[c] (0.3182)	n/a[c] (0.3769)	Not tested	Not tested	Not tested	Not tested
DP 1851	18.2 (0.9997)	0.57 (0.9984)	30.9 (0.9445)	1.51 (0.9171)	24.5 (0.9753)	1.04 (0.9501)
All varieties	8.8[d] (0.9392)	0.27[d] (0.8546)	16.5[e] (0.9303)	0.81[e] (0.9570)	11.9[d] (0.9343)	0.49[d] (0.9279)

[a] Picking loss increase as kilograms per hectare of seed cotton per each kilometer per hour above 4.8 kph. Convert to pounds per acre of seed cotton per each mile per hour above 3.0 mph by multiplying by a factor of 1.4.
[b] Picking loss increase as percent of production per each kilometer per hour above 4.8 kph. Convert to percent of production per each mile per hour above 3.0 mph by multiplying by a factor of 1.6.
[c] Picking loss increase not reported because of poor correlation with speed.
[d] Includes data from DP 1646, 1835, and 1851 varieties.
[e] Includes data from only DP 1646 and DP 1851 varieties (DP 1835 only had on-time harvest timing).

To assess optimum speed for maximum profitability some assumptions were made relative to operating costs. Fuel consumption was estimated as 54.1, 62.1, 88.2 L hr^{-1} (14.3, 16.4, and 23.3 gal hr^{-1}) for a 4-row basket picker, 6-row basket picker, and 6-row modulating picker, respectively, fuel cost was conservatively estimated as \$0.92 L^{-1} (\$3.5 gal^{-1}), labor costs were estimated as \$42 hr^{-1} for the basket pickers and \$18 hr^{-1} for the modulating picker, average seed cotton yield was input as 2,242 kg ha^{-1} (2,000 lb ac^{-1}), gin turnout was 38%, and lint price was assumed to be \$1.54 kg^{-1} (\$0.70 lb^{-1}). Hourly labor for the basket pickers was higher than that for the modulating picker because it includes an assumption that two individuals are employed at \$12 hr^{-1} to operate a boll buggy and module builder; a labor rate of \$18 hr^{-1} was assumed for the picker operators. Figure 3a shows the trend in per acre operating costs (fuel plus labor costs) as a function of harvesting speed; as operating speed increases, the per acre fuel and labor costs decrease. The higher hourly fuel rate on the 6-row module picker was virtually equal to the higher hourly labor rate on the 6-row basket picker so these two series are approximately equal in Figure 3a; fuel and labor costs were \$92.05 hr^{-1} for the four row basket picker, \$99.40 hr^{-1} for the six row basket picker and \$99.55 hr^{-1} for the six row module picker. Figure 3b shows an example of loss costs as a function of harvest speed for one of the varieties, Deltapine 1851, where losses generally increased as a function of harvest speed.



(a) (b)

Figure 3. Operating costs (as labor and fuel) as a function of harvesting speed for a four-row basket picker, six-row basket picker, and 6-row module picker (a) and an example of loss costs as a function of harvesting speed for Deltapine 1851 (b).

Harvest speed to maximize profitability can be assessed if the fuel and labor costs are added to the loss costs, which can be seen in Figure 4. For Deltapine 1835, where only the on-time harvest timing was tested, there was no evidence that going slower than the maximum speed of the picker was more profitable. The same could be said for the late and combined (on-time and late) timings in Deltapine 1646. In Deltapine 1851, the data suggests that there were optimum picking speeds to maximize profitability, regardless of timing. Second order polynomials fitted to the data in Figure 4b suggest that optimum harvesting speeds in Deltapine 1851 for the on-time, late, and combined timings were 6.0, 5.1, and 5.3 kph (3.7, 3.2, and 3.3 mph) for a 4-row basket picker and 5.5, 5.0, and 5.1 kph (3.4, 3.1, and 3.2 mph) for 6-row (basket or module) pickers. Assuming use of a 6-row picker in Deltapine 1851, the data suggest that savings from harvesting at the optimum speeds, versus the maximum tested speed of 7.7 kph (4.8 mph), would be \$11.9, \$54, and \$35 per hectare (\$4.8, \$22, and \$13.5 per acre) for the on-time, late, and combined timings, respectively. In Deltapine 1646, the optimum speed for on-time picking with a six row picker was found to be 5.6 kph (3.5 mph), representing a savings of \$14.1 ha^{-1} (\$5.7 ac^{-1}). In the merged dataset across varieties, the optimum speed for on-time picking was found to be 5.5 kph (3.4 mph), representing a savings of \$12.6 ha^{-1} (\$5.1 ac^{-1}).

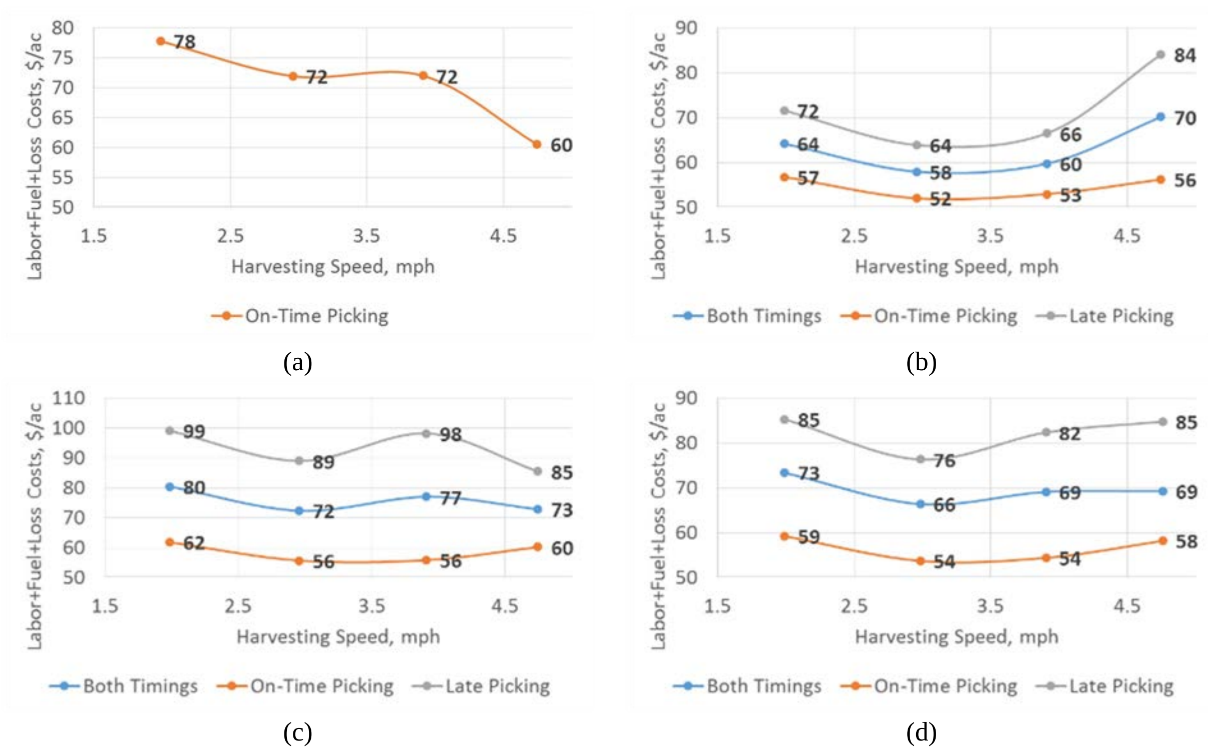


Figure 4. Projections of operating and loss costs as a function of picking speed with a six row module picker for Deltapine 1835 (a, field D3A), Deltapine 1851 (b, field E8A), Deltapine 1646 (c, field E8B), and the merged dataset of all three varieties (d).

Although the primary objective of this study was to evaluate picking losses as a function of picker speed, the data also allows analysis of losses as a function of harvest timing (Figure 5), with the exception of Deltapine 1835, where only the on-time harvest timing was tested. Losses for the late harvest timing were significantly greater than those for the on-time picking in all cases evaluated. The factor that likely contributed greatest to these observed differences was weather incurred between the harvest dates. During the 16 days between the on-time harvest treatment and late harvest treatment, 5.6 cm (2.2 in.) of precipitation fell across 7 days, maximum daily precipitation was 2.8 cm (1.1 in.), maximum daily average wind speed was 26.4 kph (16.4 mph), and the maximum wind speed was 38.6 kph (24.0 mph). In this test, increased seed cotton losses equated to 4.3 kg ha^{-1} day^{-1} (3.8 lb ac^{-1} day^{-1}) for Deltapine 1851, 8.9 kg ha^{-1} day^{-1} (7.9 lb ac^{-1} day^{-1}) for Deltapine 1646, and 6.5 kg ha^{-1} day^{-1} (5.8 lb ac^{-1} day^{-1}) for the two varieties, combined. At assumed gin turnouts of 38% and lint price of $1.54 kg^{-1} ($0.70 lb^{-1}), these values translate to lost value of $2.49 ha^{-1} day^{-1} ($1.01 ac^{-1} day^{-1}) for Deltapine 1851, $5.19 ha^{-1} day^{-1} ($2.10 ac-1 day-1) for Deltapine 1646, and $3.80 ha^{-1} day^{-1} ($1.54 ac^{-1} day^{-1}) for the two varieties, combined.

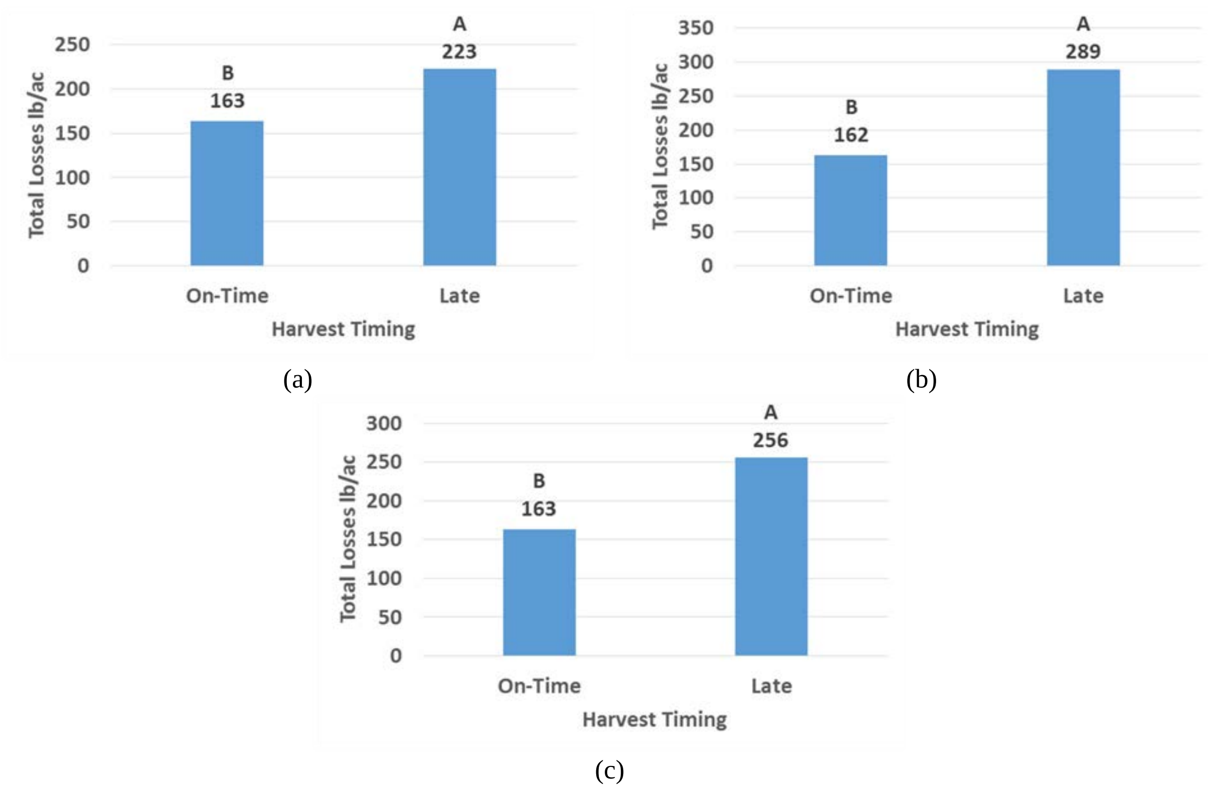


Figure 5. Total seed cotton picking losses (on-plant and on-ground) as a function of harvest timing in Deltapine 1851 (a, field E8A), Deltapine 1646 (b, field E8B), and the merged dataset of both varieties (c).

Conclusions

- Cotton picking losses as a function of harvester speed can be economically important and significant, depending on variety and crop condition.
- The accuracy of the mass flow sensor response was indicated to be inconsistent across harvesting speeds; the yield monitor may not be an effective tool for evaluation without independent calibrations for each ground speed.
- Effect of harvester speed is greater when crop condition is compromised; an economic balance between harvester speed and harvest timeliness makes selection of economically optimal harvester speed challenging.

Specific Findings of Note Include

- In Deltapine 1835, there was no evidence suggesting that harvesting at any speed lower than the maximum speed of the picker would be beneficial. There were no significant differences between picking losses at different picking speeds. Numerically, the lowest seed cotton losses (179 kg ha^{-1} or 160 lb ac^{-1}) were observed at the highest speed, 7.7 kph (4.8 mph).
- In Deltapine 1851, seed cotton picking losses at 7.7 kph (4.8 mph) equal to 269 kg ha^{-1} (240 lb ac^{-1}) were significantly higher than those at 3.2 and 4.8 kph (2.0 and 3.0 mph), which were 186 and 191 kg ha^{-1} (166 and 170 lb ac^{-1}). There were no significant differences in picking losses for the on-time harvest, but a strong linear trend was observed as a function of speed (R^2=0.9997). Seed cotton losses for the late harvest were 317 kg ha^{-1} (283 lb ac^{-1}) at 7.7 kph (4.8 mph) and were significantly higher than those at 3.2 and 4.8 kph (2.0 and 3.0 mph), which were 216 and 219 kg ha^{-1} (193 and 195 lb ac^{-1}).
- In Deltapine 1851, there were strong linear relationships between picking losses and picking speed at speeds greater than or equal to 4.8 kph (3.0 mph), demonstrating increased seed cotton losses of 18.2 and 30.9 kg ha^{-1} per increased kilometer per hour (26.0 and 44.1 lb/ac per increased mile per hour) for the on-time and late harvest timings, respectively.

- In Deltapine 1851, the optimum harvest speeds for maximizing profitability were calculated to be 6.0 kph (3.7 mph) for the on-time harvest and 5.1 kph (3.2 mph) for the late harvest for a four row basket picker, and 5.5 kph (3.4 mph) for the on-time harvest and 5.0 kph (3.1 mph) for the late harvest for a six row basket or module picker. Savings from operating at these speeds versus 7.7 kph (4.8 mph) were calculated to be \$9.1 ha^{-1} (\$3.7 ac^{-1}) for the on-time harvest and \$50.9 ha^{-1} (\$20.6 ac^{-1}) for the late harvest for a four row basket picker, and \$11.9 ha^{-1} (\$4.8 ac^{-1}) for the on-time harvest and \$55.3 ha^{-1} (\$22.4 ac^{-1}) for the late harvest for a six row basket or module picker.
- In Deltapine 1646, there were no significant differences in picking losses as a function of speed. There was a strong relationship between picking losses and harvest speed at the early timing (R^2=0.9776), but not at the late timing. The relationship at the early timing suggested increased seed cotton losses of 14.3 kg ha^{-1} per kilometer per hour above 4.8 kph (20.4 lb ac^{-1} per mile per hour above 3 mph).
- In Deltapine 1646, optimum harvest speed to maximize profit for the on-time picking was calculated to be 6.0 kph (3.7 mph) for a four row basket picker and 5.6 kph (3.5 mph) for a six row basket or module picker. Savings from operating at these speeds versus 7.7 kph (4.8 mph) were calculated to be \$11.4 ha^{-1} (\$4.6 ac^{-1}) for a four row basket picker and \$14.1 ha^{-1} (\$5.7 ac^{-1}) for a six row basket or module picker.
- Across all three varieties and both harvest timings, there was a strong linear relationship between picking losses and harvest speeds equal to or greater than 4.8 kph (3.0 mph), R^2=0.9343, demonstrating increased seed cotton losses of 11.9 kg ha^{-1} per each kilometer per hour above 4.8 kph (17.0 lb ac^{-1} per each mile per hour above 3.0 mph).
- Across all three varieties, optimum harvest speed to maximize profit for the on-time picking was calculated to be 6.0 kph (3.7 mph) for a four row basket picker and 5.5 kph (3.4 mph) for a six row basket or module picker. Savings from operating at these speeds versus 7.7 kph (4.8 mph) were calculated to be \$9.9 ha^{-1} (\$4.0 ac^{-1}) for a four row basket picker and \$12.6 ha^{-1} (\$5.1 ac^{-1}) for a six row basket or module picker.
- In Deltapine 1851 and 1646, the effect of harvest timing on seed cotton losses was significant, with increased seed cotton losses of to 4.3 kg ha^{-1} day^{-1} (3.8 lb ac^{-1} day^{-1}) for DP 1851, 8.9 kg ha^{-1} day^{-1} (7.9 lb ac^{-1} day^{-1}) for DP 1646, and 6.5 kg ha^{-1} day^{-1} (5.8 lb ac^{-1} day^{-1}) for the two varieties, combined.

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