Tine weeding as a weed management tool for wild blueberry (*Vaccinium augustifolium*) growers in Maine

L. Calderwood

University of Maine, Orono, Maine, USA.

Abstract

Annual and perennial weeds compete with commercially grown wild blueberry (*Vaccinium angustifolium*) in Maine and Atlantic Canada. This two-year study sought to explore tine weeding as a mechanical weed management tool for both conventional and certified organic wild blueberry systems. Tine weeding is a method of shallow early spring cultivation used on vegetable and small grain farms. At two locations in Jonesboro Maine, tine weeding was explored on one date, two dates, and as 2 and 4 passes during the prune year. While each location had a different starting weed community, sheep sorrel (*Rumex acetosella*), Canada mayflower (*Maianthemum canadense*), and horse weed (*Erigeron canadensis*) were among those weeds dislodged by this early tine-weeding exploration. Tine weeding reduced the number of weeds in one of two locations, which had a less diverse weed community. In both locations two passes with the tine weeder on one date in early May was most effective at removing the white thread stage weeds while causing the least damage to wild blueberry rhizomes.

Keywords: wild blueberry, mechanical weed management, tine weed

INTRODUCTION

Wild, or lowbush, blueberry (*Vaccinium angustifolium* Ait.) is an economically and culturally important crop to Maine. A native plant, first cultivated by several native tribes is currently grown on 16,680 ha (41,200 acres) by 485 farms in Maine, 46 of which were certified organic covering 1,066 ha (2,635 acres) as of June 2020. Due to the increasing demand for organic, IPM (integrated pest management), and low-residue wild blueberries, there is a need to explore mechanical weeding options in the wild blueberry farming system. To date, the University of Maine has found that removing weeds from a wild blueberry field can double yield in a conventional system (Yarborough and Marra, 1997).

Conventional systems have a variety of chemical weed control options while certified organic wild blueberry production relies more heavily on mechanical and cultural weed management because there are very few effective OMRI (Organic Materials Review Institute) approved herbicides available. The effective cultural weed management practices used in wild blueberry production include applying sulfur to reduce soil pH (Yarborough and Marra, 1997; Saunders, 2016), mechanically cutting, mowing or pulling woody weeds (Drummond et al., 2012), and burn pruning (Jensen and Yarborough, 2004). It takes 2-3 years for sulfur to reduce soil pH to the goal of 4.0-4.5. Reducing the pH of the soil is very effective in managing grasses and some broadleaf weeds. However, woody weeds, ferns, and some herbaceous perennials also prefer acidic soil. Removing woody weeds via mowing, weed whacking, and/or hand pulling are the most effective methods of mechanical weed management to date, but must be performed 3-times per season to significantly reduce the weed population (Drummond et al., 2012). Burn pruning selectively removes susceptible weeds such as shallow-rooted woodland species but creates space for other burn tolerant species (Jensen and Yarborough, 2004). This two-year study was intended to explore tine weeding as a mechanical and cultural weed management tool for the wild blueberry system.

Tine weeding is a method of shallow early spring cultivation used on vegetable and small grain farms just as the first winter annual weed seedlings emerge. The stiffness of tines allows them to break through the soil crust and the vibration of tines uproots young weed seedlings (Bowman, 2002). Flex-tine weeders are specifically designed to dislodge the white thread stage of the weeds when the machine is run at a “fast” speed. A flex-tine weeder was used in this study as a tractor attachment with metal fingers called “tines” that drag through the top one inch of soil dislodging weed seedlings (Figure 1).

Figure 1. Williams flex-tine weeder at Blueberry Hill Farm in Jonesboro, ME.

The objectives of this study were to A) explore tine weeding as a mechanical means of removing early spring weeds in two prune Maine wild blueberry fields and B) monitor wild blueberry and weed cover changes in response to tine weeding on different dates and number of passes over the course of two years (2019 and 2020).

METHODS

In April 2019, the first prune location (A) was selected at the University of Maine Blueberry Hill Farm Experiment Station in Jonesboro, ME, to evaluate tine weeding on 1 and 2 dates compared to hand weeding. This trial site covered 0.20 ha and the weed community in May 2019 when tine weeding occurred comprised but not limited to the following: sheep sorrel (*Rumex acetosella*), violet (*Viola* spp.), Canada mayflower (*Maianthemum canadense*), bunchberry (*Cornus canadensis*), horse weed (*Erigeron canadensis*), goldenrod (*Solidago* spp.), wild lettuce (*Lactuca* spp.), Saint John’s wort (*Hypericum perforatum*), dogbane (*Apocynum cannabinum*), and toadflax (*Linaria* spp). In April 2020, a second prune field location (B) was selected in a different section of Blueberry Hill Farm in Jonesboro ME, and was established to evaluate tine weeding with 2 passes compared to 4 passes. This trial site covered 0.0011 ha and the weed community in May 2020 when tine weeding occurred was comprised but not limited to sheep sorrel (*Rumex acetosella*), violet (*Viola* spp.), goldenrod (*Solidago* spp.) and Saint John’s wort (*Hypericum perforatum*). The study design in both locations was randomized complete block, replicated six times with 16.7 m^2 (1.8×9 m) plots and 0.9 m wide buffers between plots.

Treatments are listed in Table 1. Two controls were employed consisting of no weeding and hand weeding on one date per year. Each pass with the tine weeder was considered down a plot in one direction. Tines on the Williams flex-tine weeder were set to have the greatest down pressure (setting 8). Although both locations have been land leveled and de-rocked, wild blueberry fields have more dips and high points than tilled cropping system fields. The tractor was run slower than recommended at 1 mph due to bumpy field conditions. After performing a trial run of the tine weeder outside of research plots, it was determined that 1 pass would not be enough to dislodge weeds and that 2 passes would be the starting point.

Table 1. Tine weed treatments in both locations and years at Blueberry Hill Farm, Jonesboro ME.

Treatment	Date(s)	Year(s)	Location
Control, no tine weeding		2019, 2020	A, B
Hand weeded	June 12	2019	A
Tine weeded 2 passes, 1 date	May 13	2019	A
Tine weeded 2 passes, 2 dates	May 13, June 12	2019	A
Tine weeded 2 passes, 1 date	May 11	2020	B
Tine weeded 4 passes, 1 date	May 11	2020	B

Data collection

Measures of weed and blueberry crop growth were collected using two 0.25 m^2 quadrats per plot. Quadrats were placed on the north and south ends of each plot to reduce wild blueberry plant genetic variability. Quadrat locations were flagged for repeated measurements throughout the study in both locations. Weed control efficacy was evaluated within each quadrat by ranking overall weed cover using the Daubenmire scale of 0-6 (Table 2). In 2019, weeds were identified into two groups; grass and broadleaf, each of which were also given a severity rating on the same 0-6 scale and sampled twice throughout the season (June 27 and August 28). In 2020 the total number of weeds per quadrat were counted with an overall rank of weed cover using the Daubenmire scale. The top three weeds that covered the most area within each quadrat were also documented. These measurements were taken three times throughout the 2020 crop-year (May 14, May 27 and July 2).

Table 2. Daubenmire scale ranks with corresponding midpoint percentage for analysis.

Rank	Percent coverage (%)	
	Range	Midpoint
1	0-5	2.5
2	5-25	15.0
3	25-50	37.5
4	50-75	62.5
5	75-95	85.0
6	95-100	97.5

Wild blueberry response to tine weeding in both locations was monitored through repeated observations. In 2020, location A as a crop field was monitored by labeling six random stems per plot for fruit-set, fruit-drop, yield, and quality. Fruit-set measures included bud counts in the late spring, flower counts at peak bloom, green fruit counts prior to ripening, and blue fruit counts during harvest. Percent fruit-set was calculated from the number of green fruit and the number of flowers $stem^{-1}$, while fruit-drop was calculated from the number of blue fruit and the original number of green fruits observed on each stem. Harvest occurred on August 17, 2020, in location A. Harvest procedure included hand raking exact quadrats in the flagged locations where repeated measurements were taken throughout the season. Then a walk behind harvester, harvested a 0.9-m strip down the center of each plot. The two modes of harvesting provided an 'exact' yield and a more 'realistic' yield which accounted for % loss that may occur with a mechanical harvester.

Data analysis

Due to the nature of count data collected in the field, data failed the assumptions of normality and equal variance required to run parametric statistical tests. Spatial differences across the field and temporal differences across sample dates may also be impacting the normality of these data. Non-normal data were square root transformed prior to all statistical testing.

Single date measurements including: counts of buds, flowers, green fruit and blue fruit, percent fruit-set and fruit-drop, harvest yield, berry size, and sugar content were evaluated using a generalized linear model (GLM), followed by a Tukey's Pairwise comparison in JMP (JMP®, Version 14.3) across all tine weed management treatments and the controls (α=0.05). Ranked weed and blueberry cover data were transformed to their corresponding percent mid-point and compared across both locations (2019 and 2020) using a full-factorial repeated-measures mixed model design in JMP. Here, the full-factorial tested the effects of year, treatment and any interaction between year and treatment for the ranked response variables. Weed number was collected in the 2020 field season and this was tested using a linear repeated-measures mixed model design in JMP. Additionally, the effect of weed pressure (weed number weighted by rank) on yield was investigated using a non-parametric Spearman ρ Correlation also in JMP.

RESULTS

Impact of tine weeding on weeds

In 2019 and 2020 at locations A and B, two tine weed passes were more effective than one or four passes on a single date at both uprooting weeds and impacting wild blueberry cover. The first pass loosened the soil allowing the second pass to then dislodge weeds. Sheep sorrel, Canada mayflower and horse weed were uprooted. In 2019, we found no significant differences between weed management treatments and the presence of broadleaf or grass weeds. However, in 2020 there was a significant reduction in the number of weeds present after tine weeding.

At location A, where two years of data were collected (2019 prune and 2020 crop), weed composition by treatment shifted in terms of the weed species present and our ranking of the top 3 broadleaf species present. In the control, bunchberry and bracken fern remained persistent over both years, while in the hand weeded treatment there was a slight shift from larger weeds that may be easier to pull by hand (bunchberry and vetch), to smaller weeds (sheep sorrel and toadflax) that could be easily missed. Overall, the variety of weeds observed, and the occurrence of broadleaf weeds increased in the tine weeded plots from 2019 to 2020 while increasing in both controls (Figure 2).

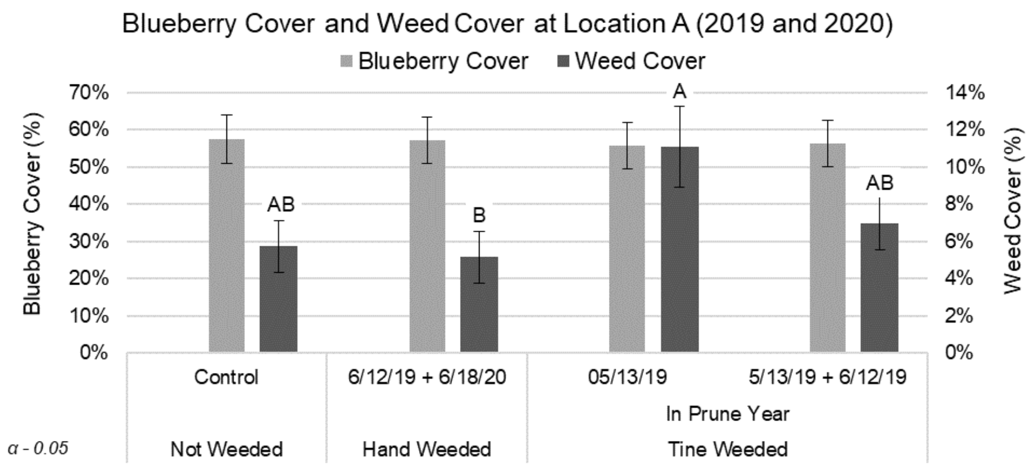

Figure 2. At location A, wild blueberry cover and weed cover averaged over 2019 and 2020 for tine-weed treatments. Treatment differences between blueberry cover were not significant. Letters indicate significance at the 0.05 level of significance for weed cover. Error bars indicate the standard error of the mean.

At location B, where one year of prune data was collected (2020 prune), the number of weeds present decreased significantly from pre- to post-tine weeding (Figure 3). There was a 17% decrease in weed cover m^{-2} and a 52% decrease in weed number m^{-2} in the 2-pass tine weed treatment. In the 4-pass tine weed treatments a 21% decrease in weed cover m^{-2} and 65% decrease in weed number m^{-2} was observed (Figure 4) while weed cover m^{-2} increased by 23% in the control.

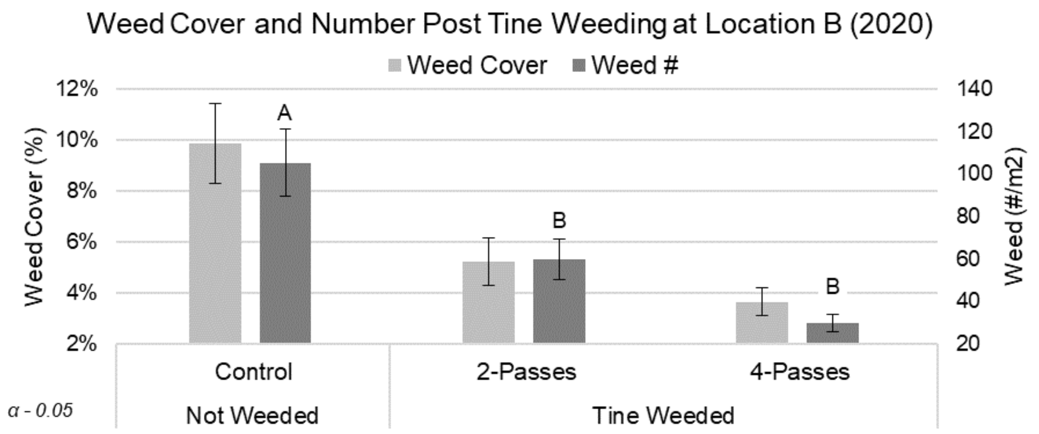

Figure 3. Weed cover and weed number following tine weeding at location B in 2020. Treatment differences were not significant for weed cover. Letters indicate significance at the 0.05 level of significance for weed number. Error bars indicate the standard error of the mean.

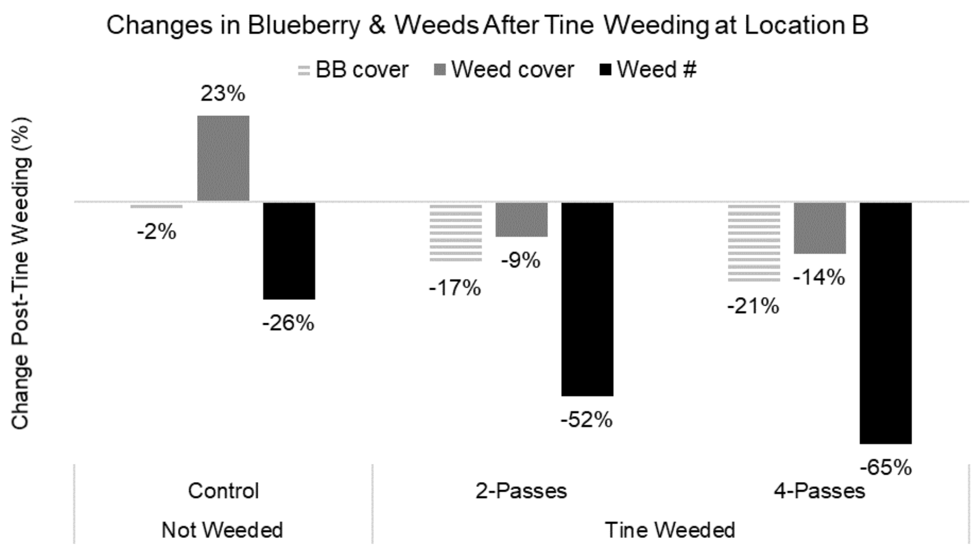

Figure 4. At location B, changes in wild blueberry cover, weed cover and weed number following prune tine weeding.

Impact of tine weeding on wild blueberry

Tine weeding disturbed wild blueberry rhizomes, and in some cases, loose wild blueberry ramets were pulled up and above the soil. The most damage to the wild blueberry crop occurred on the late tine weeding date of June 12, 2019, from the tractor driving over tender wild blueberry shoots. Tine weeding in early May when certain weeds were present, but when the wild blueberry had not yet emerged, did not cause as much damage to the wild blueberry.

The average number of wild blueberry ramets in tine weeded plots increased by 15% at location A in 2019 and by 11% at location B in 2020. Stem counts of new growth were also taken in location B in 2020 revealing the opposite trend. Stem number decreased by 15% in plots tine weeded with 2 passes and 25% in plots tine weeded with 4 passes. During the crop year of location A, percent fruit set (flower to green fruit) and fruit drop (green fruit to blue fruit) did not present significant differences between treatments.

Impact of tine weeding on wild blueberry yield and quality

Wild blueberry in location A did not exhibit significant treatment differences in harvest yield (Figure 5), however, there was a slight trend toward reduced yield in all weeded plots (both hand weeded and tine weeded). The hand weeded plot had very little mechanical disturbance except for slightly greater foot-traffic. When comparing yield from the prune-tined treatments to hand weed treatment, the prune-tined treatments performed slightly better despite the observed increase in weed pressure in these plots.

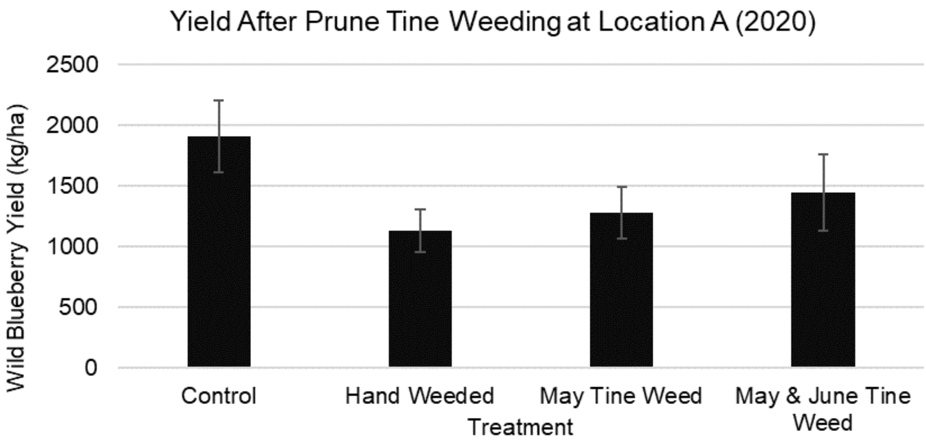

Figure 5. Yield harvested on August 17, 2020, from plots tine weeded in 2019. Treatment differences for blueberry yield were not significant. Error bars indicate the standard error of the mean.

DISCUSSION

This work suggests that shallow mechanical weeding in wild blueberry warrants further investigation due to weed control achieved and the possibility of wild blueberry stimulation. Tine weeding as a mechanical weed management tool reduced the number of weeds in location B, which was comprised primarily of sheep sorrel, violet, goldenrod, and Saint John's wort. This location with a less diverse weed community showed more weed control than location A which comprised a more diverse weed community. In both locations we identified that 2 passes (1 down and 1 back) on one date in early May was most effective at removing the white thread stage weeds while causing less damage to wild blueberry rhizomes.

Wild blueberry yield was not significant between treatments yet we observed a trend toward higher yield in locations that were tine weeded compared to hand weeding. Although the data are not shown, we also observed a trend toward higher yield in plots that were tine weeded with 2 passes compared to 4 passes. Four passes showed a trend toward reduced wild blueberry yield compared to the control and 2 passes. In both locations, the number of wild blueberry ramets m^{-2} showed an increase in number from the controls to the 2-pass tine weed treatments, which occurred on one date. However, when the number of stems m^{-2} were counted as an added methodology in 2020, the opposite trend was observed. This is most likely because the tine weeder pulled weak or loose rhizomes to the soil surface, increasing the number of ramets counted. Stem counts appear to be a more accurate measure of wild blueberry stand health in this context. There is, however, potential for an increase in vegetative and reproductive growth from the disturbance of tine weeding or similar rhizome tickling. Similar mechanical stimulus (i.e., pruning, burning and the cutting of rhizomes) has been observed to benefit wild blueberry (Libby, 2011). Further research should investigate the impact of other mechanical weeders on the wild blueberry system, particularly those that uproot weeds but not wild blueberry and those that cut weeds.

Tine weeding is a very direct and physically aggressive mode of weed management and therefore we anticipated a decrease in the number of weeds and overall weed cover in the tine weeded plots, yet this was only seen in one of the two locations. Interestingly, the treatments tine weeded in the 2019 prune-year, exhibited a greater number of weeds and weed cover in 2020 relative to the control. This increase in weed pressure could be due to a variety of factors including the diversity of the original weed community, phenology of weeds in May 2019 compared to May 2020, or topography of the field location. The location A field was in organic transition and was last sprayed with herbicide in 2017. As the effect of the herbicide applied in the past wares off, we expect weed pressure to increase. However, the top weeds in these plots shifted from bunch berry in 2019 to red sorrel in 2020. A successional shift in weed type and the presence of opportunist weeds in an organically managed field may be a driving factor in location A compared to the conventionally managed location B. Similar to burn pruning, tine weeding may be more effective on certain types of weeds, providing an opportunity for other species to emerge after mechanical disturbance (Jensen and Yarborough, 2004).

An alternative theory is that the mechanism of tine weeding may have facilitated the germination of these weeds. Both locations are primarily flail-mow pruned which has been shown to increase seed deposition and weed seed banks over time (Jensen and Yarborough, 2004). There may have been dormant seed banks stored below the surface in the organic pad that were "planted" by the tine weeder, providing weed seeds the resources they needed for establishment. Therefore, a comparison of tine weeding in mowed vs. burned fields is warranted.

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