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"If I need to put more armor on, I can't carry more guns": the collective action problem of breeding for productivity in the California strawberry industry

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JULIE GUTHMAN & ERICA ZURAWSKI

Abstract.

Facing the appearance of novel soil-borne plant diseases as well as increasing restrictions on the chemical fumigants that have long been used to treat them, developing disease resistant cultivars is one strategy among several that the California strawberry industry is supporting. Yet, under the assumption that growers most desire high yielding varieties, university strawberry breeders continue to emphasize productivity, despite knowing the difficulty of breeding for multiple diseases, much less for the array of qualities that consumers, intermediaries, and growers differentially want.. They make this assumption even as industry per acre productivity reached an all-time high in 2018 while prices continued to slip, a dynamic predicted by Willard Cochrane's famous technology treadmill. This paper explores if and why growers want yield over disease resistant varieties, to assess if there are ways to slow or stop the treadmill. Based on twenty in-depth interviews with strawberry growers, we found that growers want yield to remain individually competitive, even as they largely recognize that prioritizing yield over other qualities can be self-defeating for the industry. We additionally found that this desire is being augmented by buyer-grower contractual relationships, conditions of land access and rising land values, and practices of labor remuneration. Given that those structural forces are not easily addressed, we also consider the role that university scientists play in constructing this desire for yield. On this question we draw on work in science and technology studies as it relates to university agricultural science to suggest that farmers' needs and desires are a reflection of what university research and extension can offer and conclude that university breeders are best positioned to level the playing field by ceasing to breed for productivity.

Julie Guthman
Division of Social Sciences, Community Studies Program
Community Studies mailstop
1156 High St.
University of California, Santa Cruz
Santa Cruz, CA 95064

Erica Zurawski
Department of Sociology
1156 High St.
University of California, Santa Cruz
Santa Cruz, CA 95064

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"IF I NEED TO PUT MORE ARMOR ON, I CAN'T CARRY MORE GUNS": THE COLLECTIVE ACTION PROBLEM OF BREEDING FOR PRODUCTIVITY IN THE CALIFORNIA STRAWBERRY INDUSTRY

In summer of 2018 first author Guthman attended a field day held at a strawberry field in Castroville, California. Castroville is situated in one of California's prime strawberry-growing regions - in a state that grows nearly 90% of US strawberries. The event showcased the new cultivars being developed by the University of California's (UC) breeding team, cultivars that have since been released for commercial use. Many industry bigwigs were there to witness UC's renewed commitment to plant breeding on behalf of the strawberry industry after somewhat of a hiatus.[1] In discussing the new varieties and comparing them to previously released varieties, team members certainly mentioned qualities of disease resistance, a renewed emphasis of breeding. But they primarily focused on productivity, providing data that showed how well these new varieties would perform relative to existing ones. Mingling among attendees, I overheard several question why UC was continuing to breed for productivity when the year had seen such huge gluts and concomitant low prices. Others averred that yield remained important to growers and suggested that the breeding team was appropriately responding to growers' needs. Months later, when I was interviewing growers about cultivar choice, I learned that indeed most growers prioritize yield, even though this priority is almost always entangled with other qualities of concern such as size, flavor and shippability, and, in some instances, disease resistance.

Writing in 1958, agricultural economist Willard Cochrane first brought attention to a phenomenon he characterized as a technology treadmill. He noted the tendency of farmers to adopt technologies that bring higher yield because early adopters initially make greater-than-normal profits, while those who do not adopt go out of business. However, as he also noted, such yields eventually negatively affect crop prices because other farmers join in and price competition ensues – a dynamic that may benefit consumers but decidedly not farmers. In the case of the contemporary strawberry industry, this long-acknowledged problem has taken on new urgency. This is an industry challenged in multiple spheres, not least of which is the appearance of novel soil-borne diseases, coupled with the increasing restriction of the chemical fumigants that have historically been used to treat them (Guthman 2019, Koike et al. 2013, Tourte et al. 2016). There is even a possibility that pre-plant fumigation could be phased out altogether, making breeding for disease resistance an important direction among a suite of proposed alternatives to soil fumigation (Department of Pesticide Regulation 2013). It is in this context that in 2017, with strong stakeholder support, the USDA funded a major collaborative project, the objectives of which were to identify natural sources of resistance to pathogens affecting strawberries in particular and to accelerate the development of commercial cultivars resistant to a broad spectrum of soil-borne and above-ground pathogens.

The research reported herein is a subset of that project, designed to support development of a long-term strategy for disease management and cultivar adoption in strawberries by better understanding how growers' cultivar choices are shaped. Based on in-depth interviews, in this paper we explore why growers continue to want high-yielding cultivars, despite the dual threats of soil disease and increased regulation on fumigants. In a nutshell, growers want to stay competitive – and do not yet feel completely pressured by these threats. Nevertheless, in the current predicament of the strawberry industry, prioritizing yield is a highly questionable and possibly irrational path, especially since it is very difficult to breed for multiple diseases, much less for the

[1] The hiatus was related to protracted legal battles following the departure of the previous breeding team.

array of qualities that consumers, shippers, retailers, and growers differentially want. Therefore, it is important to dig into growers' desires for highly productive plants to assess if there are ways to slow or stop the treadmill. Here we build on scholarship in the sociology of agriculture to show that the desire for yield reflects a collective action problem, which is being augmented by buyer-grower contractual relationships, conditions of land access and rising land values, and practices of labor remuneration not heretofore theorized as playing into the treadmill. Given that those shaping forces are not easily addressed, it is also important to dig into the role that university scientists play in constructing this desire for yield. On this question we draw on work in science and technology studies as it relates to university agricultural science to suggest that farmers' needs and desires are a reflection of what university research and extension can offer. So if, indeed, the strawberry industry is serious about meeting the dual challenges of novel pathogens and a more restrictive regulatory environment for soil fumigation, those super-industry actors might be better positioned than growers to address the collective action problem of the productivity treadmill.

THE TECHNOLOGY TREADMILL REVISITED

Agricultural social scientists (and many agricultural practitioners) have long recognized the phenomenon of the technology treadmill (Archer et al. 2008, Gillespie and Buttel 1989, Lehmann and Pengue 2000, Ramey 2010, Röling 2009, Stone and Flachs 2018). It is however most attributed to the work of agriculture economist Willard Cochrane, who first discussed it in 1958 and then expanded on it in *The Development of American Agriculture*. As he explained in the second edition (1993), "early-bird" farmers who adopt a new and improved technology see a reduction in per unit costs (427). At first, the increased output of a few farmers has a negligible effect on prices, but as more farmers adopt the technology, the supply on the market increases, causing prices to fall. With widespread adoption, prices eventually fall to the point that all gains are eliminated. And "laggard" farmers, those who do not adopt, experience losses, as their expenses end up surpassing existing prices. At this point, the only group to benefit are consumers who see lower prices (428). But then, as laggard farmers go out of business, the more aggressive farmers are able to snatch up their productive assets, increasing the latter's wealth or market share (428). Consolidation can then have an opposite effect on consumer prices: fewer sellers in the market allows them to be price setters. It is worth noting here that with plant breeding the treadmill works somewhat differently. A higher-yield cultivar does not so much reduce per unit costs as increase the number of sellable units with the same fixed costs (Dexter 1977). At the same time, increasing the amount of harvestable units may raise the variable costs of something like harvest labor.

The technology treadmill identified by Cochrane is in effect a collective action problem. As first described by the economist Mancur Olson in his widely cited *Logic of Collective Action* (1965), a collective action problem exists when it is in the group's long term interest to act collectively, but those interests are undermined by individual actors who can benefit by acting on their own. Olson specifically noted the behavior of competitive firms. A collective of firms can withhold output to shore up higher prices, but each individual firm has an individual interest in selling as much as they can by increasing their own output, but in effect lowering prices for all. Those writing on the technology treadmill in agriculture have suggested that this dynamic is all

the worse for farmers with their abiding adherence to ideologies of individualism and self-sufficiency (Levins 2001, Ramey 2010). But it is not only farmers who contribute to the treadmill.

In 1996, Cochrane revisited the theory with Levins and amended it to include land dynamics (Levins and Cochrane 1996). Noting that government price supports have kept farmers in business even when technologies have been widely adopted, they argued that price supports have given rise to what they call the "land market treadmill" (550). In this dynamic, government price supports incentivize farmers to obtain more land, resulting in rising land prices. Here it is high land prices rather than low sales prices which diminish profits and threaten least productive farmers. It must now be said that specialty crops like strawberries are rarely supported with government subsidy programs. Yet, as Guthman (2004) has argued, specialty crop farming contributes to what is effectively a land market treadmill in another way. High value crops raise the expectations of how much revenue can be obtained from a piece of land, which is then imputed into land values. Increasing the productivity of those high value crops with breeding would then augment this effect.

An additional land dynamic raised by the 1996 piece by Cochrane and Levins is about the difference between farmers who own land and farmers who rent. Land owners may find they can make more money renting their land and chose to leave farming to let others run on the treadmill (550-551). As it happens, this is also a dynamic that has been salient in California where "farming farmers" has become quite lucrative (FitzSimmons 1986). Farmers who continue to farm not only lease their land but, in the words of Cochrane and Levins, are "continually thwarted" by rising land values here taking the form of higher rents (551).

Scholars have also speculated on the role that agribusiness plays in driving the productivity treadmill. While most agree that because of the intense competition they face it is farmers who set it into motion, agribusiness certainly benefits from it (Levins 2001, Ramey 2010, Röling 2009). Although the sectors of agribusiness that sell farmers technologies clearly stand to gain (Goodman et al. 1987), here the suggestion is that the sectors of agribusiness that buy from farmers benefit as well. Certainly those buyers involved in value-added processing benefit from having cheap inputs, and they may encourage competition among farmers (Ramey 2010, Winders 2009). The value that agribusiness extracts from farmers is commonly recognized as a squeeze (Mooney 1983).

Yet farmers do not adopt technology from nowhere – someone has to develop and provide it to them – and not all technologies come from private sector organizations. To be sure, agricultural scientists affiliated with the U.S. land grant universities have long been in the business of creating and disseminating applicable technologies. With farmers as the primary clientele of research and extension, the agenda for agricultural science has nominally been set with farmers' interests in mind, and scientific findings have been translated in ways that are applicable to farmers (Buttel 2001, Henke 2008).

At the same time, land grant agricultural scientists in some sense have to produce expectations that what they can provide is needed (Borup et al. 2006). As explained by historian of agricultural science Christopher Henke (2008), land grant university research and extension has been much better at producing and disseminating technologies that increase yields – here he includes crop protection – than dealing with the inevitable gluts from such productivity. As such, "these combined forces - economics and technology - form a powerful discourse about the inevitability of one kind of agricultural future and not others" (172). What he is suggesting is that

the advice of university extension is performative, less about responding to what farmers want than creating desire for what it can provide – which is primarily yield. That said, not all farmers take on those desires. Some studies have suggested that farmers are skeptical of technological innovation coming from the land grant universities precisely because of the impact on prices resulting from the treadmill (Buttel and Busch 1988, Gillespie and Buttel 1989).

A focus on the yield that farmers are guided to want has additional drawbacks besides the contribution to declining prices. University science has tended to develop simple, easy to take-up solutions, whether chemical pest control or high yielding varieties. Historian of science Frank Uekötter's (2014) work on the fate of biological approaches to soil fertility in postwar Germany is illustrative of the problem with such easy solutions. As he argues, integrated approaches produce uncertain results, and scientists investigating these approaches face stiff competition from agrichemical industries and their advisors (130). As for farmers, they embrace the easy fix of agro-chemistry, absolving scientists of further investigation into the multiple and interacting causes of various production problems. The issue here is one of path dependence – once "yield" becomes the thing of value, it can lead to knowledge erosion on the part of both agricultural advisors and farmers regarding other potential solutions, many of which address the complexity needed for something like soil disease (Sassenrath et al. 2008, Stone and Flachs 2018). And this is precisely the situation with the California strawberry industry: a focus on productivity comes at new costs besides market fluctuations and a secular decline in prices. Sustaining an interest in yield in some sense is relieving farmers from dealing with the complexity of soil disease in ways that may be crucial for the future. Or, as Lloyd and Gordon (2016) seem to suggest in relation to the fate of the industry, were scientists and farmers to prioritize an integrated approach to soil disease, they might at least be able to sustain current yields. A brief history of how this situation came to be is in order.

PATHOGENS, BREEDING, AND FUMIGATION IN THE CALIFORNIA STRAWBERRY INDUSTRY

Until the 1930s, strawberry breeding was conducted by private plant breeders, in California and elsewhere. However, a set of scourges affecting California's nascent strawberry industry in the early part of the twentieth century eventually pushed the industry to call on UC to understand the nature of the diseases afflicting the industry and to do something about it. UC scientists were able to determine that the pathogen causing many strawberry plants to wilt and die was the soil-borne fungus *Verticillium dahliae*, and one of the first orders of business was to develop a plant breeding program that would develop varieties suitable for local conditions and that would be resistant to diseases (Wilhelm and Sagen 1974). The result of experiments launched in 1929 was the release of five new varietals in 1945, only one of which, the Sierra, showed particular resistance to *Verticillium* disease (Darrow 1966). Despite the original rationale for the plant-breeding program – to combat disease – growers opted for productivity in their cultivars, as opposed to disease resistance. Hence, it was the Lassen and Shasta varieties that were responsible for the tremendous expansion in acreage, yield, production, and farm value. By 1955, 95% percent of the California acreage was planted to with these new varieties, and the value of the California crop rose from about $2 million to over more than $30 million annually (Wilhelm and Sagen 1974, 227-228).

The years that immediately followed saw a reversal of fortune, however, and growers again began to experience crop loss (Baum 2005). This time the day was saved by the development of underground fumigation, also a product of UC agricultural science. A combination of the fire retardant methyl bromide and the tear gas chloropicrin turned out to be particularly efficacious in controlling soil-borne pathogens, as well as weeds and nematodes. By the end of the 1960s growers had widely adopted the practice. Industry-wide productivity increased sharply and consistently. Yields of three to five tons per acre of years prior increased to twenty to thirty tons per acre (Wilhelm et al. 1974). With chemical fumigants controlling diseases, breeders now could give even greater focus to other desired qualities – not only yield for growers, including cultivars that could bear for long periods, thereby increasing the length of seasons, but sturdiness for shippers, taste, shape and color for consumers, and, as it happens, size for workers.

Things changed again when methyl bromide became subject to the international Montreal Protocol on Ozone Depleting Substances in 1991. Following years of successful efforts by the US to delay the mandated phase-out by obtaining Critical Use Exemptions (Gareau 2008), the chemical was finally banned in 2016, except for in nursery uses. Meanwhile, another chemical fumigant, chloropicrin, was designated a toxic air contaminant, and 1,3D (Telone), was deemed a carcinogen, precipitating more stringent application protocols, taking the form of larger buffer zones and township caps, for example. A 2013 report issued by the California Department of Pesticide Regulation (2013) suggested that additional restrictions were not out of the question, especially given the increase in urban development near strawberry fields, both of which fare well within a few miles of the California coast and the natural air-conditioning of the Pacific Ocean. Concurrent with these increased restrictions, two "novel" soil pathogens, *Macrophomina phaseolina* and *Fusarium oxysporum sp. fragariae,* began regularly appearing in growers' fields, precipitating growing fears of significant die off (Koike et al. 2013, Tourte et al. 2016).

It is in this context that the industry began to double down in supporting research which would augment the efficacy of existing tools or otherwise develop alternative means of controlling these pathogens. As noted in that 2013 report, without a magic bullet disease management would be more complex, and strawberry growers would likely need to incorporate a combination of complementary methods and technologies. Among several areas of research emphasis, one identified was of particular importance: plant breeding for disease resistance, a breeding priority that was minimized when methyl bromide was available (Department of Pesticide Regulation 2013). The project of which this study is a part was a response to that public imperative. In July 2019, UC released five new cultivars (the ones introduced at that field day). An announcement of their release claimed that all five would be less susceptible to soil diseases, two could reduce labor costs by sprouting fewer runners, but two *would increase yield by up to 29 percent* (Nelson 2019).

In those same years between 2013 and 2019, the industry underwent significant restructuring, a product of both internally and externally generated forces. Many growers went out of business or reduced acreage. According to the U.S. Agricultural Census, the total number of California strawberry growers shrunk from 995 in 2012 to 676 in 2017. Subtracting farms (or patches, more accurately) of less than five acres, better reflecting the number of commercial growers, these numbers declined from 375 to 241 (United States Bureau of the Census 2012, United States Bureau of the Census 2017). Some shippers cut back their operations as well. Dole left the strawberry industry as did Eclipse/Success Valley, and WellPict allegedly dropped some

contract growers. Some of these growers, however, were apparently grabbed up by Driscoll's, and another large operation hired previously independent growers as staff (interview data). Those years also saw significant decline in acres, especially in the southern part of the state, with acres planted dropping from an all-time high of 40,816 in 2013 to 32,957 in 2019 (California Strawberry Commission 2013, California Strawberry Commission 2019a). This was only in part due to expansion of acres in Mexico. Here it is important to understand that Mexico production mainly takes place in winter, as it does in southern California, although the length of the growing season in Mexico has been expanding with the acquisition of higher elevation land, with cooler climates suitable for strawberry production. This acreage contraction was also an outcome of the hardships of the strawberry industry more generally, including tighter regulation, disease related to plant stress, and labor shortages. And yet, per acre productivity grew from 43,001 pounds to at an all-time high of 58,708 pounds by 2018 (the year of the field day observation), with typical strawberry growers harvesting 6,634 trays an acre, and total production exceeding 2,020,423,185 pounds even with the drop in acres (California Strawberry Commission 2019b). That represents a 37% increase in yield per acre over five years!

During this same period, expenses have been rising considerably, especially labor costs related to increases in minimum wages and the elimination of exemptions on overtime for agricultural workers. Importantly, strawberry production is one of the most labor intensive endeavors in California agriculture, with harvest labor representing no less than 60% of total costs (Tourte et al. 2016). Promises (or threats) of robotics notwithstanding, currently virtually all California strawberries are picked by hand. Meanwhile, prices, though always volatile, have slightly declined over this same period (California Strawberry Commission 2019b). As a result, many growers are barely breaking even and, again, many are exiting the business. In these conditions, increasing productivity may be the only thing keeping growers in business. The question is how far that can go.

COMPETING BREEDING IMPERATIVES

The findings of the study must be viewed in recognition of the challenges of breeding strawberries. At the most basic level, genetic material can be directed to only a limited number of functions, limiting the array of qualities for which strawberries can be bred. Moreover, unlike undifferentiated commodity crops upon which arguments about the technology treadmill are based, specialty crops are designed to appeal to different markets and have variable aesthetic and production qualities. That breeding is subject to competing imperatives has been borne out by a series of studies conducted by the RosBREED project, which focuses on developing new Rosaceous family cultivars: Consumers may most value flavor but they balance that with price and shelf life (Wang et al. 2017). Market intermediaries who both ship and sell berries want what is attractive to consumers, long shelf life, and especially value firmness (Gallardo et al. 2015). Producers rank flavor as most important, with the critical exception of those in California and Florida who happen to grow the vast majority of United States strawberries and do so for national and international markets rather than for local markets (Yue et al. 2014). In these regions production qualities such as yield and harvest ease may be more important. As for breeders, RosBREED researchers have found that they generally rate market-related factors highly, with

another critical exception: university and federal breeding programs are more closely tied to growers' organizations, conduct field trials with growers, and therefore are most attuned to grower preferences and their predilection for production qualities (Yue et al. 2012).

In addition, plant-breeding requires significant investments of time and funding (Yue et al. 2017). With strawberries, it takes a long time to identify an acceptable cultivar, and tens of thousands of seedlings are propagated and tested to find a few that might work. Once a useful cultivar is identified and registered, it takes three to four years to propagate enough plant material from clones of the varietal to make it available commercially. With luck, it is about ten years between discovery and use. Adding to this temporal problem, the lifespan of a plant patent begins at the time of discovery and registration and not when first planted commercially. This means most commercial varietals are under patent protection for only 12-15 years. Of course it is possible for growers to use non-patented varietals, and growers save a lot of money by doing so, but it may be less easy to get a nursery to propagate a varietal with little demand. Also, for some inexplicable reason, some of these cultivars lose their vigor, and growers lose their interest in them, a phenomenon also noted by Stone and Flachs (2018). To earn returns on their inventions, breeders, including UC breeders who share royalties with the university, have to get it right and breed varieties that growers will want to adopt.

Although the California industry has long enjoyed strawberries bred for yield and long seasons for producers, sturdiness and firmness for shippers, and size, shape, and to some degree flavor for consumers, emphasis in one area has most definitely come at the expense of another. Of currently favored varieties, for example, the Fronteras and Cabrillo are the highest yielding, producing in a recent trial an average cumulative marketable fruit weight of about 11,000 grams per plot. But they lack flavor. In contrast, the Albion has by far the best flavor, but yields are about 40% lower. They are thus primarily of interest to growers who market directly, or simply care about flavor. The Monterey is a fairly high yielder, in that same trial yielding about 9,500 grams per plot, but it balances other qualities to make quite popular among those growing in wholesale markets. None of the most popular cultivars show a great deal of resistance to soil disease, except the San Andreas which shows some tolerance to Fusarium outbreaks. It yields only slightly more than the Albion (Cole et al. 2018). Further complicating things, varieties that show tolerance to some diseases may have nearly inverse reactions to others. For example, in trials conducted at the Cal Poly Strawberry Center, the Sweet Ann, a proprietary variety bred to be resistant to *Verticillium* showed an average mortality of 6.6% in a field infested with the disease, but showed a 57.5% average mortality in a field infested with *Macrophomina* (Ivors et al. 2018a, Ivors et al. 2018b).

STUDYING CULTIVAR CHOICE

As qualitative social scientists we sought to understand the factors and institutions that guide growers' cultivar choice in the context of today's challenges. A survey conducted in 2018 showed that growers as a whole prioritized yield above all else, with marketability (e.g., size, shape, and to some degree flavor) and disease resistance being secondary priorities (Guthman in press). With a low response rate to the survey and a dearth of answers to open-ended questions, this piece of the study was developed to delve further into the question of why yield in the face of

what would seem to be other, competing imperatives. The research involved in-depth interviews with twenty growers, conducted in 2018-2019.

With contact information very hard to come by and a research population increasingly elusive to journalists and social science scholars, we sought out informants who had participated in a prior study conducted by the first author and who had explicitly welcomed additional follow-up. As such, this study was necessarily biased toward those willing to engage with researchers, and all who were reached agreed to participate. Still, the population of potential interviewees was reduced because, significantly, many growers interviewed in the previous project were not reachable and/or had gone out of business, and even three interviewed for this study had retired or all but exited strawberry production, corroborating evidence of the industry's restructuring. As with the previous study, we interviewed growers from all four of the major strawberry fruit-growing counties in California: Santa Cruz, Monterey, Santa Barbara and Ventura, and interviewees were a mix of white, Japanese, and Latinx growers, generally reflecting the research population. In deciding whom to contact for interviews, we did emphasize growers who primarily use university-developed varieties (n=15) and therefore presumably exercise more choice in what cultivars they grow, although not to the exclusion of those who only use proprietary cultivars (n = 5) by dint of their shippers.[2] Wanting to understand the influence of different buyers, we also focused almost exclusively on growers who sold to shippers. Only two interviewed growers engaged in direct sales. Most of the growers interviewed therefore had (or once had) significant commercial operations of at least 50 acres. As it happens, this small, somewhat stratified sample worked well and, indeed, we reached saturation before completing interviews, such that additional interviews neither produced more themes, nor differences across grower characteristics, nor deepened understanding (Crouch and McKenzie 2006, Hennink et al. 2016).

All but two interviews took place at growers' farms or offices; the others by phone. Interviews generally lasted 30 – 45 minutes. Since the goal for the interviews was to achieve depth rather than establish statistically significant patterns, these were open-ended interviews, guided by just a small set of pre-determined questions. We transcribed and coded interview data with NVivo qualitative research software, identifying both themes identified through the research questions, as well as some surprises that were revealed through open coding.

FINDINGS: WHAT GROWERS WANT

Nuancing evidence collected in the previous survey, sixteen out of twenty interviewed said yield or productivity was *an* important quality of a cultivar but much fewer were willing to say it was *the* most important quality. More significantly, many began the interview complaining about the current conditions of the industry, including pervasive over-supply. In what follows, we examine grower rationales for both wanting yield, as well as their skepticism that high yielding cultivars are best for the industry.

[2] Some shippers require that growers use proprietary varietals associated with the brand name, while other shippers generally allow growers to choose whatever varietal they want. They thus tend to use what are call university varieties. License fees for proprietary varietals tend to be much higher than those for university varieties.

Growers want yield

Many growers with whom we spoke were implicated in the competitive dynamic theorized as the productivity treadmill. They recognize that if they choose a lesser yielding variety they will lose out.

> We're in a competitive environment. We like to say we don't grow a commodity but there are commodity-like characteristics. So if you have a variety and neighbor selling into the same market, if he's more productive he will have an edge.

Likewise suggested by the literature cited, the treadmill effect is augmented by low market prices and increasing expenses.

> As an individual, you have to have the units because the fixed costs are so high and you grow every year. Everybody has to have a certain minimum amount to break even. And if you want to stay in business a long time you've got to have something to feed the program.

Some growers say that were market prices higher, they would be willing to forego yield for other qualities. Yet other growers say there is an imperative to keep prices low for consumers.

Growers also corroborate the roles played by land markets and agribusiness in contributing to the treadmill. Regarding land, growers complain of high land rents related to the scarcity of good strawberry land, and note that both factors incentivize productivity. As for the role of agribusiness, growers note that buyers are chipping away at their profits. Driscoll's well-known practices of charging an 18% commission in addition to fees for supplies and equipment, puts pressure on that treadmill, as do its much higher cull rates. Growers who work with Driscoll's note they receive higher prices but they also leave up to 30% of the berries they pick in the fields. Yet, growers who work with shippers that do not require them to grow proprietary varieties also feel the pressure of the productivity treadmill, as these (lower cost) shippers do not receive high market prices and thus cannot pay as well.

In addition to these widely understood dynamics, growers want yield for another reason, very specific to the strawberry industry, having to do with its labor intensity. Historically, California strawberry growers have enjoyed labor surpluses and paid harvest workers on piece rates (or a combination of piece rates and hourly wages) in order to ensure labor productivity and keep overall labor costs down (Wells 1996). With significant tightening of the US-Mexico border and better jobs elsewhere, the industry has seen increasing labor shortages, putting growers in the position of competing for workers (Guthman 2017). Growers claim that growing large berries, abundant on the vine and easy to pick, for longer growing seasons helps attract these piece rate workers who can pick more volume per hour than they could with sparse vines.

As put by one grower,

> If they can make 25 cents an hour somewhere else they leave. If you can hold up with a fairly decent variety they will stay with you 'til the end of the season. That's super important. So size is one thing, you know enough productivity to try to cover your costs is part of that factor.

Somewhat paradoxically, growers also speak of the need to improve yield because of increasing variable costs related to labor.

> Every single one of our costs is going up in the state of California with all the laws that are being passed, like on the labor with the 40 hour. I mean our costs are going through the roof. The only way we can bring some of the costs down is through yield.

We will return to this paradox below.

Growers want other qualities, too

In our discussion, we learned that many growers recognize the importance of other cultivar qualities besides productivity. For some growers flavor and beauty remain especially important. They recognize that growing strawberries that people do not want to eat can be bad for the industry. One grower who spoke at length about costs pressures went on to say:

> I would say quality is actually first [priority] . . . . It's gotta taste decent, right? Maybe it doesn't have to be THE sweetest but it has to be where people want to eat it. And eat it again.

One often discussed reason growers say quality cannot be neglected is that once mid-summer comes along, strawberries are competing with other fruits for supermarket space and consumer interest. They want consumers to remember that the last strawberry tasted better than the cherries, peaches, or grapes they might otherwise choose.

Industry concerns about flavor notwithstanding, the way that contracts with buyers are structured may mitigate against growers choosing more flavorful varieties. Companies such as Driscoll's and WellPict require growers to select from their own proprietary varieties. In the case of Driscoll's, the company's breeding apparatus has allegedly focused on disease resistance for some time, although more important has been a flavor profile and size that maintains the company's brand image. Independent growers who choose to contract with Driscoll's – Driscoll's does not produce berries – do so because they believe they will get a better price overall because of Driscoll's branding.

> So you can pick a berry for resistance because you know they have already provided you with choices they know will be sellable. This is what I am going to say about Driscoll's, and I know others feel this way too. There is no other company I will survive in, even if they take a lot of money and play by their rules, they have better marketing. There is more culling, more standards.

With a limited menu of choices and choices dictated by other company priorities growers then understandably choose productivity, although this often is presented as a berry that works best with their local conditions. Growers who work with lower cost shippers such as Giant or Naturipe, who tend to use university varieties, have a wider range of options but have other reasons to neglect flavor in their choices. As long as they meet basic grading standards, growers do not have the responsibility of marketing a berry that might be less tasty. When shippers set prices for berries in advance and do not stipulate which cultivar to grow, as most do not, it would be folly for a grower not to adopt the most productive varietal.

For a few growers we interviewed, however, yield comes at a great sacrifice to berry quality. A grower who lamented opting to move into a higher yield variety after years of selling what he saw as a much tastier variety said this:

> I wanted the good tasting berries coming out of my land and that's not what the ballgame is about. The ballgame is about production...That's exactly what is happening and that's why I stuck with the Albion because, I thought, I wanted a good tasting berry coming here, but when it comes down to it, a crate of berries is a crate of berries. . . . Because they look at their margins at what are they going to get per box, and it's all about money. And so get their berry at a cheap price, they would rather just take it and throw it on the market and make the margin. It's all about money; it's not about having a great product out there, it's not about having a real juicy, ripe tasting berry.

As for disease resistance, growers of course would not mind having it, but surprisingly few would prioritize it over other qualities. The salient exceptions are those who have lost large amounts of acreage to disease who already tend to opt for disease resistant varieties. After losing large percentages of production to disease over two years, one grower moved to the San Andreas, which he says, "has a bad reputation in quality, but it is very resistant." Small losses, however, do not necessarily change the calculus because growers have their eyes on what they see as marketable yield. A high yielding variety that loses some plants to disease may still be more profitable than a lower yield disease resistant variety. Disease resistance becomes just part of the mix:

> I: What's a good cultivar?
>
> G: It's something that I can produce, whether it tastes good or it's disease resistant or it's a high yielding variety, or it ships good. It's all of that goes into being able to be profitable so, sometimes I'm willing to give up one thing for the other so long as I can be profitable.

A critical reason that disease resistance has thus far taken lower priority is that growers have found other ways to deal with disease. Most find that existing allowable fumigants are effective enough at managing soil disease and will continue to use them unless they are completely restricted. Those experimenting with organics, many because of market conditions, are having moderate success with alternative methods of disease control, such as anaerobic soil disinfestation, and thus far see price premiums that allow them to make up for losses or additional costs. Growers game their use of land, as well, a strategy that works particularly well for lessors. They take up leases on land that has been in pasture and shows no sign of disease. They let go of the leases on

diseased land. But since they do this in a tight land market, this is in itself a collective action problem, potentially fobbing off diseased land to an unknowing grower.

Growers want to stay in business – and are actually skeptical of yield

When pushed, most growers admit that the dynamics of the treadmill are not good for the industry as a whole and can amount to a beggar-thy-neighbor strategy. For one, there is the problem of diminishing returns. They know that prices decline with every extra unit on the market.

> So we want these varieties to give out more numbers and last longer but it's hurting us in the long run. We need to find a happy medium where this is our threshold this is where we're going to be more efficient and make more money and we're not finding that. It seems like people think that if I plant 100 acres and make such amount of dollars, if I put 200 acres in, I'm going to make double that and it don't work that way.

One grower specifically invoked the notion of the treadmill.

> Well it's a self-fulfilling prophecy because the retailers want it cheap and the consumer wants it cheap. Every time I give a speech I have this saying I like to say: "Do any of you go to the grocery store and demand to pay a higher price?" And of course nobody does. You're kind of on a hamstrung treadmill. The yield on these strawberries isn't infinite, at some point you're going to hit a [wall]….. Going into business in California isn't inexpensive to begin with. The only thing that has made up for that is yield. That's not a good business model. And this is true in all of ag. You can't raise the price because people won't pay for it. But secondly, you get on the hamster wheel and you're just trying to outdo each other with yield. I don't know if that's a good business model. I don't know what the end result is.

Another even gave an account of the collective action problem at work.

> It's rough . . market price is being driven by oversupply. And as we try to convince each other as an industry to reduce acres We've been somewhat successful in doing that but newer varieties are so much more productive, techniques are so much more productive, that the total volume has not really decreased very much. So we are hurting ourselves with the overproduction . . . We all KNOW there's an oversupply. We all are thinking about cutting back, but historically, for generations, farmers have always said yea let's all cut back, what they really mean is, I want YOU to cut back. We've been through this in cycles since I've been farming, so here comes the bloodbath and the only way anybody makes any money is if it rains or hails or freezes on somebody else.

Instructively, several growers noted the folly of choosing productive cultivars as a means to address the labor shortage.

> You have to be able to manage the farm, if you get by with two people an acre and all of a sudden you need six, there's no way you can get the work force. So that creates a problem with keeping up with the pick, quality of the fruit that's being harvested. It just adds to a lot of problems. I don't understand what some of these growers are thinking when they go so heavy in one variety that they couldn't keep up with the year before.

Labor is of course a variable cost, so having more fruit to harvest in effect can raise, not lower costs as the grower quoted earlier suggested. With a dearth of pickers to harvest the fruit it also raises labor costs, if indeed labor can be found. As put by one grower who had left production and was now leasing his owned land.

> Another reason why I didn't plant the Monterey was because when the Monterey would come in there would be too much berries and I didn't have the personnel to pick it. Being a small farmer I couldn't pay the wages that these bigger guys were paying.

Which brings us to the final point. As predicted by Cochrane, the productivity treadmill is indeed driving growers out of business.

> Right, I don't know what the answer is because there's more people going out of business than there are going into business. In our area, really, there's no independence left. You're either affiliated with Driscoll or WellPict or Naturipe - those type of guys. There's no mom and pop out there like there used to be.
>
> Oh I know a lot of people who have [gone out of business]. And a lot of people continue to. But it's still a catch because we keep dropping acres, we're dropping acres this way but our volumes are going up. So we're not losing anything. We're still at the same place of too much volume.
>
> We know that the market will only do so much, we can really hurt ourselves by overproducing, and yet the drivers for farmers and the drivers for the coolers are to maximize, NOT optimize, maximize the productivity. How can you get from maximum to optimum, is tricky. It's gonna be painful for somebody. Because to make money somebody has to get hurt, leave, drop out, not play the game or something.

What remains to be seen is whether the shake-out will go so far as to eliminate over-production and raise berry prices that way. There are those in the business who would welcome it precisely for that possibility. The question is whether those acting on behalf of the entire industry should be encouraging it.

ADDRESSING THE COLLECTIVE ACTION PROBLEM

To sum up so far, there are several factors that contribute to strawberry growers' desires for high-yielding cultivars despite some recognition that it is self-defeating for the industry. Growers know that if they do not choose a higher yielding variety, others will, and out-compete them on volume. Growers feel squeezed by the price of land and the prices they receive from shippers. The way that many contracts are set up further incentivizes the choice of high-yielding cultivars. Finally, growers' abiding practices of labor remuneration in the form of piece rates appears to incentivize higher yielding varieties as a way to attract workers – although having more fruit to pick may worsen the problem. All of these contribute to declining prices and further consolidation, as fully predicted by theories of the treadmill.

With those as abiding concerns, those who have identified the productivity treadmill as a collective action problem have implied that farmers ought to be marketing cooperatively (e.g., Levins 2001, Levins and Cochrane 1996). But two things make the case discussed here a different sort of collective action problem. One is that strawberries are not undifferentiated commodity crops that can be easily pooled together and sold. As are many specialty crops, strawberries are bred for a variety of qualities and qualities that matter for different sorts of markets. The other speaks to the larger study's concern: that the strawberry industry is not fully readying itself for increasing problems with soil disease in a potentially stricter regulatory environment on fumigants by prioritizing yield over disease resistance.

That being the case, it is important to turn to those actors and factors that induce farmers to get on the treadmill. Yet, many of the augmenting factors involve broader structural conditions that are very hard to address at the industry level, particularly those related to land and labor. In the coastal areas of California, where strawberries do best, crop value is not the only determinant of agricultural land values. Strawberry land is largely coterminous with suburban development, making it unlikely that declines in productivity will lead to declines in land values. To the contrary, developers may be waiting in the wings to scoop up land no longer profitable. In that context, land owners cannot be counted to be concerned with industry fate, which is one of the reasons that land-owning growers have largely rejected efforts to maintain these lands for agricultural uses.

As for labor, growers are using field conditions to attract workers at a time of labor shortage because they feel they are unable to pay higher wages and stay in business. They see a worsening situation with the state-specific increase in minimum wage to $15/hour and the end of exemptions for overtime work for agricultural workers. Although reverting to the use of hourly wages rather than piece rates would dis-incentivize growers' use of high-yielding cultivars to attract workers – and might be desirable from a social justice standpoint, it is unclear that it would improve the problems with profitability that drives the treadmill. Addressing wages in any meaningful way while keeping farmers in business would take a policy response heretofore unprecedented.

Perhaps, then, it is shippers who might best be positioned to slow the treadmill. They certainly have a stake in these issues, as evidenced by nearly across the board stakeholder support for the project on which this article reports. But, as with land owners (or wage laborers, for that matter), their interests do not really align with growers (Levins 2001, Mooney 1983). If strawberry growers over-produce and need to move their crops, that is beneficial for shippers. Indeed their ability to set prices which growers have little choice but to take is a key force in keeping the treadmill revolving.

Given these "contradictory class positions" between growers and rentiers, growers and laborers, and growers and shippers, slowing or stopping the treadmill may require the action of a body that explicitly acts on behalf of growers. The California Strawberry Commission (CSC) is one such body. Established in 1955, it supports the industry with both marketing promotion and research. The commission is supported by a "check-off" program, meaning that growers and other industry actors pay required assessments to support its work. Given its charge, it could probably do more to forge agreements among growers to address the problem of overproduction, even as it has already invested in substantial research to address solutions to soil disease.

Ultimately, though, the institutions that are in the best place to address the specificity of this particular technology treadmill problem are those that are producing the technologies in the first place, and especially those that are producing them as a public service. In the case of the California strawberry industry, these are the research and extension arms of Cal Poly and UC, both of which are public institutions that exist in part to serve agricultural interests. Their breeding facilities are most directly responsible for putting out the varieties that they do and, equally importantly, putting out the ideas that shape growers' desires. To be sure, the field day discussed in the opening paragraph is not the only one we attended where we witnessed UC researchers emphasizing that their varieties would be high-yielding. Yes, these institutions want and need to be responsive to growers, but following Borup et al. (2006) and Henke (2008) and their attention to performativity, university breeders may not be entirely attuned to the power they have in setting expectations about what it is that growers want, to which they can then respond with what they are willing and able to provide. What we are suggesting, in short, is that public breeders may be best positioned to address this collective action problem, specifically by changing expectations of what they could and should provide in the context of growing disease pressure and stricter regulations on fumigation.

CONCLUSION: WHY BREEDING FOR PRODUCTIVITY CONTINUES

It is incontrovertible that the productivity treadmill is spinning briskly in the California strawberry industry. While per acre yields continue to increase, acreage in production is down, prices are flat, expenses are high, and, predictably, growers are going out of business. It would seem also incontrovertible that more attention should be given to discovery about and implementation of techniques and technologies that will address the growing problem with soil disease. Without it, many more growers will get hurt and consumers may no longer enjoy the nearly year-round availability of strawberries at reasonable prices. And breeding for disease resistance seems to be an important part of that package that ought to take paramount priority. As trained geneticists, university breeders are acutely aware that breeding for yield may work at cross purposes for breeding for disease resistance – especially to the *multiple* diseases that currently plague the strawberry industry. As put by one public breeder precisely in relationship to the yield-productivity trade-off, "if I need to put more armor on, I can't be carrying more guns."

It is nevertheless understandable why public breeders would be reticent to let go of breeding for productivity. For one, these public institutions face structural conditions of their own that incentivize them to develop higher yielding varieties. They make royalties on volume sold. With the increasing pressure of universities to make programs revenue-generating, these royalties are all but an imperative (Rudy et al. 2007). Among other things that puts university

breeders in some competition with proprietary breeders who also want grower business and who may be equally tempted to breed for yield. UC is in a particularly tricky situation both because of a protracted series of lawsuits between UC and the CSC over the alleged abandonment of its breeding program (see e.g., Filmer 2017) and because they sell to low cost producers who make money on margin, to the extent they make it at all. So UC agricultural scientists want to make good on their mission to support their clientele. Yet, as we have shown, this same clientele recognizes the collective action problem of planting high yield varieties, and many hint that they would prioritize other qualities of the strawberry *were the playing field leveled* regarding productivity. And that is what public institutions are in a position to do, with the support of other super-industry actors like the CSC. They could help change the discourse about yield while ceasing to put out ever higher-yielding varieties.

That they do not and that growers do not demand it may well be because the problem is not urgent enough. As long as fumigants are allowable, and the pathogens reasonably controllable with fumigation, most growers do not feel the pain of soil disease. And as long as productivity is whipped high they can abandon land that is diseased and yield more per acre on existing land. Take those conditions away, and needs might change. Hopefully, it will not be too late, given the lengthy time it takes to develop, test, and propagate new varietals.

The implications here go beyond the California strawberry industry, as volatile as it is. Other specialty crops grown around the world are prone to over-production, share the multiple imperatives of breeding in order to sustain markets, and are susceptible to manifold diseases. As with strawberries, breeding for productivity can work at cross purposes for both farmer prices (and farmer livelihoods) as well as plant health. As with strawberries, agricultural scientists have important roles to play in adjusting expectations of what should be done and how to do it.

Understanding the collective action problem of productivity is thus of renewed importance in a world where the drive toward productivity has created problems beyond the decline in farmer prices – where indeed the technologies of heightened productivity, in this case certain pesticides, have contributed to pest virulence and have also engendered public push back against their use. Building on classic and largely theoretical renditions of the technology treadmill, here we have shown, through farmer accounts, the dynamics that lead them to choose high yielding varietals while recognizing that doing so may hurt them in the long run. Yet, as we have also suggested, farmers' choices are not only shaped by abiding structural conditions of agriculture. They are also shaped by the imagined imperatives of university scientists and extension agents to give farmers what they want, even though what they want, as science and technology studies scholarship suggests, has been conditioned by what university applied science has been able to give – technologies aimed at productivity. Drawing on such insights, we have thus suggested that sociologists of agriculture should consider the performative role of university scientists in agricultural contexts that are increasingly and irrevocably fraught.

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