Experiment Associations and Agricultural Innovation

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Abstract

Economic historians have rarely been able to trace the information flow that leads to the diffusion of technology. In this paper I investigate the role of the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA) in the development and dissemination of agricultural innovations within their respective regions. These organizations were networks of scientifically literate farmers working in cooperation with researchers at the agricultural experiment stations both to conduct localized tests in their own fields and to disseminate biological and non-biological innovations within their communities. I focus on efforts to improve productivity of field crops during the early years of each organization's existence. I observe the location of members and the crops each experimenter was testing or growing for seed each year. I study the changes crop productivity at the county level and seek to understand the extent to which this was affected by the activity of the OAEU or WAEA. My empirical results suggest that experiment association activity was associated with an increase in productivity of the oats crop that was statistically significant in both Wisconsin and Ontario. I am also able to gain insight into timing of the diffusion and I show that the effect of the OAEU was delayed while the effect of the WAEA came immediately. Finally, in both cases the effects of each association tended to occur with crops that figured prominently in their activities.

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1 Introduction

Innovation has the potential to increase productivity and lead to economic growth, however, these gains cannot be fully realized if the technological advancements are unable to reach those who ought to implement them. Efficient diffusion of technology requires potential adopters to know that the innovation exists and to have the ability to gain access. Further, to the extent that people prefer known quantities, it may be advantageous for these potential adopters first to observe the experience of others in order to make wiser decisions themselves. Not only can local trials of a new innovation benefit adopters, but they can be a vital source of information for researchers as well. This is especially true if the success of the new technology varies with characteristics unique to the location, as is the case with agricultural technology, or if its value depends on idiosyncratic features of users or usage patterns that cannot easily be recreated in the laboratory. In these cases it can be beneficial for researchers receive reports from trial runs by early adopters. Researchers with access to feedback on the performance of the product during the development phase can then make minor adjustments to improve the final version. One way in which these aims can be accomplished is by directing the innovation to diffuse initially through a network of folks familiar with the new technology that can both communicate with the researchers and also advertise its merits to other potential adopters. Good examples of such networks are the experiment associations comprised of scientifically literate farmers who cooperated with agricultural experiment stations to test and disseminate biological and non-biological innovations. Among the earliest were the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA), which was modeled after its Canadian predecessor.

Economic historians have rarely been able to trace the information flow that leads to the diffusion of technology. In this paper I seek to make a contribution by studying the OAEU and WAEA to better understand their role in facilitating the transmission of innovations from the agricultural college and experiment stations to ordinary farmers. The central purpose of each organization was to improve the agricultural productivity of their respective regions and through my empirical analysis I investigate the extent to which each was successful. I observe the locations of experimenting members and argue that the presence of experimenting members benefited farmers within a county by assisting the researchers in directing particular varieties to the region, by helping farmers make better decisions about what varieties to plant having observed others in their community, and by making available improved varieties for purchase by farmers from known sources. I examine whether counties with greater numbers of experimenters saw higher crop productivity as measured by yield per acre in the crops those experimenters tested. The results of the paper illuminate the mechanism of diffusion. For the OAEU there is a slightly delayed, positive, and statistically significant effect on the productivity of oats and peas. Findings for the WAEA show an immediate, positive and statistically significant effect on the productivity of oats and barley. Taken together the results provide evidence that these experiment associations were each an effective means for rapid technology diffusion.

2 Related Literature

There is already a large literature concerning the diffusion of agricultural technology more generally. Griliches (1957) describes the S-shaped pattern of adoption seen in the diffusion of hybrid corn; Griliches (1960) associated the decision to adopt, and the rates at which this occurred, with the profitability of hybrid corn in one's region. Here there is also an observation about the resistance of farmers to accept new hybrid seed corn which was in part due to a reluctance to trust researchers especially in light of the large upfront investment required to use the seed. One of the motivations for farmer experiment associations was to overcome this mistrust of new technology by allowing farmers access to it through their peers. More recently, Sutch (2008) provides evidence that adoption of hybrid corn was driven by effective adverting rather than by a clear yield advantage over other varieties and mentions anecdotally that sometimes hybrid corn seed was provided to farmers to allow them to conduct their own comparison trials for demonstration to themselves and their neighbors. A very similar process underlies part of the mechanism of diffusion from experiment stations to farmers through the OAEU and WAEA as one of their objectives was to spread knowledge through demonstration.

There has also been much work studying the role of the experiment station in the development and diffusion of agricultural technology. Olmstead & Rhode (2008) provide extensive evidence for the ways in which agriculture in the United States was changing both in thought and in practice, and discuss the extent to which these innovations affected productivity. They describe the efforts of the experiment stations to test new varieties and the eventual adoption by farmers and they explain the role of improved varieties in extending the crops into new regions, primarily northward and westward. Most relevant to my paper is their work discussing biological innovations in the wheat and corn crops and I contribute to the understanding of one mechanism supporting the diffusion they document. Regarding the wheat crop they show that biological innovations were largely responsible for preventing significant crop losses in the face of disease, pests, weeds, and climate conditions. With respect to the corn crop they demonstrate how the process of innovation led to varieties designed to suit specific counties. It is this sort of process for the optimal selection of varieties that the OAEU attempted to facilitate, albeit with different crops. Perhaps closest to my paper is work by Kantor & Whalley (2012) which is interested in the effects university research conducted through experiment stations had on agriculture. I take a much narrower focus and with the OAEU and WAEA study one specific path through which innovations originating at the experiment station reached ordinary farmers. From my work it is possible to learn something about a particular means through which diffusion of innovation and research spillovers occurred.

There is also research documenting the factors affecting individual adoption decisions. Conley & Udry (2010) investigates the role of social learning in the patterns for diffusion of non-biological innovation through networks of pineapple farmers in Ghana. Their model and empirical analysis demonstrate the effects of a farmer's experience on the behavior of others within the network. They also find evidence that inexperienced farmers are more responsive to the successes and failures of others. Duflo, Kremer, & Robinson (2011) provide an example of a program that can work to improve the diffusion of technology sold by a private company. They consider fertilizer usage by farmers in Kenya and note that a major hinderance to adoption is its price, however, due to enormous returns to applying fertilizer it would more than pay for itself if one could overcome the initial obstacle. Their findings suggest that small subsidies strategically offered around harvest rather than during other times lead to higher adoption rates than larger subsidies away from the harvest season. A contribution of my paper is to study how experiment stations handle diffusion of their innovations and to analyze the structure of this mechanism. In order to encourage rapid dissemination without concern for maintaining property rights over the innovations, improved varieties were provided to experimenters for free. After testing had shown success in the region the seed was then to be distributed to other farmers at modest prices in light of the fact that these were government funded entities.

Finally, part of the purpose of the OAEU and WAEA was to educate farmers about the benefits of implementing the innovations developed at the experiment stations and agricultural college. Parman (2009) considers the agricultural innovations of the early twentieth century, their subsequent diffusion, and the role of human capital. In particular he estimates the spillover effects of public schooling on agricultural productivity in Iowa during this time period and finds a positive effect. In my paper I am in part picking up the effect due to the educational efforts of these organizations by including a measure for the number of experimenters within a county. For the OAEU, however, I am unable to disentangle the education and seed dissemination effects. For the WAEA I am able to separate the effects of seed growers and ordinary members who most likely spread information rather than seed during that particular year. However, I find no evidence of an effect through the latter channel.

3 Experiment Associations Background

In the mid to late nineteenth century there were big changes occurring in North American agriculture that would eventually lead to technological advancements that would forever transform the practice of farming. In the United States the Morrill Act of 1862 had led to the establishment of agricultural colleges and with the Hatch Act of 1887 came the rise of the experiment station. In Canada the first agricultural college had opened in Quebec in 1859 and the Ontario Agricultural College and Experimental Farm was established in Guelph, Ontario in 1874. It began a program of experimental work two years later. These developments signaled the beginning of an institutionalized shift to a more systematic and academic approach to farming; agriculture was becoming a science in the truest sense complete with controlled laboratories and a research program. Although enrollments were generally low by today's standards it was certainly possible for young farmers to come to the agricultural college to learn the latest techniques. While the work of the agricultural colleges and experiment stations undoubtedly increased the amount of knowledge and led to the availability of improved crop varieties, it was not clear that the spillovers would necessarily be fully realized by ordinary farmers. That farmers would be eager to adopt the new technology based on the work of the stations was by no means a forgone conclusion; nor was it clear that the innovations derived through the work of the agricultural college would be effective in regions distant from the agricultural college once implemented there. Farmer experiment associations were created in part to address concerns such as these and had the advantage of essentially allowing researchers laboratory space in members' fields while giving farmers access to the experiment stations' latest innovations. Two such organizations will receive special attention in my paper, the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA). Both organizations were comprised of farmers who had received some formal training in agriculture, usually at the agricultural college. This was by design as researchers needed to be confident in the organization's ability to perform experiments. The general structure allowed for a systematic program of further testing of promising biological and non-biological innovations that had been developed through the research conducted by college and experiment station officials. The role of the experimenter was therefore to report the results to the researcher and to transmit the innovation to others in their community. The latter was to be done with a sort of evangelical fervor and there is anecdotal evidence suggesting this actually was the case.[1]

During this time period farmer associations were by no means a rarity. In the United States and Canada dairy producing areas had large, active associations for dairy farmers. The states of New York, Oregon, Minnesota, Texas, Alabama, and Illinois had experiment or seed growing associations of one sort or another during the time period I focus on. However, what set apart the OAEU and WAEA from most of the others was their structure and objectives. For these reasons I focus on these two organizations in particular. Created in Guelph, Ontario in 1879, to the best of my knowledge the OAEU was the first of its kind. In 1901 the WAEA was formed in Madison, Wisconsin and was patterned after the Canadian organization. Both shared important characteristics that made them unique for their time. First, each had a criteria for participation that included a level of scientific knowledge often based on formal training at the agriculture college. Second, each had the goal of conducting controlled experiments across their respective regions to continue research begun at the agricultural college to determine the optimal varieties and methods of cultivation for each area. This was important so that officials could determine which particular varieties should be directed to each county or district. Third, each had the goal of educating farmers so they might be more willing to adopt innovations from the agricultural college. Fourth, each had the goal of making improved varieties of seed available to ordinary farmers from those in their community. Both organizations were designed with the purpose of testing and disseminating biological and non-biological innovations and structured to allow diffusion to occur as fast as possible.

While the two organizations were otherwise quite similar, it is worth observing that there were differences. The OAEU placed a higher emphasis on uniform, controlled experiments and conducted trials with many varieties, seeking to educate farmers to make wise decisions regarding their seed acquisition. The WAEA was concerned more with the eventual dissemination of purebred seed and tested fewer varieties while working toward the goal of increasing the quantity of seed in order to distribute the improved varieties directly to farmers. Nevertheless in both the OAEU and the WAEA the researchers at the respective agricultural colleges were able to gain insights into their varieties from the results. This was probably a larger advantage in Ontario. Also, at the other end of the arrow of information flow, both organizations held similar benefits for participating experimenters and other farmers. In both cases experimenters were given access to the latest knowledge and best varieties earlier than non-participants. While in year t each experimenter would not have enough seed to plant their entire field, by year $t+1$ not only would seed be available, but so would knowledge

[1] In the comments section of the OAEU Annual Report for 1899, J.E. Frith of Oxford County proclaims,“The experiment actually became the leading topic of the village talk.”

about whether or not that variety was actually successful in their locality. In either case farmers were able to scale up their production of the variety for their own use and to sell to others. This was probably a larger advantage in Wisconsin where experimenters were to eventually become distributors of the particular variety they were testing. To the best of my knowledge the OAEU and WAEA were responsible for controlling the diffusion of all of the improved varieties developed at their respective experiment stations. Finally, the presence of a test in an area had the potential to lead to knowledge spillovers as nearby farmers were able to witness the results and learn about the specific innovation from the experimenter.

3.1 Ontario Agricultural and Experimental Union

The OAEU was formed by a group of college officials, students, and former students in 1879. The first experiments conducted through the organization were in 1886 and involved twelve members. Prior to that point the OAEU's biggest function was meeting annually at the Ontario Agricultural College (OAC). I am most interested in the activity of the OAEU from 1892-1899 which approximately coincides with the first years of testing crop varieties. Earlier experiments had mainly concerned the use of fertilizers or other cultivation techniques. During this time and for several decades afterwards the fellow in charge of the field crop experiments was Charles Ambrose Zavitz, himself an 1888 graduate of the Ontario Agricultural College. Originally the bylaws of the organization allowed only for paid members to receive experimental materials. However, the constraint was never binding since it was removed in 1886. Even so, scientific literacy was certainly important to ensure experimenters understood what they were doing to the extent necessary to conduct the experiment and therefore priority was given to paid members and to those who the OAEU believed could perform the experiments correctly.

From rather sparse beginnings the number of farmers conducting experiments through the OAEU grew steadily until early in the next decade when it expanded more rapidly. Some of the rapid expansion is attributable to its strategic recruitment efforts. For instance, in 1891 county secretaries were asked to provide names and mailing addresses of all former OAC students in each township, and in the event that there was not at least two, they were to nominate other farmers for participation. As a result, the OAEU was able to send a recruitment letter to around 800 farmers for that season. The recruitment efforts were successful and soon the number of experimenters greatly exceeded paid membership. Members of the OAEU initially paid a fee of $0.50 annually which rose to $1.00, but this was not a necessary condition for taking part in experiments. Therefore additional funds beyond annual dues were required to cover the costs of sending materials for each trial. To help it achieve its purpose the organization began receiving a government grant in the amount of $75 per year beginning in 1888. This amount was increased annually to allow the organization to accommodate growing numbers of experimenters. The total expenditure on experiments on field crops from 1886-1901 was $7528.20, (Zavitz 1903).

As membership grew, so did the scope of its activities. Eventually experiments encompassed many areas of agriculture outside of the study of field crops to include dairy, apiculture, and forestry among many others. My focus is on the activities of the OAEU with field crops and in particular concerning oats, peas, wheat, corn, and barley. Table 1 below displays these crops by acreage and shows the number of varieties that had been experimented upon at the Ontario Agricultural College and the number of varieties distributed throughout the province.[2]

Table 1: Significance of Field Crops in Ontario and Prominence with OAEU

Crops	Acreage, 1898	OAC Varieties since 1886	OAEU Varieties, 1898
Hay and clover:	2,453,503	71	9
Oats:	2,736,360	210	5
Winter wheat:	1,048,183	148	7
Peas:	865,951	100	5
Corn	520,696	219	6
Barley:	438,784	94	4
Spring wheat:	389,205	144	3
Potatoes:	169,946	236	6
Rye:	165,089	6	1
Turnips:	151,601	179	4
Buckwheat:	150,394	6	3
Mangels:	47,923	102	4
Beans:	45,220	41	3
Carrots:	12,418	60	5

The process of cooperative experimentation went as follows. After a period of trials at the Experimental Farm, often 3-5 years, the best performing varieties were selected for cooperative experiments and the poorest varieties were discontinued. As an example, during the 1894 season 80 varieties of oats were tested. Of these researchers decided to continue working with 17 varieties through cooperative experiments, (Zavitz 1894). According to (Zavitz 1903), the preparation for the experiments was tremendous. With the successful varieties identified a committee would determine what experiments would be conducted and would then work to assemble materials and instructions. These experiments were designed to meet the criteria of being valuable both to the researchers at the Ontario Agricultural

[2]Table 1 essentially reproduces the table found on pg. 15 of the 1898 annual report of the OAEU.

College and to the participating farmers themselves and to accomplish both they had to be feasible for experimenters to operate. Experimenters were to follow a strict protocol including specific dimensions of the plot to be used and were to report complete results back to the OAEU on a form that had been provided. Part of the purpose of the cooperative experiments was to spread information about the innovations being tested and so directly stated in the instructions was the imperative command to invite one's neighbors to observe the experiment, discuss it with friends, and mention it in the local newspaper (Zavitz 1903).[3]

With the preparation complete, each spring the OAEU mailed out a description of the experiments available that year and interested farmers returned the form indicating their top two choices. In addition to the preference indicated by one's response to the recruitment letter the materials for each experiment were distributed according to the following order of priority: first to official members who had paid their fee, then to experimenters who had participated the past year and done satisfactory work, then to other farmers whose participation had been recommended by officials from farmers' institutes, agricultural societies, agricultural colleges, or the public schools, and finally to those who had learned about the experiments and were interested, (Zavitz 1903). As an example of the magnitude of the recruitment efforts and response rate, in 1892 the recruitment letter had been sent to 1,500 folks and 754 participated in experiments. Nevertheless, relative to the stock of experiment materials typically there was excess demand because there was not always the financial resources provided for all of those who were willing to participate.

According to Zavitz, only reports that had been filled out completely and correctly would be counted as satisfactory. These are the experimenters that I am able to observe. Also I generally do not observe non-experimenting members during the relevant period. Even minor deficiencies was sufficient for excluding a report as unsatisfactory. Because the OAEU only reported results of satisfactory experiments in its annual reports, and not of all experiments that had taken place, it is unclear how many total experiments were performed on field crops in a given year, nor is it clear what share of those conducting experiments had no other affiliation with the Ontario Agricultural College and were otherwise ordinary farmers, albeit scientifically inclined. At best my results can say something concrete about the effectiveness of *successful* experimenters.

Any effect the OAEU had probably came through the following means. With the benefit of having results from trials across the province, researchers at the experimental farm were in a much better position to assess the potential of particular varieties. Further, to the extent that the experimenters were successful in sharing knowledge of their experience with others,

[3]Based on the reports received, Zavitz claimed that in 1902 at least 25,000 people had seen the cooperative experiments with oats.

Table 2: Summary of OAEU Agriculture Experiments 1891-1899

Year:	1891	1892	1893	1894	1895	1896	1897	1898	1899
Experiments:	12	12	13	14	15	16	18	19	23
Experimenters:	203	754	1,204	1,440	1,699	2,260	2,835	3,028	3,485
Satisfactory Reports:	126	295	416	504	513	501	610	667	739

nearby farmers would have a better idea of which variety would be best for their own fields. Experimenters were generally allowed to keep the seed and crop produced through the trials and were encouraged to sell the seed to their neighbors. In this way those in the community would have access to the successful varieties the following year.

3.2 Wisconsin Agricultural Experiment Association

In 1848 Wisconsin gained statehood and its flagship university was founded in Madison. In 1883, four years prior to the federal Hatch Act, the Wisconsin state legislature provided for the creation of an experiment station to work in conjunction with the existing University Farm. In 1905 additional station branches opened in the northern regions of the state to create laboratory conditions more relevant to those areas. The primary means of information diffusion in the state at this time were annual reports and other bulletins. In addition there were Farmer's Institutes that had been held across the state beginning in 1885 and the Wisconsin College of Agriculture's Short Course in Agriculture that was started in 1895. The course was geared toward young farmers who could come to study in Madison for a short period of time in order to quickly learn practical applications of the knowledge developed through research at the stations. The WAEA was formed in 1901 with 187 members many of whom would cooperate to test and disseminate both biological and non-biological innovations originating from the Experiment Station. By 1908 there were over 1,500 members of the organization. Examples of their activities include selecting the best varieties of seed to plant in the state and determining the optimal formaldehyde solution to deal with smut affecting oats and barley. I focus on their work with oats, corn, and barley because these three crops not only comprised the majority of the experimental activity but were important to the state. I am most interested in its activity from 1903-1911 which coincides with the first years of activity with these crop varieties. R.A. Moore, a professor of agronomy at the University of Wisconsin, oversaw the field crops branch of experimentation for the WAEA.

To become a member one must have attended a Short Course or have had some equivalent formal training in agriculture at a county school or another agricultural college as well as pay $0.50 in annual dues. As in Ontario the reason for the strict membership requirement was to

Table 3: Significance of Field Crops in Wisconsin

Crops	Acreage, 1906
Oats:	2,072,381
Corn	1,315,724
Barley:	712,845
Rye:	306,460
Wheat:	213,754
Potatoes:	222,447

ensure that experimenters would have a certain level of scientific literacy that could be relied upon by station researchers. Unlike in the OAEU, here this membership requirement was generally not relaxed. However others could be admitted into the organization as honorary members by way of majority vote at the annual meeting and therefore become eligible to conduct official WAEA cooperative trials. The WAEA began receiving a grant from the state legislature in 1903 of $1000. State funding from this same act also covered the cost of distributing 5,000 copies of the organization's annual report which published findings from the experiments and lists of those with seed for distribution that year.

The experimentation and dissemination process of the WAEA began at the Experiment Station where researchers would isolate a particular promising variety. Once the station had grown enough seed of that variety, it would be distributed to members for acre sized trials. Those receiving seed and conducting experiments were then to report the results of their tests back to the station so that the results would be compiled, analyzed, and published in the annual bulletin of the WAEA. As with the OAEU, quite often the number of reports the WAEA counted was smaller than the total number of experiments from that season. It is unclear whether the WAEA ever tossed out submissions, but it seems in many cases this gap was due to experimenters failing to submit their report altogether. Sometimes the annual report of the WAEA would provide numbers of experiments conducted, numbers of reports received, and numbers of good results but none of these measures identified particular members. As far as members, what I actually observe from the WAEA is a list for each year without mention of their involvement with particular experiments.

In each annual report the WAEA also published a list of seed grain growers in order to help farmers find those nearby from whom they could obtain the improved seed for the upcoming season. The 1905 WAEA Seed Grain Growers list is prefaced by the following statement, "Members of the Experiment Association are rapidly becoming the seed growers of the state, and by systematic selection of seed and care in culture and curing of the crop, produce a fine grade of pure-bred seed grains. These seed grains are sold by the producer either in small or large quantities, at reasonable rates." Ordinary farmers inquiring at the experiment station or agricultural college for seed were directed to the experimenting member located nearest to them. Experimenters were therefore able to sell the seed to their neighbors and others who approached them looking for seed. The growers appearing in these lists were often members although there are a number of names each year that are not found on the official membership roll. However, the crop varieties listed all came from the experiment station and since the dissemination of these improved varieties went through the WAEA, it is reasonable to assume that even if particular individuals on the lists were not members themselves at minimum they had obtained their initial stock of seed from one who was. Additional criteria for appearing on the list mostly dealt with meeting quality standards such as having grown the seed on land without weeds and having treated the seeds to prevent smut.

Unlike the Canadian organization, the WAEA focused on testing and distributing fewer varieties of each crop. The primary varieties were Swedish Select oats, Oderbrucker barley, and Silver King corn. Each of these followed a similar pattern from acquisition by the station to eventual widespread dissemination within the state. The Wisconsin Experiment Station had obtained Swedish Select in 1899 and had worked to improve it until 1902 when it was first distributed to the WAEA for cooperative experiments. By 1906 the testing phase had been completed and members had grown the variety only for seed. In 1911 the WAEA resumed experimentation on oats with an improved variety called Wisconsin Select. The Wisconsin Experiment Station had obtained Oderbrucker in 1898 from the Ontario Agricultural College; by 1905 the variety was improved and sent to the WAEA for trials. In 1908 the variety was officially released for dissemination. R.A. Moore first began testing Silver King corn in 1903 and released it for cooperative experiments in 1904. This information is collected in Table 4 below:

Table 4: Approximate Timeline of Important WAEA Crop Varieties

Variety:	Swedish Select (oats)	Oderbrucker (barley)	Silver King (corn)
Year obtained:	1899	1898	1903
Year released to WAEA:	1902	1905	1904
Year disseminated:	1906	1908	1907

4 Data and Empirical Strategy

4.1 Data

The primary data for the experiment association in Ontario is obtained from three sources. From the Annual Report of the Bureau of Industries for the Province of Ontario I obtain county and district level, crop, livestock, and market data for years 1882-1902. From the Annual Report of the Ontario Agricultural College and Experimental Farm, which often contained the Annual Report of the Agricultural and Experimental Union, I have obtained names and counties of each successful experimenter. I observe those experimenting with oats, corn, and wheat from 1891-1899, with barley from 1892-1899, and with peas from 1893-1899. Prior to 1891 there was some experimentation on crop varieties but few experimenters were involved and the listings reveal nothing about specific crops. I am unable to observe membership of the OAEU with the exception of one year, 1893. Climate data has been accessed through the National Climate Data and Information Archive. From this source I observe monthly average temperature and monthly rainfall at several weather stations within Ontario.

The primary data for the WAEA comes from three sources. From the Annual Report of the Wisconsin State Board of Agriculture I obtain county level crop and livestock statistics for the years 1903-1912. A typical report from year t includes acreage for year t and bushels harvested in year $t-1$. These reports do not specify whether these are acres planted or acres harvested, nor is it mentioned if the yield includes crop removed for silage. It appears from the language used that the listed acreages do in fact refer to acres planted and yields do not include crop for silo.[4] From the annual reports of the Wisconsin Agricultural Experiment Association I obtain membership lists from 1903-1912 and lists of the growers of seed from 1904-1911 which allow me to observe names and counties.[5] The bulletins were published over the winter and in order to be included in the list of growers one must have seed available for the upcoming season. After 1912 the WAEA published its list of purebred seed growers separately from the annual report apparently since it had become lengthy and also since a separate publication could be released within a better timeframe relative to the planting season.[6] I obtain monthly weather data from the U.S. Historic Climatology Network

[4]Further anecdotal evidence for belief that the acreage data includes crop for silage while my yield data is missing crop removed for silo is that the these agricultural statistics later appeared in biennial reports beginning around 1916, some of which disaggregate acreage into harvest for market and for silo with total acreages comparable to those reported 1903-1912.

[5]For the years 1904-1906 cities were included instead of counties and so counties were determined from city data.

[6]These have been obtained sporadically for years extending into the 1920's but with large gaps.

for the year 1900-1915. With these records I am able to observe monthly temperatures (minimum, maximum, and average) and precipitation collected at weather stations in the region. Through the use of a triangular interpolation method it is possible to obtain county level observations. This is discussed in further detail later in this section.

4.2 Empirical Strategy

Both the OAEU and the WAEA were structured to encourage the diffusion of information and improved seed with the goal of both allowing researchers to determine the best varieties and to help farmers make wise planting decisions. I conduct an empirical analysis of each organization and estimate the extent of their success in facilitating the diffusion of biological and non-biological innovations originating from the experiment stations. If the OAEU and WAEA were successful I expect to see counties with a higher concentration of experimenters to have higher yield rates, ceteris paribus. With the model for the OAEU I am primarily able to study the flow of information regarding the performance of crop varieties because what I observe are experimenting members each of whom may or may not have been also distributing seed. With the model for the WAEA I am able to investigate the flow of both information and improved seed. I observe seed growers affiliated with the association and therefore look for their influence on seed diffusion. I also separately observe members of the WAEA and this can capture their educational and information transmission function.

The models I estimate for these experiment associations each makes use of a separate panel dataset consisting of all counties and districts in the respective state or province. In order to analyze the impact of their activities I am interested in the effect of the measure of experimenters, seed growers, and members on the crop yield per acre in a county for each of the crops in my dataset that the associations worked with. For Ontario this is oats, peas, corn, barley, and wheat while for Wisconsin this is oats, corn, and barley.

For both regressions the central identifying assumption is that changes in experiment association activity within a county is unrelated to changes in unobserved determinants of crop productivity. In order to estimate the effect of the OAEU, I model yield per acre for a specific crop in county t and in year i under the following linear assumption,

$$y_{i,t} = \alpha_0 + \alpha_1 exper_{i,t} + \alpha_2 exper_{i,t-1} + \alpha_3 exper_{i,t-2} + \gamma W_{i,t} + C_i + T_t + \varepsilon_{i,t} \quad (1)$$

In equation (1) the dependent variable $y_{i,t}$ represents bushels per acre harvested in a county for a specific crop and is directly observed from the Ontario crop data while α_0, α_1, α_2, α_3, and γ are unknown parameters to be estimated. The OAEU experimenter count in the county is represented by $exper_{i,t}$. Given that experiments were conducted in period t with results and seed available in $t+1$ it is appropriate for this variable to be lagged in the regression. However, in order to account for the possibility that the effect is distributed over a period of time I include two lags, $exper_{i,t-1}$ and $exper_{i,t-2}$. I denote the vector of weather controls by W. County and year fixed effects are represented by C_i and T_t, respectively. Lastly, ε is a vector of unobserved variables that effect the bushels per acre harvested.

In order to estimate the effect of the WAEA, I model yield per acre for a specific crop in county t and in year i under the following linear assumption,

$$y_{i,t} = \beta_0 + \beta_1 mem_{i,t} + \beta_2 grow_{i,t} + \beta_3 grow_{i,t-1} + \delta W_{i,t} + C_i + T_t + \varepsilon_{i,t}. \tag{2}$$

In equation (2) the dependent variable $y_{i,t}$ represents bushels per acre harvested in a county for a specific crop. This is not directly observed from the Wisconsin crop data and therefore is calculated from the yield and acreage data that is present. The coefficients β_0, β_1, β_2, β_3, and δ are unknown parameters to be estimated. The WAEA membership count in the county is represented by $mem_{i,t}$ and the number of WAEA seed growers in the county is represented by $grow_{i,t}$. The timing of the program is such that the growers I observe in year t are to have seed ready for distribution and planting in year t. However, I include the lag, $grow_{i,t-1}$, in the regression because it is reasonable to expect the effect to occur over more than one year. I include a vector of weather controls, W, and represent county and year fixed effects with C_t and T_t, respectively. Lastly, ε is a vector of unobserved variables that effect the bushels per acre harvested.

4.3 Identification

In equation (1) the parameters I am interested in identifying are α_1, α_2, and α_3 which serve to capture the effects and lagged effects of experimentation. If the OAEU was successful in determining through experimentation the best varieties for a particular locality and in spreading this knowledge, I expect areas with higher numbers of experimenters to have higher yielding crops, ceteris paribus. Therefore, I expect to see $\alpha_2 > 0$, and if the effect is distributed over time, I expect $\alpha_3 > 0$ where α_2 and α_3 are the coefficients on $exper_{i,t-1}$ and $exper_{i,t-2}$ respectively. There is no strong reason to expect to measure a contemporaneous effect, but if one were present then I should see $\alpha_1 > 0$ where α_1 is the coefficient on $exper_{i,t}$.

In equation (2) the parameters I am interested in identifying are β_1, β_2, and β_3 which correspond to the effects of members, growers, and lagged growers respectively.[7] The WAEA

[7] As mentioned earlier there is a great deal of overlap between lists of WAEA members and seed growers, however, neither list is a proper subset of the other. If any of those listed on the grower list were not actual members of the WAEA, I can at least be confident that they obtained their original stock of seed from one who was.

attempted to disseminate seed as well as to educate farmers through formal workshops, published reports, and word of mouth. If the WAEA was successful in diffusing knowledge and improved seed, I expect areas with higher numbers of members and growers to have higher yielding crops, ceteris paribus. Since I observe WAEA seed growers with seed for sale that season it is reasonable to expect a contemporaneous effect, however, the lagged measure has been included in case this effect is distributed over time. This is reasonable because with more growers from the prior year, there is more seed available for sale to other farmers in which case I expect to see yields expand. Therefore, I expect to see $\beta_1 > 0$ and $\beta_2 > 0$ from the coefficients on mem and $grow_{i,t}$ respectively. If the effect of the seed dissemination efforts occurs over a longer time period I expect also to see $\beta_3 > 0$ from the coefficient on $grow_{i,t-1}$. Potential buyers from the WAEA seed growers were often non-WAEA members and therefore β_2 and β_3 measure the effect of this program.

Time-variant data allows me to plausibly consistently estimate equations (1) and (2) after controlling for county fixed effects. Time invariant county fixed effects control for aspects such as soil type, access to irrigation, and distance to the Ontario Agricultural College and Experimental Farm or to the Wisconsin Agricultural Experiment Station and its branches. Therefore the identification of the effect from the OAEU and WAEA comes through within county variation over time. I cluster the standard errors on the county. Also, year fixed effects control for all influences that are constant across counties in each time period. I control for weather shocks through the use of monthly climate variables. In order to control for temperature and precipitation in Wisconsin I use data from the U.S. Historic Climate Network for the years 1900-1915. In order to control for temperature and precipitation in Ontario I use data from the National Climate Data & Information Archive for the years 1886-1902. This climate data was collected at weather stations throughout the state or province and during the period studied often a county lacked a station. Therefore, to create county-year weather controls I use a method of triangular interpolation as in Kitchens (2012).[8] For each year, the latitude and longitude of each weather station is used to determine the three closest weather stations to each county seat and for each county the weather station data are weighted by this distance. Specifically, the weight for each measure is $w_i = \frac{1}{2}(1 - \frac{d_i}{d_1+d_2+d_3})$.

There are several sources of endogeneity that may enter regression equations (1) and (2). One potential source has to do with the selection of farmers into the association as experimenters. If it were true that on average the experimenters who joined were better farmers to begin with and therefore also had better crops it certainly could lead to my results overstating the effectiveness of the experiment associations. On the other hand it could be that experimenters joined in larger numbers when they sensed their crops were in

[8]I appreciate the generosity of Carl Kitchens for access to the code and U.S. Historic Climate Data.

trouble hoping to have access to better technology and to catch the attention of researchers. If this were the case and farmers tended to join when they had a negative forecast, thereby increasing the census of experimenters within a county, any effect I find should be a lower bound. Another potential source of endogeneity, as discussed earlier, arises if those experimenting had systematically underreported negative findings or had been excluded for other reasons for instance as per the policies of the OAEU. To the extent that one believes that the unsuccessful reports still resulted in information gains for farmers or researchers this would also probably introduce downward bias and cause the effect I estimate to be lower than in actuality. County and year fixed effects should control for many issues however this non-classical measurement error could introduce bias in a detrimental way if correlated with dependent variables. Relatedly, endogeneity may also enter if it was the case that experimenters used their best land for the trials. If this were true then it could be the case that the presence of experimenters was less valuable because the yield advantages in their reported results would be overstated. Finally, there could be cross county spillovers; counties with few experimenters may still benefit if there are experiments conducted near the county line. In this case my results should be a lower bound on the true effect. In many cases the potential sources of endogeneity should go in a direction causing downward bias. Nevertheless, as mentioned, it is also possible that endogeneity could present more of a problem.

5 Results

My main findings are that both the OAEU and WAEA had a statistically significant effect on the crop productivity of their respective regions, that the timing of this effect provides evidence for rapid diffusion through these networks, and that the greatest effect tended to be present in the crops that figured more prominently in their program of cooperative experimentation. When the OAEU had an effect on crop productivity it was delayed and often distributed over the two years beyond an experimental trial. On the other hand, the effect from the WAEA was immediate and it was necessary not only to have members present in a county, but also to have seed growers making the improved varieties available. These findings suggest that not only did the OAEU and WAEA have an effect on crop productivity, but that they accomplished their goal of swift diffusion. From the results it is possible to conclude that either the programs worked or there is an endogenous selection issue that is getting picked up and reflected in the findings. Based on the anecdotal evidence in the annual reports it seems the former is the case. Full results are collected in the appendix. One specification was used for all crops of the OAEU and these are reported in Table 8. For the WAEA results are reported for all three crops both with and without dropping Dane county. These are reported in Table 9. All regressions use both county and year fixed effects as well as monthly climate variables which control for weather shocks.[9]

Column (1) in Table 8 displays results demonstrating the statistically significant effect of OAEU experimenters on oats productivity. The coefficient of the lagged experimenter count within a county is 0.216 and a one standard deviation increase in oats experimenters in year $t-1$ is associated with a 0.075 standard deviation increase in oats bushels per acre in year t. The coefficient on $exper_{i,t-2}$ is 0.223 and a one standard deviation increase in oats experimenters in year $t-2$ is associated with a 0.077 standard deviation increase in oats bushels per acre in year t.[10] Both effects are statistically significant at the 5% level and the distributed lag provides evidence that the impact was not fully realized over a single time period. Complementary to my empirical results is anecdotal evidence suggesting the OAEU perceived its own effectiveness. Some annual reports included favorable testimonials of farmers who had experimented with the crop. One such comment attested to the fact that the writer had been successful in promoting the usage of the variety in his community.[11] Further, in a typical annual bulletin following the numerical summary of experimental results they would provide a small section with conclusions which typically listed which varieties had performed the best or were most popular. For oats during my sample period the preferred type was often the Siberian variety which, according to Zavitz (1903), became widely grown in the province.

My findings also show a statistically significant effect of the OAEU on the productivity of Ontario's peas crop as shown in column (3) of Table 8. The coefficient of $exper_{i,t-1}$ is 0.238 and a one-standard-deviation increase in the number of experimenters is associated with a 0.089 standard deviation increase in yields per acre the following year.[12] There are mixed results pertaining to the effectiveness of the OAEU with other crops. The effect of experimentation on barley and winter wheat was also shown to be statistically significant, however, the results show that for these crops there was an immediate effect. This is illustrated in Table 8 in columns (4) and (5), respectively. It seems odd that the data would allow observation of any immediate effect of the OAEU on crop productivities and it is possible that these results are reflecting omitted variable bias. Another possible explanation, at least for winter wheat, could be that the results are instead picking up a timing issue in the data. Winter wheat was planted in the fall and harvested the following summer. A problem

[9]The tables report robust standard errors in parentheses clustered on the county and $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

[10]The elasticities are 0.009 for both lagged variables on oats.

[11]In the 1899 OAEU Annual Report, Nelson Montieth of Perth County recounts his experience, "By an experiment with oats, I introduced an early variety into our section, which has been of material advantage to the farmers, and is now generally grown by them."

[12]The elasticity is 0.01 for peas

would arise if there was inconsistencies across crops with how either the Ontario Bureau of Industries or the OAEU assigned crop years in the data I have collected. Were this to be the case I could be assigning year t to a winter wheat experimenter count that really should be assigned year $t-1$. At any rate, winter wheat was an important crop both for the province and for the OAEU and it stands to reason there would have been some effect. There was no statistically significant effect demonstrated by the results for corn or spring wheat. That this would be the case is not surprising; much of the activity of the OAEU with corn was with growing crop for fodder and spring wheat was of relatively low prominence for both Ontario and the association.

The results from the WAEA are reported in Table 9 with and without including Dane County which is home to Madison and the University of Wisconsin. As indicated in the bottom row of the table Dane has been dropped from the estimation reported in even numbered columns. The reason for doing this is because many of those involved with the WAEA were likely associated with the Experiment Station or agricultural college and therefore not likely to be quite the same as ordinary members or growers in terms of disseminating seed to ordinary farmers. The findings displayed in column 7 of Table 9 show that the coefficient on $grow_{i,t}$ is 0.327 and statistically significant at the 5% level.[13] A one standard deviation increase in the number of oats growers was associated with a 0.084 standard deviation increase in the yield of oats. The success of the Swedish Select oats was recognized by members of the WAEA and documented in their annual reports. Each year a few members would submit a letter explaining their experience with the variety. In one such letter Edward F. Heuer of Waushara county explains that his crop yielded about 40 bushels per acre while that of his neighbor yielded 26 bushels per acre. He points out that assuming a market price of $0.35 per bushel and 20 acres devoted to oats, the net advantage associated with this improved variety would be $98. (WAEA 1904).

Also of note is the statistically significant positive effect on barley which reflects the efforts of WAEA seed growers to disseminate barley. The coefficient on barley growers is 0.111 which is statistically significant at the 10% level.[14] Their efforts were concentrated primarily on promoting a variety called Oderbrucker which was known to be higher in a type of protein that may have made them better for feeding than the existing variety, Manshury. However, it was unclear at least initially whether this new variety would be good for brewing. In reporting on the experiments in 1904, R.A. Moore mentioned that the Oderbrucker variety would not be released until a laboratory in Chicago had completed a malting test and he expressed his concern that entire communities would successfully coordinate on the same

[13] The elasticity is 0.02 for oats.

[14] The elasticity for barley is 0.033

variety to suit the market conditions which were strongly influenced by the brewing industry (WAEA 1904). This variety was later demonstrated to be acceptable both for brewing and for feed. Brewers desired a uniformity across the barley crop and so it was advantageous to work to resolve a coordination problem. This being the case, it is possible my empirical results are reflecting best responding behavior in light of farmers' purposes for growing the crop and the actions of the others in their county.

Finally, the coefficient on corn is -0.381 which is significant at the 5% level when Dane county, which lies in prime Wisconsin corn country, is removed from the estimation. Returning this county does not change the sign, but the effect loses significance. While my empirical results show a negative and statistically significant effect of the WAEA's work on the productivity of corn there is also anecdotal evidence at least to support the absence of a significant, positive effect. In the WAEA Annual Bulletin of 1905, R.A. Moore had indicated his expectation that Silver King corn would follow the same trajectory as Swedish Select oats. Shortly thereafter a number of members had submitted favorable reviews of their experience with this variety. However, in the 1910 Annual Bulletin, Moore describes their present position with their work on corn and barley as "at the threshold of success" (WAEA 1910). Indeed this would be an odd way to describe the progress of the past five years had he believed that the results had fulfilled the initial optimism. On the other hand, Moore was not ready to declare success with barley either, contrary to my findings. It is possible that some of the difficulty with these crops had to do with the failure to find appropriate varieties for particular regions. After all, the WAEA worked with comparatively few varieties of each crop and it may be the case that oats with its Swedish Select variety was simply much more appropriate for universal adoption of a single variety than corn.

Besides simply having found a statistically significant effect for both the OAEU and WAEA something more can be said about the time period over which the diffusion occurred. The distributed lag demonstrates that the influence of the OAEU on crop productivity was delayed and spread over time. Given the structure of the program the finding of a delay in its impact is reasonable. In year t, varieties were provided to experimenters to plant small test plots and in the year $t+1$ researchers learned the results of the tests and experimenters had seed to plant and sell. Further, given the sort of information to be spread it is reasonable that there would be evidence suggesting a delay is natural. In addition to the time needed to complete experiments and scale up production of seed it likely took some time for farmers and seed suppliers to adjust their behavior. Similarly, for the WAEA, that the results show an immediate impact is reasonable given the fact that my measure of growers is of members that had seed available for distribution that same year. There is no statistically significant lagged effect of grower count which runs against what one might have expected. While there is an effect on productivity due to the dissemination activities of seed growers, my findings demonstrate no effect from the WAEA members who were not growing seed for distribution that year. Therefore, in order for there to be an effect from the WAEA the county needed to have members that were also seed growers. However, when seed growers were present the effect was immediate. So while the timing of the effect differed for each association, the findings concerning both experiment associations are intuitive as explained by the preceding.

Finally, the results show that the effects tended to show up in the crops for which the respective association had most focused on. For both the OAEU and WAEA the effect on oats was positive and statistically significant and in both cases this was among the very first crops tested by the association. In the OAEU there generally were more experimenters working with oats than any other crop. The exception was winter wheat which received the greatest focus beginning in 1895. Behind oats in experimenter count was peas, the other OAEU crop for which there was a statistically significant positive, delayed effect. The story is similar in Wisconsin. In the WAEA by 1906 the number of growers of barley and corn had exceeded that of oats. However, Swedish Select had been their first success and continued to be mentioned frequently in the annual reports despite it no longer being necessary to determine the effectiveness of the variety through experimentation. It is then reasonable that they would shift their resources largely into corn and barley in the hopes of making progress there as well. Taken altogether, the effectiveness of these two organizations tended to be associated with crops that were prominent in their experimentation programs.

6 Concluding Discussion

Rarely have economic historians been able to trace the information flow that leads to the diffusion of technology. In this paper I aim to fill this gap using data on two experiment associations that were used as intermediaries to bring innovations directly to farmers. I study the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA) during the early years of their existence, 1886-1900 and 1903-1911, respectively. I find that both organizations had a positive and statistically significant effect on the productivity of oats as measured by average yield per acre within a county. I also find a positive and statistically significant effect of the experimentation activities of the OAEU on the productivity of peas, barley, and wheat. My results provide insight into how the timing of the diffusion patterns through each mechanism worked. I find a delayed effect of the cooperative experiment activities of the OAEU and an immediate effect of the dissemination activities of the WAEA. These results provide insight into the rate of diffusion through the network, which in both cases, was quite rapid. Finally it is noteworthy that the effects of the OAEU and WAEA tended to be present in crops for which experimental activity was relatively intense during the period I study. These results match the historical evidence for how these associations were structured and behaved.

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Table 5: Summary Statistics: Ontario Crop Yields

	Oats					Corn					Peas				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1886	35.59	3.85	30	44	45	.	.	.	.	.	21.93	2.19	17	27	45
1887	28.99	5.13	20	41	45	48.51	13.11	27	92	45	16.58	4.64	10	31	45
1888	34.65	7.94	20	47	45	64.39	18.38	28	95	45	20.28	5.05	10	28	45
1889	32.70	4.41	25	41	45	52.67	10.15	35	81	45	18.34	3.69	9	27	45
1890	27.00	3.49	18	36	46	56.54	10.50	37	75	46	19.37	2.90	12	25	46
1891	39.08	5.25	26	49	46	69.36	13.33	40	89	46	23.51	3.19	14	29	46
1892	33.61	4.56	25	41	46	60.34	9.57	40	90	46	17.42	4.13	7	27	46
1893	28.88	4.36	19	38	46	56.49	10.58	38	76	46	18.26	3.08	13	28	46
1894	28.24	4.69	17	38	46	56.46	9.35	30	79	46	17.07	2.82	11	22	46
1895	34.44	5.07	26	46	46	68.44	13.59	40	95	46	19.23	3.21	14	28	46
1896	33.39	3.77	25	41	47	62.66	13.72	38	88	47	20.35	2.76	15	26	47
1897	33.63	4.41	22	42	47	64.01	13.26	36	83	47	15.96	2.86	10	24	47
1898	35.06	4.58	23	45	47	54.74	13.96	30	89	47	15.81	3.26	9	24	47
1899	36.31	4.67	27	47	47	.	.	.	.	0	19.25	2.98	12	25	47
1900	36.37	4.41	28	45	47	.	.	.	.	0	19.80	2.85	14	25	47
	Barley					W.Wheat					S.Wheat				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1886	26.33	3.07	20	34	45	20.14	2.95	15	26	45	15.76	2.52	12	22	45
1887	22.41	3.20	17	30	45	16.45	2.40	11	26	45	11.50	3.09	6	21	45
1888	26.74	5.75	16	35	45	17.86	4.28	8	28	44	16.92	3.13	12	24	45
1889	25.78	3.15	20	32	45	16.60	2.76	12	24	44	14.03	2.34	10	20	45
1890	21.96	3.19	16	30	46	17.94	3.27	12	24	46	13.36	2.27	9	18	46
1891	28.25	3.93	16	40	46	23.12	4.15	16	30	44	20.11	3.21	14	30	46
1892	23.81	3.08	17	32	46	21.40	2.77	15	27	44	12.85	2.78	8	19	46
1893	20.77	2.97	14	26	46	18.78	2.40	12	23	46	11.82	2.35	6	18	46
1894	21.56	3.40	14	28	46	20.01	2.95	12	25	46	14.03	2.52	9	21	45
1895	24.91	3.82	18	33	46	20.03	3.95	10	28	46	15.38	2.82	8	21	46
1896	26.12	3.23	18	33	47	18.24	4.58	7	27	47	13.21	2.88	8	20	47
1897	25.31	3.00	18	30	47	21.25	5.48	10	30	47	14.93	2.05	10	20	46
1898	27.41	3.70	16	33	47	23.62	2.91	18	30	47	16.81	2.59	11	23	47
1899	28.39	3.53	22	35	47	14.84	3.80	8	27	47	16.20	2.60	11	21	47
1900	28.06	3.23	21	34	47	20.86	3.29	12	26	47	17.42	2.23	12	22	47

Table 6: Summary Statistics: OAEU Experimenters

	Oats					Corn					Peas				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1890	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.00	0.00	0	0	46
1891	0.78	1.11	0	4	46	0.22	0.59	0	3	46	0.00	0.00	0	0	46
1892	2.65	2.81	0	12	46	0.43	0.78	0	4	46	0.00	0.00	0	0	46
1893	2.15	2.22	0	11	46	0.72	0.83	0	3	46	1.52	1.96	0	8	46
1894	2.59	2.35	0	9	46	0.43	0.58	0	2	46	1.35	1.58	0	6	46
1895	1.83	1.76	0	6	47	0.60	0.74	0	2	47	1.49	1.98	0	10	47
1896	1.85	2.11	0	8	46	1.06	1.17	0	4	47	1.53	1.87	0	7	47
1897	1.89	2.24	0	9	46	0.83	1.03	0	4	47	1.19	1.45	0	6	47
1898	2.24	2.57	0	12	46	0.94	1.33	0	5	47	1.47	1.91	0	7	47
1899	2.47	2.45	0	11	47	0.26	0.57	0	2	47	1.91	2.13	0	8	47
1900	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0
	Barley					W.Wheat					S.Wheat				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1890	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.00	0.00	0	0	46
1891	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.78	1.11	0	4	46
1892	0.11	0.31	0	1	46	1.26	1.87	0	7	46	0.78	1.05	0	4	46
1893	0.24	0.52	0	2	46	1.28	1.94	0	7	46	0.61	0.98	0	4	46
1894	0.61	1.02	0	4	46	1.70	2.43	0	8	46	0.41	0.88	0	5	46
1895	0.47	0.86	0	4	47	2.13	2.60	0	10	47	0.26	0.49	0	2	47
1896	0.55	0.88	0	4	47	1.98	2.46	0	10	47	0.36	0.70	0	3	47
1897	0.36	0.92	0	5	47	4.96	6.51	0	26	47	0.66	0.96	0	4	47
1898	0.66	1.03	0	4	47	4.02	4.46	0	20	47	1.32	1.29	0	5	47
1899	1.11	1.20	0	4	47	1.47	2.06	0	10	47	0.62	0.97	0	4	47
1900	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0

Table 7: Summary Statistics: Wisconsin

	Wisconsin Crop Yields														
	Oats					Corn					Barley				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1903	27.31	8.53	8	61	69	21.64	14.36	0	101	69	23.31	11.33	2	84	69
1904	29.00	8.18	8	61	66	18.09	10.02	0	39	66	27.59	16.92	1	136	66
1905	31.10	10.58	10	72	66	29.94	22.44	1	188	66	26.05	10.36	0	61	66
1906	29.34	8.25	4	57	66	32.71	13.98	2	101	66	26.74	12.86	1	91	66
1907	19.82	5.46	9	41	70	20.97	8.40	1	53	70	20.35	12.58	2	103	70
1908	25.23	7.32	7	46	70	23.31	17.41	1	141	70	26.24	15.79	5	141	70
1909	28.17	7.24	10	47	68	24.09	9.80	0	46	68	22.78	5.91	3	50	68
1910	19.81	8.66	5	42	69	23.34	12.39	2	70	69	16.79	8.99	2	50	69
1911	23.41	7.00	2	35	70	25.54	7.86	4	42	70	18.92	5.37	1	35	70
1912	29.73	8.89	4	54	71	23.65	21.29	1	184	71	20.40	7.11	8	45	71
	WAEA Seed Growers														
	Oats					Corn					Barley				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1903	0.00	0.00	0	0	69	0.00	0.00	0	0	66	0.00	0.00	0	0	66
1904	0.85	0.95	0	5	66	0.00	0.00	0	0	66	0.00	0.00	0	0	66
1905	1.08	1.23	0	7	66	0.38	0.67	0	3	66	0.00	0.00	0	0	66
1906	1.45	1.66	0	8	66	2.24	2.71	0	16	66	3.70	4.78	0	29	66
1907	2.53	3.03	0	17	70	8.14	9.93	0	63	70	5.74	6.54	0	40	70
1908	2.56	2.59	0	12	70	5.67	7.47	0	42	70	4.97	5.71	0	31	70
1909	2.97	3.03	0	13	68	13.31	16.17	0	100	68	12.97	16.97	0	123	68
1910	3.41	3.57	0	16	69	12.91	15.55	0	92	69	25.57	31.43	0	211	69
1911	0.47	0.91	0	5	70	17.27	20.19	0	125	70	15.70	19.52	0	127	70
1912	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0

Table 8: OAEU Regression Results 1886-1900

Crop	Oats	Corn	Peas	Barley	W. Wheat	S. Wheat
	(1)	(2)	(3)	(4)	(5)	(6)
Experimenters_t	0.159	-0.727	0.116	0.420**	0.233**	0.022
	(0.097)	(0.699)	(0.103)	(0.175)	(0.082)	(0.109)
$\text{Experimenters}_{t-1}$	0.216**	0.766	0.238**	0.366	-0.125	0.065
	(0.105)	(0.642)	(0.110)	(0.222)	(0.072)	(0.129)
$\text{Experimenters}_{t-2}$	0.223**	1.091	-0.165	0.088	0.085	0.143
	(0.103)	(0.901)	(0.123)	(0.189)	(0.076)	(0.188)
County	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.619	0.388	0.527	0.598	0.428	0.632
N	409	363	409	409	405	408

Table 9: WAEA Regression Results 1903-1911

Crop	Oats	Oats	Corn	Corn	Barley	Barley
	(7)	(8)	(9)	(10)	(11)	(12)
Members	0.012	-0.005	0.047	0.091	-0.004	0.004
	(0.033)	(0.054)	0.101	(0.118)	(0.062)	(0.098)
Growers_t	0.327**	0.403**	-0.221	-0.381**	0.111*	0.177*
	(0.159)	(0.175)	(0.153)	(0.189)	(0.062)	(0.099)
Growers_{t-1}	0.021	0.117	0.307	0.413	-0.088	-0.133
	(0.184)	(0.188)	(0.226)	(0.317)	(0.042)	(0.061)
County	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.370	0.369	0.212	0.226	0.167	0.167
N	529	521	529	521	529	521
Dane County	Yes	No	Yes	No	Yes	No