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Increasing the effectiveness of technology transfer for conservation cropping systems through research and field design

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Abstract

A survey was conducted in 2002 to measure the success of technology transfered to growers (i.e., changes in attitudes and behaviors) from a long-term, large-scale, integrated cropping systems experiment called the Ralston Project, near Ralston, Washington, USA. Non-irrigated, cereal and oilseed growers who participated in biennial field tours (1996–2000) were mailed a self-administered questionnaire, which asked about: (1) their interest, use and adoption of technology developed or demonstrated in the project; (2) their opinions about the project's collaborators, planning and design; and (3) their overall impressions of the project. One hundred and one eligible growers responded to the questionnaire, for a 55% overall response rate and a 62% completion rate. Survey results confirmed that the Ralston Project field tours were a successful means of technology transfer among participants. Seventy-seven percent of growers found one or more project technologies particularly useful to their own production operation(s). More than 60% conducted independent trials with one or more technologies, with 50% of these trials resulting in permanent adoptions. The project's planning and design had a more positive effect on growers' opinion of the project than the type of collaborations and sources of funding. Specific strategies that had a substantially positive effect on growers' opinions included: (1) the project's 'whole system' treatment design; (2) use of large plots to accommodate field-sized equipment; and (3) collaboration among scientific disciplines and with local growers. Seven variables known to influence the adoption of innovation were also tested against growers' decisions to try any of the project's technology in their own farm operations. Personal character variables influenced individuals' decisions to try project technology more so than environmental conditions. Level of education, previous adoption behavior and average annual rainfall significantly influenced growers' behavior ($P < 0.05$). Our survey population consisted of early users of conservation-based farming technology, primarily innovators and early adopters. The Ralston Project made the greatest impact on current adopters and users of conservation-based farming technology. Interest among non-users was also high enough to suggest that the Ralston Project contributed positively to the diffusion of conservation cropping systems and associated technology into the greater grower community. We discovered from this survey that the planning and execution of field research plays a significant and influential role in transferring more complex, and perhaps high-risk, conservation-based farm technology. By understanding how research and field design affect different user groups within the grower community, professionals can identify appropriate strategies to expand interest beyond their primary target audience and influence attitudes and behaviors that facilitate widespread adoption.

Key words: diffusion, adoption, impact, conservation cropping systems, technology transfer, Ralston Project

Introduction

Agricultural research for commercial food production has improved the health and wealth of individuals in many countries around the world, but research and development's (R&D's) yield-enhancing technologies have also come with severe environmental consequences. Soil erosion and invasive species plague food systems worldwide. Current conditions present today's researchers with a tougher challenge of balancing economic, agronomic and environmental priorities. Innovative trends in crop research are rapidly spreading within US agriculture to meet this challenge of developing profitable and agronomically feasible conservation cropping systems. These trends include long-term, large-scale, multidisciplinary and systems-level field experiments, along with an increased emphasis on grower participation. In spite of the known environmental and social benefits of conservation cropping systems (e.g., no-till), long-term, conservation crop research continues to struggle for funding sources against more traditional, short-term, maximum-yield oriented research.

The environmental objectives of conservation crop research revolve mainly around lowering the intensity of synthetic inputs and reducing activities that instigate topsoil loss. Such objectives are not always conducive to the quick turnaround of data or maximized yield and profit margins. In addition, the complexity of such crop systems does not lend itself to immediate, or even complete, adoption by end-users. In the absence of more immediate measures for validating time and effort spent, researchers can measure the social impact of their technology transfer activities to establish their research's worth to science, industry and society. Case evaluation studies are an effective means of documenting the impact of research on growers. Impact can be estimated by measuring changes in growers' attitudes and behaviors towards technology, treatments or other points of interest in the research project. An evaluation study may provide researchers with a tool powerful enough to: (1) justify their expenditures; (2) reaffirm the outward contributions of their research; (3) increase current spheres of influence; and (4) enhance their effectiveness in technology transfer.

Field researchers in the inland Northwest (eastern Washington, northeastern Oregon, northern Idaho) have increasingly used innovative research strategies to develop conservation-based farming alternatives to a traditional, monocrop wheat/fallow system, and to refine best management practices for more complex farming technologies (e.g., no-till drill). The impacts of recently developed technologies and field research methodologies on the research community are well-documented[1–3]. However, the impact of individual field studies on growers has not been formally established. We evaluated an innovative, conservation-based, field research study in 2002 called the 'Ralston Project' to find out how growers responded to what they saw and learned at field tours. In other words, we measured the changes in growers' attitudes and behaviors as a result of this particular kind of research study.

The Diffusion of Research Innovation: A Theoretical Framework

Developing new farm technology, such as a no-till drill or optimal seeding rate, represents one part of applied field research. Another important task is the transfer of new ideas and technology beyond the scientific community. More and more, funding agencies require researchers to incorporate technology transfer activities into their research goals and experimental planning. Technology transfer activities range from writing journal articles and technical manuals to conducting field tours or plot demonstrations, and, more recently, constructing Internet websites. New ideas and technology, whatever their benefit, do not always travel far from the point of origin. The rate and extent to which any new idea or technology (i.e., innovation) from research travels through a community depends a great deal on factors external to the research. For this reason, it is necessary for researchers to grasp how society and environment influence their R&D, transfer activities and spheres of influence.

Technology transfer comprises one aspect of a larger sociological process called the diffusion of innovation. Diffusion is the 'process in which an innovation is communicated through certain channels over time among the members of a social system'[4]. The diffusion–adoption model[4,5] provides a comprehensive analysis of factors influencing adoption, and is perhaps the most widely known explanation for how and why innovations become accepted/rejected within a community. For example, a grower's location and formal education will often alter his/her level of risk tolerance[5,6], which will vary the perceived utility or value of a new farming practice. The diffusion–adoption model accounts for these social and environmental dynamics that surround an innovation and affect its rate, direction and extent of diffusion.

The acceptance and/or adoption of a new idea, technique or technology can vary considerably among innovations and communities. In the USA, hybrid seed corn reached nearly 100% adoption by Iowa farmers within 15 years of introduction[5], whereas adoption of the no-till drill is still low after 30 years of crop R&D[7]. Diffusion timelines are determined by the rate at which individuals within a community work through the decision-making process[6] and are influenced by: (1) the characteristics of the innovation: relative advantage, compatibility, complexity, trialability, observability; (2) the context of its introduction (e.g., prevailing regulations and markets); and (3) the characteristics of individuals (e.g., education, age, land ownership)[7]. For example, a grower's mechanical skill may increase his/her chances of adopting an intricate, conservation-based crop program, but only if favorable niche markets exist to offer a premium price for his/her 'eco-friendly' product. Researchers can affect diffusion timelines by understanding the degree of influence of these three major conditions on a particular innovation. Although the innovation itself is fairly static, the favorability of its characteristics (listed above) can change by how it was incorporated within an experiment. For example, using a no-till drill as part of an integrated crop/weed competition study might increase a growers' interest over a basic tillage demonstration, because the grower is able to see how the drill affects other elements that determine crop performance. An innovation that can be broken down or tried out on a partial basis also increases the probability of use and adoption[5]. Still, the

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favorability of an innovation is greatly influenced by the characteristics of individuals that comprise the community or group of interest.

Personal characteristics form the 'viewing lens' through which an innovation is judged. Character traits of the individual have the potential to override seemingly negative points and overcome barriers to adopting the innovation. Collectively, these traits segregate individuals of a community into categories according to their likeliness to adopt. Adopter categories, which we'll refer to as user groups, are generally divided among five behavior types—innovators, early adopters, early majority, late majority and laggards[5]. The group into which an individual falls is relative to the innovation of interest. Among these five groups, innovators and early adopters are generally more curious, more formally educated, able to process abstract ideas and accept a higher level of risk than individuals in other groups. Innovators possess a more daring nature that allows them to try new ideas with little regard to public opinion, while early adopters are more selective in their experimentation and have a higher level of community influence. For these reasons, both innovators and early adopters are important target groups for research and extension. However, the historical USA extension model has drastically underutilized the assets of all user groups[8,9] in formulating technology transfer strategies for widespread diffusion of research.

Rural America's increased mobility and access to information has significantly diminished the passivity of growers[10]. Growers are steadily becoming more active participants in research as well as the developers of conservation technology. The traditional model of extension has yet to fully adjust to current social conditions[10], where growers are more independently informed about research and industry and have a higher degree of influence over research[8,9] and other growers[11]. Extension's traditional approach to technology transfer can actually cripple diffusion by stratifying relations among developers and users[9,12] of technology, underutilizing available resources[8,9,12], and limiting acceptable avenues for idea exchange[9,11,12].

A prime example of this dilemma occurred during the Integrated Pest Management Project (1985–1994) in Pullman, Washington, USA[13]. At the conclusion of the project, several growers voiced concern over the lack of research/grower interaction and government research agency's exclusive use of research farms to conduct experiments. Their dissatisfaction culminated into accusations that scientists did not share research results. A communication gap such as this may have discredited the research among local growers and crippled the diffusion[5] of even its successful production strategies. As more individuals worldwide move into the 'information era', it becomes more important for research organizations to reflect on how they view and utilize growers in the promotion of R&D. In 1995, several local researchers attempted to address this issue by constructing a full-scale, collaborative experiment based on the suggestions and concerns of local growers.

The Ralston Project: Case Evaluation Study

Dryland (i.e., non-irrigated) crop producers on the Columbia Plateau and Columbia Basin regions of the inland Northwest struggle with a wide range of agronomic concerns, given the area's low annual rainfall (150–460 mm), erratic winds, highly variable topography and fine-textured soils. Soil erosion from wind alone causes soil losses of >4.5 Mg $ha^{-1} yr^{-1}$ on approximately 1 Mha of cropland each spring[14]. A significant portion of this erosion is attributed to growers' traditional use of the winter wheat–fallow system. The research and adoption of this rotation has persisted over much of the past century because of its low risk of crop failure and cost-effective control of pests and storage of soil moisture[15]. Yet, the frequency of exposed topsoil from tillage practices in crop and fallow management has cumulatively jeopardized environmental and agronomic sustainability[1] and public health and safety[16].

The No-till Integrated Spring Cropping Systems Research Project, better known as the 'Ralston Project' was initiated on private land in the fall of 1995 near Ralston, Washington, USA, to examine the economic, environmental and agronomic feasibility of reduced tillage and continuous spring cropping systems in a low rainfall regime[17]. New crop systems were developed to either replace or supplement the traditional winter wheat–fallow system. The focus of selected treatments reflected a compromise between scientists' interests and growers' needs expressed during planning meetings, namely: (1) using reduced or no-till drills for simultaneous planting and fertilizing; (2) retaining crop stubble for erosion control and soil moisture retention; (3) managing crop stubble for pest/disease control; (4) evaluating crop varieties for pest/disease resistance; (5) using spring crop rotations in lieu of fallow; (6) spring cropping for pest/disease control; and (7) determining the economics for each treatment rotation. A greatly enlarged plot size was also proposed, extending it beyond the typical plot measure of 3 m × 9 or 12 m, in order to accommodate for 'real world' field variation, commercial-size machinery and scientific validation.

The experimental design consisted of four replications of four different crop systems on 152 m × 9 m (500 ft × 30 ft) plots set over two adjacent fields[18]. This arrangement allowed each crop within each rotation (treatment system) to be grown every year. Treatment rotations consisted of: (1) reduced-till winter wheat/fallow; (2) no-till soft white spring wheat/chemical fallow; (3) no-till continuous hard red spring wheat; and (4) no-till hard red spring wheat/spring barley. Procedures and equipment used in the management of each treatment system incorporated the best management prescriptions (BMPs) of previous single-component/disciplinary studies and several short-term side experiments conducted in conjunction with the Ralston

Project. From 1996 to 2000, scientists from ten disciplines monitored and evaluated treatments annually for: (1) weed population dynamics; (2) soil fertility; (3) variety/pest resistance; (4) performance of tillage operations; (5) soil moisture and erosion control; (6) pest incidence; (7) grain yield and quality; and (8) economic profitability and risk. Cooperating researchers held half-day, public field tours at the project site every other year to report their findings, demonstrate new equipment, consult with other scientists, and engage in discussion with growers.

At the conclusion of the 5 years, collaborators and associated scientists agreed that the unusually large design and integrated focus of the project positively impacted the quantity and quality of field data collected. The project's integrated crop management (ICM) approach, through its 'whole crop system' simulations, also served to benefit technology transfer and further R&D[12]. Some collaborators felt that the major benefit to growers was the immediate application of project technology to their production operations because each technology was already tested within the larger context of the cropping system. This position was supported by previous studies in other agricultural centers, which found that local relevance, adaptability and the applicability of research to growers improved their acceptance of research[19,20] and influenced adoption[7], particularly among complex and conservation-based farming technology. The question of whether or not the Ralston Project impacted local growers in ways that encouraged the diffusion of its technology has remained speculative and undocumented. We chose to evaluate and document the impact of this specific project because it represented the wheat–fallow region's first and longest-running project that combined multiple design elements previously documented to increase grower receptivity to research[12,13,19], specifically long-term, large-scale, multi-/interdisciplinary, multi-agency, grower-directed, integrated and crop system-level research.

Study Objectives

In our survey study, we wanted to find out if and how the Ralston Project had an impact on technology transfer of conservation cropping systems and associated technology. In other words, did growers change their attitudes or behaviors in response to what they saw or learnt at Ralston Project field tours? What specifically influenced these changes? We addressed this objective by evaluating the Ralston Project, via survey, based on the following research questions:

1. Who were the growers that attended the Ralston Project field tours?
2. Did growers find the project useful in addressing their production concerns?
3. To what extent did growers change their behavior by using practices/technologies seen in the Ralston Project?
4. Was there anything in particular that increased their opinion about the project as a whole?
5. What variables most influenced the growers' decision to try project technologies?

Methods

One major avenue for technology transfer is the research field tour. During field tours, growers have direct contact with new and developing technology. It also provides researchers with a readily available population for surveying. We evaluated the Ralston Project by surveying growers who attended the project's biennial field tours in at least one of the following years: 1996, 1998 and 2000. Registration rosters, furnished by Washington State University Cooperative Extension, afforded us the opportunity to locate growers who had direct contact with the Ralston Project, to find out what information and technology was taken directly from the project and how it was being used.

Those attending Ralston Project field tours included farming families, agribusiness representatives, federal and state agency representatives, academic and agency research personnel, and local extension professionals. Individuals from the above list who were easily identified in professions other than farming were removed from survey. All other individuals were contacted for surveying, but we restricted survey eligibility to dryland cereal and oilseed growers who considered themselves the primary production decision-maker for their operation(s).

Eligible growers were surveyed via mail (post) using a self-administered questionnaire. This method was determined to be the most effective means of collecting data among a population widely distributed across several states. In addition, the high volume of farming activity during our survey timeline significantly restricted the availability of individuals for telephone or personal interviews. The mail survey allowed respondents more flexibility in how and when they completed the questionnaire, and gave them the opportunity to change or expand upon answers after further reflection. Only individuals attending field tours were surveyed, so that we could establish direct links between growers' attitudes and behaviors and the Ralston Project. Lastly, field tour attendance assured us that surveyed growers had some level of direct exposure to the project and contact with cooperating professionals, in order to provide more detailed and meaningful data about their attitudes and behaviors.

We administered the survey using a five-part mailing system[21,22]. All mailings, except the fifth, were delivered first-class through the public postal service[21,22] (United States Postal Service). Use of a private courier service was deemed inappropriate for this study because of the distance between each respondent from the survey office and frequency of post office boxes (PO Box) listed for contact addresses. Given that private couriers only deliver to residential addresses, the removal of these individuals would have effectively lowered the population.

The first mailing was sent on 21 May 2002 in a hand-printed envelope[22]. The single-page letter described the purpose of the survey, the importance of individuals' participation, and notice of the coming questionnaire. A packet containing a four-page, double-sided, booklet-style questionnaire and stamped return envelope[22] was mailed on 23 May 2002. Subsequent mailings were sent 3 June 2002 and 24 June 2002, but only to those individuals not responding to previous mailings. Intervals between mailings deviated slightly from the recommended protocol[21,23] to reduce costs associated with a national postage rate increase and to accommodate for growers' restrictive fieldwork schedules. A final packet containing an 8-page, single-sided, packet-style questionnaire[22] was mailed on 12 September. We selected the two-day, expedited mail service, in order to make this mailing distinctly different from previous attempts and to emphasize the importance of their participation[22]. The resulting response rate for the survey totaled 55% with a completion rate of 62%, which included individuals who answered the questionnaire but were later determined ineligible. Both rates are considered high by today's mail survey standards, especially for a survey administered during the growing season.

The questionnaire consisted of 31 open-ended, partially open-ended, closed-ended and categorical questions. We chose to include incomplete questionnaires for data analysis despite missing data, given the small population size. Eligible questionnaires were coded and frequencies tabulated using SAS® software[24]. Open-ended portions were recorded verbatim and then combined with frequency distributions for basic descriptive statistics. Next, we conducted the chi-square test of independence, $\chi^2 = (N-1)s^2/\sigma^2$ with $\alpha = 0.05$, to determine which variables had the greatest influence on the growers' decision to experiment with project technologies. Statistical tests are usually reserved for instances in which one is attempting to generalize from a sample to a population from which that sample is drawn. We attempted to survey the entire field tour population, so the more appropriate interpretation of the chi-square test used here is whether the distributions differed from a distribution due entirely to chance[25].

The demographic variables tested were similar to those tested in other local surveys[26,27] and discussed extensively within the diffusion of innovation literature[5]. The variables we tested were age, farm size, land ownership, education, previous adoption, rainfall and relative distance. We selected these specific variables based on their relevance to influencing innovativeness among individuals and predicting adoption behavior according to the diffusion–adoption model[5]. In addition, it allowed us to see how our particular population fit within the larger local grower community depicted in other surveys previously conducted within this area. The independent variables were broken down into categories shown in Table 1, and subjected to conditions given in parentheses.

All variables were obtained directly from the demographic questions in the questionnaire, with the exception of rainfall and relative distance. These were estimated using precipitation[28] and state road maps, respectively. Relative distance was determined to be the number of kilometers from the town a grower listed as closest to their primary residence (i.e., homestead) to the Ralston Project site. Rainfall was divided into three categories according to whether a grower's homestead area received less (<254 mm), similar (254–356 mm) or more (>356 mm) rainfall than recorded for the project site. Although it's not unusual in this region for growers to farm segmented fields over an extended area that may experience variations in rainfall, we could not account for such variations with this dataset.

Table 1. Categories into which the demographic variables were divided.

Age (population average)	⩽51 years
	>51 years
Education (completed degree)	High school
	Post-secondary education
Farm size (rent + owned)	Small ⩽1242 hectares
	Medium/large >1242 hectares
Land ownership (% hectares currently in production as rented)	<50% rented
	⩾50% rented
Previous adoption (of project technology prior to first visit)	Yes
	No
Relative distance (from primary residence to project site)	⩽80.5 km
	>80.5 km
Rainfall (average annual precipitation at homestead location)	<254 mm
	254–356 mm
	>356 mm

Results

Identification of growers

A total of 101 eligible growers from 16 counties across eastern Washington and northeastern Oregon participated in the survey. The population consisted entirely of males, and their average age was 51 years (Table 2) with 67% ($N = 99$) falling between the ages 40 and 60. The average duration of farming experience was 27.5 years. A majority of the growers acquired educational degrees past high school, with 56% ($N = 98$) completing a 4-year or graduate degree. The population's average farm size, excluding acreage enrolled in the Conservation Reserve Program (CRP), was 1247 ha (3080 acres) with <50% of the land owned. Only 25% of the population ($N = 98$) engaged in occupations in addition to farming. Personal characteristics of our population were fairly comparable to those of growers from other local surveys[26,27], but exceeded other surveys in terms of average area farmed and level of education.

The combination of these characteristics placed this population within the realm of innovators and early adopters[5]. Innovators and early adopters, as previously discussed, have been traditional target groups of research and

Table 2. The influence of personal characteristics and environmental conditions on growers' decisions to try out technology developed or featured in the Ralston Project.[1]

Was there anything of interest that you tried out in your own production operation?

	N	Yes	No
Age			
≤51 years	57	60%	40%
>51 years	38	63%	37%
			$\chi^2 = 0.118$, *P* value = 0.731
Education			
High school	20	40%	60%
Vocational/2-year/4-year/graduate degree	74	66%	34%
			$\chi^2 = 4.534$, *P* value = 0.033*
Farm size			
Small farm	35	54%	46%
Medium/large farm	54	67%	33%
			$\chi^2 = 1.379$, *P* value = 0.240
Land ownership			
<50% rent	42	60%	40%
≥50% rent	47	64%	36%
			$\chi^2 = 0.174$, *P* value = 0.676
Previous adoption			
No adoptions	39	49%	51%
1+adoptions	55	69%	31%
			$\chi^2 = 3.968$, *P* value = 0.046*
Relative distance			
≤50 miles	36	58%	42%
>50 miles	60	63%	37%
			$\chi^2 = 0.238$, *P* value = 0.626
Annual rainfall			
Below site average	19	37%	63%
Same as site average	51	69%	31%
Above site average	26	65%	35%
			$\chi^2 = 6.136$, *P* value = 0.047*

[1] Percentages are compared between 'yes' and 'no' for test categories of each independent variable. *P* values pertain to values across the categories of variable. An * following *P* values denotes significance, with $\alpha = 0.05$.

extension. It was not surprising that other user groups were largely absent from field tours, given the long standing tradition of the winter wheat–fallow system, the complexity of the crop systems tested, the historical diffusion of no-till technology[7,10], and the tendency of field tours to attract early users of technology[11]. The size and selectivity of this population indicated that the conservation cropping systems remain in the very early stages of diffusion within the larger grower community. The presence of early adopters, who tend to have larger social networks and community influence[5], further suggests that information and technology will continue to influence attitudes and behaviors beyond the participants in field tours[11].

Diffusion of innovations

Ninety-three percent ($N = 81$) of respondents had heard of the Ralston Project by the second field tour in 1998. Fifty-four percent ($N = 98$) acquired information through university/agency researchers or cooperative extension personnel, and 32% ($N = 98$) from other growers. Additional information about the project ($N = 97$) was also obtained through industry news (78%), other field tours (66%) and grower meetings (53%). The diffusion of information about the Ralston Project thus occurred over several levels of communication and authority. This flow of information highlights an important triangulation among the grower, researcher and other growers[11] in the diffusion of agricultural innovations.

During field tours, researchers discussed their findings with respect to nine specific issues the project was set up to address (Table 3). The issues that received the highest amount of interest included: (1) economic analysis for each crop system; (2) use of no-till drills for spring planting and fertilizing operations; (3) production of continuous spring crops as an alternative to fallow; and (4) managing crop

Table 3. Survey question asked to determine growers' level of interest in the Ralston Project's experimental objectives.

Listed below are some of the issues that the research at the Ralston Project has attempted to address. Indicate whether what you observed during the June Field Day(s) or at any other time was *very interesting, somewhat interesting, not interesting, don't remember.*

	% of respondents[1]			
	Very interesting	Somewhat interesting	Not interesting	Don't remember
A. The use of no-till drill for spring planting operations and fertilizing	73	26	1	0
B. The use of crop stubble for erosion control	50	47	2	1
C. The use of crop stubble to increase soil moisture	71	28	1	0
D. The management of crop stubble to control pests/disease	44	45	6	5
E. The selection of crop varieties for disease resistance	54	42	3	1
F. The use of a spring crop rotation as an alternative to fallowing	72	22	6	0
G. The use of a spring crop cycle to increase control of pests	45	38	12	5
H. The use of spring crop cycle to increase control of plant disease	54	38	5	3
I. The economic market analysis for each crop rotation (treatment)	74	24	1	1

[1] Percentage of respondents calculated from a sample size (N) of 99, except for question A, where $N=100$, and question C, where $N=98$.

stubble to increase soil moisture. While 77% ($N=94$) of the growers found one or more of these topics particularly useful (Table 3), 15% stated that everything was useful to them.

Growers did not appear intimidated by the technology of the Ralston Project. When asked if they had tried anything of interest from the project within their own farm operation (Fig. 1), 61% ($N=96$) responded yes, with >30% trying multiple technologies. Fifty-one percent ($N=63$) of growers reported that they permanently adopted some technology from these independent trials. In addition, 58% ($N=3$) said they were using one or more technologies in the project prior to their first visit to the site. We suspected that the total number of new adoptions was slightly higher than recorded, after considering some individuals' hesitation to classify their changes as permanent. As one grower explained, 'My direct seeding system is constantly changing. It is hard to pinpoint ''permanent'' changes.' Finally, 41% ($N=98$) of growers recalled sharing specific information or insights with other growers regardless of whether they adopted some technology or not.

Conservation cropping systems, such as those tested in the Ralston Project, remain difficult innovations to diffuse because of their high degree of complexity and risk[5]. These systems require more mechanical precision and abstract thinking and a higher risk tolerance over more conventional systems, as well as changes in personal beliefs, to make them work effectively[5,10]. It was not surprising to learn that almost half of the population was either unable or unwilling to adopt some of the technology. However, these growers' concerns centered more often on contextual variables, such as recent drought and market conditions, than on the direct mechanical or technical challenges to implementing the new systems. These findings suggest that the Ralston Project attracted innovative individuals who had already adopted project technology, as well as individuals, users and non-users, interested enough to adopt once conditions became more consistent.

The combined rate of use and adoption was high among this population, especially given the complexity of the treatment systems tested over a rather short period of 5 years. Some might argue that individual technologies used (e.g., no-till drill) have been around longer than the 5 years of the project. However, since older technologies were used within a newly developed crop system, the technologies collectively constituted new invention. In other words, a new innovation subjected to a new diffusion timeline. Regardless of this point, the high level of interest (Table 3), combined with the documented use and adoption rates, show that collaborators' efforts to improve technology transfer through field tours were successful. The recorded levels of interest, use and adoption also provided a positive outlook for further diffusion. The current state of diffusion into the larger grower community (i.e., technology transfer has begun to influence the masses) would best be confirmed with a follow-up survey of growers following the final field tour, held 1 June 2004. The continued diffusion of the Ralston Project's cropping systems and associated technology may require researchers to rethink their current technology transfer activities, to better fit the concerns and priorities of the latest user group(s) to show interest in the project.

Growers' attitudes and behaviors

The final section of the survey questionnaire asked growers how project collaborations, funding sources and design characteristics affected their overall opinion of the Ralston Project (Table 4). The project's collaborations did not have as great an impact on growers' opinion as did project

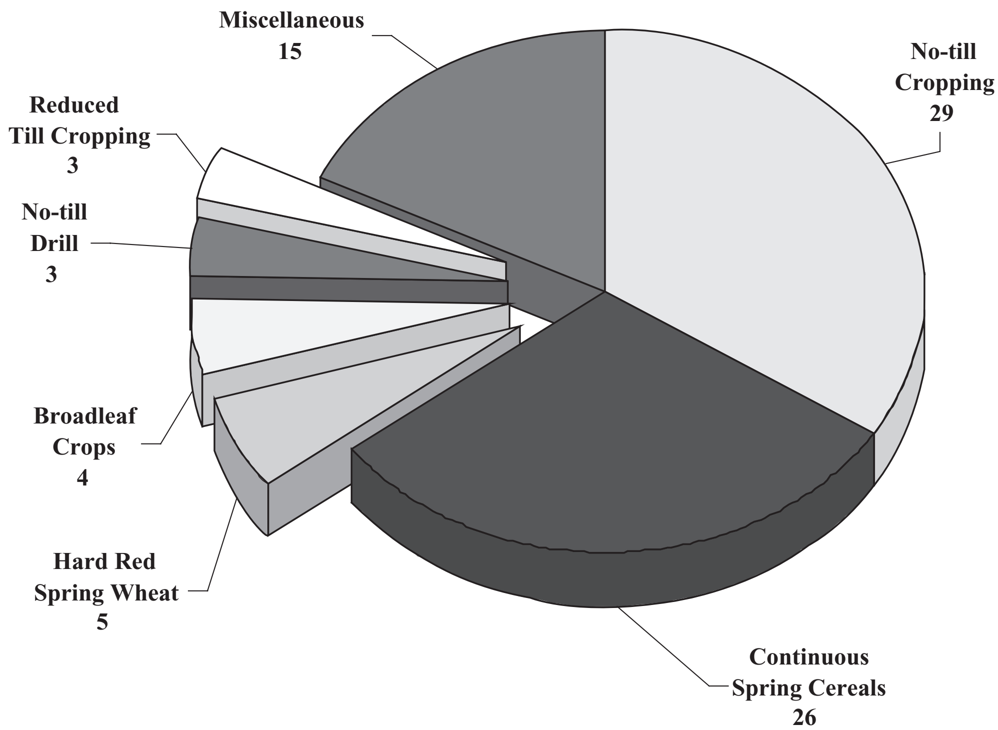

Figure 1. The number of independent trials by growers with individual technologies used in the Ralston Project, based on the survey question, 'Was there anything of interest from the Ralston Project that you have tried out in *your* farm operation?' 'No-till cropping' also represents direct seeding and recropping; 'Continuous spring cereals' represents unspecified spring wheat and other spring cereal rotations; 'Hard red spring wheat' also represents dark northern spring wheat varieties.

Table 4. Survey question asked to determine how research funding sources and experimental design influenced growers' opinions of the Ralston Project.

	% of respondents		
	Improved opinion	Worsened opinion	No change[1]
Funding[2]			
A. The Washington Wheat Commission co-funded the Ralston Project	48	3	49
B. STEEP III and CP_3 co-funded the Ralston Project	48	7	45
C. WSU and OSU co-funded the Ralston Project	58	1	41
D. The USDA-ARS co-funded the Ralston Project	50	2	48
E. Public and private organizations cooperatively funded the Ralston Project	47	0	53
Design[3]			
A. Local growers' input was used to determine the crop rotations of the experiment	81	1	18
B. Local growers and researchers cooperatively designed the Ralston Project	79	2	19
C. The Ralston Project was conducted on a private grower's land	57	0	43
D. The USDA-ARS directed the Ralston Project	31	7	62
E. The Ralston Project was designed as a long-term experiment (×2 crop rotation cycles)	82	0	18
F. The Ralston Project was designed to use farm-size equipment	90	0	10
G. The Ralston Project was designed to look at elements that affect crop production simultaneously (e.g., soil, weeds, disease, economics)	91	0	9
H. The Ralston Project involved researchers from several different universities	78	1	21

[1] 'No change' was regarded as a positive response, although it did not provide a clear indication of how good or bad current opinion was.
[2] Percentage calculated from a population of 96 respondents, except question E where $N = 97$.
[3] Percentage calculated from a population of 100 respondents, except questions C, F, H, where $N = 99$, and question D, where $N = 97$.

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planning and design. Most collaborations either improved or had little effect on growers' opinion, although the involvement of academic institutions improved the opinion of 58% ($N = 96$) of growers. This was the highest improvement rating among all causative factors. This result likely stems from a long-standing relationship between agricultural producers and the local land grant universities. Project funding through federal conservation research programs (STEEP and CP_3) left 7% of growers with a lower opinion of the project, and may be attributed to a belief that increased environmental regulations prompted funding. As one grower speculated, 'There seems to be a big government push to make direct seed mandatory for all ag [agriculture].'

The design and planning of the Ralston Project substantially improved growers' opinions of the project. The elements of significant influence (Table 4) included the project's integrated and multiple component research (91%), plot size (90%), project duration (82%), grower input (81%) and growers' collaboration with researchers (79%) from several universities (78%). Many growers felt that the project's credibility resulted from researchers' designation of entire cropping systems as individual treatments; plot design that accommodated commercial-size equipment, and use of a grower advisory panel. In contrast, a small number of individuals felt that the project's credibility was weakened because investigators selected a site that they considered unrepresentative of regional topography, and by the poor economic performance of the new crop rotations. Still, several growers clarified that the value of the Ralston Project to them increased because, 'one technique was not stressed for success...environmental factors and economic sustainability were [collectively] addressed to benefit growers in these challenging farming areas'.

According to the diffusion-adoption model, individuals are often motivated to seek evaluation information about an innovation in order to learn about potential consequences of use and to reduce uncertainty[11]. Much of the Ralston Project's underlying appeal came from its ability to absorb some of the risk, normally borne by the growers, in learning, implementing and adapting the technology in conservation cropping systems to drier areas of the inland Northwest. In other words, positive changes in growers' opinions manifested a confidence in the research that, in turn, reduced the perceived risk of use of new crop systems or farming practices and encouraged use and adoption. Two growers explained that, 'It helps that I don't have to try to fail or succeed because they are closely monitoring and experimenting in so many areas [affecting production]', and 'Any help to try new things without sacrificing potential income is crucial [to me]'. Such positive changes in attitude are important indicators of future behaviors toward adoption[5]. However, it is harder to speculate about the project's impact in other areas, or among other growers in our region, because field tour participants differed from other growers randomly sampled in other regional surveys[26,27].

What evidence is there that the Ralston Project will ever impact growers beyond those at field tours? Again, the presence of peer-influencing individuals[6] within this population, a majority of positive attitudes toward the project, and the documented movement toward use and adoption increases our confidence in the extension of the project's impact beyond field tours. In addition, the continual participation of growers in project planning and evaluation appears to have had an effect on their communication with other growers. This means that as the number of individuals using part or all of the newly developed crop systems increases, and they share their experiences, the more risk and uncertainty decreases for hesitant growers, helping them move further through the decision-making process.

Deciding to experiment with new technology

The disciplinary study of innovation diffusion has defined sets of character, contextual and environmental variables that help predict the likelihood of an individual's adoption of new technology[5]. Of the seven variables tested (Table 2), growers' level of formal education, their previous adoption of technologies used in the Ralston Project, and the average annual rainfall received in their homestead area significantly influenced their decision to try out (other) project technologies. Education was a significant factor ($P < 0.05$) once we pooled all forms of post-secondary education into one test category. Sixty-six percent ($N = 74$) of growers having post-secondary education experimented with project technologies, compared to only 40% ($N = 20$) of growers with only a high school education. We also found that growers who adopted technology used in the project prior to their first visit to the Ralston Project, tried out other technologies 20% more often than those with no adoption history. Not surprisingly, these independent trials occurred most often among growers located in areas receiving similar average annual rainfall (254–356 mm) to the project site. Discrepancies in experimentation rates among growers of different rainfall regimes is easily explained by the biological limitations of spring cereal varieties in areas receiving <254 mm of rain, in addition to multiple years of regional drought in the late 1990s.

Again, we tested these seven variables over the population of growers who attended Ralston Project field tours. It would not be prudent to make assumptions about how significant these variables would be within the larger grower community, nor if they would serve as the best predictors of adoption for the community as a whole. This is especially true after having already established our population as primarily innovators and early adopters, a fairly small proportion of any given community in terms of innovation diffusion[5]. What we gained from testing these variables was the greater sense of the factors currently motivating the use and adoption of conservation cropping systems within our area and, more specifically, who was impacted the most from field tours. Ralston Project field tour events catered toward both non-adopters and adopters, but had a bigger influence on those individuals with a prior history of using the technologies incorporated within the project. This case study showed that among more innovative groups of commercial growers, personal characteristics significantly reduced the limitations of environment, which is generally perceived by growers as a major hindrance to use and adoption of conservation-based farming technology (personal communication).

Conclusion

The development of profitable conservation cropping systems for commercial-scale production remains difficult and slow because of the tension between short-term economic stability[29] and long-term biological sustainability[30]. In addition, the complexity of such systems does not encourage immediate or even complete adoption by end users[5,7], compounding a researcher's difficulty in justifying their costs and contributions to science and industry. Public field tours, a long-standing tradition of Extension, provide an excellent means of disseminating information, directly exposing interested growers to innovative research, and provide opportunities for idea exchange between the developers and users of technology. The evaluation of the Ralston Project revealed that collaborating researchers' unconventional planning and design strategies increased the effectiveness of its field tours in transferring technology. The combined efforts of researchers and growers to design and evaluate a long-term, large-scale, multidisciplinary field study improved the researchers' ability to: (1) mimic common field conditions; (2) study whole crop systems over several rotations; and (3) improve the applicability of developed techniques to growers' own operations. These strategies resulted in high use and adoption rates among the growers, and positive changes in attitudes toward the project as a whole among adopters and non-adopters alike.

In the midst of decreased time horizons, global competition, and the increased costs of field research, conservation-based field researchers should continually explore ways to maximize the potential of their technology transfer activities. Researchers can accomplish this successfully by understanding more about the characteristics of their target audience in relation to the greater farming community, and how the characteristics of their research technology affect its transfer. By understanding these relations, researchers may discover new ways to increase the receptiveness of their audience and influence attitudes and behaviors that foster adoption. As conservation-based farming technology continues to evolve, the ways in which researchers plan and design experiments becomes as important to adoption and diffusion as developing the technology itself.

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