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Growing Kiwiberries in New England: A Guide for Regional Producers

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GROWING KIWIBERRIES IN NEW ENGLAND: A GUIDE FOR REGIONAL PRODUCERS

By

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Agricultural Sciences (B.S.), University of New Hampshire, 2015

THESIS

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GROWING KIWIBERRIES IN NEW ENGLAND: A GUIDE FOR REGIONAL PRODUCERS

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UNH NHAES farm crew and staff

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ABSTRACT

GROWING KIWIBERRIES IN NEW ENGLAND: A GUIDE FOR REGIONAL PRODUCERS

By

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The kiwiberry (*Actinidia arguta*) has an extensive 140-year history of being grown in New England as an ornamental vine but has only recently been adopted as a commercial fruit crop. As regional and international acreage in commercial production continues to increase, the need for a comprehensive production guides and regionally-specific enterprise analyses has become evident. This thesis brings together the most recent findings of the Kiwiberry Development Program at the New Hampshire Agricultural Experiment Station, along with available commercial kiwiberry production information, to address this need. Specifically, this guide presents an overview of the species, current best production practices, regionally-relevant market information, and an enterprise analysis for this emerging fruit crop in the northeastern US.

CHAPTER I: INTRODUCTION

Preface

This kiwiberry production and enterprise viability guide was developed in response to a growing community of current and prospective small-scale fruit producers throughout the northeast looking for in-depth, regionally-relevant information on this emerging specialty crop. Kiwiberry has an extensive 140-year history of cultivation in New England, first as an ornamental landscape vine and subsequently as a novel fruit crop on private estates and in backyard gardens. Throughout recent decades, a handful of producers experimented with field-scale kiwiberry production; and such pioneering work not only demonstrated the commercial viability of the crop in our region but also helped catalyze interest among both consumers and researchers.

To support the development of kiwiberry as a new, high-value fruit crop for the northeast, the New Hampshire Agricultural Experiment Station launched a long-term kiwiberry research and breeding program in 2013. This guide, comprised of a statewide market assessment, a detailed production manual, and an enterprise viability guide, is a synthesis of the knowledge gathered and generated over the first five years of that program. Globally, kiwiberry production is on the rise, signaling a transition of the crop from the realm of novel fruit enthusiasts to a high-value horticultural commodity. With the information presented here, it is our hope that interested producers in the Northeastern U.S. will be better prepared to decide whether or not to integrate kiwiberries into their current production systems.

Overview of the species

        Actinidia arguta (Siebold & Zucc.) Planch. ex Miq. is a perennial woody vine native to the temperate forests of eastern and north-eastern Asia, growing endemically in central and northern China, throughout Japan and the Korean peninsula, and in eastern Siberia(Kataoka et al., 2010) (Fig 1). The highly diverse kiwifruit, or Chinese Gooseberry, family *Actinidiaceae* (Hongwen Huang, 2014) consists of more than 50 species, among which *A. arguta* exhibits the widest native geographic range(Ferguson & Huang, 2007).   The species was referred to by a variety of common names throughout the 20th century, including hardy kiwi, northern kiwi, dessert kiwi, cocktail kiwi, arctic kiwi, big/little kishmish, bower vine, tara fig, and others(Kempler & Kabaluk, 1996). In this guide, we adopt the emerging convention among producers and marketers worldwide in using the term "kiwiberry" to refer to fruit produced by vines of the species *A. arguta*.

Figure 1 A map of eastern Asia, showing the natural distribution of *Actinidia arguta*, in grey. Map credit: Lai et al. (2015).

Along with *A. kolomikta* and *A. polygama*, *A. arguta* is one of only three kiwifruit species noted for their cold-hardiness. Specifically, *A. arguta* is capable of withstanding temperatures down to -29°F (-30℃) (Latocha, 2007) during winter dormancy, making the species well-adapted to many locations within the northeast (Guthrie, 2018). In comparison, *A. kolomikta* is hardy to -40°F (-40℃) (Strik, 2005) and *A. polygama* is hardy to -24°F (-31°C) (Chat, 1995).

Like all kiwifruit species, *A. arguta* is dioecious, meaning that a given individual vine is either functionally male, bearing exclusively male flowers with no female organs, or functionally female, bearing exclusively female flowers with no viable pollen. Both male and female vines are required to produce fruit (see *Image 1*); and botanically, the fruits produced are berries, as is true of all *Actinidia* species.

Image 1 Female (left) and male (right) kiwiberry flowers. Female flowers are identifiable by the presence of the stigma and lack of viable anthers.
Photo credit: W. Hastings

Kiwiberries are much smaller (~50 berries per pound, 0.5-1.0 inches x 1.0-1.5 inches) than the more familiar fuzzy kiwifruits (~7 berries per pound, 1.5-2.5 inches x 2.5-3.0 inches) (Strik, 2005) that dominate the global kiwifruit industry (*A. chinensis* var. *chinensis* and *A. chinensis* var. *deliciosa*). Because kiwiberries lack the fuzzy outer skin (exocarp) characteristic of their larger more temperate relatives, the smooth, tender-skinned, grape-sized berries are consumed whole. This feature lends itself well to a myriad of value-added products such as jams, cooking additives, and beverages due to the reduced processing requirement.

Convenient to eat and a versatile value-added ingredient, the kiwiberry is also rightly referred to as a "super-fruit" due to its high nutrient density in marketing campaigns. Ounce-per-ounce, kiwiberries contain twice the vitamin C of an average orange, 80% of the potassium of a

banana, and 1.6 times the dietary fiber of an apple (see *Table 1*). The berries also contain a

higher lutein content than nearly all other common fruits; and they are an excellent source for B-

complex vitamins, vitamins A and E, and minerals including iron, calcium, and manganese.

Table 1 Nutritional attributes of kiwiberries (Latocha, 2017)

Nutrient/Vitamin	Reported Range/Value	Units
Potassium	152.7 - 382	mg/100gFresh Weight (FW)
Iron	0.31 - 1.15	mg/100gFW
Calcium	51.5 - 120.1	mg/100gFW
Manganese	0.03 -0.24	mg/100gFW
Zinc	0.18 - 1.45	mg/100gFW
Magnesium	10.0 - 23.2	mg/100gFW
Vitamin C	45.4-107.7	mg/100gFW
Citric Acid	5.75-9.56	mg/100gFW
β-carotene	0.29	mg/100gFW
Lutein	0.93	mg/100gFW
Vitamin B1	0.01-0.05	mg/100gFW
Vitamin B2	0.02-0.11	mg/100gFW
Vitamin B3	0.50-1.55	mg/100gFW
Vitamin B5	3.80-5.60	mg/100gFW
Vitamin B6	1.10-1.90	mg/100gFW
Vitamin B8	266.0-982.0	mg/100gFW
Vitamin A	37.3-84.5	μg RAE (Retinol activity equivalents)/100gFW
Vitamin E	4.6 - 5.3	mg/100gFW
Sugars	3.9-9.6	g/100gFW
Fiber	2.9 -4.1%	%FW
pH range	3.1 - 3.6	pH

Complementing the nutritional benefits of the kiwiberry is its taste. With the sugar

content exceeding that of a table grape and the acidity akin to grapefruit, the smooth-skinned

fruits possess a pleasantly complex profile, combining banana, floral, and melon aromas with

blackcurrant, fruit candy, melon, citrus, and tropical flavors (Matich et al., 2003) (Fisk et al. ,

2006). Even within the relatively narrow collection of kiwiberry cultivars here in the United

States, berry size, shape, color, and taste vary widely (*Image 2*), representing great opportunity to

develop novel varieties to satisfy consumer preferences.

Image 2 From "round, ovoid, to oblong"(Kataoka et al., 2010), a range of diversity exists among kiwiberry fruits, including flavor and color profiles as well. Note the orange fruit (second from left top row), which is not *A. arguta* but rather that of *A. polygama* cv. 'Hot Pepper'. This cultivar produces a spicy fruit.
Photo credit: W. Hastings

History of kiwiberry in the United States

Actinidia arguta was introduced into the US by Colonel William S. Clark, who later became the founding president of the Massachusetts Agricultural College, now UMass Amherst. From plant surveys conducted in Japan in 1876, Clark imported seeds from wild collected fruits the following year (Melo et al., 2017). The species enjoyed rapid dissemination over the next several decades via regional nurseries advertising it as an ornamental climber (*Images 3 and 4*). Prominent landscape architects of the era, including Frederick Law Olmsted and Beatrix Farrand, garden superintendent John Dallas, and others, came to favor *A. arguta* as a versatile "utility vine" to soften the edges of walls, fences, and buildings in their designs.

Image 3 An example of kiwiberry vine trellised on a pergola with minimal management. This public park at Wave Hill Arboretum, Bronx, NY, was formally a collection of large estates.
Photo credit: W. Hastings

By the 1930's, however, following a period of widespread use in elaborate estate gardens in North America, even this interest in the ornamental value of *A. arguta* largely ceased. The early grouping of *A. arguta* with ornamental plants, rather than with small fruits and berries, combined with the practice of selling unsexed seedlings, set the stage for the almost complete disregard of the fruiting potential of the species for nearly 50 years after its initial introduction into the country (Hale et al., 2018).

ACTINIDIA ARGUTA HEDGE, EIGHT FEET HIGH
Grown for wind protection in the Nurseries' gardens. This Japanese
vine grows more vigorously than any native one in Maine
and is free as yet from insect enemies

THE MOUNT DESERT NURSERIES, BAR HARBOR, MAINE

Image 4 In the 1916 catalog of George Dorr's Mt. Desert Nurseries in Bar Harbor, ME, *A. arguta* was marketed as unsexed ornamental landscaping vines, in line with the thinking of other nurseries in the decades after its introduction to the US.

It was not until the latter half of the twentieth century that *A. arguta* emerged as a species of active interest among novel fruit growers and backyard producers across the northern US (see *Image 5*). The first sustained attempts at small-scale commercial production appeared in the 1970s, roughly the same time that similar experimentation began in northern Europe, New Zealand, and Japan. Development of the crop was relatively slow over the next few decades, however, such that the estimated 100 acres of kiwiberries in Oregon qualified that state as the largest producer of kiwiberries in the world by the year 2000 (Strik, 2005). Since that time, research investment and commercial production have increased significantly, with production centers rapidly emerging in China, Japan, Northern Europe, New Zealand, North America, and South America (see *Table 2*). The large number of acres which have recently been planted, but are not yet bearing, in China is particularly noteworthy, as it signals a shift from the traditional

wild harvesting of wild fuzzy kiwifruit species (an estimated 110,000-165,000 tons annually (H

Huang & Ferguson, 2001)) to their managed cultivation to meet growing domestic demand.

Today, Hurst Berry Farm International's network of growers continues to place the

Pacific Northwest at the forefront of US production, with over 100 acres (Cossio, Debersaques,

& Latocha, 2015) (Strik, 2005) planted almost exclusively to Ananasnaya, a variety imported to

the US from Belgium in 1972 (Whealy, 1989). In the upper Midwest, with active support from

the University of Minnesota, commercial production has seen slow growth, with ~2 acres planted

in recent years. In the eastern US, Kiwi Korners Farm, founded in 1988, is the largest producer,

with roughly 20 acres of organically-certified vines under trellis in central PA (see *Image 6*). In

contrast, the trace amount of current commercial production in the northeast is limited to a

handful of highly diversified direct-market enterprises. Such operations follow a wide range of

management strategies and are extremely small scale, with none exceeding an acre and some

with as few as two fruiting vines. Despite the 140 year history of *A. arguta* in the region, the

potential of kiwiberry production in New England remains largely unexplored.

Image 5 An example of small scale kiwiberry production on a diversified organic farm in Coos County, NH. Photo credit: W. Hastings

Image 6 Kiwi Korners / Kiwiberry Organics located in Danville, PA, is the largest commercial kiwiberry farm in the eastern US. Photo credit: Kiwi Korners/Kiwiberry Organics.

Table 2 Global kiwiberry production
The current status of kiwiberry production throughout the world, with harvest data based on the 2015-16 season. The company Nergi™ has recently invested in significant acreage, as indicated. Data courtesy of F. Debersaques (2018).

Country	Total Acres	Bearing Acres	Yield 2015/2016 (tons)
USA	197	197	800
New Zealand	111	111	157
China	3113	148	25
Chile	24	24	85
France	98 (Nergi)	98 (Nergi)	80
Portugal	264	198 (Nergi)	123
Belgium/The Netherlands	111	111	110
Great Britain	29	29	20
Germany	60-75	60-75	25
Switzerland	32	32	43
Austria	50	50	20
Italy	209	197 (Nergi)	120
Poland	111	25	25

Regional Market Analysis

The recent increase in global kiwiberry production suggests the existence of unmet demand, yet the fruit remains unfamiliar to most consumers. With no regional data available regarding consumer acceptance and demand for this novel crop, New England growers interested in kiwiberries as a potential enterprise have essentially no information upon which to develop enterprise budgets or base production decisions. To address this basic lack of regionally-relevant market information, NHAES researchers conducted a statewide survey of farmers market customers to determine consumer acceptance of and willingness to pay for kiwiberries in the Granite State.

Supported by a USDA Rural Business Development Grant, the Kiwiberry Local Market Assessment was undertaken in the Fall of 2016 to establish a statistically relevant benchmark of

demand in NH for locally grown kiwiberries. At 22 farmers markets across the state, market attendees were invited to sample a kiwiberry and complete a short survey form, providing written feedback regarding trait preferences and acceptable price point for a 6 oz. clamshell of **Appendix III** 'Market Analysis'.

In total, written responses were obtained from 2,003 customers, more than five times the number required to achieve the desired level of confidence for the target population. Of those respondents, 62% indicated they would be "very likely" to purchase regionally grown kiwiberries in the future (see *Figure 2*). Statewide, the average price respondents were willing to pay was $10.64/lb ($3.99 per 6 oz. clamshell) for grade A fruit, meaning berries of uniform size and free of cosmetic blemishes and defects. On average, organic fruit commanded a slightly higher perceived value of $11.23/lb ($4.21 per 6 oz. clamshell). Market-by-market results are indicated in *Figure 3*.

How Likely Would You be to Buy NE Grown Kiwiberries?
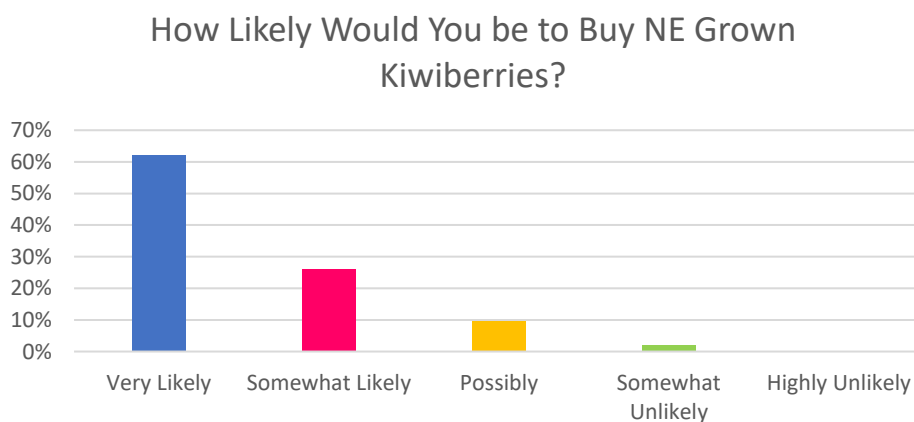
Figure 2 Participant responses indicated a strong interest in kiwiberries produced in New England. Margin of error +/- 2%.
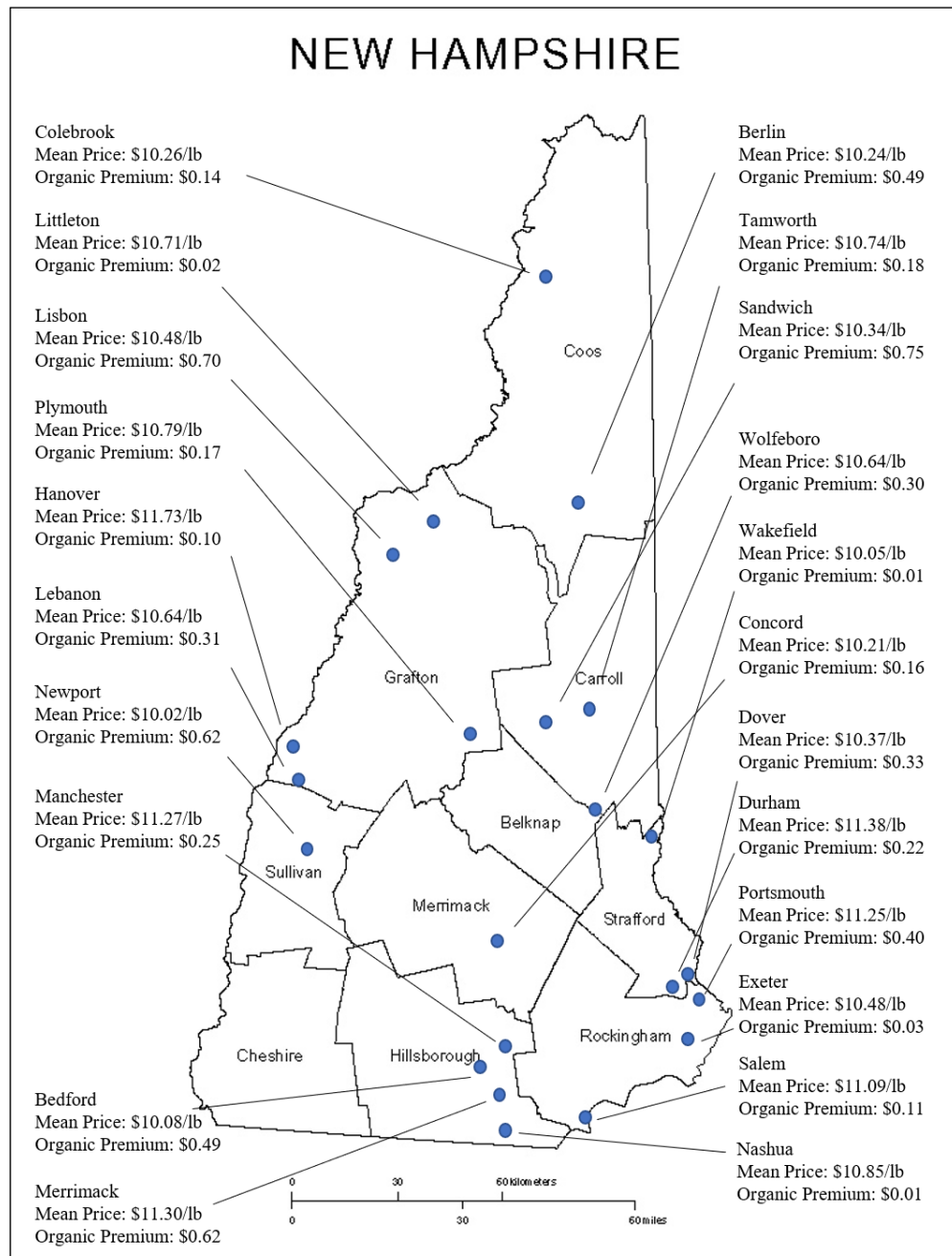
Figure 3 Surveys were conducted at 22 farmers markets throughout the state. Based on written responses from 1,999 participants, the average willingness to pay for conventionally produced fruit was $10.64/lb. Organically certified fruits were valued at $11.23/lb. See **Appendix III** *'Market Analysis Results and Methodology'* for more detail.

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To help guide research priorities for the NHAES breeding program and inform marketing strategies, survey participants were also asked to indicate which attributes of the kiwiberry they particularly liked or did not like. Approximately 95% of the survey respondents indicated some attribute they particularly liked (see *Figure* 4). In general, consumers appear to prize the attributes of sweetness, overall flavor, juiciness, and small size above other attributes (63%, 62%, 53%, and 47% of total respondents, respectively).

Attributes Consumers like about Kiwiberries

Attribute	% Total Respondents
Sweetness	63%
Overall Flavor	62%
Juciness	53%
Small Size	47%
Health Benefits	37%
Tartness	30%
Texture	28%
Novelty	26%
Appearance	13%
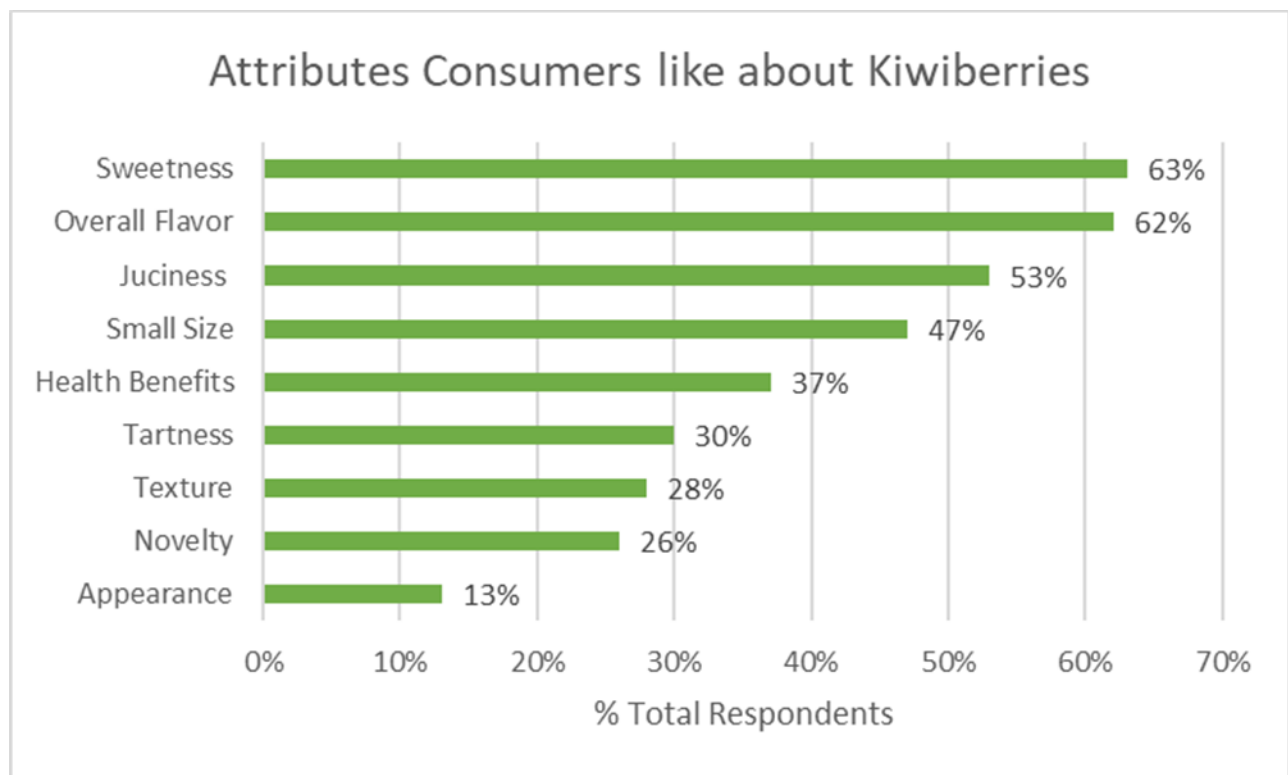
Figure 4 The percentages of total respondents indicating kiwiberry qualities they liked.
Margin of error +/- 2%.

Of the 1,999 respondents, approximately 25% indicated some attribute of the kiwiberry they did not like. Rising to the top of that list (11% of total respondents) was the perceived toughness, or chewiness, of the skin. Dislike of either the overall appearance (e.g. blemishes) or the unfamiliar texture followed, at 5% and 4% of total respondents, respectively. Other traits

were noted at lower frequency (see *Figure 5*), at least some of which are likely due to variation

in ripeness among the berries sampled (e.g. skin, texture, juiciness, and flavor).

Attributes Consumers don't like about Kiwiberries

Attribute	Percent
Other	2%
Appearance	5%
Too unfamiliar	2%
Strange texture	4%
Too tart	2%
Tough skin	11%
Too small	1%
Too juicy	0%
Strange flavor	1%
Too Sweet	1%

Percent of Consumers
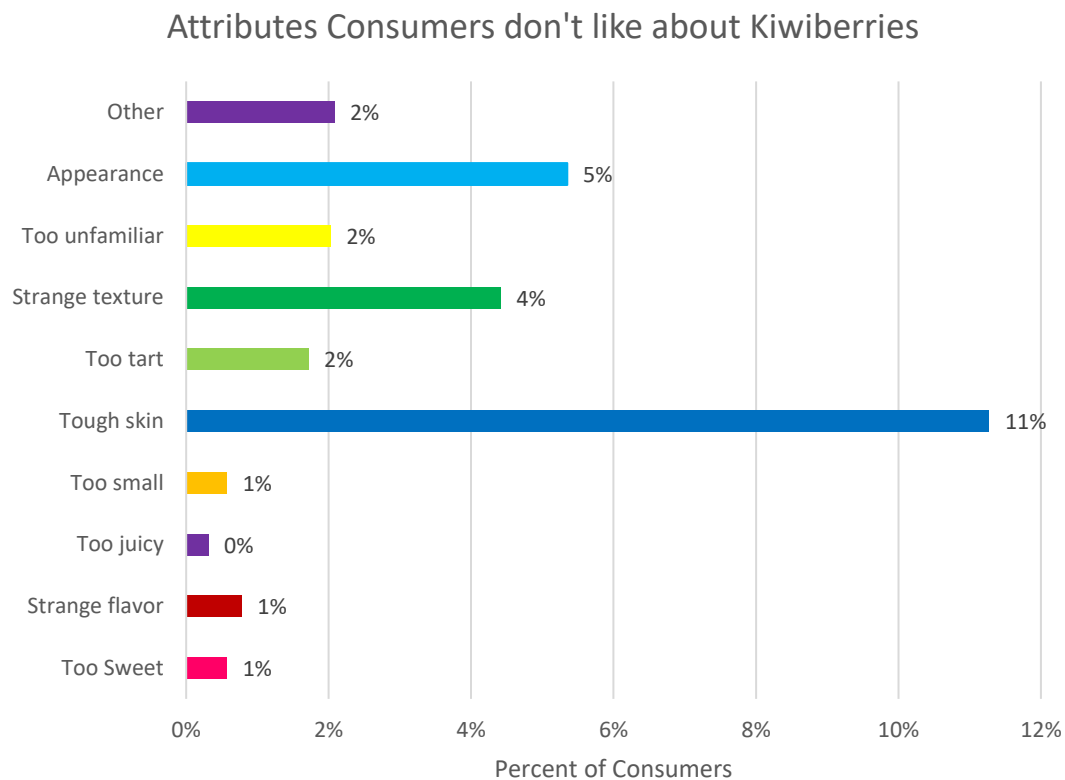
Figure 5 The percentages of total respondents indicating a kiwiberry quality which they disliked. The issue surrounding skin thickness and by relationship, texture, is one of the goals of the NHAES breeding program as some varieties have thicker skins than others. Consumer dislike of appearance may be based, in part, on the slightly wrinkled appearance of a perfectly ripe kiwiberry. Consumer training and advertising is required to address this issue. Margin of error +/- 2%.

Based on these survey results, the NHAES kiwiberry breeding program is focusing its

attention on developing new varieties with improved berry uniformity (size, ripening), texture,

cosmetic appearance, and nutritional aspects while preserving the overall flavor profile (sweet-

acid balance) in a bite-sized fruit. Consumer willingness-to-pay data were used to develop a

regional kiwiberry enterprise analysis (see **Section III**).

Brand Development and Marketing

Various domestic and international efforts are underway to promote kiwiberries on the basis of their novelty, small size ("cuteness"), and associated health benefits (see *Image* 7). While indications exist for high US consumer acceptance, the fact remains that the vast majority of potential consumers remain unaware of the fruit. Strategic marketing and branding, combined with a concerted investment in both consumer and producer education, will be essential for the growth of the industry.

Image 7 Examples of different kiwiberry marketing and branding strategies from Europe, Oceania, North America, South America, Europe and Asia.

As mentioned in the previous section, the berries of *A. arguta* have throughout history been referred to by a dizzying array of names (Kempler & Kabaluk, 1996). To help bring coherence to the marketplace and facilitate consumer awareness of this crop, it is recommended that producers use the term 'kiwiberry' in their marketing, not least of all so that they can may leverage the considerable investment made in promoting that name in both domestic and global markets. Complementing this generic name of the commodity itself, growers may also want to consider using variety, or cultivar, names to build brand recognition and help establish consumer expectations. The reason for this is that profound variation exists among kiwiberry varieties in terms of size, appearance, and taste; and potential consumers should understand this. If the first kiwiberry a consumer tries is "bad," he or she should recognize that it may only be that specific berry (or variety) they dislike, rather than kiwiberries generally. While most consumers would not conclude from one bad apple that apples are bad, the risk of such a conclusion for a novel species is real, with potentially significant market consequences downstream. For this reason, growers are encouraged to know and market their berries using cultivar names, as is standard with apples (see **Introduction** '*Currently Available Commercial Varieties'*). This practice has already been pursued successfully by Kiwi Korners/Kiwiberry Organics with their innovative 'Aloha Annas' and 'Passion Poppers' labeling.

In communicating with potential consumers, there is a range of diverse attributes that producers and marketers can draw attention to. For example, with their small size and intensely sweet flavor, kiwiberries are ideal, snackable fruits for children. As a 'super' or 'nutrient dense' fruit, kiwiberries naturally lend themselves to promotion as a healthy food choice. As a regionally-adapted, perennial crop, kiwiberries require neither annual tillage nor prime agricultural land for their production; thus they promote conservation agriculture practices.

Finally, the versatility of end uses of the crop should not be overlooked. While currently the bulk of domestic production is sold for fresh eating, there is a growing market around value-added kiwiberry products. Due to their naturally high sugar and pectin content (Latocha, 2017), kiwiberries are well suited for jam and jelly production; and small-scale direct market producers of such products report overwhelming consumer acceptance in the region. In addition to kiwiberry wines, which have been successfully produced and marketed in the Northeastern U.S. for many years, experimentation with ciders, liqueurs, cordials, and even kiwiberry-infused beer are underway. By selling Grade A berries at a high unit price for fresh eating and channeling lesser quality fruits to value-added processors, New England producers have the potential to capitalize on a diverse and under-sourced regional market.

Important Traits and Currently Available Commercial Cultivars

Currently, a regional kiwiberry nursery trade in support of field-scale commercial producers, as opposed to backyard growers, is practically non-existent. Compounding this lack of affordable, high volume supply is a fundamental confusion in variety identification even among those that are available to the home grower. A century of plant material collection and exchange among the USDA, private individuals, and nurseries resulted in significant levels of genetic overlap and mis-labeling between putatively distinct cultivars (see *Figure 6*).

Michigan State – PI 617136   Jumbo, Chico - PI 617128

Figure 6 Despite being sold under the same cultivar name, these two versions of 'Michigan State' are wildly different. The vine producing the fruit on the left is USDA Plant Introduction #617136, while the vine producing the fruit on the right is USDA PI617128. As is typical of the cultivar confusion in the marketplace, both varieties are sold under the name 'Michigan State' (Melo et al. 2017). Genetically, PI617136 is similar to varieties '74-49,' 'Ananasnaja,' and 'Rossana'; in comparison, PI617128 is similar to vines sold under the names 'Jumbo' and 'Chico'. USDA PI 617128 is the true 'Michigan State,' first propagated by D. Sorensen in 1983 from a vine found growing on the Michigan State University campus (R. Guthrie, pers. communication). Henceforth, USDA PI617136 will be referred to as 'Michigan State – small fruit variant (SFV)'. Compared to the large berried 'Michigan State,' Michigan State – SFV' exhibits superior fruit flavor and quality characteristics.

Photo credit: W. Hastings

One of the first research objectives achieved by the NHAES kiwiberry program was the genetic de-convolution of the North American collection of varieties, with the intent of characterizing existing diversity and establishing a baseline for future improvement (Melo et al., 2017). It is clear from that work that a system of nursery stock certification is needed, and the program is investing in capacity to propagate confirmed varieties for producers interested in sourcing vines of certified identity. In the meantime, there are several nurseries within and beyond the region from which growers may source materials (see **Appendix 1 '*Grower Resources*'**). Care should be taken, however, to determine the origin of the plant stock (i.e. its pedigree) if possible. In the event pedigree information is not available growers should make note of fruiting characteristics and vine growth habit to ensure they meet individual expectations for performance, ideally this observation could occur on another commercial farm using recognized best practices for kiwiberry production. As the nursery trade continues to develop and standard descriptors for cultivars are established issues surrounding plant pedigree will begin to dissipate.

While breeding for improved varieties is now underway, several existing cultivars in the North American collection appear well-suited for regional production (see *Table 3*).

Commercially Recommended Female Varieties				
Variety	**Description**	**Vegetative Bud Break**	**Flowering Window**	**Notes**.
Michigan State (SFV) PI 617136	Medium to large sized round fruits. Fruits are green with a red blush when exposed to good sun exposure. Fruits grow in clustered bunches.	April 20th	June 14 - June 22	Found growing on the campus of Michigan State University as part of the landscape design. Excellent fruit quality.
Geneva 3 PI 617133	Medium sized round fruits which are green in color	April 20th	June 13- June 22	Found growing on the Geneva, NY Agricultural Experiment Station. Vines exhibit excellent lateral renewal and vigor.
Commercially Recommended Male Varieties				
Flowercloud	High flower count male with sustained very late flowering window.	April 22nd	June 19+	Flowercloud should not be used as the primary male polinizor due to latency of flowering. May be used to supplement end of female flowering pollen availability.
74-52 KHF	Long flowering window.	April 18th	June 13 - June 22	One of the longest flowering ranges observed, this variety is an excellent match for commercially produced females.
Meader	Commonly sold male. Slightly earlier flowering window.	April 18th	June 11 - June 19	A variety release of the NHAES researcher Prof. Elwin Meader. Appears to be somewhat slower to reach maturity than other varieties. Recommendation due to compatibility with commercial females and early flowering window.

Table 3 Observations made on currently recommended commercial cultivars between 2015-2018 at the NHAES (USDA Plant Hardiness Zone 5b). Dates and values are averaged over a period of 3 harvest seasons. Variety identity confirmed by Hale Lab genotyping by sequencing. Variety name is followed by either the USDA plant introduction (PI) number or the initials of its non-USDA source (Melo et al. 2017).

Based on feedback from experienced growers in the region and elsewhere, in combination with observations at the NH Agricultural Experiment Station (NHAES), the following varietal characteristics emerge as being of primary importance to the commercial production of kiwiberries:

Delayed dormancy break Delayed emergence from winter dormancy is a useful trait in that it can help decrease the risk of vine damage from late spring frosts. At the NHAES, the average date of vegetative bud break in the period 2016-2018 was April 20, with a difference of approximately 7 days between varieties. The significant variation in the timing of budbreak indicates potential to further improve this trait through breeding, so the program considers this in its selections.

Timing of flowering Full fruit set depends on the abundant and well-timed availability of high quality pollen, so it is essential that the chosen set of male and female varieties flower synchronously. Ideally, the period of pollen availability should completely encompass the period of female flower receptibility, such that male flowering begins earlier than and continues beyond the period of female flowering. Under ideal pollination conditions the pollen should come into contact with the stigma within three days of anthesis (R. Guthrie, pers. communication). At the NHAES, the average flowering period of male cultivars ranges from June 10-25, while that of female cultivars spans June 12-22. One way to ensure the presence of sufficient pollen in the vineyard throughout the period of female flowering is to plant multiple cultivars of males with overlapping flowering periods. For example, a vineyard with both Meader Male (early) and Flowercloud (late) will enable a longer period of pollen availability than can be achieved by either variety alone.

Yield Before commenting on the differences among female varieties in terms of yield potential, it is essential to note that realized yield is strongly determined by the age of a vine and, perhaps more importantly, by its management. As described in detail in the next section (**Production Guide**), a high-yielding variety will only realize its production potential under a regimen of intensive vine management. Vine age and management practices aside, yield differences do exist among female varieties; and the NHAES breeding program bases its early generation selections on such traits as inflorescence structure (number of flowers per node), flowering density, lateral renewal, and overall plant vigor. Among currently available varieties, reported yields from 5-6 year old commercial vines in Oregon range from 30-100 lbs per plant (Strik & Hummer, 2006). In Pennsylvania, organic producer Kiwi Korners reports an average of 60 lbs of Grade A berries per vine (D. Jackson, pers. communication); and yields at the NHAES have reached 50 lbs for 4-year-old vines and ~60 lbs for 5-year-old vines.

Berry size Uniform berry size is important for both ease of handling and meeting consumer expectations. While uniformity may be achieved via post-harvest sorting technologies a more uniform berry size will help to ease this process. Berries should be similar in size to a table grape, weighing approximately 5-9g. Smaller berries, whether due to varietal differences or to poor/partial pollination, can exhibit inferior eating quality because of high seed-to-pulp and/or skin-to-pulp ratios. If the result of poor pollination, small berries may also be visually unappealing due to collapsed sides or other aspects of misshapenness. On the other extreme, larger fruits (>10 g) often suffer from a relatively watery flavor and texture, in addition to being difficult to consume in one bite.

Berry shape and appearance While overall berry shape (e.g. round vs. blocky) may have little relevance to hand-sorting, round berries may be preferred by those growers interested in

investing in an automated pack-line. Regardless of the shape, however, varieties should be grown that have an appealing berry color (e.g. vibrant green, with or without a rosy blush) and are not susceptible to cosmetic damage (e.g. scabbing, flyspeck, sooty blotch, etc.). According to observations at the NHAES, cosmetic damage of this kind can reduce the amount of Grade A fruit in some varieties to essentially zero. In contrast, varieties like Michigan State and Geneva 3 appear less susceptible, at the NHAES, with Grade A fruit comprising >50% of the total harvest.

Flavor Kiwiberries are intensely flavorful with a complex sweet-acid balance. To be commercially successful, a cultivar should possess a pleasant and widely acceptable flavor profile, which largely means the absence of off-flavors such that tropical notes can be highlighted. Some of the varieties of kiwiberry in the North American collection exhibit poor, or even disagreeable flavor, with intensely grassy or "skunky" tones; so taste remains a key selection criteria in the NHAES program. Another important factor of eating quality is what is commonly referred to as 'catch'. High levels of oxalic acid in some varieties can produce in an aggravated 'catch' at the back of the throat, creating an unpleasant eating experience and limiting consumption. Investment is currently underway to develop a method for early generation selection of low-oxalate vines.

Shelf-life Finally, storage life is an important aspect, especially as production volume and consumer base increases. The storage of fruit allows for an increased market window and the potential for shipping fruit. Cultivars discussed in Table 2 have good storage potential when proper harvest and storage conditions are met and may be ripened to eating quality following six weeks of cold storage.

In summary, an ideal, commercially viable female kiwiberry variety will:

I.   Exhibit delayed dormancy breaking and flower in a timely manner with male varieties in the vineyard;

II.   Produce bite-sized, uniform berries with a complex flavor profile and low oxalate content (no 'catch');

III.   Have an attractive internal and external fruit appearance, free of excessive cosmetic defects.

IV.   Generate sufficient yield for profitability, at least 60 lbs of Grade A fruit per mature (5+ year-old) vine; and

V.   Bear fruit that may be stored[1] for a minimum of six weeks without negatively affecting eating quality

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[1] Except for 'Michigan State (SFV)', no replicated storability trials have been conducted at the NHAES.

CHAPTER II. Kiwiberry Production

Because of the combination of consumer interest, an established valuation of local produce, the culture of direct-market horticultural crops, and the extremely low level of regional production to date, there is great potential for establishment and growth of a kiwiberry sector in the northeast. Prior to investing the time and resources required for a successful kiwiberry operation, however, prospective producers should be aware of the details of such an enterprise, whether as a standalone system or as added component to an already diversified farm. Vines of currently available varieties may take up to seven years to reach full production, and growers should not consider kiwiberry production anything other than a long-term, intensively managed investment. The following step-by-step production guide, coupled with the best available regional enterprise data (see **Enterprise Analysis**), is intended to provide interested growers the necessary information to decide if, how, and at what scale they should embark upon such an enterprise. A timeline of seasonal kiwiberry tasks may be found in **Appendix VII**.

Vineyard Establishment
Site Selection

Proper site selection will positively influence kiwiberry vine health, maturation, and productivity in the long term. To begin, the site of the vineyard should be relatively well-drained; at a bare minimum, to avoid waterlogging of roots, the site should be free of standing water throughout the year. Commercial kiwiberry plantings in Oregon have suffered losses from Phytophthora root rot due to excessive moisture (Strik & Hummer, 2006). Long-term observations of commercial vineyards in northern Europe indicate that kiwiberry vines grown in sandy, well-drained soils are more productive than those planted in heavy soils (F. Debersaques, pers. communication; P. Latocha, pers. communication). Appropriate sites must also be irrigable as needed throughout the season, with the establishment period (Years 1-4) being a particularly essential time to avoid water stress.

When considering potential sites, it is worth remembering that kiwiberry is a woody, perennial crop planted at relatively low density (~400 vines per acre); therefore, vineyards need not be limited to high-quality, flat, and/or tillable agricultural fields. Plots with undulating terrain or large field stones and boulders should not be discounted as options. Vineyards should, however, be sited such that they receive full sun exposure, as this will accelerate vineyard establishment and maximize production.

As with many northern-latitude fruit crops, important factors which should be taken into consideration when siting kiwiberry vines are the slope and aspect of the land. If available, a northward-facing slope is preferred as a means of mitigating wide spring temperature swings which can accelerate emergence from winter dormancy. By extending the period of vine dormancy, a northward-sloping site can help reduce the risk of damage from late-spring frost events. Even if a northern aspect is unavailable, sites should have good cold air drainage because vines growing in depressions or valleys are at greater risk of chilling injury than those growing on well-drained slopes.

If possible, sites with consistently high winds or those prone to heavy gusting should be avoided to prevent unnecessary mechanical damage to vines, flower loss during anthesis, and fruit rubbing which can lead to cosmetic defects in the berries. That being said, if the only available site is windy, the installation of a well-designed windbreak can mitigate these issues. The use of windbreaks to slow wind speed is a considered to be an essential practice in fuzzy kiwifruit production (McAneney et al., 1984) and may benefit all kiwiberry production sites. Common practice dictates that windbreaks should be a minimum of 10x longer than they are tall and spaced no more than 10x their height between windbreaks (Brandle & Hodges, 2006); however, such standardized recommendations should be used with caution (Finch, 1988).

Effective windbreaks must take into account primary windspeed and direction; windbreak height, spacing, and composition; as well as other production limitations and site features (Finch, 1988; McAneney et al., 1984).

Prevailing wind direction may also have an impact on efficiency of pollination and a higher density rows of male plants should be established upwind of the prevailing wind direction, see **Pollination** for discussion of male:female planting ratios.

In terms of previous cropping history, sites affected by root knot nematodes (*Meloidogyne* spp.) or verticillium wilt should be avoided, as should those previously covered with oak or walnut trees, the former due to kiwiberry's presumed susceptibility to Armillaria oak root fungus (Strik, 2005) and the latter to the sensitivity of *Actinidia* spp. to the allelopathic compound juglone (R. Guthrie, pers. communication).

The construction of a fence or other plant protection systems may be desirable based on local vertebrate pest population levels. See **Other Production Concerns** for further information.

Site Preparation

Once an appropriate site is identified, time should be taken to carefully develop it, preparing a solid foundation for successful vine establishment and long-term production. The importance of such preparation is underscored by the fact that the expected lifetime of a vineyard may be anywhere from 20 to 50+ years (R. Guthrie, pers. communication; D. Jackson, pers. communication). To begin, the site should be cleared of all debris and rocks, as required for efficient trellis installation and projected equipment use. Hidden stones can split posts, if using a post-pounder, as well as damage cultivation equipment. If a hardpan is present, an initial series of cultivations may be necessary to improve the soil structure, followed by subsequent passes for

the incorporation of any amendments or soil treatments. It is recommended that the entire production site be subjected to a series of initial cultivation, rather than just the areas where planting will occur. Full site cultivation will help to suppress long term weed pressure and provide a clean establishment site.

For optimum vine health and productivity, it is important to establish and maintain a soil pH between 5.5-6.0 (Strik, 2005), thus reducing vine stress and enabling efficient nutrient uptake. A preplant soil test is strongly recommended, and all necessary steps should be taken to ensure an informative and representative analysis. For example, soil samples should be taken throughout the prospective site in such a way as to account for known differences in previous use and other site characteristics (e.g. soil texture, moisture, etc.). Ideally, the samples submitted for analysis should be homogenized mixtures of multiple subsamples taken throughout each vineyard section being screened, with the required amounts specified by the soil lab being used. When sampling for production on sites less than 10 acres, an individual submitted soil sample should not be considered representative of more than approximately one acre.

Proper soil fertility, including sufficient soil organic matter, is of primary importance to vine establishment and productivity, as kiwiberry is sensitive to both macro- and micro-nutrient deficiencies (Jonas Decorte, 2018). Although precise preplant fertilizer and soil amendment recommendations are currently unavailable for kiwiberry, growers should do their best to provide sufficient annual levels of N, P, and K (see **Fertilization**). Research at the NHAES and other research institutions is currently underway to develop soil and foliar nutrient analysis testing. Growers should take the time to learn how their specific cultivars respond under nutrient stress to respond as required.

In addition to establishing the vines themselves, growers should approach initial site preparation with an eye toward proper vineyard floor (i.e. alleyway) establishment as well. The alleys influence vineyard health and productivity in many ways, including reducing soil runoff, mitigating nutrient loss, buffering soil temperature, and controlling weeds (Hongwen Huang, 2014). Bunching species of cover crops (e.g. fescue, orchard grass, etc..) are recommended to prevent creeping into cultivated areas, and prevent resource competition between the cover and commercial crop. At least one experienced grower who has experimented with various cover crops believes that light-colored grass species facilitate sunlight bounce into the underside of the canopy, with beneficial effects on fruit quality, notably °Brix and blush (D. Jackson, pers. communication). After first experimenting with clover species, the NHAES kiwiberry program now uses Chewings fescue, a light-colored, fine-leafed, bunching fescue, seeded at a rate of 5 lbs per 1,000 feet[2] and mowed to a height of 1.5-2.0 inches, as needed (see *Image 8*). Due to the alleyway traffic and disturbance inherent to trellis establishment, growers are advised to establish the vineyard floor cover *after* trellis construction is completed. Once a vineyard has been established, an orchard floor may be established in-row between vines and managed with an orchard mower, string trimmer, or livestock grazing.

Image 8 – The Chewings fescue alleyway in the NHAES breeding vineyard provides good weed suppression. The alleyway was seeded at 5 lbs per 1,000 feet^2.
Photo credit: W. Hastings

Trellis System

Economically viable kiwiberry production depends critically on the intensive management of vines supported by a robust trellis system. Apart from the vines themselves, this support infrastructure is arguably the most important, and certainly the most capital intensive, element of a kiwiberry vineyard. In addition to the sizeable fruit loads of commercially-spaced mature vines (up to 100 lbs. per vine), a strong, well-constructed trellis system is required to bear the weight of substantial vegetation as well as its associated ice and snow loads during the winter months. In contrast to the training techniques common in grape production (e.g. the Vertical Shoot Positioning system), the canopy in a commercial kiwiberry vineyard is comprised of a

horizontal plane resting directly atop a series of support wires. This large vegetative and fruit-bearing area presents an ideal location for snow buildup, and trellis design should honor regional weather expectations. In light of the expected lifespan of the vines, commonly 30 years or more, growers should take care to invest in building materials with a minimum expected working life of 20 years. While the costs of such materials, not to mention their installation, may be higher than those associated with other crops, investing the time and resources to ensure a high-quality product is well worth the effort over the life of the vineyard.

The fuzzy kiwifruit and the kiwiberry are grown on different trellis systems to meet their distinct production needs. The fuzzy kiwi is most commonly grown on a pergola, consisting of a high-density grid of tensioned wires (see *Image 9*). Such a system accommodates the significantly greater fruit load and shading requirements of the fuzzy kiwifruit.

Image 9 Fuzzy kiwifruit growing on a pergola trellis sysem in Northern Spain.
Photo credit: W. Hastings

In contrast, the recommended practice for the relatively more vegetatively vigorous kiwiberries is to grow them on an open row trellis system referred to as a 'T-bar' system, in which the vines are trained to a series of parallel wires supported by a row of T-shaped posts (see Image *10*).

Image 10 An example of the T-bar trellis system located at the UNH Woodman Farm. Right to left: An aerial view of the T-Bar, the cable staples holding the wires down, and the mounting bolt and nails securing the cross bar.
Photo credit: W. Hastings

Although some kiwiberry production is done on pergolas, the T-bar system is recommended for northeast growers for several reasons. First, by maintaining clear separations between rows, the system facilitates pruning access, thus simplifying the task of preventing within- and between-row vine entanglements. Opening the canopy results in a suite of other benefits as well, including increased airflow to reduce humidity reducing instances of fungal

disease, better pollinator access (Strik, 2005), and greater exposure for the developing and

ripening berries to sunlight. Direct exposure to the sun has been observed to increase total sugar

levels as well as to promote attractive red blushing in several cultivars. Finally, T-bar systems

are simpler and less expensive to build than pergolas; and the open alleyways permit the

movement of a small tractor for cultivation.

A schematic of the T-bar system used in the NHAES program is shown in *Figure 7*,

consisting of the following components:

I.   **Support post** The in-row support posts are 8-9 feet long x 6-9 inch diameter wooden

poles, buried or pounded 2-3 feet into the ground, such that the top of the posts are 6 feet

aboveground. The distance between support posts is 32 feet, which accommodates 2-3

vines between posts (at a plant spacing of 16 feet or ~10 feet, respectively). Note that the

post height may be adjusted based on the management requirements of the grower, such

that the canopy is at a comfortable height to prevent undue exertion during pruning and

harvest. Although black locust poles are used in the NHAES vineyard, other materials

will work as well (see below).

II. **Cross bar** A board rests horizontally atop each support post, completing the 'T' shape.

The cross bar runs perpendicular to the row and provides direct support to the set of

parallel wires in each row. At the NHAES, each rough-sawn pine bar (6 feet long $\times$ 4

inches high $\times$ 6 inches wide) is secured to a support post via two 6 inch lag bolts into the

end-grain of the post.

III. **Support wires** Five parallel, high-tensile lateral support wires run the length of each row, resting directly on the cross bars. The wires should be evenly spaced along the 6 foot cross bars (i.e. 18 inches apart), one on center and two on either side of center. Additionally, we recommend using 12.5 gauge (2.5 mm diameter) wire to ensure compatibility with many common "clip-to-wire" fasteners used for tying down lateral shoots (see Grower Resources). A high tensile wire dispenser, also known as a Spinning Jenny, should be used to efficiently run wire.

IV. **Cable staples** To guide the five wires and maintain their relative spacing, five 1.5-1.74 inch galvanized barbed staples are driven into the top surface of each cross bar. To facilitate installation and to accommodate thermal expansion and contraction of the wires, the staples should be firmly secured while still allowing enough space for each wire to slide back and forth.
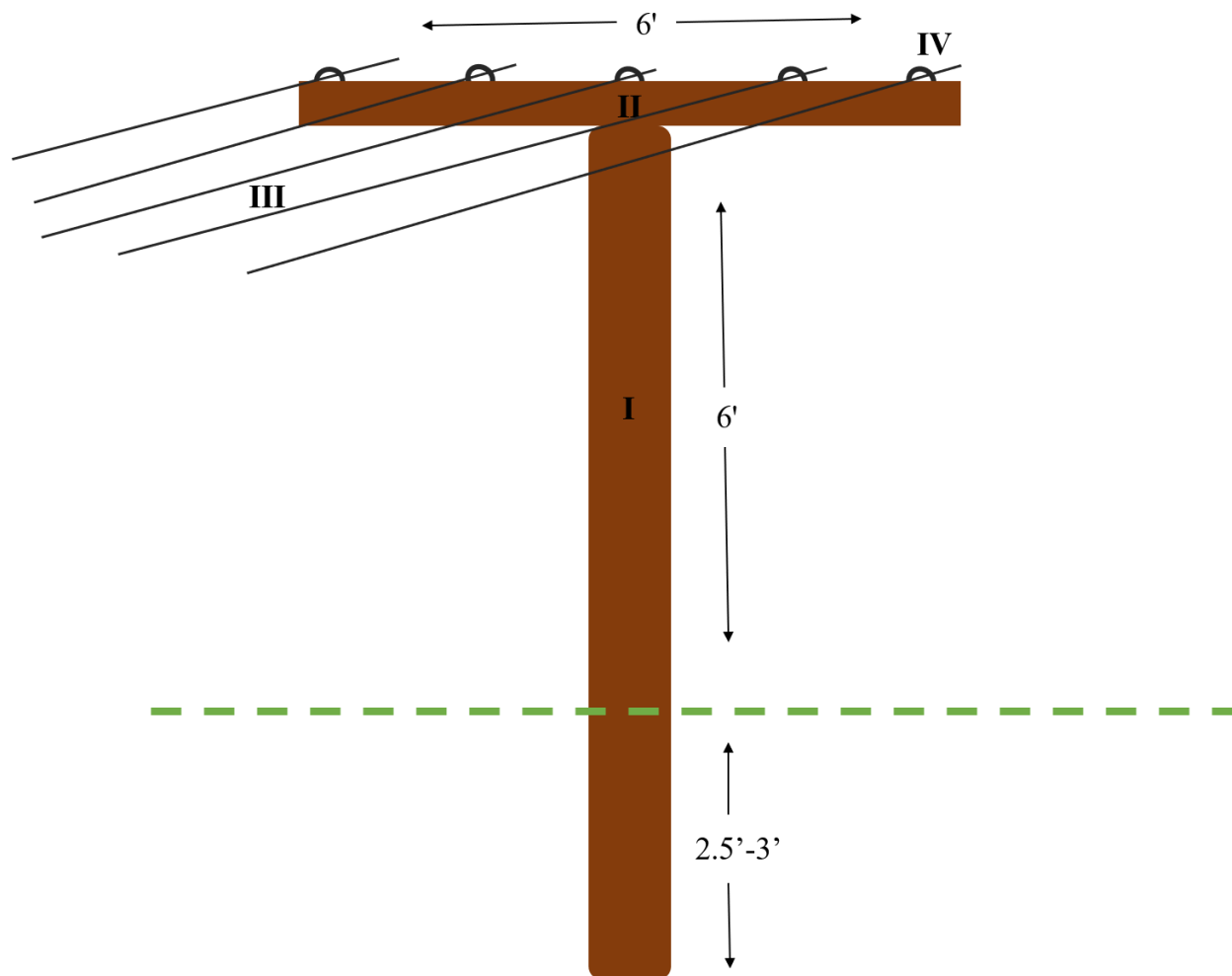
Figure 7 A schematic of the T-bar system used at the NHAES vineyard and commonly seen in kiwiberry production. I) The support post for the t-bar structure. II) The top post on which the support wires rest. III) The lateral support wires for the vines. IV) The cable staples which secure the wires to the top bar.

As mentioned in the beginning of this section, trellis materials should be selected with the minimum expectation of a 20 year lifespan, primarily because replacement of supporting infrastructure under the weight of mature vines is a difficult task (R. Guthrie, pers. communication). Although concrete and pressure treated wood are both common trellis post materials, the NHAES program uses regionally-sourced black locust posts (see **Appendix I** *'Grower Resources'*), noted for their rot resistance. If using black locust, try to source poles that have been seasoned for at least 2 years, because fresh poles may still contain moisture and be partially

susceptible to rot. If freshly harvested posts are used, it is recommended to char their ends before using, as this will help remove remaining moisture and seal the ends of the logs (A Black Locust Connection, pers. communication).

Some sort of anchoring system is needed at the ends of each row of T-bars, against which the wires can be pulled into tension. Wires under high tension (i.e. no slack) are required to train vines into their desired architecture and support their weight under fruit set. Adjustable hardware that permits both tensioning and loosening is recommended, as wires will need to be adjusted seasonally due to thermal expansion and contraction, which can place undue stress on wires under static tension.

An earth anchor may be used at the ends of rows (see *Figure* 8), and has a reduced overall cost compared with the H-brace system. This system is common in vineyard and orchard production systems in the Midwest (R. Guthrie, pers. communication). The soil anchor is sunken to the maximum depth obtainable to provide maximum hold. The five high tension wires are then secured to both the earth anchor and end post. The wires are then distributed out in a fan pattern towards the top of the first T-bar in row, see *Figure 8* for further detail. If earth anchors are used the vineyard end-post should be of a larger diameter than the in-row posts and installation is best done in the spring when soils are moist. The NHAES program uses an H-brace system due to a high volume of field stones on site and concerns over seasonal freeze-thaw ground movement. As single earth anchors have not been trialed at the NHAES more extensive detail is provided for the use of the H-brace system. Producers interested in further information about earth anchor construction should consult **Appendix I** 'Grower Resources'.
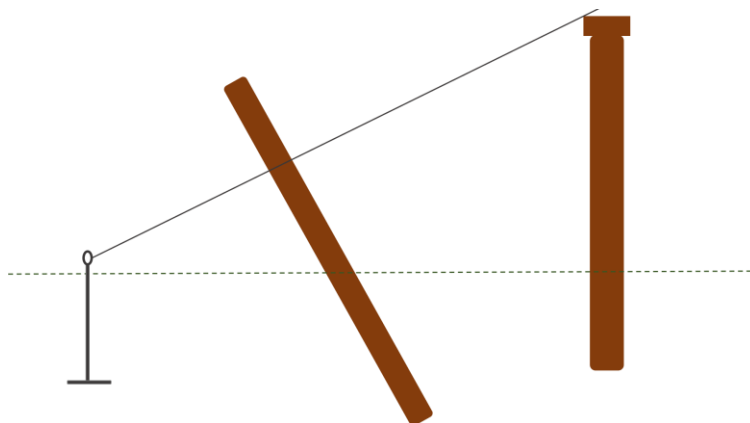
Figure 8 A support is anchored by a single sunken soil anchor allowing further tension to be placed on the wires.

Below are the specifications of the components comprising the H-braces in the NHAES vineyard:

I.   **Support posts** Similar to the support posts for the T-bars, each H-brace requires two 9 foot long × 8 - 9 inch diameter black locust poles. The inner post is buried or pounded 3 feet into the ground, such that its top is 6 feet aboveground. The outer post is buried or pounded 4feet into the ground, such that its top is 5 feet aboveground. The two posts are spaced 8 feet apart, in row.

II. **Cross bar** The inner post functions as the terminal T-bar for the row; thus it requires a cross bar, as described previously.

III. **H-beam** This 4 inches × 4 inches × 8 feet pine beam, installed horizontally between the two support posts at a height of 4 feet off the ground, maintains the verticality of the support posts and provides counterforce to the diagonal tensioning wire. This beam is held in position by 10-12 inch. galvanized brace pins. One pin is sunk halfway into the support post while the other is driven completely through allowing the H-beam to be placed (see *Figure 9*).

IV. **Diagonal tensioning wire** Pulling the two support posts together against the H-beam is a diagonally mounted loop of 12.5 gauge wire, held under tension by a strainer. The vertical position of the wire against the inner post is maintained by its resting on the protruding end of the inset rod. On the outer post, its position is maintained by a barbed wire staple (see *Figure 9*).

V. **Wire tensioners** Once the H-brace is constructed, five wire tensioners can be secured to the outer post via five loops of wire, each anchored by a wire staple (*Figure 9*). Each tensioner then receives one of the five trellis wires, which can then be brought under tension.

Figure 9 The H-brace system used in the NHAES vineyard to anchor the ends of rows. Two support posts (I) are set into the ground. The post closest to the production site is mounted with a cross bar (II). Spanned between the two support posts is the H-beam (III) mounted on brace pins. A diagonal tensioning wire (IV) used to hold the H-brace together. Wire tensioners (V) are used to strain the trellising wire, 3 on one end and 2 on the far H-brace to avoid crowding.

Please note that the spacing between rows (i.e. alley width) should be carefully considered before installing the trellis system. A row spacing of 10 feet -8 inches (center-to-center) has been found to work well in the NHAES vineyard, allowing sufficient working room within the aisles and movement of our specific equipment through the vineyard (see **Cultivation**). T-bars extend ~2 feet into the alleyway on either side, allowing for ~5.5 - 6 feet of working room within isle.

Irrigation System

The frequency and extent of irrigation needed will vary across years and within seasons and will also closely depend on a range of site- and operation-specific factors such as soil texture, soil quality, aspect, slope, and the age of the vines. As mentioned above (Site Selection), kiwiberry vines do not tolerate excessive water or poorly drained soils, with overall growth being severely impacted if the rootzone is waterlogged for more than 3 days (Strik, 2005) (P. Latocha, pers. communication). On the other extreme, plants can suffer a range of short-to-medium term production setbacks if exposed to drought stress (Hongwen Huang, 2014), including poor in-season growth (e.g. lateral renewal), increased susceptibility to subsequent winter damage, and prolonged juvenility (i.e. establishment period). The NHAES vineyard is maintained to receive a minimum of 4in. of rainfall or irrigation per month during the active growing season (May-September). In the fall, as vines harden off in preparation for winter dormancy, access to adequate moisture is essential to avoid undue dieback of current season growth. The established practice in fuzzy kiwifruit production is to irrigate when soil water content falls below 60% field capacity (Hongwen Huang, 2014), and a similar practice should be employed in kiwiberry production to ensure rootzone formation will not be hindered.

The amount of water applied may have little relationship to the amount of water available to and taken up by the vines; so a well-designed irrigation system, combined with efficient application practices, can greatly reduce operational costs. While subsoil drip irrigation systems have been reported to increase effective water utilization by up to 95% (Hongwen Huang, 2014), such systems are not the observed standard in the Northeast. Rather, the NHAES recommendation for kiwiberry is an elevated system in which the irrigation lines run approximately 4ft. off the ground, attached to an in-row support wire (see *Figure* 10).

Figure 10 The NHAES irrigation system uses a zoned header to deliver water to select location within the vineyard. Further irrigation control is available at the point of connection between the header pipe and the irrigation hose via a stop-value. The suspended irrigation line keeps the cultivation area clear during mowing and cultivation. Length of spaghetti tubing run between the irrigation line and the sprinkler emitters.

The benefits of such a system are various. Raising the irrigation line prevents accidental damage which may occur during regular mowing or cultivation operations. Irrigation components can be accessed, serviced, and/or replaced easily, something important to consider with a long-lived crop like kiwiberry. Finally, when paired with microsprinklers or shower-head emitters, such a system enables the fair distribution of water over rooting area, which in general will equal or exceed the canopy area (D. Jackson, pers. communication).

When designing the irrigation system for a kiwiberry vineyard, consider the following factors:

1. Based on your water supply, what is the maximum flow rate (e.g. gal/hr) that can be supplied to the vineyard and at what pressure? This will impact decision-making around the need for zoning and the choice of emitter type.

2. Apart from the inherent limitation of maximum flow rate, is zoning required for other reasons (e.g. differential soil properties, differently aged vines, etc.)?

3. Finally, is mechanical cultivation planned and, if so, with what implements? Irrigation lines should run high enough off the ground to prevent accidental damage to them during cultivation.

How does the NHAES irrigate?

The NHAES vineyard went through several design iterations over its first five years, in an attempt to identify a practical irrigation system for kiwiberry vines. The practice of running elevated irrigation lines along in-row support wires has been used since the first generation of vines were planted in 2013. Initially, the lines were run only 1 foot off the ground but have since been raised to 4 feet, a height which allows for easier movement under the canopy during pruning and harvesting. Each irrigation line (i.e. 150 foot row) has an independent on/off valve to allow the targeting of individual rows; and the entire 1.75 acre vineyard is broken into three separate irrigation zones to accommodate pressure restrictions. The primary irrigation tubing is 1in diameter Toro Blue-Stripe (see **Grower Resources**). Initially, pressure-compensating drip emitters (~2 gallons per hour) were used, providing a steady trickle to newly transplanted vines. While this style worked adequately for early vine establishment, starting with two emitters per plant and adding additional emitters as needed, the need to apply water over a larger surface area became apparent. By Year 3, the root area had extending well beyond the reach of the emitters, and the ensuing water stress led to establishment and productivity setbacks, as referenced above.

Rather than using drip emitters, producers in northern Europe use microsprinklers attached to the irrigation line via a length of spaghetti tubing (see *Figure 10*). The microsprinklers deliver a wide, evenly dispersed dose of water during irrigation events; and the intermediate length of tubing allows for sprinkler heads to be raised above the canopy for use in frost protection during the early spring. Regional fruit growers have used micro-sprinklers for frost protection to some effect(Extension, 2018). By running sprinklers during a frost event, it is possible to

coat susceptible tissues with a thin layer of ice that protects them from significant drops in temperature below the freezing point (Trought et al., 1999). It is still unknown to what extent this practice will increase yields or prevent crop loss in kiwiberry production. Growers wishing to experiment with frost protection should consider overall water availability and needed infrastructure costs to supply an entire vineyard with large volumes of water simultaneously.

Based on the benefits of the microsprinkler system, it was implemented in the NHAES vineyard in 2018. As shown in *Figure 10*, for each row, a line of 1in Toro Blue Stripe is connected to the primary header pipe. A pressure-compensating microsprinkler head (9 gal/hr) is connected to the line every 16ft via a 4ft length of spaghetti tubing. Finally, the microsprinklers are supported in an upright orientation by 3ft bamboo stakes below the canopy. See **Appendix 1** *'Grower Resources'* for more product information.

Planting material

Sourcing plant material, especially in large quantities, is currently one of the main barriers for aspiring commercial kiwiberry producers wishing to produce kiwiberries commercially in the region. While existing nurseries that market locally (either directly or online) offer various kiwiberry selections (see **Appendix 1** *'Grower Resources'*), such vendors are generally geared towards supplying homeowners, with vines costing $15-26 apiece. In addition to these high costs, claimed varietal identities are suspect (see **Important Traits and Currently Available Commercial Cultivars**). To reduce costs and increase the availability of

certified varieties, the NHAES Kiwiberry Improvement program is exploring options for the low-cost, large-scale generation of commercial planting materials (see **Appendix I** *'Grower Resources'*). In the meantime, assuming access to a desired variety, growers may clonally propagate their own materials with little investment or technical training.

Planting from seed

Before discussing clonal propagation, it is important to note that growing kiwiberry vines from seed is feasible, but that it is not recommended for commercial or home producers. A single well-pollinated berry can contain up to 250 seeds (Strik, 2005), and each seed will produce a unique vine, none of which will be true-to-type. *Actinidia arguta* is an obligate outcrossing species by virtue of its dioecy; therefore, individual vines are highly genetically heterozygous and seedlings will exhibit unpredictable characteristics resulting from the random genetic combination of two parental vines. Observations within the NHAES program also indicate that seedling populations are male-biased, composed of slightly more males than females. Because vine sex is unobservable until the plant reaches maturity (at least 3 years), this male bias is a further disadvantage to growers who are limited by time, space, and financial constraints (i.e. all growers). For these reasons, producing vines from seed is a waste of time and resources for producers.

At the NHAES, seedling populations are created and evaluated as part of the long-term breeding program to develop improved varieties for the region. To facilitate this work, we employ molecular screening methods to determine vine sex at the time of germination (Hale et al., 2018). For those interested in pursuing their own breeding efforts, we provide the following seed processing and germination protocol used in our program:

After separating the seeds from the berry, submerge them in over-the-counter hydrogen peroxide (3%) until bubbling has ended, approximately 20 minutes. This treatment facilitates the complete separation of any remaining pulp, which contains germination inhibitors, from the seed. Triple rinse the seeds with clean water and spread them on a paper towel to air dry. Following cleaning, stratify seeds at 33°F for 8 weeks to simulate winter chilling (vernalization) and break dormancy. To stratify, place the seeds on a moistened paper towel and hold at temperature within an airtight container, adding water to the towel as needed to maintain damp conditions. Following stratification, seeds may optionally be treated with gibberellic acid (2.5-5 g/L) (Hongwen Huang, 2014) for 24 hours before planting into a high quality well drained and aerated soilless potting media. To facilitate germination, seeded flats should be subjected to 40-60°F diurnal temperature swings (16 hour days) to simulate warming spring weather. Seed germination should occur in 3-6 weeks. Once emerged, seedlings should be provided with elevated light levels (16 hours per day) and consistent irrigation. In the NHAES greenhouses, thrips and fungus gnats are the primary pests of concern. If growing outside, be sure to protect the seedlings from slugs, which can devastate a flat overnight.

Clonal propagation

In contrast to propagation from seed, propagation via rooted cuttings is a clonal method of reproduction that successfully captures the traits of the original kiwiberry variety. Straightforward methods for propagating both softwood and hardwood cuttings are provided below:

Softwood propagation

Softwood cuttings are actively growing, vegetative cuttings that should be removed from the chosen parent vine in late July or early August, as berries are beginning to form. Material selected for propagation should be approximately the diameter of a pencil, with visible lenticels, and be should be transitioning from succulent to lignified woody material (i.e. current season's growth, just beginning to harden off). To propagate:

1. Select a shoot as described above, measuring approximately 4-6in. long and containing two or more nodes.

2. Make the basal cut immediately below the lowest node and the terminal cut approximately 1/2in. above the top node; both cuts should be perpendicular to the direction of growth.

3. Remove nearly all leaves from the cutting, leaving only one healthy leaf at the top node.

4. Trim the edges of the remaining leaf so that its final surface is approximately 1 in^2.

5. Using a sharp knife, superficially wound the lowest node via a shallow scrape.

6. Dip both ends of the cutting in Hormodin 2 (0.3% IBA) or a similar rooting hormone product.

7. Stick the basal end of the prepared cutting into a 50/50 mixture of high porosity media and either perlite or a vermiculite/perlite blend.

8. Maintain warm temperatures (70-80°F) and high humidity (85-95% RH) until the cutting has callused, rooted out, and started to produce leaves. Misting cuttings is an excellent way to maintain humidity levels and reduce transpiration.

After sticking the harvesting softwood cuttings, the length of time to leaf out can take anywhere

from 2-4 weeks. Callus formation will begin forming Week 1 and continue up until Week 3.

Root initiation from the callus may begin as early as the end of Week 1, but significant root

formation will not be noted until Week 3 or Week 4. Leaf out, while encouraging, is not a sure

sign of successful propagation. Leaf out may occur anytime from Week 1 onward but successful

callusing and root formation are still required for the cutting to survive.

Figure 11 The steps propagate kiwiberry from softwood cuttings, direction of growth is indicated by the arrow. First select an arm's length shoot from which to take multiple cuttings. Select several pencil width sections which have multiple nodes while maintaining direction of growth. Remove all but the topmost leaf. Shallowly wound both sides of the base as well as reduce the total leaf surface area. Treat cutting with growth hormone if using one.

Hardwood propagation

Hardwood cuttings are fully lignified, dormant cuttings that should be removed from the chosen parent vine during winter pruning, prior to sap-flow (typically January-February). To propagate:

1. Select a roughly pencil diameter shoot, measuring approximately 10-12 inches long and containing at least 8 nodes.

2. Make the basal cut immediately below the lowest node and the terminal cut approximately ½ inch above the top node; both cuts should be perpendicular to the direction of growth.

3. Using a sharp knife, superficially wound all nodes in the lowest 4in. of the cutting via shallow scrapes. [NOTE: Once removed from the parental vine, it is easy to confuse the direction of growth of a cutting due to the counterintuitive morphology of kiwiberry nodes (see *Image 11*). Take care to maintain the proper orientation of the cutting.]

6. Dip both ends of the cutting in Hormodin 2 (0.3% IBA) or a similar rooting hormone product. Ensure that all wounded nodes come in contact with the hormone.

7. If propagating indoors in containers, stick the basal end of the prepared cutting approximately 5" deep into a 50/50 mixture of high porosity media and either perlite or a vermiculite/perlite blend. Provide warm rootzones via a seedling germination mat and maintain air temperature between 50-60°F. Relative humidity should be between 85 – 95%, the use of overhead misting systems is an effective tool to regulate RH as well as supplement irrigation needs.

8. If propagating outside, simply push the prepared cutting into the ground (leave ~4in. visible) as soon as the ground has thawed. Root development and leaf emergence will typically occur prior to frost-free date; so measures should be taken to protect the growing cutting from late frosts.
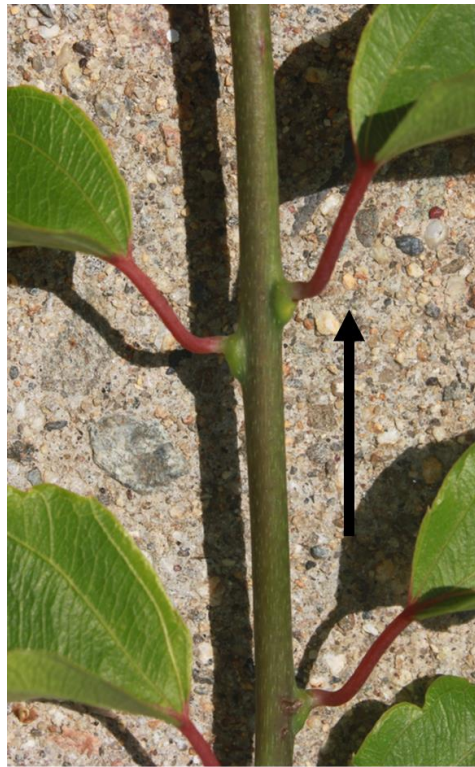

Image 11 Care should be taken when propagating kiwiberry due to the counterintuitive morphology of the leaf nodes. The arrow indicates the direction of growth towards the distal end of the shoot.

If necessary, hardwood cuttings may be stored in a refrigerator for several months before rooting. In fact, such cuttings are ideal materials for grafting, in which case they would be removed from cold storage and grafted to rootstocks typically in April/May. To store hardwood cuttings for rooting or grafting, place them in a sealed bag or container with slightly moistened sphagnum moss, squeezed of all free moisture.

Transplanting

Propagation requires time and resources, so care should be taken to ensure the success of rooted plants once they are transplanted to the field. Softwood cuttings will leaf out by late summer/early fall and should be transplanted into containers to allow for continued root development. These plants should be protected from freezing temperatures, either in a greenhouse or some other protective structure, for the duration of the winter and transplanted to the field the following spring, once the danger of frost has passed. During the winter, once the plants have been dormant for at least 4 weeks, supplemental heat and lighting (16 hour days) can be applied to force the plants, thus initiating the season's growth. This early forcing allows plants to develop a more sizeable root ball before transplanting; and more available growth from which a trunk may be selected. Supplemental heat and lighting will similarly help rooted hardwood cuttings get a jump start on the season. But whether softwood or hardwood, forced or not, all propagated plant stock being held for transplanting should be protected from temperature extremes and frequently monitored for irrigation needs.

Once the danger of frost has passed, cuttings with a well-developed root ball (the NHAES program aims for a 4 inch diameter root ball) may be transplanted into the vineyard. Prepare the planting site by loosening soil at least one foot in all directions to facilitate subsequent root and water penetration. Take care to maintain the in-ground depth of the vine to that of its original container because burying the stem below the soil can increase the risk of rot to the plant. One of the most critical factors for newly transplanted vines is the availability of irrigation. If conditions are unfavorable, new transplants can sunburn and desiccate within a matter of hours, setting them back an entire season, if they survive at all. Shade cloth may be applied to reduce the total hours of direct sun received by new transplants until they are fully

acclimated. Alternatively, while still in their containers, young vines may be held for a short time in an intermediate environment (e.g. lath house) to ease their transition to the field.

Vine Management

Kiwiberry management is relatively intensive compared to other small fruit and berry crops in the northeast, including vining crops like grape. Because of its history first as an ornamental landscape vine then as a novel fruit for backyard growers and, more recently, permaculture enthusiasts, the species has several myths surrounding it, including that it requires little to no management to be productive (e.g. trellising, irrigation, pruning, fertilization, etc.) and is inherently unruly. Such ideas have persisted in part due to the fact that kiwiberry has received virtually no research attention as a commercial horticultural crop in the region. This narrative, however, is at odds with decades of experience of a handful of domestic growers, a growing body of international research, and our initial work here at the NHAES, all of which indicate that kiwiberries are highly amenable to intensive management and, in fact, require it for commercial production. When implemented properly, the T-bar system of kiwiberry production is demanding but manageable, with clear prescriptions for each stage of vine development.

Vineyard Layout

Assumed in the following discussion of vine establishment and management is a well-planned vineyard layout. As mentioned in the Trellis System section above, rows should be spaced a minimum of 10 feet apart (center-to-center), with larger alleys possible, as dictated by equipment access considerations. Within rows, the distance between adjacent vines varies greatly among production systems, with spacings of 8 feet up to 60 feet reported. An in-row

vine spacing of 10 feet is the current recommendation for growers in the northeast. This relatively dense spacing is observed to be a reasonable compromise, resulting in a shorter time to full canopy coverage while still allowing for a sufficiently large root zone in fully matured vines. Vineyard layout should accommodate a minimum of one male for every eight females (see **Pollination** section).

Training Young Vines (Years 1-4)

Year 1 – Root establishment

Young *A. arguta* vines are sensitive to extreme temperatures and drought; therefore, spring/summer transplanting should occur as soon as the danger of frost has passed and no later than late June. If emerging from a greenhouse environment, vines should be fully hardened off before transplanting lest they suffer from excessive transpiration or sun scorch. If protected from late season heat and drought stress, it is also possible to successfully transplant vines in the early fall, though the time between planting and the first expected hard frost should be at least a month to allow sufficient root development before vines transition to dormancy. Attempts at late season transplanting has resulted in higher levels of winterkill in the NHAES program, however, despite protective measures; thus spring/summer planting is recommended and is assumed throughout this section of the manual. Regardless of the timing, steady irrigation is critical during the period directly following planting.

The primary objective of the first field season is to establish robust root systems that can support the vegetative growth required for the rapid development of desired vine architecture in subsequent years. *Actinidia* species have relatively shallow root systems, with ~90% of the roots of fuzzy kiwi vines found within 6 inches of the surface (Lemon & Considine, 1993). To

encourage root development, rootzone 'training' (i.e. light cultivation) is recommended

throughout the season, in conjunction with mechanical weed control (see *Figure* 12). Such

training is also thought to encourage root development deeper into the soil profile; however, no

research has been conducted to confirm or disprove this. In addition to root training via

mechanical cultivation, investigations are currently underway at the NHAES to determine if

subsoil root collars can encourage the formation of deeper root systems.
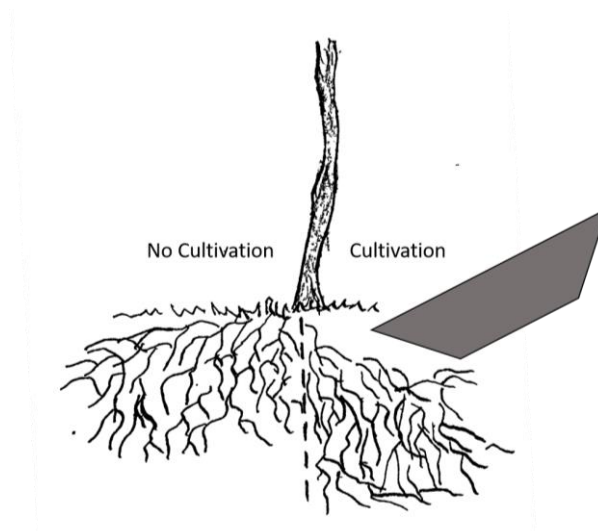

Figure 12 Light surface cultivation may help to drive some of the normally shallow roots deeper into the soil profile.

Year 2 – Trunk establishment

A vine well cared for in Year 1 will emerge from dormancy in Year 2 capable of

producing and sustaining the vegetative growth necessary for the establishment of a strong,

straight trunk, the foundational element of a mature vine's architecture. Strong architecture

(trunk + cordons) is essential to long-term vine health and productivity; therefore, the objective

of the second field season is the establishment of a straight and vigorous trunk. A strong,

straight trunk is important for two reasons. First, straight trunks facilitate efficient vascular

transport between the roots and the canopy. Second, straight trunks provide the structural integrity required to support heavy fruit loads and withstand weather events. As soon as new shoots are ~2 feet long, select a healthy, vigorous one to be the trunk and cut back all others back to the base, forcing the selected shoot to continue to grow. Subsequent removal of competing vegetative growth should occur approximately every 3-4 weeks throughout the growing season, with less attention needed during the mid-summer slump in growth (approximately mid-July to late August in Durham, NH). As a rule of thumb, wait to prune competing growth until the longest unwanted shoot reaches a length of ~1.5 feet. Excessive pruning should be avoided because it can stimulate increased budbreak and unwanted shoot initiation.

If left to their own devices, kiwiberry shoots will attempt to climb higher by twining counterclockwise around whatever is nearby, including its own shoots. To obtain a straight trunk, it is necessary to actively train the selected shoot. To do this, it is recommended to secure the trunk to an 8 foot bamboo stake (see *Image 12*), securing it every 6-12 inches with a Tapener gun or similar tool for dispensing and securing durable trellising tape (see **Appendix I** *'Grower Resources'*). Training trunks or other parts of the vine (e.g. cordons and laterals) with rigid materials like wire ties is not recommended, as vines will become restricted and begin to girdle as they continue to grow. Whenever competing growth is pruned, new succulent trunk growth should be untwined from the bamboo stake and secured straight before it begins to lignify.

Image 12 A young vine during its first field season. A bamboo stake is used to train a straight and strong trunk.
Photo credit: W. Hastings

Allow the trunk to continue to grow once it reaches the center trellis wire. At that point, it may be fastened to the center wire with a KiwiKlip or similar fastener (see **Appendix I** *'Grower Resources'*). If at least a month remains in the season before the first expected frost, cut the trunk approximately 6 inches above the wire to encourage cordon initiation (see next section). Remove all other emerging growth from the trunk, aside from the future cordons.

Year 3 – Cordon establishment

The establishment of permanent cordons is the focus of year three. Cordons are the primary horizontal growth of the vine, and the site from which all future fruiting laterals will emerge (see *Figure* 13). Once a straight trunk has been established, it should be tipped ~6 inches above the center wire to break its apical dominance and stimulate shoot initiation along its length. Such shoots should be pruned as they appear, leaving only two opposing shoots within 6 inches of the trellis wire as cordons (see *Figure* 13). As these cordons grow, they should be trained in opposite directions along the center wire. Similar to vertical trunk training against the bamboo stake, cordons should be trained as straight as possible with trellising tape against the center wire.

Once side shoots are selected and begin to be trained as cordons, the vine will assume a 'T' shape (see *Figure* 13). Like the trunk, cordons may require a progressive sequence of shoots (i.e. multiple cycles of shoot initiation and growth) to achieve their final lengths (5 feet each for vines spaced 10 feet apart). If conditions are unfavorable and the vine has experienced temperature or water stress, trunk and/or cordon establishment can potentially span multiple seasons. Once cordons extend beyond their desired final lengths, they should be tipped to force lateral shoot initiation along their lengths. These lateral shoots (or laterals) are the fruit-bearing parts of the vine and are renewed annually (see next section).
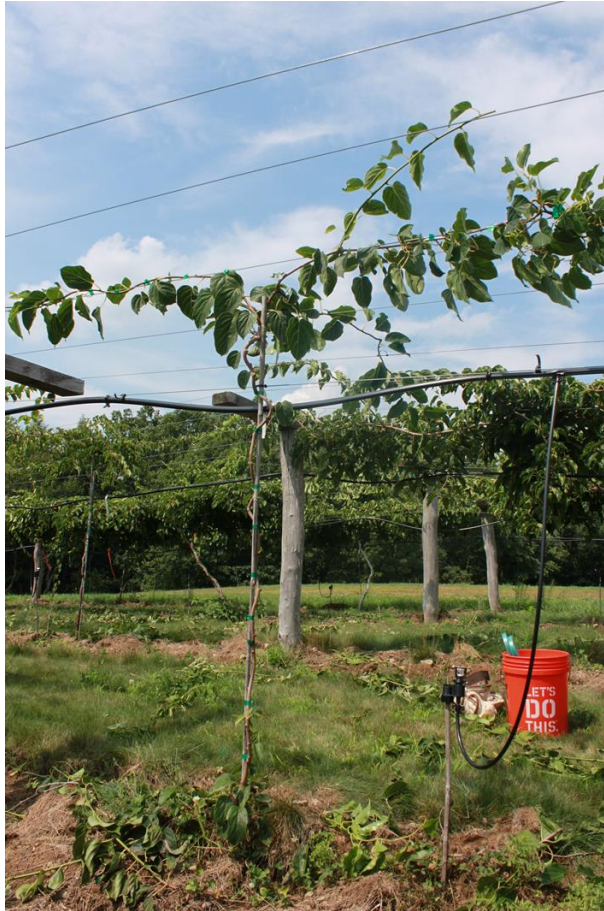
Figure 13 The establishment of cordons occurs during field years 2, 3, and 4.

Year 4 – Lateral establishment

After the first years of root system, trunk, and cordon establishment, the objective of subsequent years is fruit production through a systematic renewal of laterals. *A. arguta* vines bear flowers on wood that is at least one year old; therefore the laterals selected and trained in one season become the fruiting wood of the following season. A lateral is trained by clipping it down perpendicularly to the trellis wires, such that it extends into the alleyway. Shoots from the cordon should be selected and laid down such that the resulting laterals are spaced 18-24 inches apart, with all other competing shoots removed (see *Figure* 14).

Avoid selecting extremely vigorous, vertically-growing shoots for laterals. Such shoots, similar to waterspouts in fruit trees and dubbed "searcher shoots" by horticulturalists, are of generally greater diameter than other shoots and often break from the cordon in the process of bending them over. In later years, lateral spacing may increase as vines produce more fruit and fruiting spurs requiring more space.

Figure 14 Properly established laterals. Note the uniform spacing along the entire length of the cordon.
Photo credit: Kiwi Korners/Kiwiberry Organics

WHEN WILL A VINE REACH MATURITY?

The establishment of good architecture (trunk + cordons + initial laterals) does not necessarily mean that a vine will begin flowering. The juvenile period of a transplanted vine may be as short as 2 years or as long as 6 or more, depending on variety, original propagation material, environmental conditions, and training. To accelerate the transition to reproductive maturity, vines should be intensively managed (i.e. competitive growth controlled) and protected

from temperature, heat, and weed stress as much as possible. Well-trained vines not lacking for space, light, water, or nutrients will not only exhibit more vigorous growth but will also transition to reproductive maturity more quickly. In terms of production, a kiwiberry vine is only considered mature once it is able to generate sufficient laterals to replace those which fruited the current season. In general, vines will not reach commercial maturity (i.e. peak productivity) until a year or two after reaching reproductive maturity (i.e. 5-8 years after transplanting) (Strik & Hummer, 2006), although some level of intermediate fruit production will be realized in the intervening years (see **Enterprise Analysis**).

Pruning Mature Vines (Years 4+)

Mature kiwiberry vines are vigorous, producing multiple rounds of large quantities of rapidly-growing shoots in a single season. If not consistently maintained, plants can become tangled vegetative masses requiring a significant investment of time to return to productivity (see *Image 13*).

Image 13 - Twisted and tangled vines are difficult to extricate from each other and can ultimately lead to reduced productivity if left unaddressed.
Photo credit: W. Hastings

For this reason, kiwiberry is not a hands-off crop to be left to grow on its own with only minimal maintenance. In addition to fertilization, irrigation, and weed control activities, prospective growers should plan for 1-2 heavy summer pruning events, interspersed with more minor pruning, as needed, in addition to a single heavy winter pruning event. Male and female vines require different pruning regimes; so the following discussion addresses them separately, by season.

Summer Pruning

The purpose of summer pruning is twofold: 1) To direct desired vegetative growth and 2) To manage the canopy for light penetration and lateral density (current and replacement). As implied in the previous section on vine training, pruning directly affects growth. When a cut is made, a kiwiberry vine redistributes growth hormones, awakening dormant buds that become new points of growth, typically basal to the cut site. By understanding the response to pruning, growers can manipulate vine architecture, stimulating growth of a desired shoot to function as a trunk, cordon, or lateral. When pruning, it is important to consider not only present needs but also future needs for lateral replacement and canopy renewal.

Female Vines

Just prior to flower opening (anthesis), all non-terminating flowering shoots should be pruned back to the node beyond the last flower, thus preventing resource allocation to unusable growth (and keeping the alleys clear). Following anthesis comes a period of rampant vegetative growth, after which (approximately mid to late-July) vines should be pruned to increase light penetration through the canopy. Dense, heavily shaded canopies can result in pre-mature fruit

softening before desired sugar levels are achieved (Strik & Hummer, 2006). Proper canopy

thinning for light penetration improves fruit quality by increasing fruit total soluble solids and

promoting blushing in certain varieties (Okamoto & Goto, 2005). Beyond fruit quality

consideration, vines with good light penetration are more productive than those which are

heavily shaded (Strik, 2005).

When pruning, it is important to consider the need for replacement fruiting laterals.

Ideally, laterals should be spaced at 18-24 inch intervals along both sides of the cordon to form a

uniform horizontal canopy. To ensure sufficient availability of replacement laterals, pruning

should only be done to prevent excessive shading and remove unruly shoots during the

vegetative growing season. As mentioned before, over-pruning can stimulate excessive shoot

initiation in other areas, which not only wastes the vines energy but creates more pruning work

downstream. The small, self-terminating spurs produced along the length of the cordons should

not be removed, as they are often densely fruitful in later years (Strik, 2005). When pruning,

cuts should be made at a 90-degree angle just beyond a bud.

Male Vines

The purpose of male vines is to produce pollen; therefore, the pruning strategy for male

vines differs markedly from that for females. Put simply, males should be allowed to complete

flowering, at which point (~ early-mid July) they should be pruned back heavily, with as much as

75% of the canopy being removed. In addition to removing all growth from the previous season

(i.e. current flowering wood), new growth should be thinned out except for those shoots selected

as replacement laterals. The desired distance between lateral shoots for males is 12inches,

significantly less than that for females. As the season progresses, males should be pruned back

from the alleyways and from neighboring vines. Otherwise, any new shoots generated should be left alone, as they will bear flowers the following season.

General comments

For both males and females, unwanted growth elsewhere on the vine should be pruned. Whenever pruning the canopy, it is also important to remove all new shoots from the base of the vine (competing trunks) as well as any emerging along the trunk (competing cordons). Such clean-up greatly reduces the possibility of vines catching on vineyard equipment, encourages sub-canopy airflow, and avoids vine entanglement in irrigation hardware. Alleyways should be kept clear of reaching shoots which can pose a danger to equipment operators (see *Image 14*). In general, pre-emptive management of unwanted growth will lead to less work overall and provide a cleaner vineyard setting. All summer pruning should cease in September, or more generally at least a month before expected frost. Pruning beyond that time will only serve to encourage additional growth which will not have sufficient time to harden off before winter.

Image 14 Vines reaching into alleyways may snag on equipment, posing a risk to both vines and operators.
Photo credit: W. Hastings

Winter (dormant) Pruning

Producers have some latitude in terms of when to conduct winter pruning, beginning as early as the first hard frost (D. Jackson, pers. communication) (~November) and as late as March, just prior to the initiation of sap flow. In the northeast, winter pruning typically occurs between January and March on fully dormant vines. If pruning late, it is advisable to verify vine dormancy by taking a few small, sample cuts and checking after 10-15 minutes for the presence of flowing sap. Pruning after spring sap flow may cause vines to irrevocably 'bleed out' (Strik, 2005), especially if they experienced other stresses the previous season. It is possible that the

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recommendations presented above are conservative, as the actual sensitivity of healthy kiwiberry vines early spring pruning is not known. Particularly in well-established, mature vines, some growers report no issues pruning into the spring, despite sap flow (R. Guthrie, pers. communication). Such extended pruning practices are often done out necessity due to operation size and/or limited staff. One benefit of pruning kiwiberry vines late is the ability to better access winter injury.

Female Vines

Overall vine architecture is much easier to see in the dormant period, in the absence of obscuring vegetation. For this reason, the majority of the decisions regarding female vine architecture going into the next season should be made during the winter pruning period. To begin, all fruiting laterals from the previous season should be removed. Once removed, replacement shoots generated during the previous growing season should be selected and laid down, fixed to the outer trellis wires with clips. In thinning unwanted laterals, expect to remove up to 75% of the previous season's growth (Strik, 2005). While it may seem that you have removed an excessive amount of growth the first time you prune a vine this intensely, do not hold back. It only takes one season of dealing with a timidly pruned vine to change perceptions regarding pruning intensity.

Male Vines

To ensure maximum flower set in the spring, male vines should only be pruned enough to remove rogue shoots from the alleyways (Strik, 2005). Any major tangles or dead wood may be removed, but the bulk of the previous season's growth should be left until flowering has ended.

Fertilization

At present, there is relatively little scientific information regarding optimum soil nutrient content or nutrient requirements for kiwiberry vines at their various stages of development. While research along these lines is underway in both the Pacific Northwest and northern Europe, current best practices are largely based on the much better characterized production of fuzzy kiwis (Strik, 2005). Fertilization is important and consists mostly of split applications of nitrogen up through the middle of the growing season, with total dosages increasing as vines become established and transition to maturity.

Year 1 Young vines are extremely sensitive to fertilizer burn, so minimal fertilizer should be applied to new transplants. Specifically, apply 4 g (~0.15 oz.) elemental Nitrogen (N) per vine in three applications: May, June, and July. Evenly spread fertilizer in a 6-12in. circle around the trunk.

Year 2 During trunk and early cordon establishment, apply 8 g N (~ 0.3 oz.) per vine per month in four applications: April, May, June, July. Increase the fertilizer application area to a 36in. diameter circle.

Year 3 During initial lateral establishment, apply 16 g N (~ 0.6 oz.) per plant in three applications during: March, May, and July.

Years 4-5 For reproductively mature vines yet to reach peak productivity, apply 24 g N (~ 0.8 oz.) per plant per month in three applications: March, May, and July.

Years 6+ For fully productive vines, apply 36 g N (~ 1.3 oz.) per plant per month in three applications: March, May, and July.

Assuming a plant density of 436 vines per acre (10 foot space between rows, 10 foot space between plants), the above fertilization schedule results in an application of a little more than 10 lbs. N per acre in Year 1, up to nearly 100 lbs. N per acre for fully productive vines. Regardless of the stage of the vine, fertilization should not later than July as this can encourage excessive succulent growth that will not have a chance to harden off prior to winter. Excessive nitrogen can also delay fruit development(Łata, Stefaniak, Stasiak, & Latocha, 2018).

Kiwiberry requires high amounts of potassium (K) and phosphorus (P), and applications should provide 80 – 130 lbs K/acre and 55lbs P/acre. In the absence of specific soil tests for kiwiberry vineyards, growers should request a Commercial Orchard/Vineyard or Home Garden soil test to access levels of nutrients and soil pH. Testing is generally recommended once a season and samples should be taken in the fall, see **Site Preparation** for details on soil test sampling. While chlorine in very low concentration is considered to be beneficial for kiwiberry (F. Debersaques, pers. communication), fertilizers containing chloride should be avoided to prevent excess uptake and leaf burning (Strik, 2005). Studies are currently underway in North Europe to determine the effects and optimal levels of fertilization, including the nutrient sufficiency ranges in kiwiberry to enable informative foliar nutrient testing (J. Decorte & Debersaques, 2017). Other preliminary studies indicate that calcium (Ca) plays an important role in maintaining fruit firmness during storage (R. Guthrie, pers. communication; Łata et al., 2018), but further work is required to fully characterize the effect of Ca and other nutrients on post-harvest performance.

Fertilizing based on cultivar?

While the current practice is to treat all kiwiberries varieties alike, initial research out of Europe suggests there may be significant differences in nutrient uptake, allocation, and usage

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among cultivars (F. Debersaques, pers. communication). The potential of optimizing fertilizer

based on variety is compelling, and further studies will be needed to determine such practices

for regionally adapted cultivars.

Cultivation

Once vines have been planted, the ground beneath a kiwiberry vineyard can be thought of

as consisting of two functionally distinct areas: rows and alleys (see *Image 15*). Rows are the 2-

4' wide mulched and/or cultivated strips of land that run directly beneath the trellis wires and

within which trellis support posts and vine trunks are centered. Alleys are the uncultivated but

managed areas between rows planted to an appropriate cover (see **Site Preparation**).

Image 15 There are two distinct areas in a kiwiberry vineyard: the rows or zones of production and the alleyways or spaces between the rows.
Photo credit: W. Hastings

Woodchips are a relatively available source of mulch for many growers. An application of mulch (5-7 inches deep) has been found to be an effective methods for weed suppression over multiple seasons at the University of Minnesota Horticulture Research Center. When sourcing wood chips select those with low internal nitrogen content (such as those cut during winter) as these will not breakdown as fast as those with a high content (R. Guthrie, pers. communication).

Light cultivation of the rows is recommended to stimulate root growth in new transplants (so-called "root training; see **Root Establishment**), to encourage roots to grow deeper in the soil profile, and to manage weeds. Older vines not previously exposed to cultivation will suffer light

initial root damage, given the shallow nature of their root systems, but will adapt over the course of a season with cultivation.

Rows should be wide enough to allow the chosen cultivation implement(s) to pass comfortably by vine trunks at a distance of no less than 6" (see *Figure 15*). Based on the recommendations of experienced growers, the NHAES adopted a grape-hoe style cultivator for use in its research program (see Image 16; see **Appendix I** *'Grower Resources'*). Prior to trunk establishment, the cultivating fork is used for both root training and weed control. After trunk establishment, the hilling bar is used for ongoing weed control while developing and maintaining raised beds. Side-mounted cultivators are ideal for kiwiberry production, as they allow for continuous cultivation between vines while moving down the alley. Frequency of cultivation depends on the rate of weed emergence. Factors such as volume of the weed seed bed, rainfall, and method of cultivation will impact timing. As canopies mature weed competition will be reduced as mature vines begin to shade out the understory.

Figure 15 The area between the dashed lines is the cultivation buffer zone of at least 6 inches from the vine trunks. Using a cultivator tool such as a hill-up bar will help to cover weeds remaining in the center. Photo credit: W. Hastings

Image 16 The NHAES vineyard cultivator attachment makes short work of weed removal. This model was fabricated by GreenHoe of Geneva, NY.
Photo credit: W. Hastings

What about herbicides?

The use of herbicides for weed control within kiwiberry vineyards is currently not recommended by the NHAES due to lack of information on their effects on vine health. Growers interested in trialing herbicides may wish to consider use of protective trunk guards and follow standard operating procedures to minimize unwanted drift.

According to one commercial grower, the long-term productivity of a kiwiberry vine depends on maintaining a proper overall balance between its roots and canopy (D. Jackson, pers. communication). According to this thinking, as a vine reaches 15+ years in age, its ever-

expanding rootzone begins to overwhelm its regularly-pruned canopy, at which point it will

transition to compensatory vegetative growth with reduced flowering. One possible strategy to

prevent or postpone such a situation is to plant vines at a wider spacing (e.g. 16' apart or more),

though that will delay establishment of a full vineyard canopy. Alternatively, whatever the

chosen vine spacing, an occasional pass (e.g. every 3 years) with a single shank chisel plow or

spader may be done on older vines to deep prune their roots back to the confines of the row. It is

important to note that these recommendations are speculative. The theory that long-term

productivity may depend on maintaining a proper root-canopy balance is not uniformly shared

among growers and is in need of research.

Insect Pests & Diseases

In comparison to many other high value horticultural crops grown in the region,

kiwiberry appears to have relatively few insect pests and diseases of concern. For this reason,

the production of kiwiberries lends itself to low/no spray methods, organic practices, and

integrated pest management. As outlined below, the most common insect pests and diseases will

be familiar to those with experience producing fruit in New England.

Insect pests

Japanese beetle

Popillia japonica is the most common insect pest observed on the kiwiberry vines at the

NHAES. Adults actively feed on foliage and have also been observed feeding on immature

berries (see *Figure 16*). As discussed in detail in the above section on vine management,

kiwiberry is a vigorous vine whose vegetation must be intensely managed in a commercial

production setting, with 1-2 heavy prunings required during the summer. One upside of such

prolific growth is that even extreme foliar feeding by *P. japonica* has little effect on the

productivity of a mature vine.

Figure 16 A mature Japanese beetle actively feeding on a kiwiberry leaf (left). Early season feeding
damage from Japanese beetle which, although scabbed over, has made the fruit unsellable as Grade A
(right).
Photo credit: W. Hastings

Immature vines, however, especially in their first or second year, should be protected

from high *P. japonica* pressure. Similar to other stresses (drought, heat, etc.), such feeding can

delay vine maturation and canopy establishment. Also, while foliar feeding damage is unlikely

to exceed economic injury levels in older vines, *P. japonica* population management may be

worthwhile in a mature vineyard to reduce cosmetic damage to the berries. Actively feeding

adult populations may be managed chemically, only use materials which indicate kiwiberry

specifically on the label, or manually by hand picking individuals in conjunction with an

Integrated Pest Management program (Knodel et al., 2012). Weekly scouting and record

keeping on emergence date may increase the efficacy and reduce of amounts of materials applied.

In addition to standard approaches for controlling *P. japonica* (R. Guthrie, pers. communcation; D. Jackson, pers. communication), one seemingly effective strategy is to make strategic use of kiwiberry vine's uniquely prolific vegetative growth to draw *P. japonica* adults away from the fruit-bearing zone of the canopy. In this approach, now followed at the NHAES, all searcher shoots emerging from the canopy are allowed to grow until *P. japonica* pressure subsides later in the season. Adult beetles are preferentially drawn to the high, sacrificial shoots, which are then pruned later in the season.

Spotted wing drosophila (SWD)

Although the fruitfly *Drosophila suzukii* has the potential to be a pest of concern for kiwiberry, in practice the pest appears to only target vine-ripened fruits based on experiences at the NHAES and commercial growers (D. Jackson, pers. communication). Fortunately, kiwiberries are climacteric, which means they can be harvested while firm and ripened off vine (see Harvesting; see Postharvest Handling); thus one can manage *D. suzukii* by simple avoidance. If berries are allowed to ripen and soften on vine, adult SWD become able to pierce the skin and oviposit eggs, which can ultimately lead to the presence of SWD larvae feeding internally on the fruit. In cases where vine-ripening is preferred, SWD management should be based on an intensive scouting program with traps to monitor population levels(Extension, 2018). Cooling fruit to 33°F following harvest and holding it at that temperature for at least 6 days will kill any eggs or larvae present and arrest further berry deterioration(M. J. Kim et al., 2018).

Brown marmorated stinkbug (BMSB)

Based on scouting and identification in recent years in production vineyards in central Pennsylvania (D. Jackson, pers. communication), *Halyomorpha halys* is a species that is expected to continue to gain ground in the northeast. Its future relevance as an economic pest of kiwiberry in New England is currently unknown. At the NHAES vineyard to date, stinkbugs have been observed feeding at night on past peak fruit which had been left on the vine; however, the specific species has not been confirmed at the NHAES.

Diseases

Current knowledge of pathogens relevant to kiwiberry production in New England is limited. Two pathogens observed in our region and known to impact kiwiberry production in northern Europe, at times resulting in losses of over 50% due to cosmetic damage, are *Schizothyrium pomi* (causal organism of flyspeck) and *Pelataster fructicola* (causal organism of sooty blotch) (see *Figure 17*) (McKenna et al., 2012). Studies have shown that these fungal diseases are manageable through chemical controls (McKenna et al., 2012), but there are currently no approved chemicals for use on kiwiberry in New England. Cultural controls are also effective; however, high density planting may suffer from mildew issues due to excessive humidity.

Figure 17 Fly speck (left) and sooty blotch (right) on kiwiberries.
Photo credit: W. Hastings

In addition to the symptoms associated with flyspeck and sooty blotch (see *Figure 17)*, there are several other common cosmetic blemishes of berries, namely cracking and russeting (see *Figure 18*), which may be the result of pathogens and/or environmental factors. In speaking with growers, theories about the causes of these symptoms abound. One thought is that cracking may be due to high surface temperature fluctuations during early fruit development that result in micro fissures that become pronounced as the berries grow. If so, the use of a shade cloth, the application of a protective coating such as kaolin clay, or perhaps a modified pruning technique may potentially reduce such damage. Another theory is that the cracks may be the result of fine scratching of the surface of the ovary by the claws, rakes, or combs of some pollinators. Russeting, on the other hand, is thought by some to result from either mechanical damage (e.g. wind-induced rubbing) or sunscald. It is possible, however, that both cracking and russeting are the result of pathogens instead; and research is certainly needed in this area. In the meantime,

what is known is that some varieties are more susceptible to such symptoms than others; thus

resistance to cracking and russeting is considered in the NHAES breeding program.

Figure 18 Russeting (left) and examples of post-harvest soft rots (right) on kiwiberries.
Photo credits: W. Hastings

Finally, although it is not present in the United States, a serious pathogen of nearly all

members of the *Actinidia* genus is *Pseudomonas syringae* pv. *actinidiae*, more commonly

referred to as bacterial canker or PSA. This bacterial disease results in shoot dieback and vine

death in serious cases, and leaf spotting or flower drop in less serious cases (Everett et al., n.d.).

Currently, PSA is present in all major centers of kiwifruit production except for North

America. In 2010, the USDA Animal and Plant Health Inspection Service (APHIS) imposed an

import ban, such that no *Actinidia* plant material of any kind may be shipped into the United

States without proper phytosanitary documentation and a prolonged period of quarantine (see

Appendix 2 *'Pseduomonas Syringae pv. actinidiae (PSA) Quarantine Language'*). Although in

general kiwiberry is less susceptible to PSA than fuzzy kiwifruit (Vanneste, Cornish, Yu, &

Stokes, 2014), the introduction of PSA to the region could be devastating. Do not be the person who brings PSA into the country!

Other Production Concerns

Extreme temperatures

In temperate fruit-growing regions (Rodrigo, 2000), including New England, sporadic spring frosts pose a threat to many fruit crops; and kiwiberries are no exception. Freeze damage can occur once sap begins to flow in late winter and early spring (Latocha, 2007; Strik, 2005), harming vulnerable tissue even when concerted effort has been made to select a protected north facing site to delay emergence from dormancy. Observations at the NHAES suggest that tolerance to frost increases as a vine matures. Certainly young vines in their first few years are the most vulnerable, in that a severe frost can significantly delay vine establishment or even kill a young transplant lacking a well-establishment root system. In central PA, wind machines are used successfully for frost protection in some years (D. Jackson, pers. communication), though their upfront cost may not make sense for small operations.

Alternatively, growers in northern Europe achieve frost protection in some years with microsprinklers (F. Debersaques, pers. communication) (see **Irrigation**). At the NHAES, investigations are underway to determine the roles that air and soil temperature play in signaling dormancy breaking and whether or not it can be delayed with simple, affordable cultural practices, such as: 1) Applying white latex paint to trunks to maintain cooler trunk temperatures (Litzow & Pellett, 1983), and 2) Using root collars to drive the root systems deeper in the soil profile, where soil temperatures are less subject to temperature fluctuations. Longer-term, the

development of superior cultivars with either delayed emergence from dormancy and/or reduced frost sensitivity is a major goal of the NHAES program.

As mentioned in the previous section, excessively warm temperatures during flowering and early fruit development may also pose a risk for some cultivars, in terms of promoting micro fissures that lead to significant cosmetic damage (cracks). Further studies are needed to understand the role, if any, that temperature plays in this and whether or not its effects can be mitigated via temporary shading, protective coatings such as kaolin clay, or supplemental canopy irrigation.

Wind
Wind is a potential concern for kiwiberry production, as mechanical rubbing may be the underlying cause of the berry scabbing observed at the NHAES and other production sites. Heavy winds may also negatively impact pollinator activity/efficiency, damage growing tips, and promote desiccation. The use of windbreaks is considered an essential practice in global fuzzy kiwifruit production (McAneney et al., 1984), and it may benefit kiwiberry production as well. For best effectiveness, windbreaks should be a minimum of 10x longer than they are tall and spaced no more than 10x there height between windbreaks (Brandle & Hodges, 2006), see **Site Selection** for more information on windbreak guidelines. It is recommended to consult some form of windbreak design guide prior to any installation for best results.

Non-insect pests
Kiwiberry vines and fruit are attractive to some mammals which may become pests. Whitetail deer will browse laterals hanging into alleyways and can destroy young vines; thus fencing or some other means of vine protection or population control are recommended if

significant damage is observed. Rodent feeding damage to trunks is a potential concern during

winters with high snow levels, allowing ease of movement without fear of predation; however,

such activity has yet to be observed at the NHAES. In cases where such damage occurs,

protective trunk guards may be used to some effect; however, such devices are unable to prevent

bark damage by porcupine feeding. While birds are a pest of concern for producers of grapes

and many other small fruits and berries in the region, such is not the case for kiwiberry. In

agreement with the observations of surveyed growers, no birds have been observed feeding on

fruit at the NHAES, despite numerous nests found within the canopies. In general, by harvesting

berries while they are still firm (see **Harvesting**), producers can avoid many potential pest

issues.

Cats and kiwiberries?

More of an amusement than a pest, another animal that loves the kiwiberry is the

domesticated housecat. In 1906, the great plant explorer David Fairchild noticed

that a cat that somehow got into his USDA greenhouse went crazy for the

kiwiberry vines growing there (Fairchild, 1906; Strik, 2005). Since then, it was

discovered that some members of the *Actinidia* genus, including kiwiberry,

produce a catnip-like compound in their leaves called Actinidine (Bol et al.,

2017). Value-added kiwiberry leaf toys, anyone?

Pollination
        Ensuring adequate pollen supply and distribution within a kiwiberry vineyard is essential

to production, not only because cross-pollination is required for fruit set but also because fruit

size and symmetry are both positively correlated to seed count (Tiyayon & Strik, 2003). The

ratio of male to female vines in a vineyard is an important determinant of pollination efficiency, and a minimum of one male for every six female vines is recommended (Strik, 2005) (see *Figure 19*).
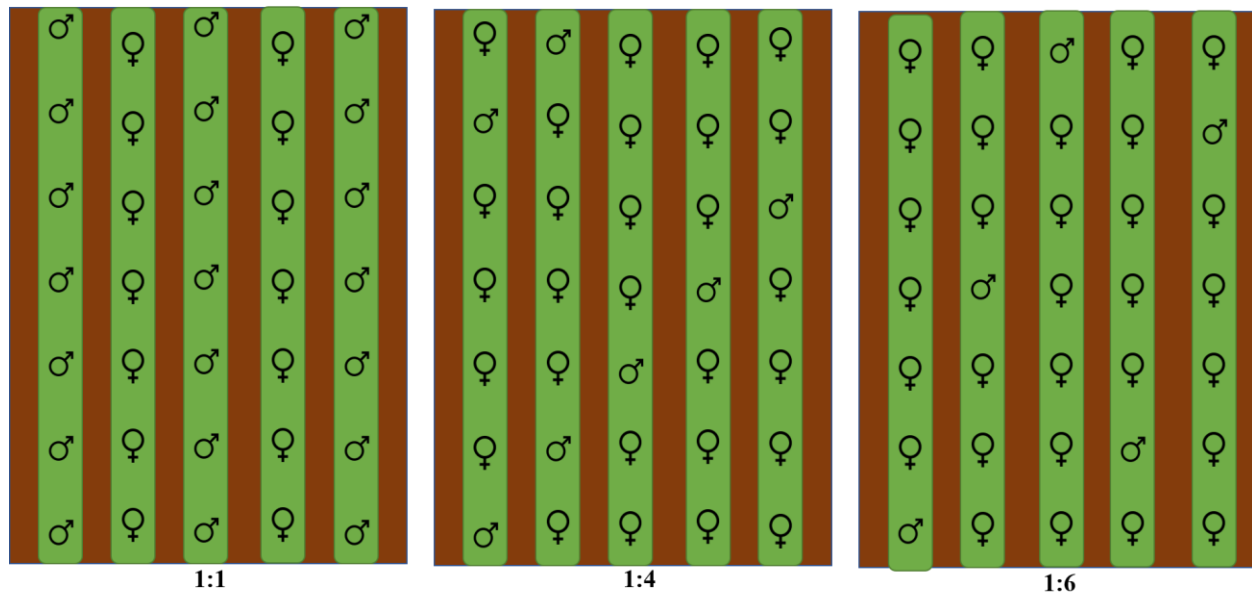

Figure 19 Examples of different ratios of male to female vines within a vineyard. Spacing should be based on pollen levels desired and the abundance of native pollinators.

In areas with low pollinator activity, it may make sense to increase the male:female ratio (e.g. to 1:6 or 1:4) (D. Jackson, pers. communication). In extreme cases, as reported in some northern European vineyards, males and females alternate every other row (1:1). Kiwiberry vines are both insect and wind pollinated (Strik, 2005), and factors such as prevailing wind direction and proximate pollinator habitat should be considered when laying out the vineyard. Alternatively, some growers maintain additional male vines around the vineyard periphery as a dual-use pollen source and windbreak hedgerow (D. Jackson, pers. communication). See **Vineyard Establishment** for further considerations on hedgerow sizing.

At the NHAES, bumblebees appear to be the primary pollinators (see *Image 17*). In

areas where native pollinator populations are insufficient, however, growers have been known to

successfully pollinate their vineyards through the use of imported hives.

Image 17 Bumblebees are frequently observed pollinating the kiwiberry vines at the NHAES. The vine
pictured is not *A. arguta* but rather *A. polygama*, another cold-hardy kiwi species.
Photo credit: W. Hastings

If managed hives are brought in to supplement pollination, a mix of bumblebees and

honeybees should be used, as bumbles tend to favor visiting male flowers which likely forces

increased activity via competition by the honeybees (Sapir & Greenblat, 2017). Even if

pollinators are present in sufficient numbers, environmental factors such as temperature and

rainfall during flowering may limit their efficacy. To mitigate the risk of such events, or to

compensate for low pollinator populations, some growers supplement pollination by air-blast

spraying fuzzy kiwi pollen, a viable pollination source for kiwiberry (see Image 18) (D. Jackson,

pers. communication) (Strik, 2005).

Image 18 A large-scale vineyard sprayer prepares to apply supplemental pollen to a European kiwiberry vineyard.
Photo credit: Management Strategies for a Productive Kiwiberry Orchard (Debersaques, 2017)

In general, a large proportion of the pollen sprayed into the canopy in this way is wasted; and given the high cost of quality pollen, more targeted options have been developed. For example, BioBest offers bumblebee hives with a pollen tray located at the exit of the hive (see **Appendix I** *'Grower Resources'*). Finally, while hand pollination is not uncommon in kiwifruit production (Hongwen Huang, 2014) and may make sense for a backyard grower with one or two vines, such a practice should not be considered by a commercial producer.

Pollen and bacterial canker disease

If purchasing fuzzy kiwi pollen for use in your kiwiberry vineyard, extreme care must be taken to source pollen that is produced in a region certified to be free of bacterial canker disease (*Pseudomonas syringae* pv. *actinidiae*; see **Insect Pests & Diseases**. Although the USDA import ban does not include pollen, there have been documented instances of transferring *Psa* from fuzzy kiwifruit to kiwiberry via contaminated pollen (G. H. Kim et al., 2017). See Grower Resources for *Psa*-free pollen suppliers.

Harvesting

Harvest indicators

While many small fruit and berry crops signal their ripeness and readiness for harvest with a clear visual indicator like skin color, the majority of kiwiberries do not (R. Guthrie, pers. communication) [2]; so determining when to harvest requires strategic scouting for less obvious signs. Leaving berries to ripen on-vine is not recommended, as such a practice significantly increases risk of loss due to pests, diseases, harvesting (e.g. tearing (Strik & Hummer, 2006)) and handling injuries, and fall weather events. Indeed, in commercial kiwiberry production, the goal should be to harvest as early as possible, with the intention of bringing berries to peak ripeness off-vine, following all necessary sorting and packaging. The guidelines in this section assume this mindset.

Beginning in early September, sampling berries for physiological maturity as an initial harvest indicator should occur approximately every other day at randomized locations throughout the vineyard. Producers should be aware that differences in elevation and microclimates can modulate the progression of berry development within the same farm by as much as two weeks (D. Jackson, pers. communication), so the total number of vines sampled should reflect these factors as well as total vineyard size. As a rule of thumb, one should sample 5-6 vines per variety per acre of production, according to the following protocol:

1. Select 4-5 berries from throughout the canopy to ensure reliable representation and minimize the chance of an early/late berry skewing results (see *Figure 20*).

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[2] Although the skin of some cultivars may develop a red blush as they mature, such color development is greatly influenced by exposure to direct sunlight and thus is not a reliable method for harvest maturity.
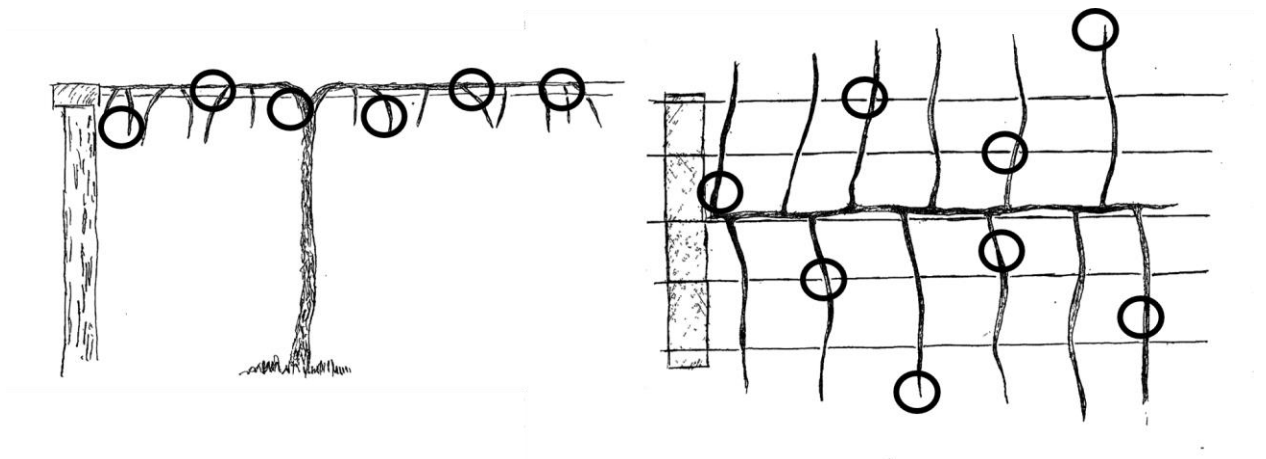
Figure 20 Example of locations within a kiwiberry canopy (Left, profile; Right, aerial) which should be sampled prior to harvest to provide to reliable information about the status of fruit maturity. The circles indicate sampling locations.

2. Cut all berries in cross-section and inspect seed color. A kiwiberry has reached physiological maturity once its turn uniformly dark brown/black in color, a condition referred to as "black seed stage" (see *Image 19*).

Image 19 "Black seed stage" indicates that a kiwiberry has reached physiological maturity.
Photo credit: W. Hastings

Once the vineyard has reached black seed stage, it is nearing time for harvest, meaning a more refined method of assessing harvest readiness is required. Two such methods are described in detail below:

1. Sugar content

An affordable, simple-to-use, and reliable tool for assessing degree of ripeness is a handheld refractometer, an instrument that estimates the total dissolved solids in a liquid (e.g. kiwiberry juice) based on the refraction of light through the sample. Because a high proportion of such soluble solids in fruits are sugars, this measurement of soluble solids concentration (SSC) serves as a usable estimate of total sugar content, expressed in

units of °Brix (degrees Brix). One unit of °Brix is defined as being equivalent to 1% total sugar content; thus a value of 24°Brix indicates that a liquid sample is roughly 24% sugar.

To ensure that kiwiberries are sufficiently mature to reach desired levels of peak ripeness off-vine (> 20 °Brix), harvest should occur between 6-8 °Brix. First-time growers should not be concerned by the fact that berries at this stage are very firm and unpleasant to eat; for they will continue to ripen post-harvest. When monitoring for progress of °Brix in the field, the same sampling protocol for black seed stage should be followed. In this case, however, the sampled berries should be cut in cross-section and the juice from one half squeezed onto the testing stage of a refractometer for measurement. Harvest can safely begin once the average of the samples lands within the target range of 6-8°Brix.

Note that refractometers should be calibrated daily using a pre-prepared sugar solution in distilled water, cleaned between samples, and operated within their manufacturer-specified temperature ranges. Hand-held refractometers, both optical and digital, are available in a wide range of prices (~$30 to more than $500), with varying levels of sensitivity.

2. Dry matter content

Soluble solids contribute to a berry's total dry matter; thus percent dry matter (%DM) is correlated to both SSC and sugar content and can serve as an indicator of

ripening. More broadly, because %DM takes into account both soluble and insoluble solids, the combination of which influence not only taste but texture, measuring %DM is considered the standard for quality control in fuzzy kiwifruit production (Crisosto, Zegbe, Hasey, & Crisosto, 2011).

Provided one has access to a drying oven and a digital scale with an accuracy of at least 0.5 g (~0.02 oz), monitoring ripening by %DM is straightforward. The same sampling protocol for black seed stage can be followed, ensuring a minimum sample size of 10 berries. After the initial total weight of the sample is taken (Weight$_{Initial}$), the fruits are cut into thirds, dried at low temperature (maximum 200℉), and re-weighed (Weight$_{Final}$). With these two weights, %DM is calculated as:

$$\%DM = \frac{Weight_{Final}}{Weight_{Initial}} * 100$$

There are advantages and disadvantages of this method relative to using a refractometer. Although drying takes time, overall the %DM method requires less hands-on time and more easily accommodates large sample sizes. Berries at early stages of ripeness are firm and can be difficult to squeeze for a liquid sample, making the use of refractometers time-intensive. Furthermore, each berry must be measured individually for °Brix (and the measurements recorded), making the processing of large samples tedious. In contrast, cutting berries for drying is quick, even if they are firm; and calculating %DM requires only two weights, regardless of the number of berries in the sample.

The disadvantage of the method lies in the fact that currently no validated, standard %DM has been established as a harvest threshold for kiwiberries. For the variety "Michigan State (SFV)," preliminary investigations in the NHAES program indicate harvest can safely begin once berries reach 20-22% dry matter. It is quite possible, however, that this result is variety (and possibly even vineyard) specific. Growers interested in using the %DM method may wish to monitor their vineyard by both methods (°Brix and %DM) the first few seasons to establish a %DM threshold appropriate to their operations.

Currently, some small-scale growers report determining when to harvest based on feeling for the presence of berries that are soft to the touch, indicating a steep increase in SSC (Hassall et al., 2016). There appears to be no standard practice for such an approach, with anywhere from 1-10% soft berries initiating harvest. And as argued above, such an on-vine ripening approach unnecessarily increases the risk of loss to pests like the spotted-wing drosophila (*D. suzuki*), as well as damage from fall weather events, harvesting, and handling. Given these increased risks, this practice is not recommended.

Harvest methods

Harvest should commence as soon as the selected harvest indicator is met. Although climacteric kiwiberries can be harvested while firm, greatly reducing the risk of damage during harvest, sorting, and shipping, care should still be taken in their handling. Unnecessary movement or handling should be avoided; and gloves should be worn during harvest to both

minimize fruit bruising and support clean handling practices from vine to consumer. Because current varieties are not amenable to whole cluster harvesting and marketing, as is done in grapes, berries must be separated for sorting and packaging. At the NHAES, this separation is accomplished in the field, with individual berries harvested one-by-one into bins. In contrast, a common practice in European production is a two-step harvesting process in which entire spurs are removed from the vineyard, after which individual berries are cut from the clusters (P. Latocha, pers. communication).

Once removed from the vine, berries should be limited to a shallow packing depth to reduce crushing damage and to maintain air flow (see *Figure 21*); and harvest containers be easily cleanable and vented to promote air circulation (see *Figure 22*).
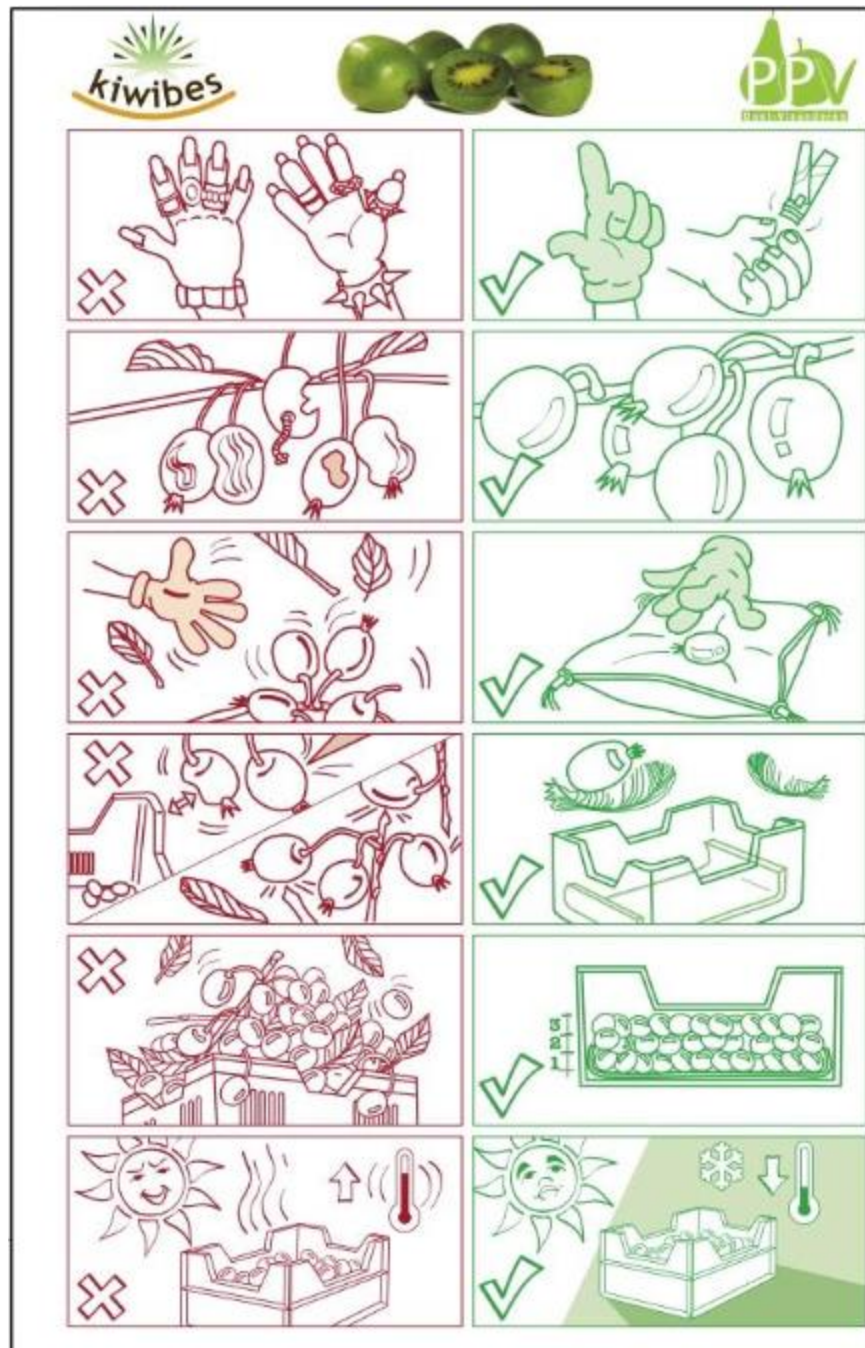
Figure 21 An infographic of best harvest and handling practices.
Figure credit: minikiwi.edu, Kiwibes

Figure 22 Wooden containers (left) are durable but are difficult to sanitize if soiled. Plastic lugs (right) are equally as durable, often able to nest within each other, and are easy to sanitize if needed.
Photo credit: W. Hastings

To limit subsequent storage disorders, harvest conditions should be such that fruit is free of all excess moisture (dew/rain) before going into storage. In the case of poor weather, in which delaying harvest by a few days could promote better drying before storage, the slight progress in ripening on the vine is more than justified.

Should I sort while harvesting?

Due to sanitation concerns as part of a well managed Integrated Pest Management Program, producers are strongly recommended to harvest all berries from the vineyard. Necessary sorting and culling should be done subsequent to harvesting (see **Postharvest Handling**) in such a way that culled/discarded fruit can be properly disposed of rather than left to ripen on the vine.

Postharvest handling

Kiwiberry breeding is in its infancy, with available varieties being only a few generations from wild plants and in many cases the result of serendipity rather than systematic breeding. One consequence of this state of affairs is that current varieties can at the time of harvest exhibit significant levels of variation, even within an individual vine, in important traits such as berry size and degree of ripeness. Such lack of uniformity in terms of both appearance and maturation presents a challenge to producers and marketers and necessitates significant investment in sorting, storage, and controlled ripening for commercial kiwiberry operations. According to one large-scale producer, sorting alone accounts for ~12% of total annual production costs(D. Jackson, pers. communication) (see **Enterprise Analysis**).

Sorting/Grading

Assuming the objective is to produce high-value berries for fresh-eating, the ability to efficiently sort and grade kiwiberries is essential for the large-scale commercial success of the crop. The few current producers in the region sort their harvests by hand, either bin-by-bin or on a pack line (conveyer belt) (see *Image 20*), and manually pack the selected berries into containers (e.g. vented clamshells) for storage. This basic approach likely represents the short- to medium-term reality of kiwiberry production in the region, but manual sorting is costly and prone to error. Fortunately, alternative methods exist which should be kept in mind as the sector grows in the region.

As with many global commodity fruits, the fuzzy kiwifruit sector has invested significant resources in developing sophisticated, automated sorting and packing equipment; and available systems for kiwiberries are increasingly being used in Europe and New Zealand.

Image 20 An example of a low volume kiwiberry pack line on which fruit is sorted and processed by hand based on chosen quality metrics.
Photo credit: W. Hastings

Such systems, like those manufactured by Stas Belgium in Belgium, rely on near-infrared (NIR) sensors to scan, sort, and cull berries based on a range of both external and internal quality attributes, including size, weight, shape, firmness, color, and degree of cosmetic damage. By providing a level of quality control far beyond what is detectable by the human eye, such systems promote uniformity in berry appearance, ripening, and post-harvest performance, thereby improving overall consumer satisfaction.

While investing in an expensive, automated, NIR-equipped pack line may make little sense for all but the largest commercial operations, the possibility exists to create cooperative pack houses to divide such a capital cost among multiple regional producers. In theory, following this regional food-hub mindset, cost sharing could be extended further if the equipment were versatile enough to process other small fruit crops as well, especially those harvested earlier in the season (e.g. blueberries and cherries). Until such facilities come online, however, innovation will be required to develop low-cost, high-throughput sorting methods for small-scale producers. Further research and innovation is required to address possible low-cost options for fruit sorting.

Storage

From 2016-2018, a set of basic post-harvest studies were conducted at the NHAES to determine both the expected shelf-life of kiwiberries and the amount of time required to bring berries to peak ripeness following various periods of cold storage. For these studies, berries of cultivar 'Michigan State (SFV)' (USDA PI617136) were harvested at 6-8°Brix, manually sorted and packed into 6 oz. vented plastic clamshell containers, and stored in non-ventilated, walk-in apple coolers (fluctuating 1-5°C with no relative humidity or ethylene control) (see *Image 21*).

Image 21 Commercial cold storage facilities are well-regulated and often sanitized environments. It is important to design cold storage to meet any future needs such as fork lift accessibility or space for ethylene scrubbers.
Photo credit: W. Hastings

Even with this minimal control on environmental conditions, data collected over three growing seasons indicate that harvested kiwiberries can be held for six weeks with no noticeable impact on appearance or eating quality (see *Figure* 23). With more precise temperature control and maintenance of high relative humidity, storage of up to two months can reasonably be expected. Research is needed to determine the additional extension of shelf-life and post-harvest performance that may be achievable via controlled atmosphere (i.e. ethylene scrubbing and O_2/CO_2 regulation), though investment in such facilities may not be viable for small-scale producers.

Harvest 09/24/2016
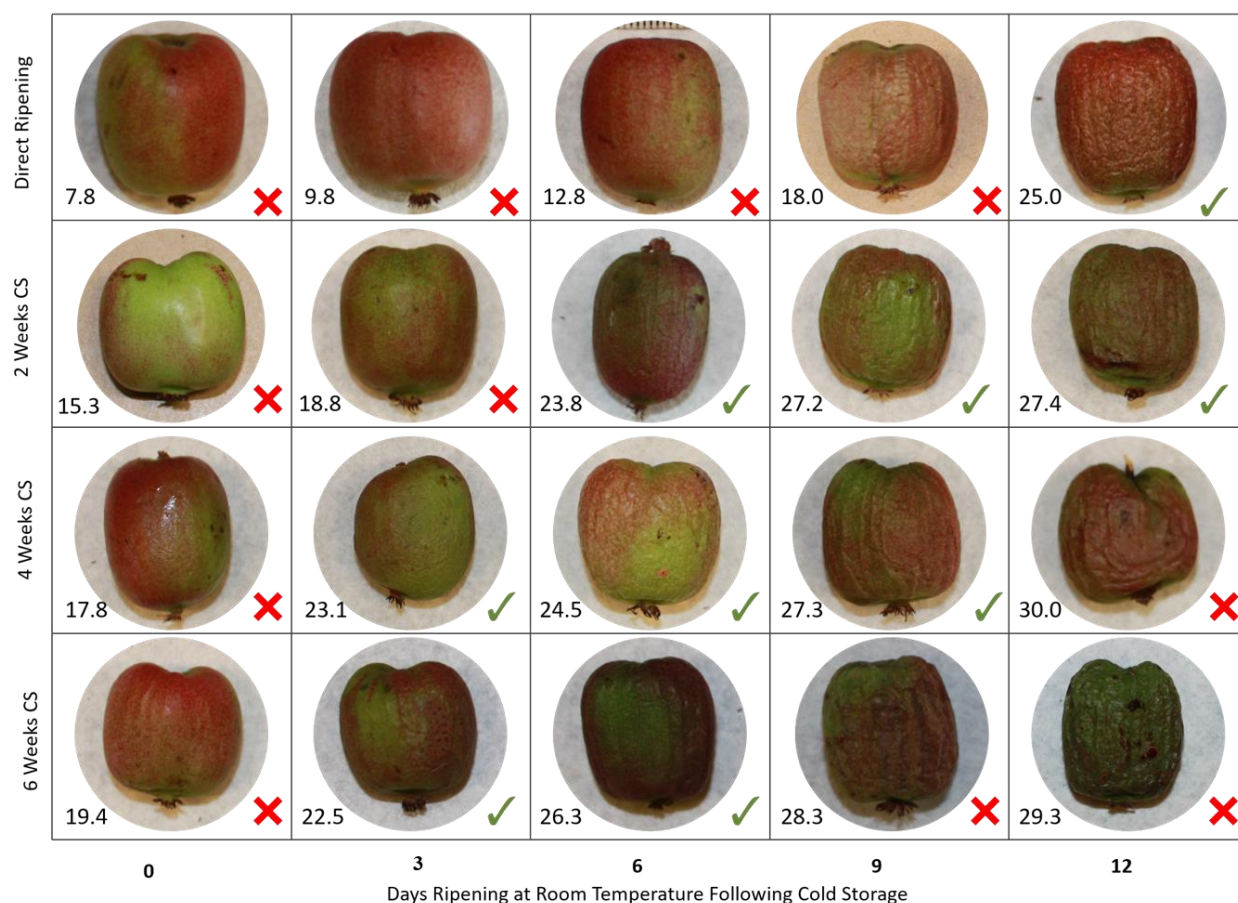
Figure 23 – Berries from the variety 'Michigan State (SFV)' harvested on September 9, 2016, and held in cold storage (CS) for a period of 0 weeks (no CS), 2 weeks, 4 weeks, or 6 weeks and subsequently ripened and tested for °Brix over a period of 12 days at room temperature. The mean °Brix levels are indicated in the lower left corners. The green check marks indicate that the fruit are of sufficient sugar content and ripeness to be of good eating quality. The red X marks indicate fruits which are either not yet ripened or past eating quality. Note the reduction in time to eating quality as well as duration of acceptable eating based on the cold storage period. See *Appendix VII* for full study methods and results.

Both fruit maturity at the time of cold storage and the storage conditions themselves can significantly affect post-ripening physiochemical, nutritive, and sensory qualities (Fisk, Silver, Strik, & Zhao, 2008). High levels of oxygen and ethylene gas, low-temperature injury, and possible microbial effects have anecdotally been associated with reduced eating quality (R. Guthrie, pers. communication). To maximize storability, kiwiberries should be removed from the

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field at the time of harvest and immediately sorted, packed, and placed in conditions of consistent cold temperature (1-2°C) (Strik, 2005; Strik & Hummer, 2006) and high relative humidity (90-95%) (Fisk et al., 2008). The berries should be free of excess moisture and packed in clean containers and bins that allow adequate ventilation for gas exchange (e.g. clamshells; see *Figure 24*), thus limiting the buildup of ripening-promoting ethylene gas.

Figure 24 Ideal storage and sale containers should be clean and well ventilated to promote quality control and facilitate gas exchange.
Photo credit: W. Hastings

Ongoing research indicates that ethylene inhibitors like 1-methlycyclopropene (1-MCP) have the ability to reduce weight loss in storage as well as improve visual appearance (Fisk et al., 2008); and edible chitosan-based coatings have the ability to reduce instances of fungal disease (Strik & Hummer, 2006). When paired with vented clamshells, such coatings have been reported to significantly extend shelf life of kiwiberry fruits (Fisk et al., 2008) (Strik, 2005).

Ripening

　　While ripening of kiwiberries can be achieved via the regulated introduction of exogenous ethylene gas (Strik & Hummer, 2006), the controlled atmosphere facility required for such a method is likely beyond the reach of small producers. In practice, ripening is as simple as allowing a container of kiwiberries to sit at room temperature for several days, while the berries respond to their own production of ethylene gas in the presence of oxygen. Here, however, a fundamental question arises: Who should do the ripening, the producer or the consumer?

　　While ripening can be undertaken by a producer in the hope of providing ready-to-eat fruit at points of sale, studies at the NHAES indicate that the rate at which 'Michigan State (SFV)' berries reach peak eating quality varies within a clamshell and strongly depends on the stage of maturity at the time of storage, the time spent in cold storage, and the ambient conditions both in storage and during ripening (see *Figure 25*). In other words, a reliable protocol for achieving containers of berries at uniform peak ripeness may not be possible; thus to instill such an expectation in consumers runs the risk of creating dissatisfaction.

Effect of Harvest Date and Storage on the Ripening of Kiwiberries
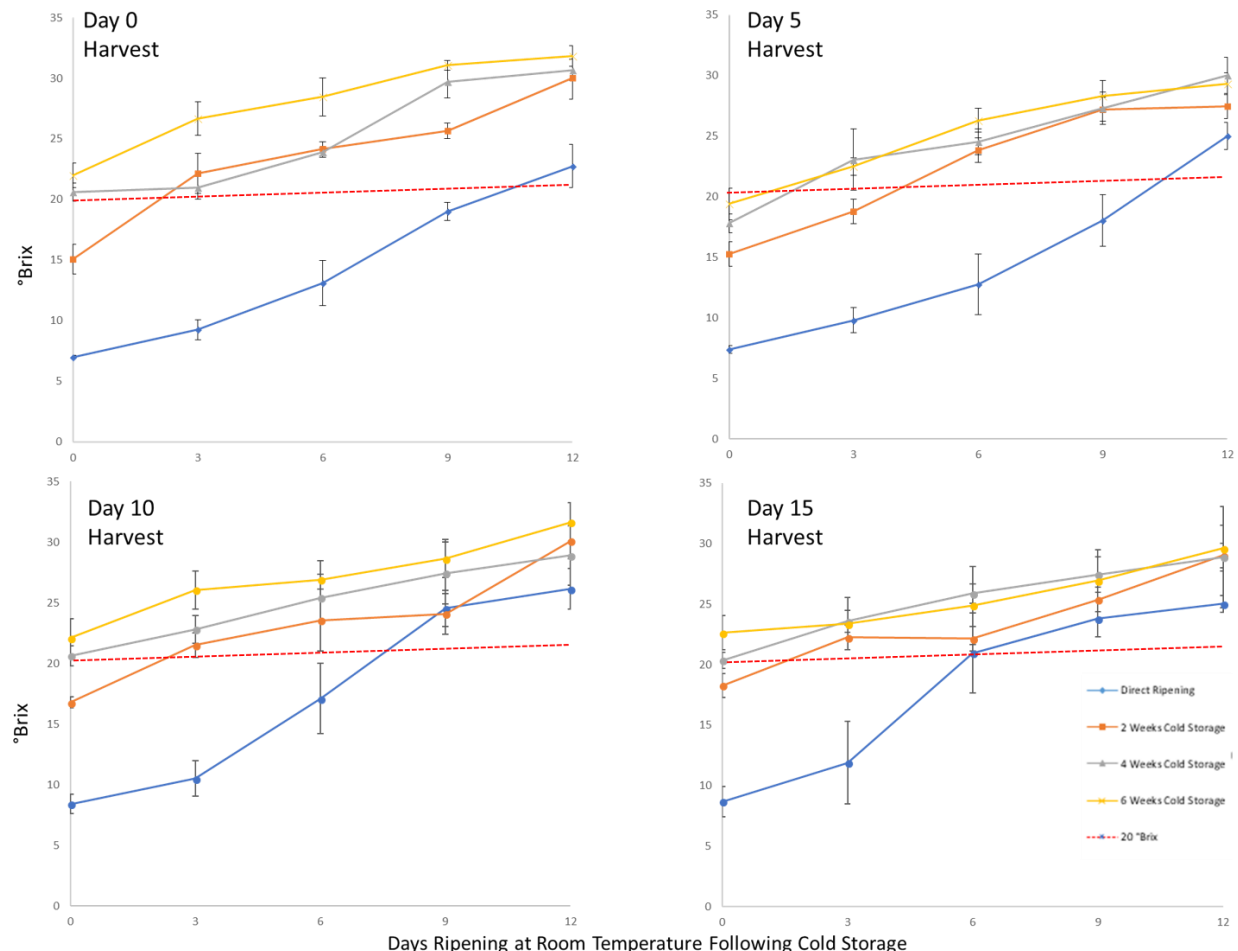
Figure 25 – The ripening of berries in 6 different cold storage conditions was tracked over a period of 15 days. The y-axes indicate ºBrix (or sugar content), and the x-axes indicate the dates of testing following removal from CS. While no differences were noted in maximum sugar content achieved, there were differences in time it took to accumulate the mimumum of 20 ºBrix. These data also illustrate the importance of tight temperature control in cold storage. In the outdated facilities used for this study, berries were seen to significantly ripen (as much as 15 ºBrix increase) while in storage – compare direct-ripened fruits to those held for 6 weeks, at Day 0. See *Appendix VII* for full study methods and results.

Alternatively, taking advantage of the fact that the kiwiberry is unfamiliar to most people, consumers can be educated from the beginning that the berries are meant to be ripened on the kitchen counter at home, similar to bananas, avocados, peaches, plums, pears, figs, and other familiar fruits. In this scenario, dissatisfaction is avoided because consumers are explicitly disavowed of any expectation of uniform ripeness. Of course, consumers must be instructed

about how to recognize peak ripeness when it occurs; and growers may wish to pull product from cold storage a few days before market in order to reduce the total length of time a consumer must wait for the berries to achieve peak ripeness.

Naturalized Vines and Invasive Concerns

As the regional kiwiberry sector becomes established it will become important to distinguish between 'kiwiberry' and 'hardy kiwi'. The latter name is not only imprecise, applying generally to any cold-hardy kiwifruit species, it is also often negatively associated with locally-aggressive, naturalized vines hailing from *A. arguta*'s earlier era as a minimally managed, ornamental vine in the region. In isolated locations in southern New England, some historic estate vines of *A. arguta* were abandoned. Such vines have since overgrown their original boundaries into surrounding forest, or in many cases the forest has grown up around them, and in some instances generated progeny from seed (see *Image 22*). Though they respond readily to control measures, naturalized *A. arguta* vines can be a nuisance due to their ability to generate large amounts of vegetation which can create dense mats on the forest floor, reducing local plant diversity. They can also lead to increased ice and snow load in trees they have climbed, ultimately leading to their collapse. In stark contrast to these abandoned, ornamental vines, it is important to note that there have been no reported escapes of kiwiberry grown under managed cultivation for fruit production anywhere in the United States, despite thousands of tons of berries produced over many decades.

Image 22 A vine located on a former estate in Lenox, MA, which has outgrown the sunken garden it once occupied and climbed the forest which has grown up around it. Photo credit: W. Hastings

History teaches us that abandoned vines can, in some cases, become a nuisance. For this reason, it is important to properly decommission vineyards going out of production. Vines should be fully uprooted from the ground and the site rechecked in subsequent seasons for any re-shooting from residual roots. Vineyards left to outgrow their boundaries and expand unchecked into surrounding habitat can be ecologically and financially costly to those left to steward such areas. Additionally, such mis-management could ultimately lead to dissolution of the entire regional kiwiberry industry. The most recent example of this risk was a proposal to add *A. arguta* to the list of prohibited plant species in Massachusetts in 2017. If approved, such a listing would have banned not only the propagation and cultivation of kiwiberry vines but also potentially the sale of kiwiberries themselves, even if they were produced outside the state.

Fortunately, after a year of reviewing the available evidence, the MA Department of Agriculture rejected the proposal (see **Appendix IV** *'MDAR decision letter'*).

Moving forward, regional growers should be aware of this issue and manage their vineyards responsibly. Vines should only be grown in an well-managed, trellised vineyard rather than allowed to grow unchecked on fences or arbors, as is sometimes suggested in backyard and permaculture grower guides (Affeld, n.d.). Unwanted/damaged fruits should be disposed of in a manner which limits their access to wildlife, for example via incorporation into actively composting materials. Failure to follow such practices with excess fruit has resulted in the unwanted distribution of feral fuzzy kiwifruit vines in New Zealand due to the presence of a naturalized bird (Silvereye) which feeds on fuzzy kiwifruits (Sullivan et al., 2007).

CHAPTER III: ENTERPRISE ANALYSIS

Introduction

In addition to presenting current best recommendations regarding the production, processing, and marketing aspects of kiwiberries, a key objective of this guide is to provide an informed enterprise analysis to aid prospective regional growers as they consider whether or not to integrate this novel crop into their production systems. Just as a consumer survey was conducted to assess kiwiberry demand, consumer preferences, and willingness-to-pay (see **Appendix III** *'Market Analysis Results and Methodology'*), a detailed producer survey was developed to refine the timeline and tally all likely incurred costs for production. Unfortunately, although kiwiberries have been grown by hobbyists in the northeast for many decades, there are extremely few commercial producers in the region; and those operations that do exist are either very small-scale (< 10 vines), not intensively managed for production, and/or only recently established.

The nearest intensively-managed commercial operation with a documented history of production data is Kiwi Korners Farm in Danville, PA. Thus the following enterprise analysis relies heavily on data generously provided by Kiwi Korners, adjusted and complemented where possible based on feedback from small-scale northeast growers and experiences to date in the NHAES program. In aggregate, these data are used to estimate the establishment timeline, production costs, and yields that prospective growers can reasonably expect from current varieties. Paired with consumer willingness-to-pay data from the statewide market survey (average of $10.64/pound for non-organic, direct-market, Grade A berries; see **Appendix III** *'Market Analysis Results and Methodology'* for details), the enterprise analysis provides an estimate of profitability as well as time to return-on-investment.

How to use this information

Although the following enterprise analysis is based on the best information available, prospective producers should be aware of its underlying assumptions and the fact that the cost associated with any given material or activity can vary widely among operations. As presented, the analysis assumes income only from the direct sale of whole, Grade A berries for fresh eating. No supplementary income, either from value-added production and/or sales of Grade B berries or culls (e.g. for winemaking), is considered. In addition, the analysis limits its consideration of costs to those associated with vineyard establishment and maintenance, berry production, harvesting, and sorting. While other costs should be expected, they can vary widely based on choices about post-harvest storage, packaging, distribution, and marketing. Additional costs inherent to any farming system, such as utilities, equipment, land, taxes, etc. are also not included due to the wide variation among farms.

Given the above scope, the appropriate use of the presented information is as a reference for developing a more precise enterprise projection based on the grower's specific circumstances. While representative costs have been used in the analysis for all materials and activities, the potential ranges of such costs are also presented and explained to facilitate operation-specific modifications. In short, this analysis should be understood as a general, modifiable template to guide decision-making rather than as a final, static projection for a potential kiwiberry operation.

Summary of analysis

       The following table presents a high-level summary of the enterprise analysis. Relevant vineyard layout specifications are declared in the upper part of the table, below which costs and returns are reported on a per-vine and per-acre basis. The underlying rationale for each line in this summary is provided in the following pages, along with indications of relative confidence and likely ranges, based on operation-specific circumstances.

Summary of Kiwiberry Enterprise Analysis

Vineyard layout assumptions	
Vine spacing within row (ft)	10
Spacing between rows (ft)	11
Ratio of male to female vines	~1:6
Total vines per acre	399
Total female vines per acre	341
Total male vines per acre	58

	per vine	per acre
Total establishment costs (Years 1 - 5 combined)	**$110.87**	**$44,342.25**
Materials		
Trellis supports (posts and top bars)	$36.15	$14,424.00
Trellis hardware	$8.05	$3,212.50
Irrigation system	$5.99	$2,390.75
Grass seed for vineyard floor	$0.97	$388.00
Kiwiberry vines	$12.00	$4,788.00
Fertilizer	$2.01	$800.00
Training materials	$1.50	$702.50
Labor		
Trellis & irrigation installation	$16.00	$6,384.00
Vine management	$37.50	$14,962.50

	per vine	per acre
Annual production costs (Year 6 and beyond)	**$41.22**	**$14,997.00**
Materials		
Fertilizer	$0.98	$391.00
Training materials	$0.24	$96.00
Labor		
Production	$15.00	$5,985.00
Harvesting	$15.00	$5,115.00
Sorting	$10.00	$3,410.00

Productivity assumptions	
Total annual production (lbs)	
Year 6	30
Year 7	40
Years 8 and beyond	50
Proportion of total production that is Grade A	60%
Proportion of total production that is discarded (unsold)	40%

Net annual income	@ $10.64 / lb		@ $8 / lb	@ $5 / lb
	per vine	per acre	per acre	per acre
Year 6	$150.30	$50,311.32	$34,107.00	$15,693.00
Year 7	$214.14	$72,080.76	$50,475.00	$25,923.00
Years 8 and beyond	$277.98	$93,850.20	$66,843.00	$36,153.00

Years to return on investment (ROI)	6-7	7-8	8-9

Vineyard layout assumptions

For this enterprise analysis, vineyard layout is assumed to follow the recommendations detailed in this guide (see *Vineyard Layout*). Specifically, vines are grown on an irrigated, T-bar trellis system with 11 feet between rows 10 feet between vines within rows, and 30 foot bays (i.e. 30 feet between posts within rows). To ensure adequate pollination using currently available varieties, a conservative male:female ratio of approximately 1:6 is also assumed. In this scenario, a square, one-acre vineyard will be comprised of nineteen 210 foot rows, in total containing 341 female (fruiting) vines and 58 male (pollinator) vines. See *Figure 26* for a detailed schematic.

Model Vineyard Layout (1 acre) for Enterprise Analysis
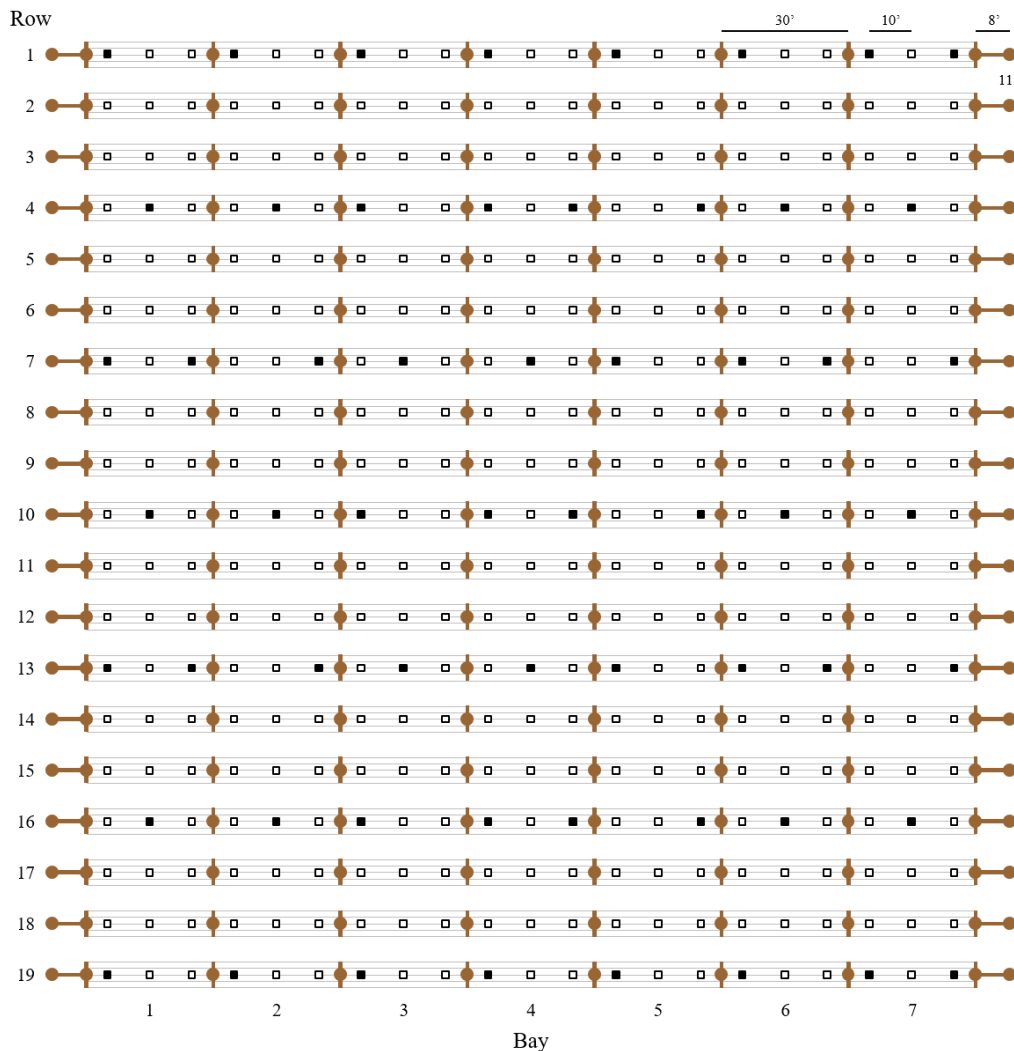
Figure #26 A representation of the vineyard assumptions used for this enterprise analysis. One acre of vineyard requires 190 posts, 152 top-bars, ~5,200 feet of high tensile wire. To achieve a 1:6 male to female ratio and ensure even dispersal of pollen the layout above should be used. Note the placement of males at all corners as well as at the very edges of the vineyard to ensure maximum coverage.

- Trellis post and cross bar (152)
- H-brace outer post and beam (38)
- 12.5 gauge trellis wires (~5,200')
- Male plant (58)
- Female plant (341)

Total establishment costs (Years 1-5)

With proper management and conducive conditions, a kiwiberry vine can begin to flower

and set fruit as early as Year 3; and appreciable harvests (~ 40 lbs. per vine) have been realized

at the NHAES as early as Year 5. Nevertheless, for this conservative analysis, it is assumed that

harvesting for sale will not commence until Year 6; thus Years 1-5 are considered establishment years (see *Training Youngs Vines*) with no harvesting or sorting expenses and no income generation. In the summary table, the total cost of establishment over this time period is broken into two main components, materials and labor, as discussed in detail below:

Trellis supports (posts and crossbars)

The cost of materials for trellis construction can vary greatly based on both the materials used and the overall geometry of the vineyard. Black locust poles, pressure treated wood, and concrete are all viable materials for the posts; but they vary in price. Furthermore, producers who are able to generate such materials onsite (e.g. via woodlots or a lumber mill) can realize greatly reduced costs compared to those who must purchase them from a retailer. In terms of geometry, long rows[3] are more cost-effective than short rows due to the reduction in the number of needed H-braces per area; thus a square acre will incur a higher trellis support cost than a rectangular acre. The costs reported in the table are based on a square acre, with black locust posts and rough-sawn pine crossbars, as used at the NHAES.

Trellis hardware

Again assuming a square acre, the costs of all necessary trellising hardware (i.e. wire tensioners, staples, bolts, wire sleeves, etc.) have been aggregated into the above summary table. The assumed per unit costs for such hardware components used in the

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[3] The maximum recommended distance for a single wire strainer is 500 linear feet. Excessively long rows have the potential for increased wind damage to both vines and fruit(Guthrie, 2018).

analysis are reported below, though it is worth noting that pricing can vary depending on volume and the source of materials.

Hardware	Unit cost
Wire strainer	$1.50 each
12.5 gauge wire	$25 / 170'
Lag bolts	~$20 / 25 ct.
Cable sleeves	$25 / 100 ct.
Cable staples	$4 / 50 ct.

Irrigation system

The reported cost of the irrigation materials is based on a square acre of the raised microsprinkler system (2 sprinklers per bay) used at the NHAES (see *Irrigation System*). In practice, irrigation system design and required components will vary based on a number of factors, including pre-existing access to water at the site and zoning requirements. Similar to trellis hardware, the realized costs of irrigation materials will depend on quantity and supplier; but the following table presents the per unit costs used in the above analysis:

Part (Model #)	Unit cost
Sprinkler head (Rainflo MS7PC9)	$3.85 each
Sprinkler stake mount (Rainflo MS7PCxx48)	$2.98 each
Toro 1/2'' BlueStripe irrigation hose	$75 / 1000'
End plugs (Rainflo #CEC-50)	$0.85 each
Header components:	
1 1/2" black polypipe	$55 / 100'
1½"x1½"x½" barb-barb-female T union (Rainflo 402-209)	$2.98 each
12" Riser pipe from T (threaded)	$2.73 each
Female 90 Elbow (Rainflo 408-005)	$0.50 each
T-valve (threaded) (Rainflo PBV05T)	$2.00 each
MIPT adapter (Rainflo #CM-50)	$0.62 each

Grass seed for vineyard floor

As discussed in the production guide (see *Vineyard Establishment*), there are multiple benefits to a well-established alleyway in the vineyard. The costs presented are for seeding an acre of vineyard floor with Chewings fescue at a rate of 5 lbs per 1,000 ft^2.

Kiwiberry vines

A highly variable and potentially significant start-up cost is the vines themselves. All current commercial nurseries offering kiwiberry vines are geared toward homeowners and hobbyists, and the cost-per-vine is variable and can be quite high (as much as $23, excluding shipping). Growers may be able to reduce their costs by negotiating bulk rates, purchasing wholesale, or even propagating vines themselves (see **Planting Material**). For this analysis, the assumption is that lower cost materials will become increasingly available as demand grows. Based on experience at the NHAES, a retail price of $12 per one-year-old vine appears reasonable from the nursery perspective and thus was used.

Training materials

Various materials are needed for vine training during the establishment period, including 8' bamboo stakes (trunk support), wire clips, and trellising tape/staples. The analysis assumes the purchase of two (2) Tapener guns and the following materials at the indicated unit costs:

Material	Unit cost
8 foot bamboo stake	$2.00 each
KiwiKlips	$170 /1,000 ct.
Tapener gun	$51.99 each
Tapener tape	$30.00 / 3,600'
Tapener staples	$4.40 / 4,800ct.

Labor

The amount of labor required for vineyard establishment can vary greatly. If you have access to a tractor with an auger and post-pounder, trellis construction can move quickly. The same task can be very time-intensive, however, if you are digging holes by hand. And if you are hiring someone else to do the work, it can be quite expensive, especially at low volumes. The analysis here assumes outsourcing post-establishment to someone with an auger and pounder, at $6/post. Having access to the correct tools for trellis construction (power tools, spinning jenny, crimpers, etc.) will also greatly increase efficiency and reduce overall labor inputs.

Beyond trellis construction and irrigation installation, the estimated labor requirements in Years 1-5 also cover vine management (pruning, training, fertilizing, irrigating), vineyard floor establishment, and mechanized weed control (see **Cultivation**). A labor rate of $15/hour is assumed, and activities such as large-scale field amendment or renovation are not considered, due to the wide range of possible costs.

Annual production costs (Year 6 and beyond)

As explained above, Year 6 in this analysis is considered to be the first harvest year; thus costs from this year onward are considered annual production costs, as distinct from vineyard

establishment costs (Years 1-5). Such annual production costs can also be divided into two main categories, materials and labor. Materials in this case is the much smaller of the two categories, comprised largely of vine training supplies, fertilizer, and trellis/irrigation maintenance materials. Labor is by far the larger category of expense once a vineyard enters production, encompassing such activities as vine management, weed control, harvesting, and sorting.

Materials

The training materials considered in this analysis include the annual purchase of tapener staples and tape as well as KiwiKlips, in bulk. Fertilizer estimates are based on numbers used by the NHAES for synthetic nitrogen fertilizer.

Annual Production Materials	Unit cost
KiwiKlips	$170 / 1,000 ct.
Tapener tape	$30.00 / 3,600'
Tapener staples	$4.40 / 4,800ct.
Nitrogen Fertilizer (21-0-0)	$50 / 50 lb. bag

Labor

Estimated labor requirements for production (vineyard management) and harvest are based largely on experiences at the NHAES. Production activities include training, pruning, irrigating, fertilizing, and weeding. Labor estimates assume the use of a fully installed, full-coverage irrigation system; access to an appropriate tractor-mounted weed cultivator; and hand harvesting of individual berries (not clusters). The estimated labor requirements for sorting are based on the experiences of Kiwi Korners Farm, where manual sorting (~50 lbs. per man-hour) is done by a team on a conveyor packline. In general, all estimated labor requirements for

vineyard management assume a level of efficiency that depends on timely training, pruning, fertilization, and weed control. Failure to enact operations in a timely manner can greatly increase labor costs in the long run. As before, the assumed labor rate is $15/hour.

[Note: Up-front and ongoing costs for tractors, cultivation equipment, packline systems, and cold storage facilities are not included in this analysis.]

Productivity and market price assumptions

Regional growers report annual per vine yields of up to 100 pounds, with yields of 60 pounds per vine considered average for current commercial varieties. At the NHAES, yields of 40 pounds per vine have been observed as early as Year 5. For this analysis, however, a conservative estimate of 50 pounds per vine (Year 8 and beyond) was used, with that yield slowly coming into production over the previous two years (30 and 40 lbs/vine in Years 6 and 7, respectively). Of this total harvest, a minimum of 60% is estimated to be Grade A, appropriate for direct sale to consumers. This estimate is based on observations at the NHAES, but it is worth noting that domestic and European growers report variability around this number, from as little as 40% to greater than 80%. One analysis assumes a direct-sale price point of $10.64/lb ($3.99 per 6 oz. clamshell), as informed by the statewide market analysis (see Appendix III *'Market Analysis Results and Methodology'*). Other potential direct-market and wholesale scenarios are also featured ($8/lb. and $5/lb.). Despite evidence of a value-added market for lower-quality berries (e.g. wines, jams, etc.), potential income from such sales are not considered.

Net annual income and return on investment (ROI)

The bottom of the enterprise summary table reports estimated net annual income once a vineyard enters production (Years 6 and beyond). These estimates of net annual income disregard establishment costs (Years 1-5) but do account for annual production costs after establishment. Even assuming highly conservative yield estimates and the sale of only Grade A berries, the analysis indicates that the income generated in Year 6 ($50,311), the first harvest year, can more than cover the establishment costs for materials and labor incurred over Years 1-5 ($44,342) at the market rate of $10.64/lb. In other words, in light of the conservative estimates used in this analysis, a 6 year return-on-investment is possible, in the absence of other large, up-front costs (e.g. significant land renovation, well drilling, large equipment purchases, cold room construction, etc.) not considered here but perhaps of relevance to some producers. Even in such cases, however, the analysis indicates a probable 7 year return-on-investment, with annual profits exceeding $90,000/acre in Year 8 and beyond. For the lower market price scenarios, the ROI timeline can be expected to increase by one or two seasons.

APPENDICES

APPENDIX I 'Grower Resources'

Vine Sourcing

Provider	Contact
Nor'east Kiwiberry	https://www.unh.edu/halelab/kiwiberry
OneGreenWorld	https://onegreenworld.com
Fedco	https://www.fedcoseeds.com
Tripple Brook Farm	http://www.tripplebrookfarm.com
Hartmann's Plant Company	https://hartmannsplantcompany.com

Vineyard Supplies and Resources

Resource	Supplier
Tapener gun and training supplies.	https://www.orchardvalleysupply.com/
KiwiKlips	http://www.klipon.co.nz/product/kiwiklip/
Irrigation Supplies (UNH source)	https://www.toro.com/en/irrigation
Trellis Supplies (UNH source)	https://www.wellscroft.com/
Locust Poles (UNH Source)	http://www.ablacklocustconnection.com/index.htm
Trellis Construction Resource	How to Build Orchard and Vineyard Trellises (with USS Max-Ten 200 Hi-Tens Fence Wire) – US Steel Publication

APPENDIX II 'Pseduomonas syringae pv. actinidiae (PSA) Quarantine Language'

SUBJECT: Federal Order for *Pseudomonas syringae* pv. *actinidiae,* bacterial
canker of kiwifruit.

TO: STATE AND TERRITORY AGRICULTURAL REGULATORY OFFICIALS

This Federal Order is being issued to prevent the introduction and dissemination of a bacterial canker of kiwifruit (*Pseudomonas syringae* pv. *actinidiae*) into the United States. The Animal and Plant Health Inspection Service (APHIS) will prohibit importations of *Actinidia* spp. plants for planting (including pollen but excluding fruit and seed) hosts of *P. syringae* pv. *actinidiae* (bacterial canker of kiwifruit) from all countries. This Federal Order is effective November 10, 2010.

Recent scientific literature identifies *Pseudomonas syringae* pv. *actinidiae* as a destructive plant pathogen that is seriously affecting orchards of kiwi plants around the world. The disease is rapidly spreading though Asia and Europe. In Italy, it is estimated that the economic losses (including impact on trade) due to *P. syringae* pv. *actinidiae* have reached 2 million Euros.

Pseudomonas syringae pv. *actinidiae* is not known to occur in the United States. Plant pathogens, including viruses and viroids, are extremely difficult to detect during a port of entry inspection of the host plants, particularly in the absence of symptoms. The pathogen is not known to be seed or fruit transmitted.

In order to prevent the entry of *Pseudomonas syringae* pv. *actinidiae,* APHIS has determined it is necessary to prohibit the importation of *Actinidia* spp. plants for planting (including pollen but excluding fruit and seed) until a pest risk analysis is completed and appropriate effective mitigation measures have been established.

For additional information regarding this Federal Order, please contact Lydia E. Colón at (301) 734-7839 or by email at Lydia.e.colon@aphis.usda.gov

Rebecca A. Bech

Deputy Administrator
Plant Protection and Quarantine

FEDERAL IMPORT QUARANTINE ORDER

Pseudomonas syringae **pv.** *actinidiae* **causal organism of
bacterial canker of kiwifruit**

November 10, 2010

The purpose of this Federal Order is to prevent the introduction into the United States of the harmful plant pest *Pseudomonas syringae* pv. *actinidiae,* causal agent of bacterial canker of kiwifruit.

This Federal Order is issued pursuant to the regulatory authority provided by the Plant Protection Act of June 20, 2000, as amended, Section 412(a), 7 U.S.C. 7712(a), which authorizes the Secretary of Agriculture to prohibit or restrict the importation, entry, exportation or movement in interstate commerce of any plant, plant product, biological control organism, noxious weed, article or means of conveyance, if the Secretary determines that the prohibition or restriction is necessary to prevent the introduction into the United States or the dissemination of a plant pest or noxious weed within the United States.

Plants species of the genus *Actinidia* are susceptible to *P. syringae* pv. *actinidiae,* the causal agent of bacterial canker of kiwifruit. The pathogen is not known to occur in the United States and is not transmitted by fruit or seed. However, the pathogen may spread through international movement of plants for planting (including pollen) which may include symptomless plant material. Plant pathogens, including viruses and viroids, are difficult to detect during a port of entry inspection of the host plants, particularly in the absence of symptoms.

The kiwi plant industry represents one of the major sources of income from fresh fruits for several countries around the world. In North America, kiwi plants are widely grown in California and are major economic crops.

Recent scientific literature reports that *Pseudomonas syringae* pv. *actinidiae* is causing economic losses in Italy, Japan, and the Republic of Korea. Bacterial canker of kiwifruit has become one of the most limiting factors for cultivating kiwi in the Republic of Korea and Japan. In Italy, where the pathogen was recently introduced, estimated losses are reported to have reached 2 million Euros.

Bacterial canker of kiwifruit can spread rapidly between plants and adjacent orchards in winddriven rain and strong winds. Low temperatures between 50° – 68 °F are favorable to the disease, with optimum temperatures at 59 °± 37.4 °F. Symptoms appear on trunks, leaders and overwintering canes from late winter to early spring as cankers and cracks. Rusty-brown bacterial ooze may exude from lesions and from apparently healthy buds, leaf scars, lenticels and joints of trunks, leaders and canes. Brown water-soaked lesions with halos appear on leaves, and

wilt or blight of vigorous canes and flower buds appear in late spring. Kiwi leaves are most susceptible to the pathogen just before maturity.

To prevent the introduction of *Pseudomonas syringae* pv. *actinidiae*, APHIS has determined that is necessary to discontinue the importation of *Actinidia* spp. plants for planting (including pollen but excluding fruit and seed) from all countries, until a pest risk analysis is completed and appropriate effective mitigation measures have been established. Due to the potential for spread of this plant pathogen, this Federal Import Quarantine Order is effective beginning November 10, 2010.

Plant genera prohibited pending pest risk assessment (PRA):

All plant parts including pollen with the exception of the fruit and seed from all species of the genera *Actinidia.*

Countries from which plants for planting are prohibited pending a PRA:

All countries.

APPENDIX III 'Market Analysis Results and Methodology '

METHODOLOGY

To gauge demand from our relevant consumer base, our Target Population consisted of the north and easternmost counties in NH:

County	Population
Carroll County	47,499
Coos County	31,997
Grafton County	89,629
Merrimack County	146,849
Hillsborough County	403,985
Rockingham County	299, 134
Strafford County	124,593

Total target population $= 1,143,686$[4]

Statistical Relevance To achieve a 95% confidence level with a 5 point confidence interval (margin of error) in our findings, the assessment required a minimum of 384 responses. The assessment received 1,999 completed surveys responses, thus for most questions we achieved a minimum 95% confidence level with a 5 point confidence interval, suggesting that we are 95% confident the responses can be extrapolated to the broader audience with a +/- 5 point margin of error. For example, if 62% of the survey respondents indicated they would be "very likely" to buy New England grown kiwiberries, we can extrapolate that 57-67% of the total 1.1 million target population would be very likely to buy New England grown kiwiberries.

Techniques One to two students and faculty related to the project were deployed over the month of September 2016 to twenty two area farmers markets. Consumers were offered a free sample kiwiberry and a survey card to be completed. The variety Passion Poppers was used for the study and sourced from Kiwi Korners Farm Danville, PA. Consumers were presented with a representative 6oz packed clamshell container for reference.

The following is the list of farmers markets attended:

Bedford, Hillsborough County
Berlin, Coos County
Colebrook, Coos County
Concord, Merrimack County
Dover, Strafford County
Durham, Strafford County
Exeter, Rockingham County
Hanover, Grafton County

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[4] https://www.google.com/search?q=merrimack+county+nh+population&ie=utf-8&oe=utf-8#q=strafford+county+nh+population. Data current as of 2013.

Lebanon, Grafton County
Lisbon, Grafton County
Littleton, Grafton County
Manchester, Hillsborough County
Merrimack, Hillsborough County
Nashua, Hillsborough County
Newport, Sullivan County
Plymouth, Grafton County
Portsmouth, Rockingham County
Salem, Rockingham County
Sandwich, Carroll County
Tamworth, Carroll County
Wakefield, Carroll County
Wolfeboro, Carroll County

Completion of the survey was voluntary. In an effort to encourage response from a wide cross-section of the consumer population the survey was advertised via press releases in local and regional newspapers and media outlets (tv and radio), and via social media.

Market Analysis All analysis was done to a 95% confidence level. Each table indicates the margin of error for each particular question. Most all margins of error are less than +/- 5 points.

Interest in the Kiwiberry Consumers in New Hampshire are highly in favor of locally grown kiwiberry. Sixty two percent (62%) would be "very likely" to purchase New England grown kiwiberry. Not a single respondent indicated they would be "highly unlikely."
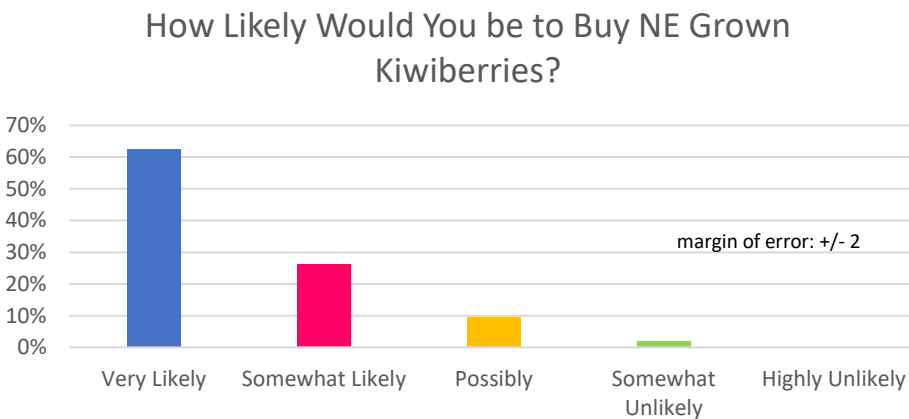
Figure 27 Consumer responses indicating likeliness to purchase kiwiberries grown in New England (NE).

Certified Organic Preference Consumers also by and large indicated New England grown kiwiberries need not be certified organic. Seventy percent (70%) would be willing to purchase conventional locally grown kiwiberries.

Would you buy only if Certified Organic?
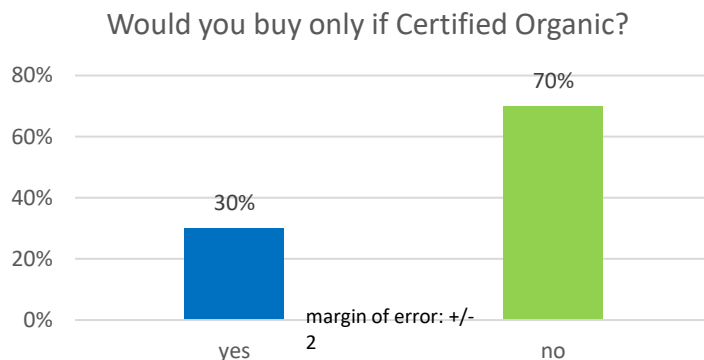
Figure 28 Consumer preferences on purchasing organically versus conventionally producer kiwiberries.

Price Sensitivity Consumers overwhelmingly associated a $3-5 value per 6 oz clamshell for New England grown kiwiberries whether certified organic or conventional. More than three quarters of consumers would pay $3-$5/ 6oz clamshell whether certified organic or conventional, which equates to a retail value of $8-13 per pound. Less than 15% of the population felt kiwiberries were worth less than $3/6oz clamshell and as much as 19% were willing to spend up to $8/6 oz clamshell. The highest price consumers were willing to pay, represented by less than half a percent of the population, was $9.47/6oz clamshell.

Mean Price Per 6 oz
Conventional	$3.99
Certified Organic	$4.21
Certified Organic Premium	$0.22

Consumer pricing preference for a 6oz clamshell.
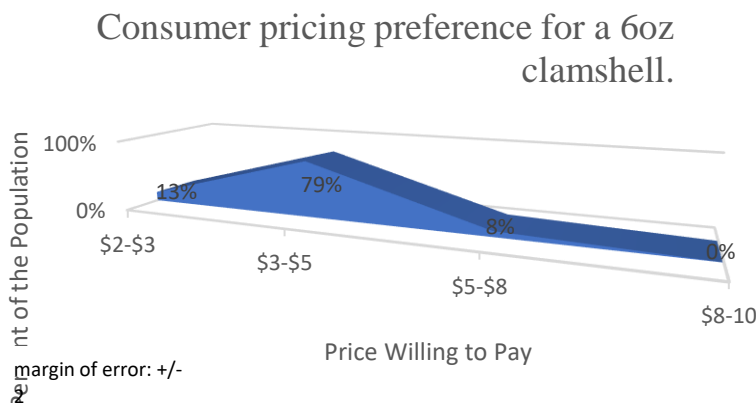
Figure 29 The reported responses of consumer willingness to pay for a 6oz clamshell of kiwiberries collected during the market survey.

Kiwiberry Feedback Card

1. How likely would you be to buy locally-grown kiwiberries? *(circle one)*

| Highly UNLIKELY | Somewhat UNLIKELY | Possibly | Somewhat LIKELY | Very LIKELY |

If you would only buy organic berries, please check this box: ☐

2. What would you consider to be a reasonable price for a 6 oz. container of kiwiberries like the one you see here today? *(circle one)*

Less than $3 $3-4 $4-5 $5-6 $6-7   More than $7

If this price assumes organic berries, please check this box: ☐

3. Have you bought any local, seasonal fruits or vegetables in 2016?

YES   NO

MORE ON BACK! ➡️

What did you <u>like</u> about the kiwiberry?
(circle as many as apply)

Sweetness	Tartness
Overall flavor	Texture
Juiciness	Novelty
Small size	Appearance
Health Benefits	

Other: _____

What did you <u>not like</u>?
(circle as many as apply)

Too sweet	Too tart
Strange flavor	Strange texture
Too juicy	Too unfamiliar
Too small	Appearance
Tough skin	

Other: _____

Anything else you'd like to tell us:

🛡️ **THANK YOU FOR YOUR FEEDBACK!** 🛡️

Figure 30 The kiwiberry response card presented to consumers during the market survey.

THE COMMONWEALTH OF MASSACHUSETTS

EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS

To: Interested Parties
From: The Massachusetts Department of Agricultural Resources, Crop and Pest Services Division
Regarding: The request to add the following plants onto the Massachusetts Prohibited Plant List:
Actinidia arguta (Hardy kiwi)
Date: August 28, 2017

On January 10, 2017, the Department held a public hearing regarding the addition of the above-listed plants to the Massachusetts Prohibited Plant List ("List"). The Department also received written comments prior and up to 5:00 pm on January 10, 2017. The vast majority of the comments received were regarding the addition of *Actinidia arguta* (Hardy kiwi), both in support and opposition to its addition to the List.

As a result of the number of comments in opposition of the addition to Hardy kiwi to the List, the Department took additional time to investigate this matter further before making a final determination.

Decision

At this time, the Department will not be adding *Actinidia arguta* to the Massachusetts Prohibited Plant list. MDAR reviewed the data along with the public comments, and feel that the distribution of hardy kiwi is primarily made up of numerous escaped plantings that are not showing signs of spreading from their original locations. Until we better understand why the large infestation in Western MA has begun to grow so aggressively we do not feel that hardy kiwi should be banned from sale at this time. This was a difficult decision that also took other factors into consideration such as the impact on current resources to ensure proper regulation, the varied scientific opinions and the number of sites impacted. The Department will still accept additional information that may lead to the Department reconsidering its decision. If the Department decides to change its determination then another public hearing will be announced and held.

The Department recognizes the importance of the control and prevention of invasive species and the associated impacts that a prohibition of a plant may have; it values the ongoing work and information provided by the Massachusetts Invasive Plant Advisory Group (MIPAG).

Another option for *Actinidia* enthusiasts to try their hand at growing is *A. kolomikta*. This cold-hardy kiwi species is often referred to as 'Super Hardy Kiwi' or the 'Arctic Kiwi'. *A. kolomikta* is capable of withstanding temperatures, when dormant, down to -40F. Vines will generally break dormancy and begin flowering about a week before kiwiberry vines. Vine spacing should be reduced to 5-10' per vine as they are less vigorous. All training and production best practice for kiwiberry may be applied to *kolomikta*. These plants have a higher shade requirement that kiwiberry vines. If growing on any site which is exposed to full sun a shade cloth is required to prevent sunburn. Shade provided should be approximately 50%. Shaded *A. kolomikta* vines will be much more vigorous in their growth habit, have an improved overall vine structure, and not be impacted by sunburn related physiological stress. Growers should not attempt to produce *kolomikta* on a commercial scale as the fruit has poor pedicle adherence. This means that fruits will drop once they are matured on the vine. While impractical for commercial harvest, homeowners have had success with shaking vines over drop clothes or an upturned umbrella. The green, pink, and white variegated foliage makes *A. kolomikta* an appealing option for incorporation into edible landscape design.

Image 25 The leaves of *A. kolomikta* pre-flowering (*left*). Following flowering the white splashes on the leaves flush hot pink (*right*). Note the shade cloth above, protecting the vines from full sun exposure.

APPENDIX VI 'Topics Requiring Further Research'

Given the relatively new status of kiwiberry as a commercial crop, there are still many unanswered questions. While research projects are being planned, growers are able to assist by making observations and gaining insight into the following questions:

- Marketing and Brand Development
- Important Traits and Current Commercial Cult.
  - What are the northern and southern most production ranges possible for kiwiberry? How do microclimates impact these production zones?
- Vineyard Establishment
  - How does planting density impact vine maturation and production?
  - What is the optimal level of irrigation for different age classes of vines? How should these levels be modified based on differencing soil characteristics?
- Planting
  - Do water holding gels have any benefit when establishing young vines in the field?
  - Do vines propagated from clones vs. seed vs micropropagation reach maturity faster?
- Fertilization
  - What are the optimal fertilizer levels for every age class of kiwiberry?
  - What is the role of specific nutrients in plant development? How do these nutrients impact growth in specific parts of the vine?
  - When is the optimal time for the application of fertilizer?
  - What are the best fertilization practices for organically certified production?
- Pruning
  - What is the optimal amount of pruning during the summer production season?
  - Where are the best locations on laterals to make cuts? What is the best number of buds to leave on pruned wood?
  - What is the productivity of previously fruiting wood compared with newly fruiting wood?
  - How does timing of winter pruning impact fruitfulness the following season?
- Cultivation
  - What is the impact of cultivating at different depths or with different styles on root structure and development.
  - Will deep tillage have a positive impact on reducing over grown rootzones/compaction.
- Pathogens/Pests
  - What is the full list of pests which impact kiwiberry in New England. What is the timing of their emergence and targeting of vines?
  - What causes cracking and russeting on fruits? If biotic – what is the infection window?
  - What chemical control materials are appropriate for kiwiberry? What are the best steps to have new materials listed for approval on kiwiberry?
  - How is best spray coverage achieved throughout the kiwiberry canopy?

- Other Concerns
    - What benefits are gained by having a windbreak around a kiwiberry vineyard?
    - What is the impact of dormancy regulation practices on vines?
    - Are there preferred pollinator species for kiwiberry in NE? Is supplemental pollination required?
    - What are the feeding preferences of large mammals on kiwiberry in NE?
- Harvest
    - Does any ripening pattern occur within a vine? Within an orchard?
    - Do weather events have an impact on fruit quality in post-harvest storage?
    - What are the best options for kiwiberry pack lines and sorting for small scale producers?
- Storage
    - Are edible coatings practical? Does any consumer aversion to these products exist?
    - What is the full possible range of storage for different kiwiberry cultivars under true controlled atmospheric storage conditions?
- Invasive Concerns
    - Why do pockets tend to misbehave, are these all linked to historical occurrences?
    - What is the full extent of naturalized pockets? Please report any suspected populations to halelab.unh.edu

'Effects of harvest time and cold-storage on the quality of berries of *Actinidia arguta* cv. 'Michigan State''
                    Work Presented at the ISHS IX International Kiwifruit Symposium, Porto, Portugal

Materials and Methods
        A. arguta cv. 'Michigan State (SFV)' (USDA National Plant Germplasm System accession PI617136) was chosen for this study based on its reliable productivity observed at the NHAES, its relatively large (5.7 g) and uniform berry size, its red blushing skin, its acceptable eating quality, and the sufficient numbers of mature vines at the NHAES to provide the quantity of berries required for adequate replication. Harvest began when seeds were black and a sampling of berries spatially distributed throughout the canopy yielded an average °Brix ≥ 8.0.

        During the 2016 growing season, this threshold mean °Brix was achieved on 9/19/16, a date designated as "Day 0" in this study; and random samples of 800 berries each were harvested on Days 0, 5, 10, and 15. On each harvest day, the harvested berries were randomly distributed into 80 6 oz. plastic, ventilated clamshells, which were randomly assigned to a factorial combination of cold storage periods (0, 2, 4, and 6 weeks) and subsequent ripening periods at room temperature (0, 3, 6, 9, and 12 days). In all, there were 4 independent replications (i.e. clamshells) of each unique combination of harvest time, cold storage duration, and RT ripening period.

        Berry selection When packing the clamshells (10 berries in each), berries which had prematurely softened or were torn at the petiole were discarded, as were those that were misshapen due to poor pollination or were otherwise injured. Berries were not, however, sorted or distributed based on size (see Figure *31*).
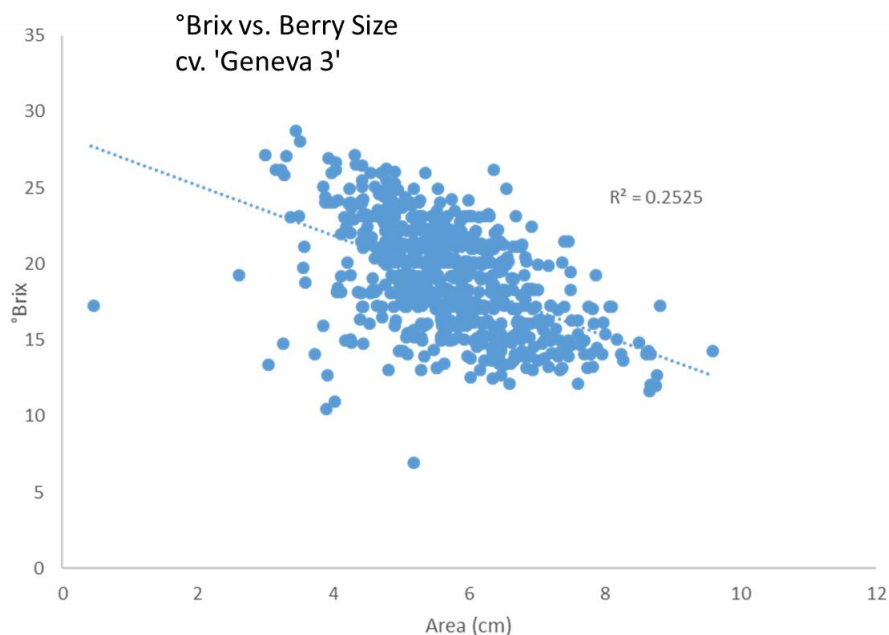
Figure 31 Intensive sampling of berries from 5 diverse cultivars of *A. arguta* (cvs. 'Chang Bai Mountain 1', 'Jumbo', 'Ogden Point', 'Ananasnaya', and 'Geneva 3') revealed no strong correlation could be detected between berry size and °Brix. Data from cv. 'Geneva 3' presented.

       Cold storage After packing, clamshells were either moved directly into ripening at room temperature (20°C; RT) or, if designated for a period of cold temperature (2, 4, or 6 weeks), were placed immediately in a chromatography refrigerator (VWR) set at 4°C. Temperature was monitored throughout the study and did not fall below 3°C or exceed 5°C. Relative humidity was not monitored or controlled.

       Ripening and measurement During the 2015 growing season, we conducted a pilot study in which berry ripening was tracked for 18 days after removal from various durations of cold storage (2, 4, and 6 weeks). Based on the results of that preliminary study (°Brix measurements and informal taste and eating quality observations), it was decided to reduce the post-cold-storage sampling in the current study to a period of 12 days. On the designated day for quality evaluation, four fruits were pulled randomly from the ten in a given clamshell and cut in half via lateral cross-section. °Brix was measured from each of the halves using a handheld refractometer and averaged, with readings exceeding the refractometer's limit (32 °Brix) noted as 32.5 °Brix. Photographs were taken for subsequent dimensional analysis (ImageJ software; see *Figure 32*) and visual quality assessment.
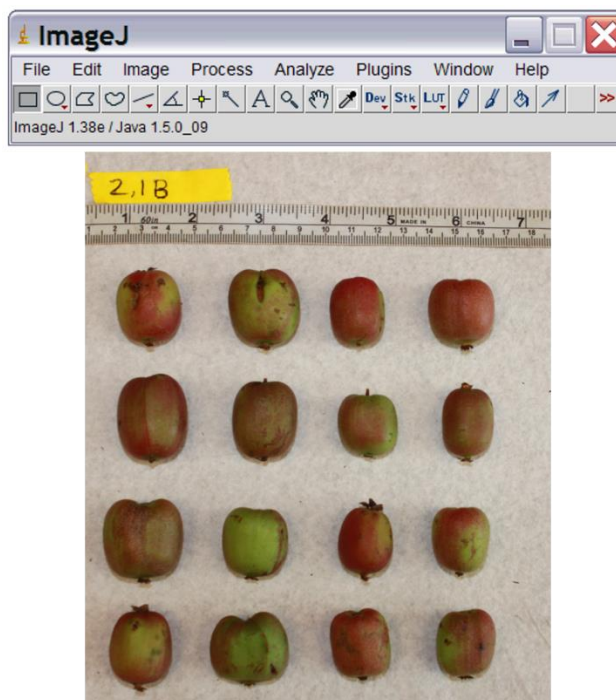
 Figure 32 Berry images were recorded for later visual analysis of post-harvest quality analysis. Dimensional analysis was done with the open-source software ImageJ.

Results

       As shown in *Figure 33*, the peak °Brix achieved by berries harvested on Day 0 (31.9 °Brix) was commensurate with the highest levels achieved by berries left to ripen on vine for an additional 15 days. Indeed, the results consistently indicate that no significant improvement in peak °Brix is realized by leaving berries to continue to ripen on-vine once they reach physiological maturity. There was, however, a difference in peak °Brix accumulation in berries held in cold storage for at least 2 weeks prior to ripening versus those that were directly ripened. Berries held in cold storage were characterized by

higher °Brix levels, with the effect more pronounced for earlier harvest times (Days 0 and 5). It is clear from the data, however, that the storage temperature was not low enough to hold the berries in metabolic stasis. Indeed, over the period of 6 weeks in cold storage, the mean sugar levels of Day 0 berries rose from 8.0 to 22 .0 °Brix, while those of Day 15 berries rose from 8.7 to 22.6 °Brix. In general, 2 weeks of cold storage in this study appears to have been roughly equivalent, in terms of ripening, to 6-9 days at RT. Because of this ongoing ripening under cold storage, it is difficult to interpret the differential rates of ripening of berries stored for varying lengths of time.

Although ripening rates are difficult to interpret from these data, it is clear that berries from all harvests reached the minimum 20 °Brix (red dashed lines, Fig. 5) necessary, in our subjective experience, for acceptable eating quality. As shown in *Figure 34*, our findings also indicate that berries can be held in storage, even at our insufficiently cold temperatures, for up to 6 weeks while remaining marketable. In this assessment of marketability or "eating quality", we considered not only °Brix but also overall taste, mouthfeel, and appearance (mainly extent of wrinkling due to desiccation). Overall, berries held for longer periods of time in cold storage appear, when ripened, to be of acceptable eating quality for shorter windows of time. For example, Day 5 berries held for 2 weeks in cold storage exhibit acceptable quality for 9 days (Days 3-12) while those held for 4 and 6 weeks do so for only 6 days (Days 3-9).

Effect of Harvest Date and Storage on the Ripening of Kiwiberries
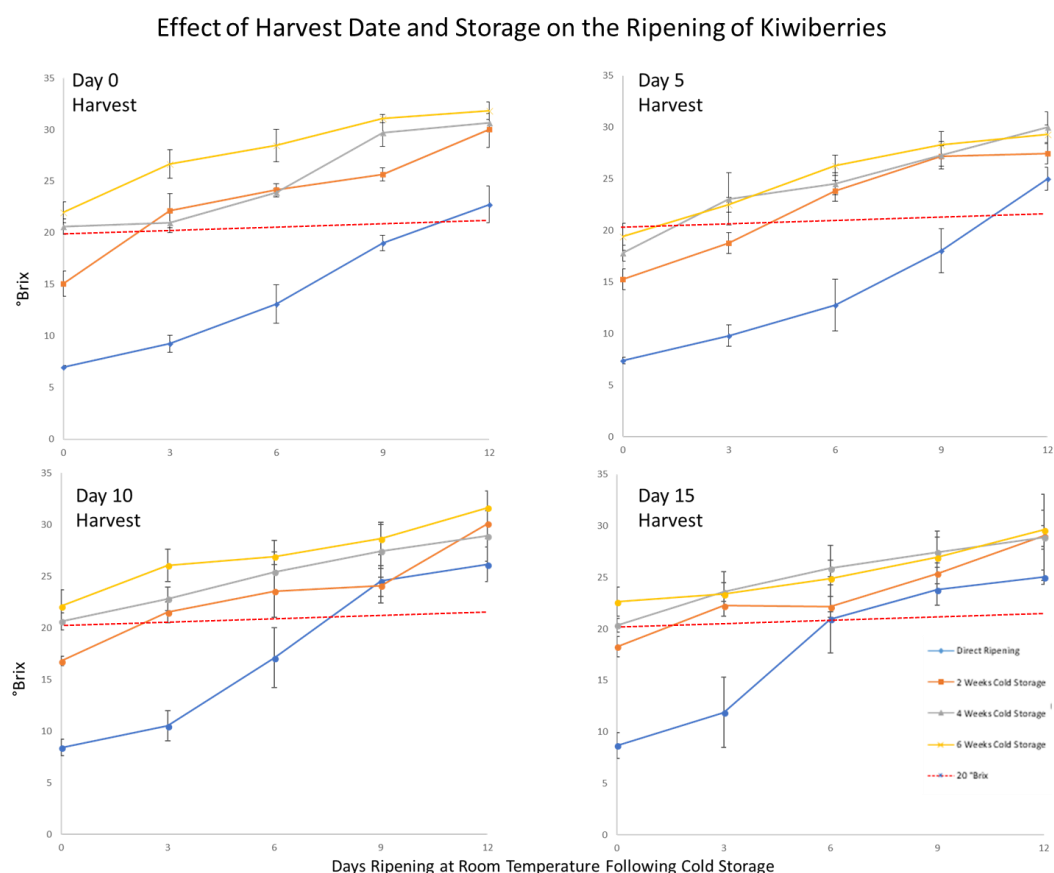
Figure 33 Plots summarizing the effects of harvest date (Days 0, 5, 10, and 15), time in cold storage (0, 2, 4, and 6 weeks), and time at room temperature after cold storage (0, 3, 6, 9, and 12 days) on °Brix level. Harvest Day 0 was September 19, 2016, the day when the mean on-vine °Brix level reached 8.0. A threshold of 20 °Brix, subjectively deemed a minimum for acceptable eating quality, is indicated by red dashed line. The axes on all four plots are uniform.

Harvest 09/24/2016
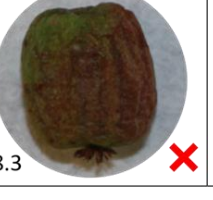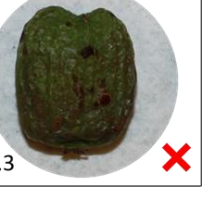
Figure 34 Representative images of Day 5 harvest berries from all four cold storage (CS) durations and five room temperature ripening periods. Mean °Brix values are shown in the lower left corner of each CS-ripening combination. The green check in the bottom right corner indicates that the berries in that treatment are of acceptable "eating quality", a composite assessment of °Brix level, flavor, mouthfeel, and appearance (mainly desiccation/wrinkling). A red X indicates unacceptable quality, due to one or more of the traits mentioned.

APPENDIX VIII 'Timeline of Seasonal Kiwiberry Vineyard Tasks'

Jan.
- Equipment Sanitation and Repair.
- Vineyard winter pruning continues.

Feb.
- Vineyard winter pruning continues.

Mar.
- Vineyard winter pruning ends (~early March at latest).
- Begin fertilizer applications in vinyard (age class dependent).
- Prepare irrigation system for seasonal use.

April
- Fertilizer applications continue.
- Begin scouting for vegetative budbread (~early April).

May
- Fertilizer applications continue.
- Weed managment begins.
- Beginning of vine pruning and training begins (~mid-May)..
- Planting of new vineyard stock (~late May).

June
- Fertilizer applications continue.
- Summer pruning and trainign continues.

July
- Fertilizer applications continue.
- Summer pruning continues.

Aug.
- Summer pruning continues.

Sept.
- Summer pruning ends.
- Begin scouting for harvest (early September in NH).
- Harvest, sorting, and storage of crop.
- Begin fruit sales.

Oct.
- Fruit sales continue.
- Managment of crop in storage.
- Vineyard cleanup and preparation for winter.

Nov.
- Sale of fruit in cold-storage (~mid-November).

Dec.
- Begin pruning vineyard (~Mid-December at earliest).

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