Consumers' Willingness to Pay for Bioplastic Plant Containers: An Experimental Auction Approach

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Abstract

We investigated consumers' willingness to pay for novel bioplastic plant containers that are bio-based and biodegradable. To determine consumers' willingness to pay, we conducted experimental auctions in a market environment in which people were likely to purchase plants in traditional plastic containers. We found consumers were willing to pay a premium of \$0.67–\$1.14 for a bioplastic plant container. Consumers exhibited higher willingness to pay for containers that biodegrade quickly in the ground and have a fertilizer effect. We found that older consumers and consumers who practice environmentally friendly behavior have a greater willingness to pay. These results suggest that consumers will pay a substantial premium for bioplastic plant containers.

Key Words: Bio-plastic Crop Container Systems, Biodegradable, Experimental Auction, Field Experiment, Green Industry, Marketing, Nursery Crops, Willingness to Pay

JEL Classifications: C93, D44, Q55, Q13, Q51, M31, C99

The horticultural specialty crop industry, which generates \$11 billion in sales annually in the U.S., grows the vast majority of their plants in petroleum-based plastic plant containers that are

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discarded after a single use (National Agricultural Statistics Service, 2009). Ultraviolet light degradation, pesticide residue, and embedded soil/growing media, which potentially contains pathogens, make the containers un-reusable and un-recyclable (C. R. Hall et al., 2010). Each year over 4 billion plastic containers are used, and 98% of them—1.6 billion pounds of petroleum-based plastics—end up in landfills (Schrader, 2013). Recent innovations in container technology seek to improve the horticulture industry's environmental footprint (Kratsch et al., 2015; Yang et al., 2015). Adoption of bioplastic containers by specialty crop producers hinges on consumers being willing to pay more than the cost of adoption (T. J. Hall et al., 2009; Dennis et al., 2010).

This article examines consumers' willingness to pay for novel plant containers that have the beneficial properties of plastic yet are bio-based and biodegradable. These containers are the first of their kind. Until now, researchers have been unable to offer biodegradable bio-plastic containers when investigating consumers' willingness to pay. Instead, most studies have only used hypothetical valuation techniques (C. R. Hall et al., 2010; Yue et al., 2010b; Ingram et al., 2015). In practice, it is difficult to elicit consumer behavior by using surveys, focus groups, and laboratory pre-test markets (Lusk et al., 2007). Stated preference arguments are hard to verify because people tend to misrepresent their preference since there is no gain or loss to answering hypothetical questions (see Murphy et al. (2005), for a review on hypothetical bias in stated preference studies). In the context of environmentally friendly products, social-desirability bias may also contribute to inflated willingness to pay as consumers want to display their "greenness" to researchers.

Yue et al. (2010a) sought to address hypothetical bias by conducting experimental auctions in a lab setting where subjects bid on actual containers. The containers, however, were given hypothetical descriptions, which could re-introduce hypothetical bias (Harrison and List, 2004).[1]

Currently, most commercially available bio-containers are constructed from compressed natural fiber, such as rice hulls, straw, poultry feathers, peat moss, cow manure fiber, or coconut coir (Kratsch et al., 2015; Nambuthiri et al., 2015a). Yue et al. (2010b) found consumers will pay a \$0.23–\$0.29 premium for a pressed-fiber or wheat starch biocontainer, and Yue et al. (2010a) found a willingness to pay of \$0.23–\$0.58 more than traditional plastic containers in an experimental auction and \$0.62–\$0.82 in a choice experiment. Through a choice experiment Ingram et al. (2015) found consumers in Kentucky will pay a \$0.82 premium for a biocontainer.

We addressed hypothetical bias by using an experimental auction to sell innovative bioplastic, biodegradable containers to consumers in a market environment where people were likely to purchase plants in traditional plastic containers. We found that consumers are willing to pay a premium of \$0.67–\$1.14 for a bioplastic plant container, depending on the exact container characteristics. Consumers exhibited greater willingness to pay for containers that biodegrade quickly in the ground and have a fertilizer effect. We found that older consumers and consumers who practice environmentally friendly behavior have a higher willingness to pay. Considering the marginal cost of producing these bioplastic containers is just \$0.15 higher than conventional plastic, these results suggest that bioplastic plant containers can substantially increase horticultural producers' profits; the containers are easily incorporated into existing production systems, and consumers will pay a substantial premium.

1 Materials and Methods

In this section we describe the bioplastic containers, the experimental design, and the method of data analysis.

1.1 Bioplastic Containers

The bioplastic containers developed in conjunction with our research have thermal and mechanical properties similar to those of petroleum plastics (Kratsch et al., 2015; Yang et al., 2015). Table 1 describes the six bioplastic containers. Four of the six containers in our study were produced with polylactic acid (PLA), which is typically derived from carbohydrate fermentation. PLA is a highly versatile thermoplastic that can be manufactured on existing plastics-processing equipment, which reduces the marginal cost of production. It is also biodegradable and nontoxic, which makes it ideal for the current application. PLA is more expensive than petroleum plastics, but it can be blended with fillers or protein polymers to substantially reduce its cost. In our study, one bioplastic formulation blends PLA with a soy-based polymer (Yang et al., 2015), another combines PLA with lignin, a complex polymer found in the cell walls of plants. Another formulation combines PLA with BioRes™, a proprietary blend of plant-based proteins. And one formulation consists entirely of recycled PLA.

Another bioplastic used in our study is Polyhydroxyalkanoate (PHA), which is produced in nature by bacterial fermentation of sugar or lipids. To reduce material costs and increase biodegrdability PHA is combined with dried distillers grains with solubles (DDGS), which are a cereal byproduct of ethanol production (Lu et al., 2014).

The final container type in our study is polyurethene-coated paper fiber containers (Mccabe et al., 2014).

1.2 Experimental Design

To determine end-consumers' preferences and willingness to pay for the six prototype bioplastic containers currently not available in the market, we conducted an experimental auction at a Midwest farmers market for three different Saturdays in the fall of 2014. This setting has several advantages. First, it is a market setting that involves a considerable vendor/customer interaction, which our research design closely approximates. Second, potted plants are regularly sold in this marketplace, further reducing the artificiality of our experiment. Third, shoppers at farmers' markets, who are reputed to be more environmentally conscious, are more likely to be representative consumers of this product.

Upon consenting to participate in the study, participants were endowed with a houseplant—a Maranta or a Dracaena—in a 4.5-inch traditional petroleum-plastic container.[2] Participants were informed that the plant was theirs to keep, regardless of the outcome of the study. They were then told they would have a chance to purchase one of the 4.5-inch bioplastic container prototypes as part of an experimental auction. The participants were also told that if they "won" the auction, a member of the research team would transplant their houseplant from the traditional petroleum-plastic container with which they were endowed into the appropriate bioplastic container to take home. The plastic and bioplastic containers were the same size. Since the participant knew they could bid zero and keep the plant in the petroleum-based container, the bid amount can be interpreted as the *premium* the participant is willing to pay for a bioplastic container.

Experimental auctions have advantages over stated-preference methods because an exchange mechanism is used. The bids obtained from the experimental auction are the revealed preferences obtained in "a real market with a real product and real money" (Lusk, 2003). This creates incentives for people to think about what they will actually pay for goods and services while accounting for their personal budget constraints. An experimental auction mechanism combines the strengths of lab experiments with the context of surveys (Lusk and Shogren, 2007).

Although we could have used many different auction designs–first price, N^{th} price (second price), Becker-Degroot-Marschack (BDM) mechanism, and the random N^{th} price auction—we employed the BDM auction mechanism (Becker et al., 1964). We chose the BDM auction mechanism because it is designed to be incentive compatible (Lusk et al., 2004), and it is one of the few auction mechanisms that can be performed with an individual consumer. In this study, we collected data in a field setting where (1) groups could not be organized for a larger auction and (2) individuals were time constrained; thus, we utilized the BDM auction mechanism.

In a BDM auction, participants are asked to place a bid on a given product—in our case, two bioplastic containers—that reflects how much they are willing to pay for the product. Although participants place bids on multiple products, only one randomly chosen product is actually sold. The binding price is also randomly chosen, generally from a uniform distribution of prices. To "win" the auction, the participant's bid must exceed the randomly drawn binding price (if this is the case, the participant then pays the binding price). If the bid is below the binding price, the participant does not win the auction and is not required to provide any payment. Because the binding price is drawn at random, participants are advised that it is in their best interest to submit a bid equal to the price they are willing to pay for the product. Bidding higher than one's true willingness to pay could lead to paying more than one's true value of the product. However, underbidding could cause an individual to miss an opportunity for a profitable purchase (see Becker et al. (1964) for more on the BDM auction mechanism).

As described previously, six unique bioplastic containers were to be evaluated. In a field setting, we expected many participants would be time-constrained, so each participant randomly selected two bioplastic containers to be evaluated by rolling a pair of dice. Once the two bio-containers were determined for the participant, the research team quickly set up the containers while the participant completed a brief questionnaire with basic socio-demographic information (including gender, age, income, education, residence type). For the assigned bio-containers, we provided information cards describing the containers, including information on the materials used to make the container and any unique features or benefits of the specific container, e.g., biodegradability, recyclability, and fertilizer effects.[3] The participant was given the opportunity to physically examine the randomly selected bio-containers and ask any clarifying questions about the information presented. The research team also had a poster available on-site that showed real pictures of plants growing in the different bio-containers, how well the bio-containers degraded in soil, etc., so participants could visualize the features associated with each bio-container.

After they inspected the containers, participants were asked to bid their willingness to pay for each of the two randomly selected containers. Since this is a novel product to participants and because the marginal cost to manufacture the containers is low (less than \$0.20), we bounded bids to be between \$0 and \$2. During the bidding process, the researchers clearly explained the Becker-Degroot-Marschack (BDM) auction mechanism and ensured that participants understood that one of their bids would be binding—if their bid was greater than the randomly drawn price, they would pay us the random price and we would transplant their houseplant from the petroleum-based plastic container they were endowed to the bioplastic container.[4] To determine which bid was binding, participants rolled a single die; an odd number would make the bid for the first container binding and an even number would make the bid for the second container binding. Following standard BDM auction procedures, the binding bid was compared to a randomly drawn price, and in the cases where the participants bids were higher than the price drawn, the participants paid the price drawn and the research team transplanted the participant's houseplant from the petroleum-plastic container to the relevant bio-container. After the auction procedure, participants were asked to fill out some general behavioral questions (related to environmentally-friendly behaviors such as recycling, carpooling, composting, etc.) and list what they liked and disliked about each of the bio-containers they examined.

1.3 Data Analysis

We calculated average willingness to pay bids for each of the six bioplastic containers. An analysis of variance (ANOVA) revealed the bids across the six bio-containers were significantly different, so we used Tukey's studentized range test for pairwise comparisons. This method is more conservative than the Fisher's least square differences (LSD) procedure or Duncan's multiple range test as it controls for the overall significance level. Additionally, we estimated an ordinary least squares (OLS) regression where the bid was modeled as a function of bio-container type, gender, age, income, residence type, and engaging in environmentally friendly behaviors.

2 Results and Discussion

In this section we report participant characteristics and their average willingness to pay for bioplastic containers. We also report the results of regression analysis.

2.1 Participant Characteristics

Table 2 reports the socio-demographic characteristics in our sample. As shown in the table, 66% of participants were female, and the majority of participants (82.5%) were between the ages of 18 and 54. Fifty-four percent of participants had an annual household income under $50,000, and 68% had obtained a bachelors degree or higher. Most people in our sample either owned their home (46.9%) or rented an apartment (30.2%).

In terms of behavioral characteristics, we asked participants to indicate the frequency they engage in six environmentally-friendly behaviors: recycling, carpooling, walking/bicycling to work or school, using public transportation, using reusable shopping bags, and composting. The frequency of each behavior was assessed on a five-point scale where 1=Never and 5=Always. In our sample, the most common behaviors were recycling (83.9% said they recycle always or often), using reusable shopping bags (58.3% indicated always or often), and walking or bicycling to work (45.7% said always or often). For each respondent, we counted the total number of behaviors (out of six) that were engaged in always or often. Participants who practiced four or more of the behaviors always or often were classified as exhibiting high levels of environmentally-friendly behaviors (variable High Env Behav in table 2). In this sample, almost a quarter of participants (24.7%) received this designation. Consumers with these characteristics are more likely to be the representative consumer of bioplastic containers than the "typical" American consumer.

2.2 Average Willingness to Pay

Table 3 shows the mean willingness to pay values for each of the six bioplastic containers. Recall that bids were bounded between \$0 and \$2 due to the low product cost. From the table, we see that the average bids ranged from \$0.67 (PLA-Lignin) to \$1.14 (PLA-Soy). Tukey tests revealed that while there was dispersion in the bids for the different bio-containers, few differences were significant. The containers that were most highly valued by consumers were the PLA-Soy, PLA-BioRes™, PHA-DDGS, and Recycled PLA containers with willingness to pay values of \$1.14, \$1.10, \$1.06, and \$0.89, respectively. There are no significant differences in the average bids for these bio-containers; however, the PLA-Soy bio-container is significantly different from the Paper Fiber and PLA-Lignin bio-containers (willingness to pay values of \$0.68 and \$0.67, respectively).

2.3 Regression Analysis

Table 4 presents regression results for the willingness to pay. Bids were modeled as a function of bio-container type, socio-demographic characteristics, and environmentally-friendly behaviors;

overall, this specification accounted for 22.6% of the variance in willingness-to-pay bids.

Confirming the results in table 3, we see that consumers are willing to pay a \$0.35, \$0.32, and \$0.33 (all p-values < 0.05) premium relative to the paper fiber bio-container for the PLA-Soy, PLA-BioRes™, and PHA-DDGS bio-containers, respectively.

Turning to demographic predictors, we see that gender, income, and education have no effect on willingness to pay. The gender result is a bit surprising, given evidence from previous studies (Yue et al., 2010a, 2011) that females are more likely to be interested in and willing to pay more for bio-containers than males. Our results reveal females are indeed willing to pay more, but the magnitude of that premium is small (approximately \$0.04) and insignificant. We found that age, however, impacts willingness to pay. Relative to individuals under the age of 35, we see that people in the 35-54 age range are willing to pay \$0.47 more, on average (p < 0.01), and people 55 and older are willing to pay \$0.11 more (non-significant). These results are in line with previous studies; Yue et al. (2010a) and Ingram et al. (2015) also found that willingness to pay for bio-containers is greater in older consumers.

In addition to these variables, we also considered residence type. Interestingly, we found that people who own their home are willing to pay \$0.48 less, on average, relative to people who classify their residence as other (p < 0.01)—in fact, people who own their home had the lowest willingness to pay of all residence types. While this finding does not have a particularly intuitive explanation, at least one other study has examined house type and found mixed results. Yue et al. (2011) asked participants to state their interest in three types of containers on a seven-point scale: bio-containers, compostable containers and recyclable containers. Their results revealed that people who own their home were less likely to be interested in bio-containers and recyclable containers than other participants (though neither was statistically significant) and more likely to be interested in compostable containers (significant at the 10% level). Based on the results from our study and the Yue et al. (2011) study, homeowners may be a group that requires further inquiry to better understand their aversion to bio-containers.

Finally, we examine how engaging in environmentally-friendly behaviors impacted willingness to pay. Recall that participants were asked about the frequency they engage in six behaviors: recycling, carpooling, walking/bicycling to work, using public transportation, using reusable shopping bags, and composting. Table 4 reveals that people who engage in four or more environmentally-friendly behaviors always or often are willing to pay \$0.21 more, on average, than those who do not ($p < 0.05$). One would expect this group to be willing to pay more for bio-containers since they frequently engage in other green behaviors.

3 Conclusions

Petroleum-based plastic plant containers are typically used in the horticultural specialty crop industry, but concern is growing about the large quantity of these containers that ends up in landfills. In this study, we examined consumers willingness to pay for a more sustainable alternative: bioplastic plant containers. The bioplastic containers used in this study possess thermal and mechanical properties which are similar to petroleum plastics yet are bio-based. This means they can be produced without substantial changes to current production processes, and they will biodegrade (either in soil or compost).

A major challenge to determining consumers willingness to pay for these bioplastic containers is that plants and their containers are complementary goods typically sold together, and the containers constitute a small share of the overall value of the plant-container combination. To avoid the artificial situation of bidding on an empty bioplastic container, we endowed subjects with a plant in a traditional petroleum-based container and gave them a chance to upgrade from the petroleum container to a bioplastic container using a Becker-DeGroot-Marschaak (BDM) experimental auction design (in total, we tested six different bio-containers). Participants' bids represent the premium they will pay for bioplastic containers above and beyond their value for a petroleum plastic container.

Our results reveal that, on average, consumers were willing to pay between \$0.67 and \$1.14 to upgrade from a traditional plastic container to a bioplastic container. The highest willingness to pay values were for the containers that enhanced plant quality (PLA-Soy and PLA-BioRes™) and degraded well in soil (PLA-Soy, PLA-BioRes™, and PHA-DDGS); each of these containers had willingness to pay values over $1.00, on average. The three containers that were evaluated less favorably were only biodegradable in industrial compost and were perceived to be similar to traditional petroleum-based plastic. In addition, we found older consumers and consumers who engage in environmentally-friendly behaviors are willing to pay more for these bioplastic containers, which is consistent with past research.

Our results show that consumers are interested in and willing to pay for bioplastic containers. It should be noted, however, factors in addition to the container materials will ultimately impact consumers' purchasing decisions. After bidding was completed, we asked consumers to write down what they liked and disliked about each of the two bio-containers they evaluated. Surprisingly, 38% and 41% of the like and dislike responses, respectively, were related to the appearance of the container, including comments about its color, texture, shape, and size. These sorts of comments were far more common than comments about the actual container characteristics such as biodegradability, materials, and plant quality effects. Thus, developing a sustainable container alternative is not enough—they must be aesthetically appealing as well.

Notes

[1]C. R. Hall et al. (2011) offers the following clarification: "It is important to note that pots were merely labeled as carbon neutral, saving or intensive. This relationship has not been established by scientific research regarding any given container type.... Again, this was only labeled according to the research design and not based on actual waste ingredient composition."

[2]To avoid the bias due to the plant type, only one type of plant was available for each day.

[3]The exact wording of the six information cards is available in table 1.

[4]Participants were offered the opportunity to practice by bidding on a candy bar.

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Table 1: Bioplastic Container Characteristics

Pot Type	Description
PLA-Soy (AR)	This container is made from Polylactic Acid (a plant-based plastic) and Soy-based Polymer. It provides up to 80% of the plant's fertilizer requirements, and it improves the root systems and eliminates root circling. It is suitable for crop cycles up to 12 weeks long. Beyond 12 weeks the containers develop a blotchy appearance and begin to lose structural integrity. It biodegrades reasonably well in soil, but may have some residue remaining after 2 years in soil. It is 100% compostable in home compost.
PLA-BioRes™(80/20)	This container is made from Polylactic Acid (a plant-based plastic) and a plant-based protein blend. Its appearance and structure holds up well for crop cycles as long as 16 weeks, perhaps longer. It grows plants of equal or better quality than petroleum-plastic containers. It is biodegradable in soil, but at a slow rate. It is 100% compostable in home compost.
PLA-Lignin (80/20)	This container is made from Polylactic Acid (a plant-based plastic) and Lignin, which is found in wood and is a byproduct of paper production. It is a very durable container. It requires no change in cultural practices from those used with current plastic containers. It is not degradable in soil, and not degradable in home compost. It is, however, degradable in industrial compost.
Recycled PLA	This container is made from recycled Polylactic Acid (a plant-based plastic). It is a very durable container. It requires no change in cultural practices from those used with current plastic containers. It is not degradable in soil, and not degradable in home compost. It is, however, degradable in industrial compost. The material may be considered eco-friendly because it is both biorenewable and recycled from used yogurt containers.
PHA-DDGS (80/20)	This container is made from Polyhydroxyalkanoate (PHA), which is produced in nature by bacterial fermentation of sugar or lipids, and Dried Distillers Grains with Solubles (DDGS), which are a cereal byproduct of the distillation process. It performs as well as petroleum-plastic containers, and biodegrades readily in soil in less than 2 years. It also biodegrades well in home compost. It may require slightly more fertilizer for plants than a petroleum-plastic container does.
Paper fiber - (Polyurethane coated)	This container is made from Polyurethane-coated paper fiber. It is sufficiently durable for crop cycles over 16 weeks. It is more durable than uncoated paper fiber, and no extra water is needed to grow plants because the coating eliminates evaporation through container wall. The source material may be considered eco-friendly because the main component is both biorenewable and recycled from used paper. It is biodegradable in soil, but at a slow rate. It biodegrades slowly in home compost.

Subjects received 4-inch by 6-in cards with container descriptions but not the container type.

Table 2: Characteristics of Study Participants and Definition of Variables (N=97)

Variable	Definition	Sample Proportion
Female	% Female	66.0%
Age1	% Age $<$ 35 years	57.7%
Age2	% 35 $\leq$ Age $\leq$ 54 years	24.7%
Age3	% Age $\geq$ 55 years	17.5%
Income1	% Annual Household Income $<$ \$50K	54.2%
Income2	% \$50K $\leq$ Annual Household Income $\leq$ \$99,999	29.2%
Income3	% Annual Household Income $\geq$ \$100,000	16.7%
Bachelors	% Bachelors Degree or Higher	68.0%
Own Home	% Classify Residence as a Home that they Own	46.9%
Rent Home	% Classify Residence as a Home that they Rent	16.7%
Rent Apt	% Classify Residence as an Apartment that they Rent	30.2%
Other Residence	% Classify Residence as Other	6.3%
High Env Behav[a]	% Engage in Four or More Environmentally-Friendly Behaviors Often or Always	24.7%

[a]Respondents were asked about the frequency that they engaged in six environmentally-friendly behaviors: recycling, carpooling, walking/bicycling to work or school, using public transportation, using reusable shopping bags, and composting. Frequency was assessed on a 5-point scale where 1=Never and 5=Always.

Table 3: Average Willingness to Pay (WTP) for Bioplastic Containers

Bioplastic container	Number of Bids	Average Willingness to Pay
PLA-Soy	25	1.14^{a}
PLA-BioRes™	41	1.10^{ab}
PHA-DDGS	36	1.06^{ab}
Recycled PLA	33	0.89^{ab}
Paper Fiber—Coated	28	0.68^{b}
PLA-Lignin	31	0.67^{b}

Note: Averages with the same letter in a column are not significantly different at the 5% significance level.

Table 4: Regression Estimates for Willingness to Pay

Variable	Estimate
Intercept	0.806**
	(0.205)
PLA-Soy[a]	0.353*
	(0.156)
PLA-BioRes™[a]	0.321*
	(0.149)
PLA-Lignin[a]	-0.086
	(0.155)
Recycled PLA[a]	0.115
	(0.153)
PHA-DDGS[a]	0.333*
	(0.149)
Female[b]	0.038
	(0.094)
Age2[c]	0.467**
	(0.140)
Age3[c]	0.112
	(0.153)
Income2[d]	-0.057
	(0.111)
Income3[d]	0.182
	(0.138)
Bachelors Degree[e]	-0.048
	(0.010)
Own Home[f]	-0.477*
	(0.202)
Rent Home[f]	-0.215
	(0.206)
Rent Apt[f]	0.024
	(0.182)
High Env Behav[g]	0.213*
	(0.100)
R-Squared	0.226

Note: ** and * denote significance at the 1% and 5% levels, respectively. Standard errors are in parenthesis.
[a]Relative to the Paper Fiber-Coated Bioplastic Pot
[b]Relative to males
[c]Relative to participants in the Age1 category (Age $<$ 35 years)
[d]Relative to participants in the Income1 category (Income $<$ \$50K)
[e]Relative to those without a bachelors degree
[f]Relative to those who classify their residence as Other
[g]Relative to those who engage in less than four environmentally-friendly behaviors Often or Always