ABSTRACT
On-farm research is a method for transferring technology to farmers, validating small plot research, generating new discovery, and evaluating field-scale, site-specific management techniques. Little has been done to understand what motivates farmers to participate in on-farm research and what the impact of their participation is on their decision making and farm profitability. This study evaluated the University of Nebraska-Lincoln’s over 25 yr-old on-farm research program using a semi-structured, in-depth interview tool to complete interviews with a stratified sample of 40 of the 140 past-participants. The focus of this qualitative study was obtaining rich descriptions of farmer participants to better understand motivation for involvement in an on-farm research program, participant research experiences, and the economic impacts of an on-farm research program. Quantitative statistical analyses of the qualitative data are included for informational purposes; however, our conclusions focus on the qualitative analysis. Farmers participated in an on-farm research program for a variety of reasons, most commonly for economic gain. Positive experiences were largely credited to the interactions with university faculty and other farmers. The participating farmers’ perception regarding whether or not the project took too much time was unrelated to whether weigh wagons or yield monitors were used. Farmers were interested in many aspects of research, including project ideaation, experimental design, and statistical analysis. Participating farmers’ satisfaction in their experience and implementation of research results was not dependent on the farmers independently generating their research topic. The most impassioned suggestion from the farmer research participants was to develop innovative research projects.

Core Ideas
• In-depth interviews with participants in an on-farm research program generated insights into motivation for participation and program impact.
• Farmers participated in the program for a variety of reasons including economic gain, seeking answers to a specific questions, general curiosity, and a desire for reliable and unbiased research results.
• Positive experiences in the on-farm research program were largely credited to interactions with university faculty and other farmers.
• The origin of the research topic or idea did not influence participant satisfaction in their experience or implementation of the results.
• Seventy-five percent of interviewees had put their research results into practice in their farm operation, either by making a change based on results or by not making a change as the research confirmed their current practice.

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from other farmers. Wood et al. (2014, p. 9) found that farmer “networking proceeds without the supervision of an overarching authority that conclusively legitimates knowledge and that circulates this knowledge as a controlled activity.” Relationships between socially similar farmers were particularly effective when complex information was being communicated. With monetary and land resource constraints, on-farm research experimentation can also provide in many cases a more feasible research option than traditional experiment station research. On-farm research may also provide a direct link between farmers and researchers. This link is valuable for ensuring researchers are focusing on relevant topics, and that farmers are benefiting from knowledge gained in university research.

Numerous institutions, including universities, commodity organizations, and grassroots farmer organizations, have developed programs to promote and conduct on-farm research. A variety of approaches to research are taken within these on-farm research programs:

- One approach could be termed “researcher-initiated”, where university or commodity group researchers and educators propose a research topic and recruit farmers to participate. The proposed research project may be focused on validation, where a product or practice which has shown success on university research stations is extended to farmers through on-farm research. The research project need not be previously well researched though. “New discovery” research may also be conducted on-farm. A researcher may choose to conduct his or her new discovery research on a farmer field for a variety of reasons including desire for “real-world” conditions, shared interest in the topic by the participating farmer, or lack of available land resources at university research stations. A researcher may also choose to work on a farmer field to obtain access to specific soils, diseases, weed populations, or insect pests.

- A second approach may be termed “industry-initiated.” In these instances, an industry representative may desire a third-party test of a product or practice. In such cases, an entity such as a university may design a research protocol which farmers can use to test the product of interest, and assist with data collection and analysis of the experiment.

- A third approach may be termed “farmer-initiated.” In such cases, the research question is generated by the farmer or group of farmers. Outside entities, such as the university, are often enlisted to design the experiment and conduct analysis of the data.

In reality, most research experiments are likely a combination of these approaches. Regardless of the approach, these examples demonstrate strong farmer involvement; in fact most experiments are conducted using the farmer’s equipment and labor. In some cases, farmers are compensated financially for their involvement with these experiments.

Project evaluations often assess knowledge gain and intended behavior changes following educational programs. Less frequently, in-depth, follow-up interviews document actual behavior changes. Therefore, one objective of this study was to evaluate the on-farm research program at Nebraska using a semi-structured, in-depth interview tool. It should be noted that an in-depth interview is fundamentally different than a survey. The instrument was focused on obtaining rich descriptions from farmer participants to understand motivations for participation in a farmer research network, the experiences of farmer researchers, and the economic impacts of participation in an on-farm research program. The findings should provide practical information for those interested in starting, expanding, or continuing on-farm research programs. The interviews draw on over 25 yr of experience with on-farm research within Nebraska Extension.

**RESEARCH SITE AND PROGRAM HISTORY**

Nebraska is a primarily agricultural state with over 91% of the land area in farm operations (USDA National Agricultural Statistics Service, 2016). While cropping diversity is limited with corn (Zea mays L.) and soybean (Glycine max (L.) Merr.) comprising the majority of the planted acres, there is tremendous climatic and geologic diversity. In the 692 km from Panorama Point in the west to the Missouri floodplain in the southeast corner of the state, elevation drops 1397 m (Nebraska Department of Agriculture; http://www.nda.nebraska.gov/publications/ne_ag_facts_brochure.pdf, accessed 22 Aug. 2017). Normal annual precipitation from 30-yr climate records (1981–2010) range from less than 51 cm of rainfall in the west to over 88 cm in the southeast (High Plains Regional Climate Center, 2017). Nebraska has the largest number of irrigated acres of any state in the United States (USDA National Agricultural Statistics Service, 2014a), with nearly 3.4 million ha under irrigation in 2012 (USDA National Agricultural Statistics Service, 2014b). Nearly 36% of farms have some irrigation (USDA National Agricultural Statistics Service, 2014b). This great diversity makes research results from traditional research stations difficult to apply to the vastly different conditions found across the state. Consequently, on-farm research is a valuable tool for farmers in Nebraska. On-farm research can be conducted in a variety of conditions across the state and farmers are able to research products or practices in the environment where they possibly would be implemented.

On-farm research within the University of Nebraska-Lincoln Extension formally began in 1990 with a select group of farmers in Saunders County in east-central Nebraska. Another on-farm research effort began in south-central Nebraska in the mid-90s. Wortmann et al. (2005a) discussed the history of these two groups. In 2012, with the joint support of the Nebraska Soybean Board, the Nebraska Corn Board, and the Nebraska Corn Growers Association, these programs were combined, allowing on-farm research efforts within the University of Nebraska-Lincoln Extension to expand to a state-wide scope. The program has evolved and grown over the years and currently employs all previously mentioned approaches to research in various combinations (researcher-initiated, industry-initiated, and farmer-initiated).

Protocols are designed to address the proposed research question and to fit the participating farmers’ land and equipment. Research treatments are generally implemented using the farmers’ own equipment, time, and labor. During the year, extension educators, students, and technicians may visit the research site to collect data. At harvest, participating farmers record the yield for each treatment strip using a yield monitor or scale. All of the collected data are processed and statistically analyzed by university faculty and evaluated for quality control. The research
to interact with farmer–researchers, develop experiments, and local educators have a great deal of latitude in how they choose that aspects of the research experience may vary drastically as occasionally a monetary incentive is offered. It is important to note not involve monetary compensation for farmers, however occasionally take the lead in presenting their research project. Research government employees, and university faculty and students all ings have a variety of attendees; farmers, agronomists, industry, and sample.

Table 1. Interview participant categories from the Nebraska On-Farm Research Network. The population number and sample number for each category are provided. Percent of the total number in each category are also provided for both the population and sample.

<table>
<thead>
<tr>
<th>Farmer–researcher category</th>
<th>Population</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year first participating</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>1990–1999</td>
<td>36</td>
<td>25.7</td>
</tr>
<tr>
<td>2000–2009</td>
<td>40</td>
<td>28.6</td>
</tr>
<tr>
<td>2010–2015</td>
<td>64</td>
<td>45.7</td>
</tr>
<tr>
<td>No. years in project</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>1–2 yr</td>
<td>87</td>
<td>62.1</td>
</tr>
<tr>
<td>3+ yr</td>
<td>53</td>
<td>37.9</td>
</tr>
<tr>
<td>Geographical region in Nebraska</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western</td>
<td>15</td>
<td>10.7</td>
</tr>
<tr>
<td>Central</td>
<td>30</td>
<td>21.4</td>
</tr>
<tr>
<td>Northeast</td>
<td>28</td>
<td>20.0</td>
</tr>
<tr>
<td>Southeast</td>
<td>67</td>
<td>47.9</td>
</tr>
</tbody>
</table>

rationale, objectives, results, and observations are compiled into an annual research report. Annual research meetings are held at locations across the state to share research findings. These meetings have a variety of attendees; farmers, agronomists, industry, government employees, and university faculty and students all gather to discuss the research results and participating farmers often take the lead in presenting their research project. Research participation is voluntary. The majority of research studies do not involve monetary compensation for farmers, however occasionally a monetary incentive is offered. It is important to note that aspects of the research experience may vary drastically as local educators have a great deal of latitude in how they choose to interact with farmer–researchers, develop experiments, and work with farmer–researchers to execute the experiment.

INTERVIEW METHODS

A semi-structured, in-depth interview tool was used to evaluate the on-farm research program at Nebraska. Since formalized on-farm research efforts began at the University of Nebraska-Lincoln in 1990, 140 farmers participated in the program (these individuals are termed farmer–researchers). Consistent with the total quality framework for qualitative research, which advocates for representative samples in qualitative research (Roller and Lavrakas, 2015), a stratified sample of 40 of these farmer–researchers was randomly selected to participate in an initial round of interviewing. The research strategy included plans for additional samples to be drawn and interviewed as needed until saturation was reached (i.e., no new ideas or themes were emerging from new interviews (Strauss and Corbin, 1998). The initial sample of 40 was stratified by region of the state, year first involved with the on-farm research program, and the number of years the farmer conducted research with the on-farm research program (Table 2). While a participant may have begun involvement in an earlier year, they may have continued participation beyond the categorical date range to subsequent date ranges. If this was the case, they are only documented in the original date category in which they began participation. The sampling was proportionate to the population in each strata, and nonresponding farmer–researchers were replaced in the sample, resulting in interviews with forty farmer–researchers. This stratified and random approach to sampling strengthens the rigor of the qualitative research study.

Qualitative researchers do not calculate sample size the same way as quantitative researchers. In quantitative research, sample size is statistically linked to the degree of confidence associated with the findings; in qualitative research consisting of in-depth interviews, justification is needed for why the number of interviews is sufficient and the number of interviews to conduct needs to be considered at the initial research design phase and during the field execution phase (Roller and Lavrakas, 2015). The appropriate sample size depends on a number of factors, including the complexity of the research question, the sensitivity of the phenomena being studied, the experience of the researcher, and the homogeneity of the population being sampled (Roller and Lavrakas, 2015; Thomson, 2011). In this study, consideration in the initial design phase revealed the population that is relatively homogenous (the 140 individuals are all male, located in the state of Nebraska, are engaged in farming, and have engaged with the University of Nebraska-Lincoln to conduct on-farm research) and the phenomena being studied is not considered to be sensitive in nature. During the field execution phase, saturation is evaluated to determine when enough samples have been obtained. Theoretical saturation occurs when no new or relevant data is emerging from subsequent interviews, categories are well developed, and relationships among categories are well established and validated (Glaser and Strauss, 1967; Strauss and Corbin, 1998; Thomson, 2011). By 40 participant interviews, saturation was reached as new interviews were not yielding additional information and no new cases were sampled, thus interviewing was concluded.

The semi-structured in-depth interviews were conducted by the Bureau of Sociological Research at the University of Nebraska-Lincoln, a data collection organization that is independent from Nebraska Extension and the Nebraska On-Farm Research Network. Interview participants were recruited first through e-mails, then phone calls using scripts approved by the internal review board. Interviews were conducted between 8 Aug. 2016 and 23 Nov. 2016 by telephone and were digitally recorded and subsequently transcribed by the Bureau of Sociological Research staff. Interviews ranged from 7 to 52 min and averaged 22 min. All farmer–researchers interviewed were asked the same set of 13 general questions with probes for more details based on their answers. These questions ranged from general topics including their motivations for involvement, expectations, overall experience, and future suggestions, to more detailed descriptions of a research project they had conducted, how they determined the project topic, technologies they used to conduct the research, time required to conduct the research, the economic impact of the results, and implementation of the results.

The average respondent age was 54 yr old (n = 39), the average number of studies they had participated in was 8.6 (n = 40), the average year of their first study was 2006 (n = 40), and the average number of years a respondent participated was 5.5 (n = 40). Respondents were across Nebraska (Fig. 1), with 22.5% (n = 9) from the central region, 22.5% (n = 9) from the northeastern region, 42.5% (n = 17) from the southeastern region, and 12.5% (n = 5) from the western region of Nebraska.

Because on-farm research efforts in Nebraska began in the southeast region, then central, then spread to the northeast and
west, there is an interaction of region and longevity in the project among the stratifications (Table 2).

The average farm operation size was 2066 acres ($n = 37$), after removing an outlier or a respondent reporting 500,000 acres. The average amount of an operation which was irrigated was 878 acres ($n = 37$); however, eight farmers reported having no irrigation in their farming operation. Among those who reported having some level of irrigation, the average amount irrigated was 1120 acres ($n = 29$).

The interview transcripts were considered the data to be analyzed. Data were coded into themes using an axial or analytical coding process (Merriam and Tisdell, 2016). The first review of the data identified primary themes, or clusters of like information, while further reviews of the data allowed for the discovery of secondary themes. Themes were then compared and contrasted across cases. Once conclusions were drawn from these themes, the conclusions were assessed by revisiting the interviews to confirm their accuracy (Merriam and Tisdell, 2016; Patton, 2002).

In some cases, results were categorized to provide quantitative results. These cases included grouping respondents by the year in which they first participated in the farmer–researcher network, how many years they participated in the program, in what area of the state they reside, and the direction and strength of their opinion. The year in which they first participated was divided into 1990–1999, 2000–2009, and 2010–2015 to follow the decades. The number of years in the program were split into 1 to 2 yr and 3+ yr to split the groups into two fairly evenly sized groups. The areas of the state were divided by county into four regions, northeast, southeast, central, and western.

The overall satisfaction with the farmer–researcher network was also categorized as very positive, positive, neutral, negative, and very negative to allow for a quantitative assessment meant to provide a clearer interpretation of the responses. The responses were first categorized as positive, neutral, or negative. A second pass through the responses then determined the strength of the positive and negative responses to assess if they were very positive or very negative or just positive or negative. A final review then verified the consistency of the ratings across cases.

Some of the quantitative results were analyzed using the FREQ procedure in SAS (version 9.4; SAS Institute, Cary, NC). To determine whether an explanatory variable is related to the response, a Chi-square test for independence was used with $\alpha = 0.1$. The null hypothesis for the Chi-square test is that there is no relationship between the two variables; the alternative hypothesis is that the two variables are related to each other. The asymptotic Chi-square test was used in cases where the sample size was large enough and the expected cell counts of the contingency table were large enough (Agresti, 1992). In cases where the asymptotic test may not be valid, the exact Chi-square test was used to calculate the $p$-value. In most cases, the asymptotic test was determined to be potentially invalid and therefore the exact Chi-square test was used. Statistical tests are included for informational purposes, however because the sample size for these statistical tests is relatively small, our results and conclusion focus primarily on the magnitude of differences.

RESULTS AND DISCUSSION

Why Did Farmer–Researchers Participate?

Farmer–researchers interviewed gave a variety of reasons for becoming involved in the farmer–research network. These differed somewhat by longevity in the project, timeframe they joined, and geographic region in the state. The most dominant motivation for participation was economic gain ($n = 10$). Previous Nebraska research on motivations for participation also showed economic factors to be as a major reason, second only to enabling better farming (Wortmann et al., 2005b). Specifically, farmer–researchers were interested in testing a new product ($n = 4$), technique ($n = 5$), or crop ($n = 1$) to find out if it would lead to economic gains, prior to investing in it across their entire operation. Others, however, had already adopted a product or technique, and after using it for some time wanted to test if it was really effective ($n = \ldots$)
Table 2. Relationship of participant first involvement and longevity in the program and region.

<table>
<thead>
<tr>
<th>Time-frame of first involvement, %</th>
<th>Western</th>
<th>Central</th>
<th>Northeast</th>
<th>Southeast</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990–1999</td>
<td>0.0</td>
<td>10.0</td>
<td>20.0</td>
<td>70.0</td>
</tr>
<tr>
<td>2000–2009</td>
<td>0.0</td>
<td>22.2</td>
<td>33.3</td>
<td>44.4</td>
</tr>
<tr>
<td>2010–2015</td>
<td>23.8</td>
<td>28.6</td>
<td>19.0</td>
<td>28.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Longevity in project, %</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1–2 yr</td>
<td>23.8</td>
<td>19.0</td>
<td>28.6</td>
<td>28.6</td>
</tr>
<tr>
<td>3+ yr</td>
<td>0.0</td>
<td>26.3</td>
<td>15.8</td>
<td>57.9</td>
</tr>
</tbody>
</table>

4) or verified the seller’s claims (n = 2). While respondents who started participating in 1990 to 1999 expected to see results that would verify what they had already been doing (n = 6), those who started in later years were more interested in making changes and learning new processes (n = 20). Those who began participating during 1990–1999, commented on wanting to know more about products (n = 6); this was not as common in later years. Past research on similar products by the program may be providing answers to participants in later years, lessening the interest in this type of research. Many (n = 27) respondents commented that a main motivator for their involvement was that they had questions to which they wanted answers and believed that finding these answers would lead to improved productivity and better-informed decisions in the future. A few (n = 4) had very specific problems (i.e., sudden death syndrome in soybeans) for which they were looking for a solution. Other respondents (n = 14) were not seeking a specific answer but rather described themselves as “curious” or “interested in learning.” This group in particular liked the opportunity to share their results with others and enjoyed seeing other’s results. Another motivation for participation was the opportunity to work with the university. The motivation of utilizing university and extension expertise was more common among those who had participated in the network for only 1 or 2 yr.

A major motivating theme that emerged was the emphasis on reliable research results (n = 8). All groups agreed they participated in the Nebraska On-Farm Research Network because they trusted the data they collected and the statistical analysis would be sound and unbiased. One farmer stated, “I was wanting to ask or to verify for myself what the viability was of the two different practices... I went to the university because I knew good test results were important. I signed up for that because they offered to do some of the number crunching.”

Two specifically pointed to a desire for reliable information to offset what they perceived as inaccurate information from other sources within the agriculture industry. One farmer went so far as to state simply, “I didn’t rely on information from suppliers... I’m skeptical about ag salesmen.”

A final motivating factor for involvement was that the respondent was asked to participate. Many (n = 9) were asked by someone in the extension office, an individual from private company, or a graduate student. This response was somewhat more common for those who began in 2010 to 2015 as opposed to earlier years. Much of the time, the person who was asking them to participate was someone the farmer already knew, liked, and respected. Some (n = 8) who started in later years had also heard good things about the program from past participants, and this motivated them to get involved.

What Was Their Experience?

The overwhelming majority of respondents reported they had good, positive experiences working with the Nebraska On-Farm Research Network (n = 32). The dominant reasons given were that they liked the university people they worked with (n = 13) and they found value in the publications and interactions at the annual meetings (n = 8).

In general, they found the university experts they worked with to be kind, sociable people, who understood and cared about them. According to one, the best thing about the program was, “...the people I was working with. They were responsive to my needs, understanding to the problems that arose, and generous in the giving of research data.”

Farmers appreciated the flexibility and understanding of the university expert when things didn’t go as planned. They described the people they worked with as helpful, responsive, energetic, and supportive. One farmer stated, “I have to tip my hat to them. They make quite an effort to address questions for individual producers...”

This relational aspect between the farmer–researcher and the university researcher is an important aspect. Often on-farm research projects are implemented with little contact and practical cooperation between farmers and scientists, resulting in superficial communication and interaction (Hoffmann et al., 2007). With strong collaboration and communications, farmers and researchers can produce significant innovations.

The annual research meetings and publications were also cited as a reason for the positive experience. Several (n = 8) found value in the opportunity to collaborate and get feedback from other farmers in a welcoming environment, and commented on this aspect, saying, “At annual meetings we get to talk to others, share with others. Without that, it would be half the value.”

Another, recounted a comment from an acquaintance with a background in education who was also in attendance at the meeting, “She’s never been in a meeting where there was so much interaction.”

Farmer–researchers interviewed reported that the annual meetings allowed them to see what others had learned so they wouldn’t have to try the same study, or conversely, generate new ideas they wouldn’t have thought of on their own. This new idea generation process was facilitated by conversing with a group of like-minded peers. This process is consistent with observations of interaction and dialogue between socially-similar farmers by Wood et al. (2014). One farmer most enjoyed, “...talking with everybody. You could try ideas out and bounce them off somebody else and if they thought it was worth the time to look into, or no, it’s been checked into enough.”

For respondents who began in the years 1990–1999, eight commented on how beneficial the collaboration and communication was with other farmers involved in the project. Among those who began in the years 2000–2009, only two mentioned this as their favorite part of being involved, while for those who began in 2010–2015 four mentioned this as their favorite part.

The quantitative Chi-square analysis of responses concluded that there was not a relationship between farmer positivity about their experience and the starting time period of their involvement in the program (Fig. 2). Additionally, farmers participating for only 1 to 2 yr had similarly positive experiences as those participating 3+ yr (Fig. 3).
Research Project Ideation

The level of involvement in project ideation varies from the farmer determining the research topic and treatments independently, to the university researcher determining the topic and treatments and presenting it to farmers as part of a ready-made protocol, to a collaborative approach. Farmer–researchers interviewed were asked how they came up with a research topic. As expected, there was a mixture of how topics were developed. Eighteen had a specific topic in mind before planning the experiment. Twenty-two reported being approached by someone in extension or another agency or industry. Of these, four specified that a collaborative approach was used and that the final research topic was a mixture of their own idea and someone else’s. Among those who began in earlier years of 1990 to 1999, 70% reported they came up with their own topic for research and that the questions were specific to their farm. Of those who began in 2000 to 2009, 56% came up with their own topic; of those who began in 2010 to 2015, only 29% came up with their own topic. A Chi-square analysis concluded that whether farmer–researchers came up with their own researcher idea was related to the timeframe in which they participated \((p = 0.093)\). Those who started in 2010 to 2015 were most likely to comment that they were specifically asked to do a certain research project. Some helped come up with the idea or had some input, but a majority were guided by an extension educator, rather than generating the idea completely independently. There was no relationship between choosing one’s own research topic and the region in which they were located \((p = 0.884)\). There was also no relationship between farmer longevity in the project and who came up with the research idea \((p = 0.356)\); 38% of those who had participated 1 or 2 yr reported coming up with the research topic on their own compared to 53% among those who had participated 3+ yr. Those who were involved 1 or 2 yr more frequently said they read about the research topic in a magazine or someone (most commonly extension faculty or local Natural Resource District employee) brought the topic to them \((n = 13)\). Qualitative data indicated farmer researchers who participated in the program longer had greater independence in selecting their research topic.

The origin of the research idea was not related to the overall satisfaction with the experience, implementation of the research results, and longevity in the program. Both those who generated their own research ideas and those who did not, had positive experiences. Of those that did not generate their own research idea, 91% were positive or very positive about the project compared to 83% of those that did generate their own idea \((p = 0.134)\). Differences were noted among those who described very positive experiences: Among those who had their own research idea, eight reported very positive experiences as compared to only five among those who got their research idea somewhere else.

There was no relationship between implementation of the research results and whether the farmer–researcher developed their own research idea or if the idea came from somewhere else \((p = 0.587)\). Among those who developed their own research idea, only one did not intend to implement their results, compared to five for those who got their research idea somewhere else.

Of those whose research idea was developed by someone else, 11 participated 1 or 2 yr, and 11 participated 3+ yr. Farmer involvement at all stages of the research experience was critical in maintaining ownership of the research project. Farmer–researchers appreciated the ability to be equal participants and to learn about the research process.

Technology Usage

Thirty-three of the 40 participants reported using precision agriculture technologies such as GPS, guidance systems, yield monitors, or variable rate technology. Many of these also used a weigh wagon. The remaining seven reported using no precision agriculture technology or using only a weigh wagon. Among those who reported not using technology, reasons given included that they participated in the program before such
technology existed or was commonplace, or they couldn’t justify the use of the technology.

As expected, technology usage increased for those with later initial involvement in the program (Fig. 6). For those who began in 1990 to 1999, 50% used no technology or only a weigh wagon compared to 22% for those who began in 2000 to 2009, and 0% for those who began in 2010 to 2015. The increase in technology use with time is consistent with the 2015 Precision Agriculture Services Dealership Survey Results which reports an increase in GPS, yield monitor sales, and variable rate technology from 1997 to 2015 (Erickson and Widmar, 2015). For those who began involvement in the program later there was also an increase in use of variable rate technologies specifically ($p = 0.015$). Ten percent of those starting in 1990 to 1999 reported using variable rate technologies, compared to 22.2% of those starting in 2000 to 2009, and 28.6% of those starting in 2010 to 2015.

**Time Requirement**

On average, the amount of time annually spent on studies was 16 h ($n = 38$). The time required ranged from no additional time to several days. Thirty of the 40 reported they did not feel like the research was taking up too much time or that they felt like quitting, while 10+ of the 40 reported that they felt the research was taking too much time and/or they felt like quitting. When asked further for a reason why they felt it was taking too much time, respondents cited that it was annoying during the harvest season.

Historically, to document yield differences, research experiments would need to be harvested one experimental unit at a time and weighed with a weigh wagon or grain cart equipped with a scale. The time required to repeatedly auger out the grain from the combine to weigh and possibly drive the combine to the weigh wagon while not harvesting is especially undesirable due to the time-sensitivity of harvest. Precision agriculture technologies have increased the ability to collect and analyze research data. Yield monitors have allowed farmer–researchers to collect spatial yield data as they harvest the crop, eliminating the need for frequent stopping and unloading. Variable rate technologies have provided a convenient way to test various rates of fertilizer, seed, and other inputs. Rather than physically changing fertilizer rates or planting rates, this can be done automatically with a prescription map or on an in-cab monitor. These technologies have costs as well, largely related to additional time requirements. For example, yield monitors should be calibrated (Luck and Fulton, 2014) and prescriptions need to be developed for implementing variable rates. Many of these activities can be done prior to the time-sensitive field work. Additionally, if the combine head width is not a multiple of the treatment applicator width (be that planter, sprayer, or other implement) selected rows may have to be harvested to ensure various treatments are not harvested simultaneously. This may cause some combine passes to be less than full header widths, reducing harvest efficiency. Overall, these technologies are generally seen as making on-farm research more feasible. Several practical guides document how to use these technologies in conducting on-farm research (http://www.iasoybeans.com/…/ guide-to-replicated-strip-trials, accessed 22 Aug. 2017; Nebraska On-Farm Research Network, 2018).

Technology use did not impact the farmers’ perception that the project took too much time ($p = 0.338$); 87% of those who reported the project did not take too much time used precision technology and 70% of those who reported the project took too much time used precision technology (Fig. 7). While precision agriculture technology resources have the ability to make the project quicker to harvest, technology used to conduct research was not related to the farmer’s perception that the project did or did not take too much time.

**Reaction to Research Results**

Farmer–researchers may or may not have gotten the research results they expected or for which they were hoping. Most respondents felt positively about their results ($n = 27$), although those who got the results they expected were especially pleased ($n = 3$). Respondents who started in 1990 to 1999 had more positive comments and also described more positive results.
Some were satisfied overall with the results, but had been hoping for more noticeable differences (n = 3). Farmers who had participated 1 or 2 yr reported feeling positively and that they were satisfied with the results. However, those with 3+ yr experience had more mixed feelings, describing their research results as being sometimes successful and sometimes not.

**Perceived Reliability of Research Results**

Regardless if the results were what they hoped for, the farmer–researchers felt confident in the reliability of the project results and the statistical analysis. They found the results trustworthy and unbiased (n = 38). One farmer–researcher commented, “I was pleased, I guess, in that the results were what I hoped for. I felt that there was not a bias by anyone because doing the project helped me to design the research. I could rely on the results and take action based on those.”

Another appreciated having someone with statistical expertise analyzing the data, stating, “I can plant a bunch of strips and compare the yields but my statistics’ study from college was getting pretty rusty so it would have been challenging to me.”

The less experienced farmer–researchers (participants of 1 to 2 yr) were more skeptical of the reliability of the results than those with more experience. Every respondent with 3+ yr experience reported that they felt the results were reliable, compared to 85% of those with 1 or 2 yr experience. The results were similar when asked about the confidence they had in the results. One hundred percent of the farmer–researchers with 3+ yr experience had confidence in the statistical analyses, whereas 85% of the researchers with 1 or 2 yr experience said the same.

There are several possible explanations for these findings. One is that those who are not as confident in the results are choosing not to continue with the program. The other is that as participants continue with the program, they gain confidence in the research process, statistical interpretation, and results.

In addition to having confidence in the methodology used to conduct and analyze the research, several reported enjoying learning how to conduct scientific research (n = 7). This indicates some participants are not only interested in the outcome of the research, but the process as well. One farmer stated, “One of the most important things I learned was how to look at the data that we look at. The trials were always repeated and random and that skill came from the university expertise.”

These results indicate some farmer–researchers desire to engage in all portions of the research process and learn techniques of research design which would allow greater independence in conducting future research. Often researchers assume that farmers do not want to be involved in the details of data processing and statistical analysis. Hoffmann et al. (2007) expresses this concept, disagreeing with the ideas that more farmer participation is better and that innovation is strengthened by farmers doing “formal research.” The results of this study challenge this idea and indicate efforts should be taken to invite farmer engagement in all portions of the research process.

**Future Participation**

Willingness and intent to participate in the future is a key indicator of the success of the program. Twenty-three of the respondents indicated they plan to participate in the program again, five responded that they would not, and the rest gave a version of “maybe.” Of the five who said they do not plan to participate in the future, four reported retiring from farming was the reason for not continuing to participate. Among those planning to participate again, the predominant reasons given were that they learned a lot, enjoyed the program, found out something useful, found value in the meetings, and wanted to continue to improve themselves and their community.

**How Did They Use Their Results?**

While evaluation often targets intended behavior change, it can be more difficult to document actual behavior changes. Therefore, a goal for this study was to find out if the farmer researchers had put their research results into practice.
Twenty-three of the 40 farmers interviewed reported that they had put their research results into practice by making a change; seven others said they put their research results into practice by not making changes as their research results confirmed their current practice. Additionally, two said they would start using their results in the next growing season.

Many (n = 11) farmers put their results into practice by choosing to not use a product or practice going forward. This resulted in much of the economic gains seen by participants. For example, rather than gaining money from increased yields, participants saved money by not using products.

For others, participating in research gave them the confidence they needed to go ahead with changes they had been considering. One farmer explained, “...made a change I was planning on, but it gave me confidence to go ahead with it. I had been dabbling in no-till and getting some experience with it but had not done any strip trials or analysis to determine what the yield impact was. I had a pretty good idea of the difference in cost and an intuition what the yield impact was but this confirmed my thoughts about it and at the time it was before it was widely accepted so it gave me a kind of coffee-shop confidence also.”

On average, farmers had implemented their research for 7.9 growing seasons (n = 19).

Interviewees were asked to describe if they utilized their on-farm research results by making a change in the way something was done on their farm. If they answered in the affirmative (that a change had been made) they were asked to describe the economic impact of the change they made. Further probes were given if needed, asking the interviewees to think through how many acres were impacted and if there was a yield gain or input cost saving. Some respondents excitedly described the economic gains made as a result of their findings. Seven respondents were able to give a dollar estimate on the amount saved per acre. The average amount saved was (USD) $15.43 per acre. Four respondents were able to give a dollar estimate on the profit gained per acre. The average amount gained was $31.25. Both those who participated 1 to 2 yr and those who participated 3+ yr reported an overall increase in profitability as a result of implementation of their project.

Another way that farmer researchers can implement their results is by sharing their findings with others. This is a powerful means of information dissemination. For this reason, we were interested to find out how farmers were sharing their research results. Of those interviewed, 34 of the 40 shared their results with someone. Among those who had participated for a longer time (3+ yr), all shared their results with someone. This is in contrast to the 1 to 2 yr participants, of which only 77% had shared their results. Those that did share the results, did so with neighbors and other farmers. They also reported that the university had shared the results with others. Those who did not share the results explained that they have not had the opportunity because their project was not yet complete (n = 3), they did not have anyone to share the results with (n = 1), or nobody asked to see their results (n = 1). When asked about their motivations for sharing their results, the most frequent answer given was a desire to help other farmers (n = 8). Two respondents expressed, (i) “...just kind of what neighbors do, we try to make each other better” and (ii) “...because that’s the value of it— to learn from each other.”

These results are similar to a study of New Zealand farmers in a research network, which found that all farmers in the study (n = 17) emphasized the value of obtaining knowledge from other farmers (Wood et al., 2014). The second most common motivation for sharing results was being directly asked about their research (n = 9), “People were asking questions about all the flags in my field and they started asking and I told them what was going on.”

Some saw sharing their results as a means to mitigate future problems, “I think down the road there will be more rules put on us if we don’t control how much [water] we’re pumping. We have to make sure we protect that or if we get more regulations on that it’s going to cost us money. [I’m] trying to get everybody to do their part to conserve water too.”

**Participant Suggestions**

Nearly half of the respondents had no suggestions for the program. The most frequent (n = 3) and impassioned suggestion for improvement was for more current and innovative research studies. One farmer suggested, “...increased emphasis on innovative research, whatever kind, could be biological research on crops, how do cover crops truly interact within a cropping system, new innovative things that are coming out in agriculture. We don’t need to keep doing research that’s been done for 4 or 5 yr. It just takes up too much time for the educators...”

A few (n = 2) respondents expressed a desire for farmers to receive monetary compensation for their research efforts. Suggestions for improvement varied by longevity within the program. The less experienced (one to 2 yr) suggested bringing the On-Farm Research Network together with the Nebraska Agriculture Technology Association, giving more information on the results, conducting studies on topics they deemed more current, and increasing involvement with research students at the University of Nebraska-Lincoln. The more experienced group suggested emphasizing innovative research, keeping the studies simple, providing more of an incentive to participate, providing more research dollars from the university, and providing automation to reduce the amount of work farmers have to do to participate. These suggestions have been considered and some of the ideas have been implemented over time. However, on the whole, the farmers interviewed expressed appreciation and did not have suggest substantial structural changes.

When asked if there was anything else they’d like to add, many farmers added how much they appreciate the Nebraska On-Farm Research Network as an alternative, unbiased source of information compared to what they may find in magazines or hear from suppliers. One farmer explained, "I think its [Nebraska On-Farm Research Network] highly valuable and highly important. We get a lot of research from industry which all of us take with a grain of salt because they’re trying to sell us something. Having the farmers do it on the farm and making it over the geographical differences in Nebraska is extremely valuable because it gives us a better understanding of what works and doesn’t work.”

**CONCLUSIONS AND PRACTICAL CONSIDERATIONS**

Farmers were motivated to become involved with the on-farm research program for a variety of reasons. It is important to note that many became involved because someone asked them to. This request did not correlate to any negative experience as compared to those who volunteered without being asked. This
is an important consideration when looking to build an on-farm research program.

Overall, farmers who participated in the Nebraska On-Farm Research Network had a positive experience. One of the main factors contributing to this are the people (both those they worked with in extension and each other as a peer network). Because of this, providing social opportunities to network with like-minded peers is an important consideration of an on-farm research program. Another factor contributing to the positive experience was the access to unbiased research (both their own and others’ research). The type of agriculture technologies used was dependent on the timeframe the farmer was involved; later groups had greater use of yield monitors and variable rate technology, however the farmers’ perception that the project did or did not take too much time was unrelated to technologies used. No conclusion could be made regarding the primary factors which may drive the farmers’ perception that the project did or did not take too much time.

Whether or not farmers developed their own research topic was not related to whether they were first starting out and had only participated 1 to 2 yr or if they had participated 3+ yr. Qualitative analysis revealed that farmer participants also enjoyed learning how to conduct the research and about the statistics, an area researchers often assume farmers are not interested in. This indicates participants are not only interested in the outcome of the research, but the process as well. The source of the research topic was not related to overall satisfaction with the experience or implementation of the research results. Contemporary on-farm research programs take various approaches to research topic development ranging from the farmer determining the topic of interest to a university researcher or other partner determining the topic and asking the farmer to participate. This study found that the participating farmers' satisfaction in their experience and the subsequent implementation of the research results was not dependent on the farmers generating the research topic on their own; these are favorable findings for on-farm research programs where university researchers or others in similar roles determine research topics and protocols and then solicit farmer involvement.

The farmers interviewed expressed they had realized economic gains as a result of implementing their research findings. The farmers expressed this value as an amount saved (on average $15.43 per acre) or profit gained (on average $31.25 per acre).

Traditionally on-farm research was been seen as an avenue to disseminate knowledge regarding products and practices which have already been researched in an “off-farm” setting such as a university research center. This knowledge sharing is often thought of as technology transfer and on-farm research is employed in the latter stages of the research process. However, respondents consistently requested on-farm research focused on innovative topics including topics that are often considered the “new discovery” phase of research. Previous research has also asserted that on-farm research has a role in all stages of technology development (Sumberg and Okali, 1988). To meet farmer expectations, it is necessary to develop innovative projects and solicit farmer involvement in all phases of research.

SUPPLEMENTAL MATERIAL

Interview questions script for farmer–researchers interviewed. This script consists of 13 general questions with probes for more details based on answers.

REFERENCES


