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Article

Perspectives on Perennial Grain Crop Production among Organic and Conventional Farmers in France and the United States

Sandra Wayman ^{1,†}, Valentine Debray ^{2,†}, Stephen Parry ³, Christophe David ²  and Matthew R. Ryan ^{1,*}

¹ Section of Soil and Crop Sciences, Cornell University, Ithaca, NY 14853, USA; SW783@cornell.edu

² ISARA-Lyon, 69007 Lyon, France; vd228@cornell.edu (V.D.); davidc@isara.fr (C.D.)

³ Cornell Statistical Consulting Unit, Cornell University, Ithaca, NY 14853, USA; stephen.parry@cornell.edu

* Correspondence: mryan@cornell.edu

† Authors contributed equally.

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Abstract: Perennial grain crops are currently being developed, yet little is known about farmer interest in these new crops. We conducted an online survey in France and the United States to evaluate interest in perennial grains. Results show that 57% of the farmers who responded reported they were “interested” or “very interested” in growing perennial grains, whereas 41% reported they needed more information. Respondents consistently ranked “to increase or maintain farm profitability” and “to improve soil health” among the top reasons why they were interested in growing perennial grains. Reasons why farmers were interested, as well as their concerns about growing perennial grains, differed by country and farm type (i.e., conventional vs. organic). More farmers in France than in the United States ranked “to reduce labor requirements”, and more conventional farmers than organic farmers ranked “to reduce inputs” among their top reasons for their interest. Farmers were also asked about integration strategies and management. More farmers in the United States than in France and more conventional farmers than organic farmers reported that they were interested in dual-purpose perennial crops that can be harvested for both grain and forage. Results from this survey can guide future perennial grain research and development.

Keywords: survey; perennial grains; France; United States; conventional farmers; organic farmers

1. Introduction

Perennial grain crops are a potentially more sustainable alternative to annual grain crops that currently dominate the global food system. Annual cereals such as corn, wheat, and rice are staple crops that form the foundation of caloric intake around the world [1]. Globally, more than 731 million ha of cereal crops were harvested in 2017 [2]. Farmers in France harvested over nine million ha and farmers in the United States harvested over 53 million ha in 2017 [2]. Although a critically important part of the global food system, annual cereals have a number of drawbacks. For example, annual cereals need to be planted every year and thus require routine field operations and precisely timed inputs and management [3]. Intensively managed annual grain crop production is also responsible for a number of environmental problems including soil erosion, reduced water quality and availability, greenhouse gas emissions, and loss of biological diversity [3].

Perennial grain crops, which are productive for two or more years after planting, are a potential solution to some of the environmental problems that are associated with annual grain crop production [4,5]. The permanent soil cover provided by perennial grain crops can reduce soil erosion and provide habitat

for wildlife [6,7]. Perennial grain crops can also decrease nutrient losses and water pollution [5,8] and help regenerate soils that have been degraded by excessive tillage [7]. However, some potential disadvantages of perennial grains include lower grain yields compared to annuals [7], inability to control pests through crop rotation [9], and, depending on regional rainfall patterns, greater water use [10], which could limit crop persistence and future yields in dry areas [7,11]. Perennial grain crops have been developed through the domestication of wild plants [11] and through the hybridization of annual crop species with wild relatives [12,13]. For example, perennial cereal rye was developed by crossing cereal rye (*Secale cereale* L.) with perennial wild rye (*Secale montanum* Guss.). Despite low grain yields, intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth and Dewey) is the first perennial grain crop to be used in commercial products, and grain from improved lines of this recently domesticated crop is marketed as 'Kernza®' [14]. Products made from Kernza include Patagonia Provisions Long Root Ale [15] and a Honey Toasted Kernza Cereal from Cascadian Farms [16].

Increased demand for "non-wheat" grains illustrates that consumers are interested in ancient and high-protein grains [17]. Grain from intermediate wheatgrass tends to have higher protein content than annual wheat, which is mainly a function of smaller kernel size in intermediate wheatgrass [13]. For example, Tyl and Ismail [18] found protein concentrations of different intermediate wheatgrass cultivars to vary between 18% and 25%, compared with 12% for the hard red wheat used as a check. The unique flavor profile of intermediate wheatgrass could also add interest to bread or beer [19]. Consumers who purchase local or environmentally sustainable products might be interested in perennial grains [20]. In France, organic production of the alternative grains spelt and buckwheat has increased substantially in the last ten years [21]. Increased consumer interest in organic alternative grains could provide a market opportunity for organic farmers who are interested in growing perennial grains.

In addition to breeding for improved crop performance and developing management guidelines, research is needed to understand how farmers perceive perennial grains. Accordingly, the objectives of this research were to (1) evaluate farmer interest in perennial grains, (2) identify opportunities and challenges for adoption, and (3) explore differences in responses of French vs. US and conventional vs. organic farmers. We chose to focus on France and the US because both countries are among the top five global producers of wheat [2], and because we are actively working with perennial grains in both countries [7,22]. France and the US are both leaders in agroecology and thus are home to farmers who might be particularly interested in perennial grains. France and the US are also among the top three countries with the largest markets for organic food [23], and thus comparing perspectives from organic and conventional farmers was another goal of this research.

2. Materials and Methods

2.1. Survey Design

The survey was developed in both French and English and was administered through the online survey tool Qualtrics (Qualtrics, LLC.; Provo, UT, USA). The survey was deemed exempt (meaning that participants would experience "less than minimal" risk by participating) by the Cornell University Institutional Review Board (protocol number 1606006411). A pilot test was led with farmers in France and the US to gather initial feedback before the final version was distributed. Survey respondents were solicited over one month from June 23, 2016 through to July 25, 2016. No unique personal information was collected to identify respondents.

2.2. Survey Distribution and Respondents

Cereal producers were targeted as participants for the survey. We focused on organic farmers in particular because there is a growing interest in organic, local small grain production both in France and the US. The survey link was distributed through a variety of networks, including no-till growers through Revue Techniques Culturelles Simplifiées in France and No-till on the Plains in the US and to organic advisers and growers through Institut Technique de l'Agriculture Biologique in France and the

National Organic Program in the US. We used the “snowball sampling” method [24] and encouraged participants to forward the survey link to others. It is important to note that this technique does have some drawbacks. The survey was likely redistributed through venues of which we were unaware and thus total distribution, and the response rate, cannot be estimated. Farmers who received the survey may not have been representative of our target population, and thus our results should be interpreted in this light. Given the novelty of perennial grains, we anticipated that some survey respondents would have no prior knowledge about perennial grain crop production.

2.3. Survey Structure

The survey was translated from English to French to avoid differences between the two languages in presenting the questions. The survey opened with the following paragraph: “The purpose of this survey is to assess the potential of perennial grains in the United States and France. Our goal is to identify opportunities and limitations to the production and use of perennial grains. This survey aims to measure interest levels and issues that could affect adoption among farmers and grain processors. You are invited to participate in this survey because you are either a farmer or a processor. Your participation in this survey is voluntary. If you decide to participate, you may withdraw at any time. The survey is being conducted by Matthew Ryan, Sandra Wayman, and Valentine Debray at Cornell University (USA) and Christophe David at ISARA-Lyon (France). The survey will take approximately 5 to 10 minutes. To protect your confidentiality, the survey will not ask for any identifying information. The results of this study will be used for scholarly purposes and your participation will help guide further research.” Contact information for our research team was provided. Farmers were then directed to the appropriate questionnaire (French or English) by indicating their resident country.

The survey contained 18 questions in total (see Supplementary Materials). The survey started with questions about demographics (country, and state or region) and previous knowledge of perennial grains. If farmers were unfamiliar with perennial grains, the following information was provided: “To begin, here is some information about perennial grains. Most agricultural land is devoted to the production of grain crops such as corn, soybean, wheat, and rice. Combined they provide over 70% of human food calories. All these grain crops are currently annual plants, which means they need to be planted every year. Perennial grain crops are productive for two or more years after planting. Some potential benefits of perennial grains include reduced soil erosion, greater utilization of solar radiation throughout the entire year, and greater access to nutrients and water that is deeper in the soil profile. Some potential disadvantages of perennial grains include lower grain yields compared to annual grain crops, reduced ability to use crop rotation to manage pests, and greater utilization of water. For more detailed information about perennial grain crops around the world, please see the Food and Agriculture Organization of the United Nations report titled *Perennial Crops for Food Security* at <http://www.fao.org/3/a-i3495e.pdf>.” Farmer respondents were then asked about their operation: farm type (e.g., conventional or organic), acreage farmed, percentage of household income coming from farming, and production (type of crops and/or livestock produced). Next, farmers were asked to identify their top three, out of thirteen possible, motivations for growing perennial grains (see Supplementary Materials, question: “Please rank the top 3 reasons why you might be interested in growing perennial grains.”). Farmers were asked to identify their top three, out of ten possible, concerns that might dissuade them from growing perennial grains (see Supplementary Materials, question: “Given the potential challenges associated with perennial grain production, what would be your top 3 concerns?”). They were asked how perennial grains could best fit into their farm operation. Finally, if farmers had indicated they were “interested”, “very interested”, or “needed more information” on perennial grains, they were invited to respond to statements about perennial grains using a three-level scale (e.g., “agree”, “neutral”, and “disagree”). Farmers who were not interested in perennial grains were routed to finish the survey.

2.4. Categorizing Responses

The original answers to the question about on-farm operation type related to organic systems (“transitioning to organic”, “mixed organic and conventional”, and “organic (either certified or non-certified)”) were combined into one simplified category of “organic” for analysis. The “conventional” category gathered only farmers who answered “conventional production” to the question about on-farm operation type. Therefore, farmers who answered “other” were not counted as conventional or organic, and were excluded from the analyses. The original five classes for farm sizes (“under 50 acres”, “between 50 and 250 acres”, “between 251 and 450 acres”, “between 451 and 650 acres”, “above 650 acres”) were converted into hectares and combined into three categories for analysis: “small” (under 100 ha, capturing the first two of the five original size classes), “medium” (between 100 and 200 ha, capturing the middle original size class), and “large” (above 200 ha, capturing the largest two of the five original size classes). In addition, the responses to the question, “What percent of your household income on average comes from selling agricultural products?” were combined into two categories: “under 50%” and “above 50%”.

2.5. Statistical Analysis

We used R version 3.3.1 [25] for statistical analysis, with packages lme4 [26], emmeans [27], and nnet [28]. Our predictor variables were country (with two levels, France and the US) and farm type (with two levels, conventional and organic). Four models were constructed to best analyze the questions of interest (Table 1). Due to the scope of this work, variability in survey responses, and the need for models to converge, we chose not to include other factors as covariates. We did not test for interactions between country and farm type because of the limited number of responses that we received for some groups (e.g., conventional farmers in the US), which prevented model convergence. Thus, although we do acknowledge the possibility of interactions, the effects of country and farm type were analyzed separately.

We used a chi-square test to determine if there was an association between interest level and previous knowledge of perennial grains. Chi-square tests were also used to test associations between farmer response to statements on perennial grains and country, and farmer response to statements on perennial grains and farm type. Tests of proportion were then run to determine if there were significant differences between proportions of French and US farmers and conventional and organic farmers for each response level (“agree”, “neutral”, “disagree”) for each statement.

All *P* values for comparisons among factor levels within models were derived using the Tukey adjusted method. In this text, results are presented as percentages with the number (*n*) of respondents who selected a particular answer divided by the number of respondents who answered the question (e.g., 25%, *n* = 100/400). Denominator values vary by question because not all respondents who completed the survey answered all questions.

Table 1. Statistical models used to analyze survey question topics. Estimated marginal means were calculated for (1) France and the US and (2) conventional and organic farmers for all analyses.

Topic Analyzed	Model	Predictor Variables	Response Variable	Random Effect	Other Details
Interest in perennial grains	Logistic regression	Country and farm type	Interest, with two factor levels: “interested” and “need more information”	NA	Only 7 respondents who selected “Not interested” meant a multinomial model was infeasible
Motivations for growing perennial grains	Two logistic mixed regression models	Model (1) country, motivation, and interaction Model (2) farm type, motivation, and interaction	Binary variable indicating which of 13 given motivations were selected in top three	Respondents	13 motivations were ranked using estimated marginal means from each model
Concerns about growing perennial grains	Two logistic mixed regression models	Model (1) country, concern, and interaction Model (2) farm type, concern, and interaction	Binary variable indicating which of 10 given concerns were selected in top three	Respondents	10 concerns were ranked using estimated marginal means from each model
Farm integration strategy	Multinomial	Country, farm type, and interaction	Integration strategy, with five factor levels	NA	Five strategies ranked using estimated marginal means

3. Results and Discussion

3.1. Demographics of Survey Respondents

A total of 407 farmers completed the survey: 319 from France and 88 from the US. The 319 French farmers were distributed across France, with at least one farmer per region, and the greatest concentration in Auvergne–Rhône–Alpes, Bourgogne–Franche–Comté and Centre–Val de Loire (Figure 1). The 88 US farmers were distributed across the US, with greater concentrations in California, Wisconsin, and Kansas (Figure 2). It is important to note that The Land Institute, which is focused on developing perennial agriculture, is located in Kansas. Farmer respondents managed different types of farms as 22% ($n = 88/407$) managed conventional farms, 65% ($n = 263/407$) managed organic farms, and 14% ($n = 56/407$) managed “other” types of farms (which were often integrated farming practices or defined by the respondents as “conservation agriculture”). In all analyses, we excluded the 56 farmers who identified as “other” (Table 2). This constrained pool of 88 conventional farmers and 263 organic farmers varied in terms of farm size, crops grown, and other factors (Table 2). Among the 88 conventional farmers, 77% (68/88) were from France and 23% (20/88) were from the US. Among the 263 organic farmers, 77% (202/263) were from France and 23% (61/263) were from the US.

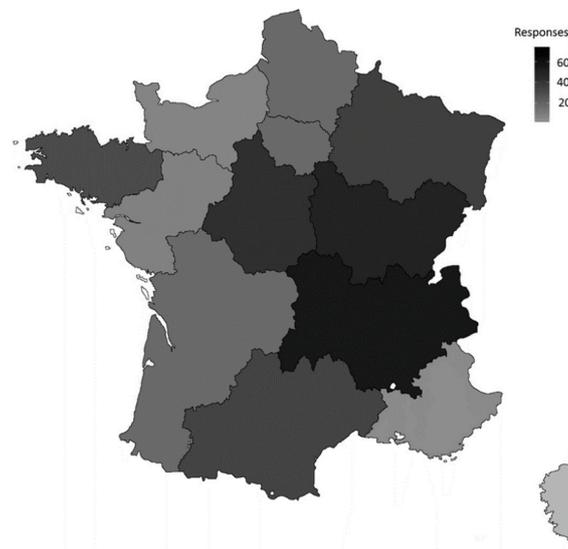


Figure 1. Total farmer survey response rate in France by region ($n = 319$).

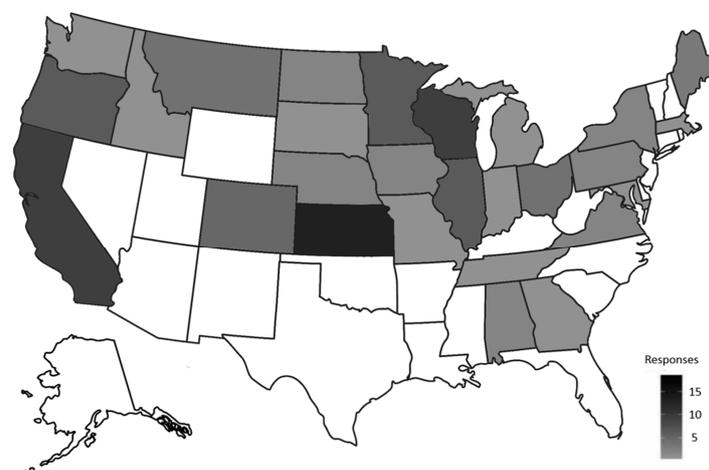


Figure 2. Total farmer survey response rate in the US by state ($n = 88$); states with no response are shown in white.

Table 2. Descriptive demographic information for the population of farmers by country, farm type, and farm size, who responded to the survey. Denominators are numbers of participants within a given demographic answering a given question, not total survey participants. Values in table do not include farmers who reported managing “other” types of farms.

	Country		Farm Type		Farm Size ¹			Total
	France	US	Conventional	Organic	Small	Medium	Large	
Farmer respondents ²	77% (270/351)	23% (81/351)	25% (88/351)	75% (263/351)	54% (188/351)	25% (88/351)	21% (75/351)	100% (351/351)
>50% of income from farming	68% (183/268)	48% (38/79)	66% (57/87)	63% (164/260)	57% (106/186)	75% (66/88)	67% (49/73)	64% (221/347)
Selected crops produced								
Other cereals ³	47% (124/264)	23% (18/78)	7% (6/86)	53% (136/256)	43% (78/182)	50% (43/86)	28% (21/74)	42% (142/342)
Other grain crops ⁴	37% (98/264)	22% (17/78)	25% (22/86)	36% (93/256)	30% (54/182)	43% (37/86)	32% (24/74)	34% (115/342)
Annual and perennial forages	66% (174/264)	56% (44/78)	40% (34/86)	72% (184/256)	64% (116/182)	71% (61/86)	55% (41/74)	64% (218/342)
Livestock	40% (106/264)	49% (38/78)	23% (20/86)	48% (124/256)	48% (88/182)	38% (33/86)	31% (23/74)	42% (144/342)
Previous knowledge of perennial grains	36% (96/270)	68% (55/81)	44% (39/88)	43% (112/263)	39% (73/188)	42% (37/88)	55% (41/75)	43% (151/351)

¹ Small = under 100 ha, Medium = 100–200 ha, Large = above 200 ha. ² Total farmers represent French and US farmers who manage conventional or organic farms (i.e., “other” types of farmers were removed from analyses). ³ Other cereals included spelt, emmer, einkorn, etc. ⁴ Other grain crops included buckwheat, amaranth, quinoa, etc.

It is important to note that our sample of farmers does not reflect the proportion of conventional to organic farmers in France or the US. For example, in France and the US, 6.3% and 0.6% respectively, of farmland was organic in 2017 [29]. Our sample of farmers does, however, represent a broad variety of farms in size, management, and location. Over half of the farmers who responded reported that more than 50% of their income was from farming (Table 2). In France, fewer large farms (above 200 ha) were reported than in the US (Table 2), which is representative of farm size differences between the two countries. The top three crops grown by farmers in France were wheat (84%, $n = 221/264$), barley (57%, $n = 150/264$), and perennial forage crops (52%, $n = 137/264$). The top three crops grown by US farmers were corn (62%, $n = 48/78$), wheat (56%, $n = 44/78$), and perennial forage crops (49%, $n = 38/78$). These results are broadly representative of field crop production in France and the US in 2016, the year in which our survey was conducted. In France in 2016, wheat accounted for 58% and barley accounted for 20% of total harvested cereal ha [2]. In the US in 2016, corn accounted for 60% and wheat accounted for 30% of total harvested cereal ha [2]. Farmer respondents also varied in terms of whether or not they produced other cereal crops (such as spelt, emmer, einkorn, etc.), other grain crops (buckwheat, amaranth, quinoa, etc.), perennial or annual forage crops, and if they raised livestock (Table 2). In general, French farms were more diversified in their crop production than US farms as a higher percentage of French farmers compared with US farmers reported growing other cereals, other grain crops, and annual and perennial forages (Table 2).

3.2. Farmer Interest in Perennial Grains

Of the farmers who answered the question “What level of interest do you have in growing perennial grains?” 57% ($n = 171/300$) reported they were “interested” or “very interested” in growing perennial grains, 41% ($n = 122/300$) reported they needed more information before deciding, and 2% ($n = 7/300$) reported they were “not interested” or “definitely not interested” in perennial grains. Interest in perennial grains did not vary by country ($p > 0.05$) or farm type ($p > 0.05$). Because only seven farmers reported they were “not interested” in perennial grains, these responses were removed from subsequent analyses.

Interest level in perennial grains was associated with previous knowledge, where 73% ($n = 93/128$) of farmers who had already heard about perennial grains reported they were “interested” or “very interested” in growing perennial grains, versus 47% ($n = 78/165$) of farmers who had no previous perennial grain knowledge ($\chi^2 = 18.1, p < 0.001$). Whereas almost a near equal proportion of conventional (44%) and organic (43%) farmers had previous knowledge of perennial grains, a lesser proportion of farmers in France (36%) than in the US (68%) had heard of perennial grains before the survey (Table 2). This could be due to a greater amount of research on perennial grains in the US over the last few decades [4,5,30–36], compared to Europe where research is limited, except for some research initiatives in Italy, Sweden, France, and Germany [6,22,37–39].

3.3. Potential Motivations for Growing Perennial Grains

Farmers were asked to rank the top three motivations why they might potentially be interested in growing perennial grains. Each of the 13 possible answers was chosen by at least 11 farmers, which shows that farmers are interested in growing perennial grains for a variety of reasons (Figure 3). The 13 motivations fell into three thematic categories: profitability, management, and environment. Generally, motivations related to profitability were more frequently chosen than were motivations related to the environment (Figure 3). Our results are congruent with Lanker et al. [40], who interviewed ten farmers in the Midwest region of the United States who were growing intermediate wheatgrass organically. These farmers reported that research on profitability and market infrastructure should be a priority [40].

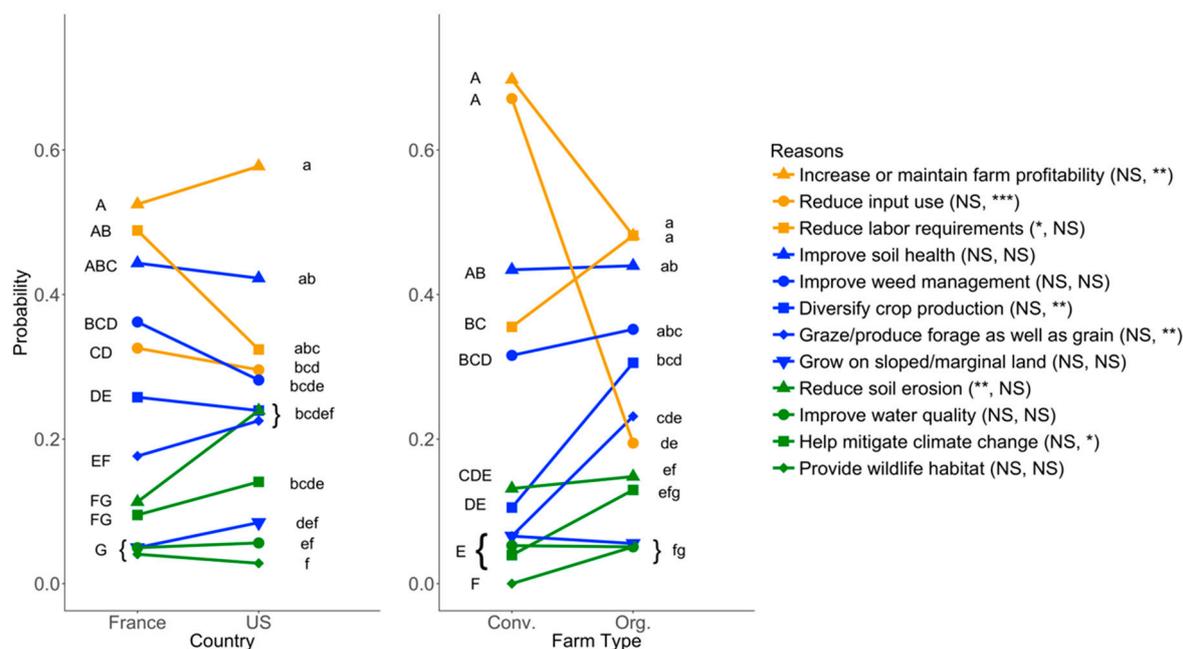


Figure 3. The proportion of farmers, presented by country (France $n = 221$, US $n = 71$) and farm type (conventional (Conv.), $n = 76$, organic (Org.), $n = 216$), who selected one of the given possible reasons in their top three motivations for growing perennial grains. The question was: “Please rank the top 3 reasons why you might be interested in growing perennial grains.” Different letters in vertical columns within an individual country or farm type represent significant differences among ranking of reasons ($p < 0.05$). Significant differences between the two countries and two farm types (respectively) are presented in parentheses in the legend. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant. Reasons are divided into categories: orange = profitability, blue = management, green = environment.

3.3.1. Motivations by Country

For both French and US farmers, to “increase or maintain profitability” was selected as one of their top three motivations most frequently. However, this motivation was not selected more frequently than the next two most frequently selected motivations, which were “improve soil health” and “reduce labor requirements” (Figure 3). Marquardt et al. [39] conducted qualitative semi-structured interviews with 14 Swedish farmers about their perceptions of perennial cereal crops and found that farmers were aware of the ability of perennial crops to improve soil health. In addition, the more extensive root systems of perennial crops compared to annual crops can provide greater access to water [41] and nutrient resources, thus increasing nutrient use efficiency compared to annual crops [33,35].

More farmers in France than in the US selected “to reduce labor requirements” as one of the top three motivations (Figure 3). As discussed previously, French farms in this study were smaller and more diversified than US farms. Small farms are often more labor-intensive, whereas large farms tend to be more mechanized, which could explain why French farmers were particularly interested in reducing labor requirements. The other motivation that varied by country was “reduce soil erosion”, which was selected less frequently in France than in the US (Figure 3). The continuous ground cover of perennial plants helps prevent soil erosion [42] and may be of particular interest to farmers in the US where no-till crop production is more common compared with France [43].

3.3.2. Motivations by Farm Type

Motivations for potentially growing perennial grain crops varied between conventional and organic farmers. The top motivation for both conventional and organic farmers, “increase or maintain farm profitability”, was selected as one of the top three motivations more frequently by conventional farmers than organic farmers (Figure 3). Among conventional farmers, “increase or maintain farm profitability”

was not different than “reduce input use” or “improve soil health”. Whereas among organic farmers, “increase or maintain farm profitability” was not different than “reduce labor requirements”, “improve soil health”, or “improve weed management”, a key issue in organic management (Figure 3). Compared to conventional farmers, more organic farmers selected “diversify crop production”, “graze/produce forage as well as grain”, and “help mitigate climate change” as one of their top three motivations (Figure 3). This illustrates that there is less of a difference between how French and US farmers view perennial grains, compared with how conventional and organic farmers view perennial grains.

“Reduce input use” was chosen among the top three motivations more frequently by conventional farmers than by organic farmers (Figure 3). Conventional farming systems generally rely more on external inputs than do organic farming systems, with higher costs linked to these inputs. Conventional farmers chose “reduce labor requirements” in their top three motivations less frequently than did organic farmers (Figure 3). Labor requirements are often lower on conventional farms than on organic farms [44]. Farmers may perceive that perennial grain crops require less cultivation, and thus use less fuel and have decreased costs [45]. Pimentel et al. [35] state that perennial grain production should allow a significant reduction of farm labor costs, energy usage, and technological inputs.

3.4. Concerns about Perennial Grain Production

Farmers were asked to choose their top three out of ten possible concerns that might dissuade them from wanting to grow perennial grains. Each of the ten possible concerns was chosen as a top-three concern by at least 33 farmers, which suggests that farmers are concerned about growing perennial grains for a variety of reasons (Figure 4). The ten concerns were more evenly chosen in the top three than were the 13 motivations. The ten concerns were grouped into three categories: profitability, management, and entry (incorporating perennial grains into farm management).

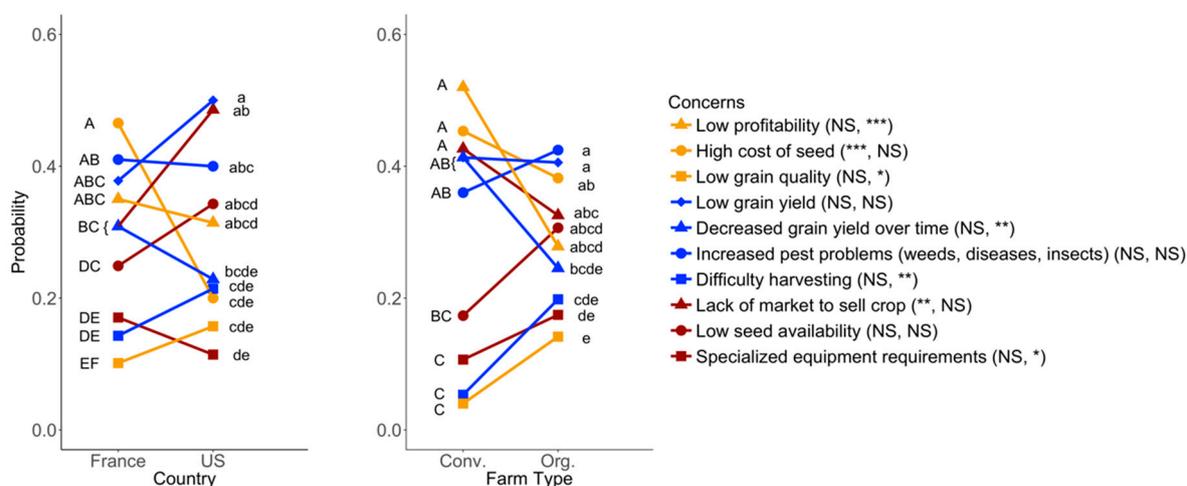


Figure 4. The proportion of farmers, presented by country (France $n = 221$, US $n = 71$) and farm type (conventional (Conv.), $n = 76$, organic (Org.), $n = 216$), who selected one of the given possible concerns in their top three concerns about growing perennial grains. The question was: “Given the potential challenges associated with perennial grain production, what would be your top 3 concerns?” Different letters in vertical columns within an individual country or farm type represent significant differences among concerns ($p < 0.05$). Significant differences between the two countries and two farm types (respectively) are presented in parentheses in the legend. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant. Concerns are divided into categories: orange = profitability, blue = management, red = entry.

3.4.1. Concerns by Country

For French farmers, “high cost of seed” was chosen as a top-three concern most frequently, although this concern was not selected more than “increased pest problems”, “low grain yield”, and

“low profitability” (Figure 4). US farmers selected “low grain yield” in their top three concerns most frequently, although this concern was not selected more than “lack of market to sell crop”, “increased pest problems”, “low seed availability”, and “low profitability” (Figure 4). Some current perennial grain crops have lower yields than their annual counterparts [13]. However, DeHaan et al. [46] state that breeding in a properly managed agricultural environment could effectively increase seed yield in the future.

More farmers in France than in the US selected “high cost of seed” as one of their top three concerns (Figure 4). Bell et al. [45] expect a higher cost for purchasing perennial grain seed than for annual grain seed, at least initially while perennial grain seed production is still limited. However, less frequent planting due to perenniality could offset this high cost of seed. The other concern that varied by country was “lack of market to sell crop”, which was selected by fewer French than US farmers (Figure 4). For perennial grains to be successful as a new crop, a system connecting farmers to processors to consumers will need to be put into place [47]. Currently, few perennial grain products are commercially available in the US while none are available in France. However, compared with the US, France tends to have more grain cooperatives, flour mills specializing in alternative grains, and bakeries that could conceivably sell perennial grain products.

3.4.2. Concerns by Farm Type

Concerns about growing perennial grains varied between conventional and organic farmers. Conventional farmers more frequently selected as a top-three concern “low profitability” and “decreased yield over time” than did organic farmers (Figure 4). Organic farmers more frequently selected “low grain quality”, “difficulty harvesting”, and “specialized equipment requirements” in their top three than did conventional farmers (Figure 4). Based on our experience with growing organic perennial grain crops in France and the US, concerns about harvesting and equipment requirements are valid for some perennial grains such as Kernza, which tends to have green stems when grain is mature. Unlike annual grains with stems that are dry at grain maturity, harvesting grain from Kernza might require different harvesting equipment such as a stripper head that removes only the grain rather than a traditional combine that cuts the entire plant and then separates the grain from the straw.

Among conventional farmers, “low profitability” was the top concern, although it was not more frequently selected than “high cost of seed”, “lack of market to sell crop”, “low grain yield”, “decreased grain yield over time”, and “increased pest problems” (Figure 4). Among organic farmers, “increased pest problems” was the top concern, although it was not more frequently selected than “low grain yield”, “high cost of seed”, “lack of market to sell crop”, “low seed availability”, and “low profitability” (Figure 4). Marquardt et al. [39] underline that Swedish farmers were concerned about pest problems such as weeds in cropping systems where practices such as crop rotation and deep soil tillage are limited. However, in areas where warm-season crops like corn and soybean are grown, introducing a perennial cool-season crop such as intermediate wheatgrass could suppress weeds [5]. Indeed, weed suppression was the most frequently highlighted ecosystem service by farmers in the Midwest US who were interviewed about their experiences and perspectives with growing organic intermediate wheatgrass for several years [40]. However, while some of these farmers expressed that weed suppression was one of the greatest benefits, others highlighted challenges with weed management. In that research, weed management problems were thought to be caused by 1) poor establishment that resulted in sparse stands and 2) establishing intermediate wheatgrass in weedy fields with relatively high soil weed seed banks [40].

3.5. Potential Integration into Existing Farming Systems

3.5.1. Integration Strategies by Country

No difference existed between French and US farmers in their selection of potential integration strategies for perennial grains (Figure 5). Forty-five percent of French farmers responded they would

grow a perennial grain crop “as a long-term perennial on sloped or less productive land”, which was the most frequently chosen integration strategy by French farmers (Figure 5). Perennial grain crops could help maintain productivity of land that is susceptible to erosion (i.e., sloped land) and that cannot support annual crops for long periods, while also providing grain [3]. Adebiyi et al. [48] found that some farmers did not perceive perennial grains as a substitute for other cash crops, but rather as a way to use underutilized land to cultivate both grain and forage. US farmers did not choose any one particular integration strategy more frequently than other strategies (Figure 5), except “as a short-term perennial crop in standard fields as part of a multi-year rotation” was more frequently chosen than “as a long-term perennial crop on your most productive land”. This suggests that US farmers might be more willing to try growing perennial grains for short periods of time while still maintaining annual crop production on their most productive land.

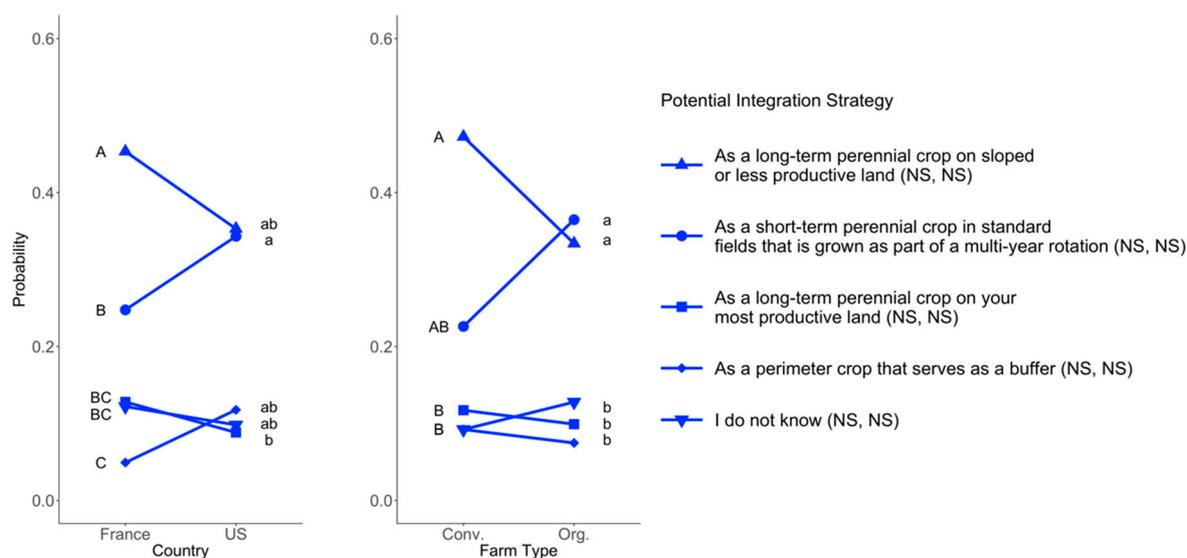


Figure 5. The proportion of farmers, presented by country (France $n = 226$, US $n = 73$) and farm type (conventional (Conv.) $n = 80$, organic (Org.) $n = 219$), who selected a given potential integration strategy. The question was: “How do you think a perennial grain could best fit into your farm operation?” Different letters in vertical columns within an individual country or farm type represent significant differences among answers ($p < 0.05$). Significant differences between the two countries and two farm types are presented in parentheses in the legend. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, NS = not significant.

3.5.2. Integration Strategies by Farm Type

Conventional and organic farmers did not differ in their choice of potential integration strategies. Conventional farmers more frequently selected “as a long-term perennial crop on sloped or less productive land” than both “as a long-term perennial on productive land” and “as a perimeter crop that serves as a buffer” (Figure 5). Among organic farmers, the most frequently selected integration strategies were “as a long-term perennial crop on sloped or less productive land” and “as a short-term perennial crop in standard fields as part of a multi-year rotation” (Figure 5).

3.6. Farmer Response to Statements about Perennial Grains

If farmers answered “very interested”, “interested”, or “need more information” about growing perennial grains, they were routed to respond to three statements on perennial grains. Farmers were asked to indicate whether they “agreed”, “disagreed”, or were “neutral” about the following three statements: (1) “I am interested in dual-purpose perennial crops that can be harvested for both grain and forage”; (2) “I would grow perennial grains to provide environmental benefits even if they were

not as profitable as other crops”; (3) “Research funding should be spent on annual grain crops rather than developing new perennial grain crops” (Figure 6).

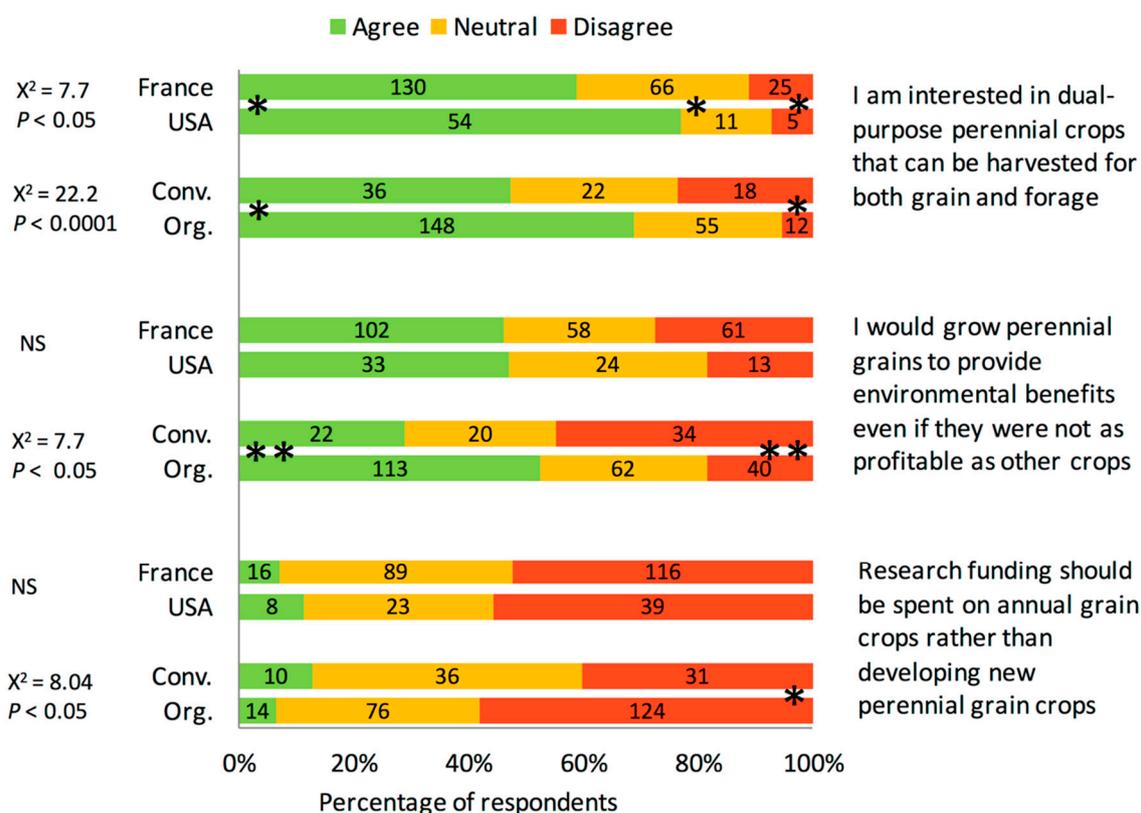


Figure 6. The percentage of farmers, presented by country (France $n = 221$, US $n = 70$) and farm type (conventional (Conv.) $n = 76$, organic (Org.) $n = 214$) who answered “agree”, “neutral” or “disagree” for three statements on perspectives about perennial grains. Numbers within bar segments indicate counts of respondents. Results of chi-square tests for country (France, US) by response level (“agree”, “neutral”, “disagree”) and chi-square tests for farm type (conventional, organic) by response level for each statement are presented on the left side of the figure. Asterisks between bar segments of the same color represent a significant difference in the proportions. * = $p < 0.05$, ** = $p > 0.01$. Numbers and percentages are raw data, not estimated marginal means.

3.6.1. Perennial Grains as Dual Purpose Crops

Responses to the statement, “I am interested in dual-purpose perennial crops that can be harvested for both grain and forage” varied by country (Figure 6). A significantly lower percentage of farmers in France (59%) than in the US (77%) agreed with this statement on dual-purpose perennial grain crops (test of proportion $\chi^2 = 6.9$, $p < 0.01$, Figure 6). Livestock management systems in the US, which generally rely on harvested forage rather than on grazed pasture, might be particularly suitable for perennial grain crops, which produce moderate quality forage that can be harvested several times a year [49,50].

Responses to the statement on dual-purpose perennial grain crops varied by farm type (Figure 6). A significantly lower percentage of conventional farmers (47%) than organic farmers (69%) agreed that they would be interested in perennial grains as dual-purpose crops (test of proportion $\chi^2 = 10.2$, $p < 0.01$, Figure 6). This finding is reasonable given that compared to conventional farms, organic farms are often more diversified [51] and include livestock [52]. Farmers with mixed crop-livestock systems can easily utilize the production of forage, by feeding their own animals or selling forage to other farmers. Lanker et al. [40] reported several farmers in the Midwest region of the United States were already using intermediate wheatgrass as a dual-purpose grain and forage crop. In-depth interviews of ten

farmers revealed that interest in dual-purpose production varied among farmers and was dependent on whether or not the farm had livestock, forage supplies, and forage quality [40].

3.6.2. Perennial Grains and Environmental Benefits

Responses to the statement, “I would grow perennial grains to provide environmental benefits even if they were not as profitable as other crops” did not vary by country (Figure 6). Responses to the statement on environmental benefits varied by farm type ($\chi^2 = 7.7, p < 0.05$, Figure 6). Fewer conventional farmers (29%) than organic farmers (53%) agreed with the statement on environmental benefits of perennial grains (test of proportion $\chi^2 = 11.7, p < 0.001$, Figure 6). Moreover, 45% of conventional farmers and only 19% of organic farmers disagreed with this statement (test of proportion $\chi^2 = 4.8, p < 0.05$, Figure 6). Environmental benefits may, therefore, be important to organic farmers in coherence with the principles of organic agriculture. Environmental benefits of perennial grains can include improved water quality, soil carbon sequestration, and providing habitat for wildlife [7,8,53].

3.6.3. Perennial Grains and Research Funding

Responses to the statement, “Research funding should be spent on annual grain crops rather than developing new perennial grain crops” did not vary by country (Figure 6). Farm type was associated with farmer response to the statement on research funding (Figure 6). Significantly fewer conventional farmers (40%) than organic farmers (58%) disagreed with the statement on research funding allocation to annual grain crops (test of proportion $\chi^2 = 6.4, p < 0.05$, Figure 6). The higher percentage of organic farmers who disagreed with this statement suggests that organic farmers would be supportive of research on perennial grains. Future research efforts about perennial grains may benefit from focusing on organically managed systems.

4. Conclusions

Our survey revealed that organic and conventional farmers in France and the US are interested in perennial grains for a variety of reasons. Across countries and farm types, reasons for interest in growing perennial grains as well as concerns about growing perennial grains were largely related to profitability. Thus, perennial grains research and development efforts should focus on factors that could potentially improve farm profitability. Although profitability was a priority for all farmers, reducing labor requirements and input use as well as improving soil health and weed management were also identified as motivations for potentially growing perennial grains. Also, while conventional farmers were particularly motivated by profitability, the majority of organic farmers who responded reported that they would grow perennial grains to provide environmental benefits even if they were not as profitable as other crops. More US farmers compared with French farmers and more organic farmers compared with conventional farmers were interested in perennial grains as a dual-purpose crop for both grain and forage. In addition to breeding efforts to increase grain yields and other desirable traits in perennial grains, research is needed to assess the potential for managing perennial grains for grain and forage and to better understand the environmental benefits that can be realized with perennial grains. As with motivations, responses about concerns should be interpreted with caution. Given that more than half of the farmer respondents did not have previous knowledge of perennial grains, responses may represent more of a first impression rather than an informed perspective based on experience and scientific evidence. Nonetheless, our results can be used to improve training and education programs, guide research activities, and facilitate the development of perennial grain cropping systems. In addition to opportunities related to the top-ranked motivations, future research should focus on addressing concerns about growing perennial grains that are validated by farmers who have experience with growing perennial grains.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2077-0472/9/11/244/s1>, Survey Questions and Answers.

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