Improving in-row cultivation efficacy in carrots through seed selection and timing optimization

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Introduction

Background

- Weed management in carrots is a major challenge because of their slow growth and lack of competitiveness
- "Pigweed" species including Powell amaranth (*Amaranthus powellii*) grow quickly and are resistant to several herbicides including Lorox
- In organic production, mechanical cultivation is used to control weeds, but at early stages in-row cultivation can damage the crop through uprooting or burial.
- We used a combination of model development and field studies to evaluate whether the selectivity of in-row mechanical cultivation could be improved through cultural practices which increase the anchorage force and/or height of crops relative to weeds at early growth stages.

Hypothesis:

The efficacy and selectivity of in-row mechanical cultivation with tools that uproot (e.g. finger weeders) or bury (e.g.hilling disks) can be improved through:

1) Use of large seed size fractions from a competitive cultivar ('Bolero') to increase crop anchorage force and height at the time of cultivation.

2) Adjustments in the type and timing of cultivation based on the relative height and anchorage forces of crops and weeds over time.

Methods

Methods: Greenhouse

- Five species of weeds and 'Bolero' carrots grown in individual pots for 3 weeks
- Measured anchorage force (Fig 1) and height every 3 days
- Used data to parameterize model based off Kurstjens et al. (2004) to predict weed and crop mortality under different levels of burial and uprooting intensity.

Fig. 1: Anchorage Force gauge to measure force required to uproot plants

- Key Model Assumptions: 1) all plants shorter than the burial depth achieved with cultivation will die; 2) plants with anchorage forces less than uprooting forces achieved with cultivation will die; 3) cultivators are calibrated to bury or uproot such that carrot mortality is 5%.

Methods: Field Study

- Field study conducted in East Lansing, MI in summer 2021
- Split split plot design to test:
  - 3 types of early in-row weed management: finger weeder (Fig 2a), hilling disk (Fig 2b), or handweeding
  - Large vs small carrot seeds separated by weight
- Flame weeded pre-emergence for stale seedbed
- 2 in-row cultivation events
- At time of cultivation, measured anchorage force and height to predict selectivity
- Measured in-row weed mortality and crop survival and growth
- Data analyzed with ANOVA in R and model written in R

Fig. 2: Mechanical Cultivation tools
a. Finger weeder primarily uproots weeds b. Hilling Disk primarily buries weeds

Results

Greenhouse Results and Model Predictions

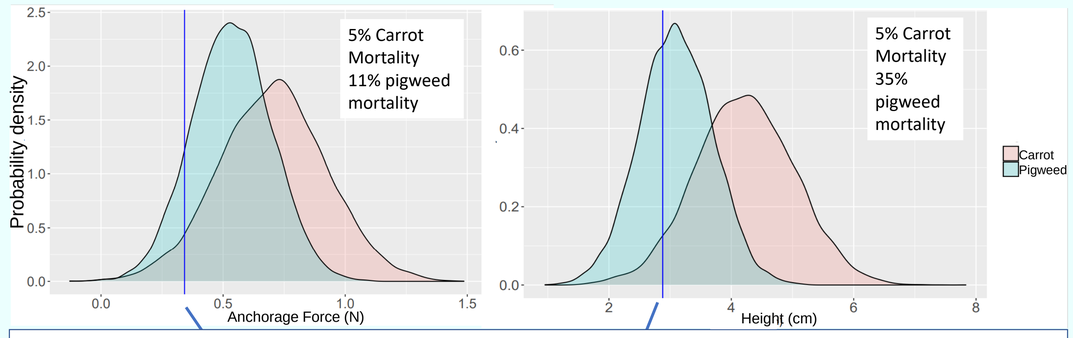

Fig. 3 : Comparison of 19 days old carrots and pigweed in the greenhouse. Blue line indicates amount of force used with of 5% predicted carrot mortality. a) Anchorage force distribution b) Height distribution

Pigweed vs. Carrot Characteristics at 19 days after seeding (DAS).

- Carrots were more strongly anchored and taller than pigweed (Fig 3)
- Greater difference between carrot and pigweed heights than between their uprooting forces (Fig 3)
- Assuming levels of burial and uprooting that result in 5% carrot mortality (blue line), our model predicts greater potential pigweed mortality from burial (35%) than uprooting (11%) (Fig 4)

Assuming 5% carrot mortality

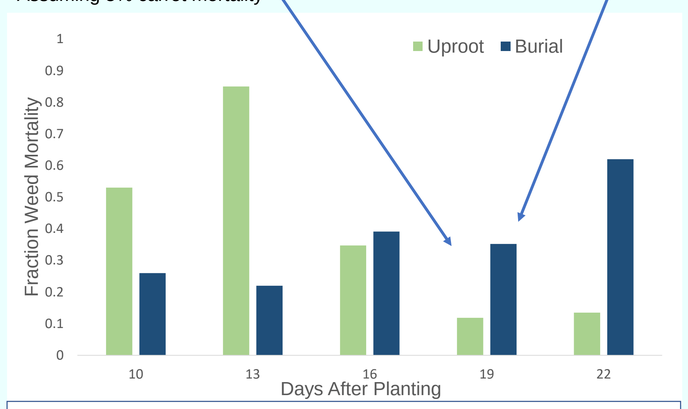

Fig. 4: Predicted potential pigweed mortality over time assuming 5% carrot mortality.

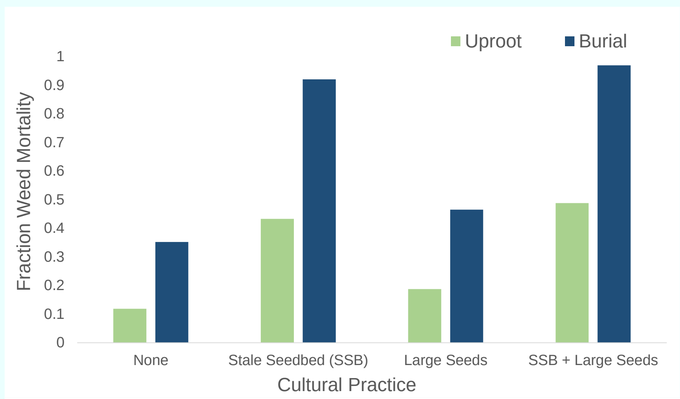

Fig. 5: Predicted potential pigweed mortality with 5% carrot mortality for different cultural management practices. SSB is stale seedbed, large seeds are large carrot seed size. Based on greenhouse data and seed size results from previous trials.

Model Predictions: Timing Effects

- Optimal tool choice changes over time
- Predicted selective potential is highest with tools that uproot (e.g. finger weeders) at 13 DAS
- At 19 DAS, burial is predicted to have higher efficacy and selective potential than uprooting.

Cultural Practice Effects

- Stale seedbed increases potential selectivity
- Large carrot seed size increases potential selectivity
- Most effective to combine large carrot seed size and stale seedbed
- None of the cultural practices change optimal tool

Field Study Results

- Carrots from larger seeds were better anchored and taller at time of cultivation
- This did not translate to improved cultivation tolerance
- No significant differences in weed or carrot mortality between tools

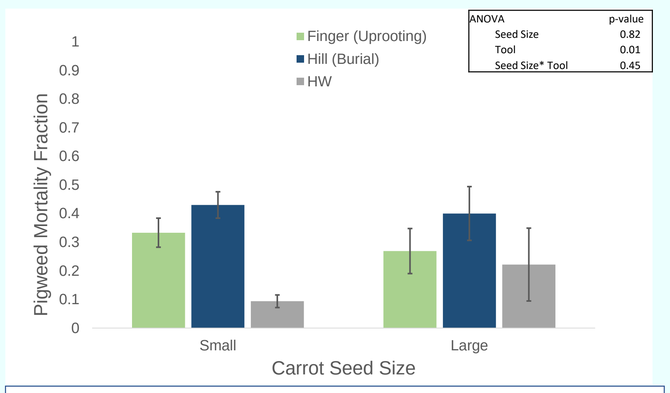

Fig. 6: Pigweed mortality in field trial at 21 DAS. ANOVA shows p-value for differences in pigweed mortality by carrot seed size and tool. Finger weeding had 10% carrot mortality, hilling disk had 17% carrot mortality, handweeding (HW) had 3% carrot mortality.

	Anchorage Force (N)	Height (cm)
Large	1.30 a	3.72 a
Small	1.04 b	3.36 b

Table 1: Mean carrot characteristics by seed size at time of cultivation events. All differences are statistically significant ($p<0.05$).

Fig. 7: Carrots after hilling

Fig. 8: Weeds uprooted after finger weeding

Conclusions

Conclusions From Model

- Optimal tool changes with time
- Cultural practices including stale seedbed and seed size can improve selective potential

Conclusions from Field Study

- No significant differences in selectivity observed from seed size or tool choice
- Mortality of pigweed from cultivation at 21 DAS ranged from 30-40%
- To attain in-row pigweed mortality of 50% or more, greater precision of mechanical cultivation in combination with cultural practices is likely needed.

Future Directions

- Test optimal tool over time in field study
- Improve model to include variation of force exerted by tool
- Explore effect of other cultural practices on selectivity and efficacy of cultivation

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Reference:
Kurstjens, D. A. G., M. J. Kropff and U. D. Perdok. 2004. Method for predicting selective uprooting by mechanical weeders from plant anchorage forces. Weed Science 52:123–132.

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