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Assessing forage research and education needs of organic dairy farms in the United States

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Abstract

The viability of organic dairy operations in the United States (US) relies on forage production. The objectives of this study were to (1) assess producer and farm information regarding current forage production practices and producer knowledge gaps and (2) identify forage research and educational needs of organic dairy producers across the US. A survey was distributed to 643 organic dairy producers across the US, with 165 respondents (26% response rate). A focus group consisting of extension professionals, university researchers and staff, consultants, dairy industry representatives and organic dairy producers was also consulted for forage research needs. Results showed that approximately half (51%) of surveyed producers were somewhat satisfied with their forage production systems and sometimes experienced negative weather-related impacts on forage yield and quality. A majority (64%) of producers felt their knowledge to meet farm goals was adequate but they reported a lack of resources to implement this knowledge especially for balancing high-forage diets and selecting soil amendments. This study revealed that 54% of producers rely on peer experiences as information resources to make decisions on forage programs. Producer knowledge gaps included pasture renovation with reduced or no-tillage, forage mixtures that match their needs, and forage management practices aiming for high-quality forage. Based on the survey and focus group findings, forage research and educational activities should foster climate change resilience regarding forage diversity adapted to local and regional climatic conditions, improve forage quality, enhance economic returns from soil fertility amendments and pasture renovation, and introduce new forages and forage mixtures that suit economical, agronomical, and environmental needs.

Introduction

Organic dairy farming has increased rapidly in the United States (US) over the past several decades, with organic milk being one of the fastest-growing sectors of organic agriculture (USDA-AMS, 2018). Retail sales was of $3.2 billion in 2016 (USDA-ERS, 2022*a*) and nearly doubled to more than $6 billion in 2020 (OTA, 2021), which explains the increasing interest of consumers for organic milk products.

In organic dairy systems, production of high-quality forages is essential to meet organic (USDA-NOP, 2020) standards. Under organic certification, dairy cattle over the age of 6 months require at least 120 d of grazing with a minimum of 30% of daily dry matter intake coming from pasture annually (USDA-NOP, 2020). Because purchased organic concentrates often cost 25–50% more than conventional concentrates (Butler, 2002), it is important to maximize production of high-quality forage to reduce production costs. However, challenges associated with climate change vary locally and regionally across the US, with droughts, floods, extreme heat or cold, and other atypical events becoming more frequent (Walsh et al., 2014), all of which can negatively impact forage yield, quality, and milk production (Hayhoe et al., 2008; US EPA, 2016).

Dairy producers need forage management strategies to reduce input costs while maximizing forage productivity, nutritive value, and stability, especially with increasingly erratic weather conditions and volatile grain prices (Hardie et al., 2014; Walsh et al., 2020).

Production of high-quality forages requires a combination of knowledge, techniques, and strategies related to soil health, nutrient cycling, grazing, harvest forage species and variety selection, and understanding how these factors interact to create resilient forage production and farm profitability (Podebradská et al., 2022). Previous work indicated that organic dairy producers from the northeastern region expressed a need for research and outreach in forage production and management to enhance the economic and environmental sustainability of organic dairies in the US (Pereira et al., 2013). Hence, identifying forage research and producer education needs across the country is paramount.

The objective of the current study was to (1) assess information regarding current forage production practices and producer knowledge gaps, and (2) identify emerging forage research and educational needs of organic dairy producers, particularly as seen through the lens of changing climate across the US, by collecting data via focus group and producer survey.

Material and methods

Data on organic forage production practices and producer educational needs were collected using a survey sent to producers while data on forage research needs were obtained via focus group interviews.

Survey questionnaire

The survey was developed through a collaboration with researchers, extension, a producer advisory group, and industry feedback. Institutional Review Board approval was obtained prior to beginning the research from the University of Vermont (IRB # 00001501). We utilized the Dillman tailored design approach to disseminate the survey in print to 643 farms from a list of producers obtained from organic dairy processors and associations in New York, Wisconsin, and California (Dillman, Smyth, and Christian, 2016). Follow-up was done through dairy processors and dairy association listserves. The survey questionnaire (Supplementary material 1) was developed in the fall of 2020 to collect information on current organic forage production practices, weather impacts, and needs for research, information, education, and outreach. A total of 165 respondents returned the survey resulting in a response rate of 26% of the direct distribution.

Survey instrument and variables

The survey consisted of eight sections including (a) demographic and general farm information, (b) forage systems and forage management, (c) impacts of forage systems on dairy production, (d) factors affecting farm forage system, (e) weather-related impacts on farm's forage system and strategies to mitigate those impacts, (f) producer-perceived knowledge that may limit their ability to achieve farm goals, (g) frequency of utilization of available tools/information resources to support forage program decision-making, and (h) knowledge and skills needed by producers for forage production and management.

Questions pertaining to demographic and descriptive general farm information included location of respondents, years certified as organic, identification of respondents as either belonging to plain-sect communities (e.g., Amish and Conservative Mennonites, termed plain-sect producers herein) or their counterparts (termed non-plain-sect producers herein), the number of mature cows managed, cropland size of the farm and perennial or annual forages, and types of forages or legumes produced. Imperial measurements of cropland size (acreage) were used during the survey, but responses were converted to metrics (hectare) afterwards.

Questions pertaining to the information scale (Likert, 1932), each rated on a 5-point Likert scale, included (a) level of producer satisfaction with their current forage system: questions were ranked from being dissatisfied to extremely satisfied; (b) how forage systems affect dairy production parameters: questions were ranked from severely limiting to significantly enhancing; (c) weather impacts on forage systems: questions were ranked from never to always; (d) other factors affecting forage systems: questions were ranked from neither limiting nor enhancing to significantly enhancing; and (e) frequency of utilization of information tools or resources to support forage program decision-making: questions were ranked from never to always.

Focus groups

In-person meetings with focus groups were originally planned to follow the completion of the survey and the meeting of the research team. However, due to the COVID-19 pandemic, the focus group meetings were held virtually. Two virtual focus group meetings were held on April 21, 2021 and April 23, 2021. A total of 24 participants from Vermont, New York, Maine, Virginia, Massachusetts, Wisconsin, Minnesota, Oregon, Washington, and California attended the virtual focus groups. Participants included organic dairy producers, extension professionals, university researchers and staff, and other industry representatives and advocates. Before the meetings, a short survey (Supplementary material 2) was sent to each participant. During the meetings, the results of the survey were shared with participants to help prepare for and facilitate discussion. Project team members recorded and took notes during each of the focus groups and met afterward to compile the main themes regarding research priorities, educational needs, and necessary resources to overcome organic dairy forage production challenges.

Statistical analyses

Data were analyzed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). Continuous outcome variables such as the number of producers per state, years certified as organic, number of producers who belong to the plain-sect or the non-plain-sect community, number of mature cows, acreage of the farm, and acreage of perennial, annual, and legumes forages were analyzed via descriptive statistics with frequencies.

For comparison purposes, responses were first grouped by producer self-identification as whether they belonged to the plain-sect community or not belonged to the plain-sect community. Responses from those two groups (plain-sect and non-plain-sect identified participants) were analyzed separately because producers who identify themselves as part of plain-sect community are reported to use low levels of technology in farm management, which could influence forage system management and education needs. In a similar way, producer locations were also grouped into three main US regions (eastern, midwestern, and western) to discern possible influences due to regional heterogeneity in climate, soil, pest populations, and disease incidences (Pereira et al., 2013). Additionally, producer responses were parsed by herd sizes, but comparisons were performed between producers who were managing herd sizes ranging from 11 to 50 mature cows (49%) and producers who were managing herd sizes ranging from 50 to 200 mature cows (40%), equating to a total of 89% of all respondents.

Information scale (Likert, 1932) was analyzed with non-parametric tests of independent samples (Kruskal–Wallis test) using the sum and averages of ranks for each group to compare variables between respondents identified as plain-sect producers and non-plain-sect producers, as well as between regions (eastern,

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midwestern, and western), and herd sizes. Significance was declared when $P \leq 0.05$, and tendencies when $0.05 < P \leq 0.10$. A two-sided χ^2 test value was reported as well to show association between variables.

Results

Descriptive statistics

Organic dairy producer demographics and general farm information

Descriptive statistics pertaining to organic dairy producers and general farm information (Table 1) indicate that the largest number of responses originated from producers with organic dairy farms located in the northeastern region (57%), followed by the midwestern (36%) and the western region (7%). New York State contributed to the most cows but few farms with large herds (with more than 400 mature cows) were found in Wisconsin, California, and Washington.

Demographically, approximately half of respondents (53%) self-identified as belonging to the plain-sect communities and were mostly from the eastern and midwestern regions. Responding, organic dairy farms had been certified for a median of 12 yr (minimum 1 yr, maximum 40 yr). Most respondents indicated they managed dairy herds ranging from 11 to 50, and herds ranging from 51 to 200 mature cows.

Land and forage management

Land and forage management practices are presented in Table 1. Respondents indicated they operated their own croplands ranging from 0 to 3523 hectare (ha) with a median of 49 ha. Rented croplands ranged from 1 to 809 ha with a median of 32 ha.

In annual forage fields, the majority of producers grew corn silage (*Zea mays L.*) or and other summer annuals such as Sudangrass.

Most producers grew perennial forages including, orchardgrass (*Dactylis glomerata L*), meadow fescue (*Festuca pratensis*), and legumes such as white clover (*Trifolium repens*) and red clover (*Trifolium pratense*), in perennial forage fields.

On average, choosing to fertilize an average 29 ha of perennial forage fields and the decision to fertilize forage fields was influenced most by the amount of manure on the farm (36%). Respondents indicated that fertilizer application rates were mostly determined by visual assessment and occasional soil tests. Most producers renovate their pastures every 5–6 yr and every 3–4 yr for forage fields harvested as conserved feeds.

Most producers indicated they harvest perennial forages upon maturity at least 3 times per yr. To determine when to re-graze the pasture, 82% of producers used visual assessment of height/density. The length of the grazing season in a typical year varied from 120 to 285 d with a median of 180 d. Most producers (83%) indicated they stored harvested forges as wrapped bales.

Information scale

Satisfaction of organic dairy producers with their forage production system

The results of the producer satisfaction with the forage production systems are presented in Table 2, across all producers and regions, because few significant differences were noted between plain- and non-plain-sect producers, or among regions. Most respondents indicated they were somewhat or extremely satisfied with their forage programs in terms of forage diversity, types of forages, pasture yields, pasture quality, stored forage yields, stored forage quality, storage methods of stored feed, soil fertility program, legume content, weed control, pest control, and legume persistence. However, producers from the midwestern region were more satisfied with the types of forages ($\chi^2 = 10.7$, $P = 0.03$), and legume content ($\chi^2 = 8.75$, $P = 0.05$) compared with those from the eastern and western regions. Additionally, non-plain-sect producers tended to be more satisfied with the soil fertility program ($\chi^2 = 5.15$, $P = 0.09$) than producers who belong to plain-sect communities. When asked about their satisfaction with the adequacy of irrigation, 26% of respondents indicated they were somewhat dissatisfied.

Impact of forage systems on dairy production parameters

Results of the impacts of forage systems on dairy production parameters are presented in Table 3. For most respondents, operation forage systems somewhat enhanced milk production (42%), cow body condition (43%), reproduction and calving (44%), quality of young stock (39%), and farm income (37%). Additionally, most producers (45%) indicated that herd health was significantly enhanced by operation forage systems.

Weather-related impacts on forage systems

Results on weather-related impacts on farm forage system are presented in Table 4. Overall, most respondents indicated that they sometimes experienced weather-related issues such as drought stress (78%), pasture availability challenges (70%), and lower-than-average forage yields. When asked about the impacts of weather on forage quality and unexpected changes in forage harvest timing, most producers indicated they sometimes experienced lower-than-average forage quality and unexpected changes in harvest timing due to inclement weather. However, plain-sect producers were affected more than their non-plain-sect counterparts regarding the lower-than-average quality ($\chi^2 = 7.91$, $P = 0.01$), and unexpected changes in harvest timing due to inclement weather ($\chi^2 = 14.1$, $P = 0.001$). In the view of most producers, winter kill (62%) occurred sometimes with producers from the midwestern region expressing the greatest concern ($\chi^2 = 14.39$, $P = 0.03$).

Strategies to mitigate weather-related impacts on operation forage systems

To mitigate adverse weather conditions on forage systems, nearly half of respondents (46%) indicated they purchase more forages than usual. From about half of the time to most of the time, 47% of respondents increased irrigation, with the use of irrigation being greater for respondents coming from the western region ($\chi^2 = 17.42$, $P < 0.001$). Other producers (43%) increased grazing acreage to mitigate the effects of weather conditions on forage systems.

Other factors impacting forage operations

Apart from weather-related impacts, respondents were asked about other factors impacting farm forage systems. Those factors included the price received for milk products, equipment costs, labor costs, seed availability, seed quality, grass mix availability, severe weather fluctuations, storage type and storage capacity, availability of equipment, labor and customer operator, and access to adequate water for irrigation. Producers were asked to rank those factors as significantly limiting, somewhat limiting, neither limiting nor enhancing, somewhat enhancing, and significantly

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Table 1. Demographic information of organic dairy farms (% of total respondents) in the US

Item	Region[a]			Herd sizes (mature cows)					
	NE	MW	W	1–10	11–50	51–200	201–400	400+	
Farm characteristics									Avg.%
No. of surveys received	94	60	11	2	76	63	10	5	26
Plain-sect respondents, %	30	22	1	0	38	15	0	0.7	53
Non-plain-sect respondent, %	27	16	5	1	12	25	6	3	47
Certified organic dairy farms (1–40 yr), %	32	23	2	1	50	40	6	3	57
Respondents owning cropland (range 0–3523 ha and 48 ha of median), %	55	38	7	1	46	43	6	4	–
Respondents renting cropland (range 1–809 ha and 40 ha median), %	48	24	4	0	43	45	7	5	–
Producers growing annual grasses, %									
Corn silage (7 ha median land size)	32	65	3	2	48	38	7	5	70
Sudangrass (4 ha median land size)	47	45	3	2	41	47	6	4	61
Producers growing perennial grasses, %									
Orchardgrass	60	36	4	1	52	39	5	3	83
Meadow fescue	55	41	4	–	54	37	5	4	61
Inclusion of legumes in pasture, %									
White clover	60	36	4	1	50	41	5	2	87
Red clover	57	38	5	2	51	42	3	2	86
Alfalfa	44	52	4	–	59	33	5	3	48
Pasture renovation, %									
Forage fields (5–6 times yr^{-1})	10	13	1	1	16	7	2	1	24
Stored forages (3–4 times yr^{-1})	14	14	0	0	14	12	2	1	28
Factors influencing the fertilization of forage fields, %									
Amount of manure	20	14	2	1	18	14	3	0	36
Finances	12	8	2	0	13	10	1	0	22
Basis of fertilizer application rate, %									
Visual assessment,	58	35	7	0	54	38	5	3	46
Occasional soil tests	57	38	5	2	52	39	6	1	42
Forage storage technique, %									
Wrapped bales	58	38	4	–	49	44	5	2	83
Dry bales inside a building	54	39	7	–	55	36	6	3	63

[a]Farms were parsed into three main regions: NE (Northeast) with farms in New York, Vermont, Pennsylvania, New Hampshire, Maryland, and Maine. MW (Midwest) with farms in Wisconsin, Indiana, Ohio, Minnesota, Maryland, Michigan, Iowa, Illinois. W (West) with farms in Washington, Oregon, California, and Idaho. S (South) with one farm in Kentucky (was not included in the table for comparison because it makes less than 1% of total responses).

enhancing farm forage systems. Respondents reported that severe weather fluctuations and equipment costs were somewhat limiting forage production systems (52 and 42%, respectively).

Labor costs were also somewhat limiting for most producers, but costs were greater for plain-sect producers ($\chi^2 = 13.87$, $P = 0.02$). Price received from milk products was also somewhat (34%) to significantly limiting (19%). Access to adequate water for irrigation was another important factor affecting the forage system as producers reported that it was somewhat (30%) or significantly limiting (25%) across regions.

Contrarily, other factors such as seed availability, seed quality, labor availability, access to adequate water for irrigation, storage type, and customer operator availability were reported to be neither limiting nor enhancing by most producers.

Self-perceived knowledge that would limit producers to meeting farm operation goals

Results on self-perceived knowledge that may limit producers from meeting farm operation goals are presented in Table 5. While 58% of producers indicated they know about balancing high-forage rations to optimize milk production, 15% of respondents reported that they were lacking the resources to implement that knowledge. In general, respondents knew how to calculate forage yields, forage production costs, identify forage species, interpret forage and soil testing results, maximize forage dry matter intake, select forage mixtures that suit needs, and select soil fertility amendments. However, 21% of respondents indicated they were lacking the resources to implement a fertilization program.

Table 2. Ranking of satisfaction of organic dairy producers with forage production systems across the United States surveyed during the fall of 2021

Ranking[a]					
	Extremely dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied
Diversity of forages in fields	0.0	12.3	10.3	58.1	19.4
Types of forages	0.7	7.3	12.6	57.0	22.5
Pasture yield	0.6	17.1	14.6	51.9	15.8
Pasture quality	0.6	15.6	11.7	54.5	17.5
Stored forage yield	1.3	16.3	11.1	53.6	17.6
Stored forage quality	1.3	14.9	11.7	53.9	18.2
Weed control	4.5	17.5	16.2	44.8	16.9
Pest control	0.7	5.7	22.7	42.6	28.4
Soil fertility program	1.9	16.0	14.1	49.4	18.6
Legume content	1.3	15.0	18.3	49.0	16.3
Legume persistence	3.3	16.3	22.9	40.5	17.0
Storage of stored feed	1.3	6.7	11.4	50.3	30.2
Adequacy of irrigation system	6.5	26.1	34.8	19.6	13.0

[a]Results form 165 surveys were analyzed and ranked according to producer's satisfaction. Producers were asked to rank their satisfaction with the forage production system on a scale from extremely dissatisfied to extremely satisfied. Values are expressed as percentages of total respondents.

Table 3. Ranking of impacts of farm's forage systems on dairy production parameters by organic dairy producers surveyed in the fall of 2021

Rank[a]					
Dairy production parameters	Severely limiting	Somewhat limiting	Neither limiting nor enhancing	Somewhat enhancing	Significantly enhancing
Milk production	1.3	17.0	13.8	41.5	26.4
Cow body condition	0.6	8.2	15.8	43.0	32.3
Reproduction and calving	0.6	5.1	17.7	44.3	32.3
Herd health	0.6	5.0	11.9	37.7	44.7
Quality of young stock	2.6	4.5	15.4	39.1	38.5
Farm income	3.1	13.8	11.9	36.5	34.6

[a]Results form 165 surveys were analyzed and ranked impacts of operation's forage system on dairy production parameters. Producers were asked to rank the impacts of operation's forage production system on a scale from severely limiting to significantly enhancing. Values are expressed as percentages of total respondents.

Producer information resources for supporting forage program decision-making

The most used information resource (54%) was the experience of other producers. Grazing plans were the second most used information resource. Other important information resources used by producers, from half of the time to always, included nutrient management plans, nutritionists, technical publications and fact sheets, and seed company catalog. For many information resources, most producers used them either sometimes or never.

Useful information, knowledge, or skills needed for improving forage production and management

Regarding useful information, knowledge, or skills that would be helpful for forage production and management, organic dairy producers indicated they needed skills in pasture renovation and rotation with reduced or no-tillage. Specifically, producers indicated they needed to know how to re-seed their forage pasture fields without turning the soil over and disturbing microbial activities. Producers also indicated they needed more information on cost-effective fertility sources that can be used to fertilize forage pasture fields. They also needed to know how to fertilize forage pasture fields with manure and composting with micronutrients.

Producers indicated the need for information on forage varieties, forage mixtures, or forage–legume mixes that are more dual-purpose that begin production earlier in spring and later into fall, or that are more resilient under different weather conditions (too wet or too dry). Additionally, producers indicated the need for research-based information about harvest timing for optimum quality, cultivar and variety information for pasture seeding, forage trials on diverse soil, and new forage species. They would like more information on new advances in forage breeding and production results for organic systems.

Table 4. Ranking of weather-related impacts on farm's forage system by organic dairy producers surveyed in the fall of 2021

Rank[a]					
Climate-related impacts	Never	Sometimes	About half the time	Most of the time	Always
Drought stress	3.2	77.8	13.9	3.8	1.3
Lower-than-average quality	3.8	82.2	8.9	5.1	3.8
Lower-than-average yields	5.0	77.4	10.7	5.7	1.3
Pasture availability challenges	17.8	69.7	9.9	2.0	0.7
Significant disease pressure	65.4	32.0	1.3	1.3	0.0
Significant insect pest pressure	57.0	41.1	2.0	0.0	0.0
Can't meet minimum organic grazing season length	84.9	7.9	1.3	1.3	4.6
Can't meet minimum organic pasture intake requirement	82.4	10.5	0.0	2.0	5.2
Unexpected harvest changes due to inclement weather	5.2	73.9	11.8	4.6	4.6
Winterkill	31.8	61.7	3.2	2.6	0.6
Significant weed pressure	22.1	63.6	7.1	5.2	1.9

[a]Results form 165 surveys were analyzed and ranked according to the frequency of climate-related impacts. Producers were asked to rank climate-related impacts on their operation's forage system on a scale from never to always. Values are expressed as percentages of total respondents.

Table 5. Ranking of self-perceived knowledge limiting to meet farm's goals by organic dairy producers surveyed in the fall of 2021

Rank[a]				
Knowledge	Lack basic knowledge	Don't know how to implement knowledge	Lack resources to implement knowledge	Not lacking
Balancing a high forage ration to optimize milk production	10.2	9.0	14.5	57.8
Calculating forage yields (tons per acre)	8.4	4.8	9.0	69.9
Calculating forage production costs	9.0	10.2	10.2	60.2
Identifying forage species	11.4	7.2	7.2	66.3
Interpreting forage testing results	10.8	9.0	4.8	62.7
Interpreting soil testing results	9.0	6.0	9.0	65.7
Managing grazing system to support soil and plant productivity	1.8	4.8	10.2	74.1
Maximizing forage dry matter intake	4.8	8.4	10.8	65.7
Selecting species/mixtures that suit needs	7.2	6.0	10.8	63.9
Irrigation system development/expansion	6.6	2.4	10.2	8.4
Selecting soil fertility amendments	6.6	6.0	21.1	53.0

[a]Results form 165 surveys were analyzed and ranked according to producer's satisfaction. Producers were asked to rank their satisfaction on self-perceived knowledge needed to meet farm operation goals on a scale from lack of basic knowledge to not lacking. Values are expressed as percentages of total respondents.

Moreover, producers highlighted the need for information about weed control in corn, timing for seeding, nurse crop decision-making, general crop management, and updating the nutrient management plan. Information on farm equipment and equipment access was revealed by producers to be an important knowledge they also needed. Specifically, producers wanted to know how to access no-till seeders or other inventory of custom operator resources, and specialized farm equipment. For educational purposes, visual aids and tools for education and management were indicated to be important. For example, producers indicated that pictures of miscellaneous forages showing optimal harvest timing and field education through pasture walks would help improve their knowledge and skills.

Forage research and education needs

Among important topics of forage research and education needs, the focus groups identified four major research areas. The first research and education need concerned climate change resilience. The focus group highlighted education needs on water and nutrient use efficiency at the farm level. Moreover, research on forage species and varieties that are resistant to pests and diseases, and forage varieties that are resistant to drought and heat during summer months were of paramount importance.

Research is also needed on factors affecting winter survival of forages is important and on the identification of new forage mixtures to increase forage yields and carbon sequestration, or to mitigate greenhouse gas emissions. In this regard, focus groups

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reported research needs on forage diversity that can adapt to local and regional environmental conditions, as well as research on soil biology connection to forage productivity and quality.

The second research and education need raised was improving forage quality. As indicated by focus groups, research on forage quality should encompass forage nutrient concentrations of energy, sugar types, minerals, non-starch carbohydrates, and pectin. Moreover, evaluation of fiber digestibility and its effect on butterfat concentration as well as milk yield per ton of forages should be other research areas of interest. Research on forage quality should also focus on harvesting time for optimum nutrient content, forage storage, forage inventory management, and nutrient management.

The third area of research and education need was to evaluate economic returns from soil fertility/soil health and the evaluation of economic returns from pasture renovation. There might be costs associated with maintaining soil fertility or pasture renovation, but limited research is available on economic returns from those efforts.

Lastly, the focus groups indicated research needs on legumes for grazing, persistent perennial ryegrass, and corn that has a gametophyte factor to prevent cross-pollination with transgenic varieties. Additionally, research on late maturity of forages and subsequent effects on nutrient content and nutrient digestibility is needed. Alternatives to common or traditional forages, research on novel forage species was also considered to be of high importance.

Discussion

Of the 634 organic dairy producers to whom the survey questionnaire was sent, 165 producers responded to the survey resulting in a 26% response rate. Some responses may have been a result of mass communications via organic outlets (newsletter, etc.) and not necessarily direct communications. As with any survey, producers who did not respond may have other challenges or needs, but our results are congruent with demographic data and farm characteristics reported by Pereira et al. (2013).

Organic dairy producer demographics

The geographic distribution of responding organic dairy producers across the US resembles to the distribution of organic dairies nationally and in line with the previous report by McBride and Greene (2009) whereby the eastern region of the US has the greatest number of organic dairy farms. Factors such as the dense human population, availability of diverse milk markets and milk buyers, as well as the presence of organic milk processors, may explain the greater concentration of organic dairy farms in the eastern and midwestern regions (Flack, 2016; Snider et al., 2021). Most respondents (53%) identified themselves as belonging to a plain-sect community which agrees with geographical data showing that higher densities of Amish and Conservative Mennonite communities are located in the eastern and midwestern regions of the US (Cross, 2016).

General farm information

On average, respondents managed cows ranging from 11 to more than 400 which agrees with the findings by Pereira et al. (2013) who reported herd sizes of 10–450 in the Northeast. Based on different herd sizes, it was observed that two major groups of producers managed between 11 and 50 mature cows (49%) and between 51 and 200 mature cows (40%). Despite the rapid increase in numbers over the last decades, organic dairy herds remained smaller, approximately half of the conventional dairy sector (Winsten et al., 2010), averaging 109–115 milk cows per farm in 2011 and 2016 (Nehring et al., 2021). This is because, in addition to the rigorous certification requirements, the production costs of organic dairies are substantially higher than those for conventional dairies, and time associated with transitioning from conventional to organic production is long (1–3 yr) and is expensive (McBride and Greene, 2007). However, estimated total costs of production per cow decrease as herd sizes increase, and potential profits increase when premium prices are provided for organic dairy production (USDA-AMRC, 2020).

Operation forage programs and forage management

In this study, most respondents produced a perennial grass–legume mixture as a strategy to increase forage yield and meet the nutrient requirements of the herd. Legumes of interest were red clover, white clover, alfalfa, and birdsfoot trefoil (*Lotus corniculatus*). Including legumes in cool-season pastures is important as legumes provide N to forage mixtures and enhance forage productivity, especially during summer (Belesky and Wright, 1994). Moreover, legumes are important for organic dairy production as they are used to optimize forage quality and energy to protein balance and increase milk fat and protein content (Brito and Silva, 2020).

The results of this study revealed that approximately 30% of producers never renovate their pasture forage fields which could have an impact on overall forage quality. Including well-adapted grasses in pastures is one of strategies to renovate pastures by reducing the need of N fertilization for increasing productivity and improving the season distribution of forages, especially for pastures dominated by less productive forage species (Cuomo et al., 1999). Perennial cool-season grasses grown by most producers included perennial ryegrass, orchardgrass, and meadow fescue as those forages provide higher forage quality and persist well in a rotational grazing system (Duiker and Williamson, 2019).

Regarding forage storage techniques, most producers stored forages as wrapped bales (83%) or dry bales (63%) for long storage periods with less dry matter loss. The most probable benefit of plastic wrapping is that it can preserve bales over a wide moisture range, and the drying time is much shorter than that required to produce dry hay (Undersander, Wood, and Foster, 2022), which could explain the choice of most producers for this method especially in humid regions of the USA. Additionally, wrapped bales are very cost-effective for smaller herds (less than 150 animals; Undersander, 2014), which aligns with the range of herd size managed by a larger portion of respondents in our study.

Weather-related impacts on operation forage systems

The results of this study revealed that most producers sometimes experienced weather-related issues, including drought stress, and unexpected harvest changes due to inclement weather which could result in having lower-than-average forage yield and forage quality, or pasture availability challenges. As strategies to mitigate those weather-related effects, producers indicated that they had to purchase more forage and more grain approximately half of the time. Armstrong et al. (2005) and Chapman et al. (2014b) reported that drought conditions slow pasture growth rates, reduce pasture intake, and increase reliance on purchased feeds which may be expensive during such periods.

In the present study, plain-sect producers were subjected more frequently to lower-than-average forage quality and unexpected changes of forage harvest timing due to inclement weather. A typical situation of heavy and prolonged precipitations can delay forage harvesting and causes forage to become overmature resulting in greater fiber concentrations and lower energy densities (Buxton, 1996). Plain-sect producers do not have ready access to many technologies (Cross, 2016) such as weather forecasting tools and reports that can help producers make short- and long-term planting and harvesting decisions.

Producers from the western region indicated they increased irrigation use in their forage systems due to persistent drought conditions. The USDA-ERS (2022*a*) reported that more than 10% of alfalfa acreage was affected by exceptional drought conditions in the West during the summer of 2021, the largest in the past decade.

Despite weather-related challenges, a large proportion of respondents indicated they were able to meet the minimum organic grazing season length as well as the minimum pasture intake requirements. This suggests that producers may be implementing different strategies to cope with climate change such as using forage and legume mixtures in the pasture as reported in our study. Additionally, producers reported that the average length of the grazing season was 184 d, ranging from 120 to 285 d, which would meet the pasture requirements for organic dairies (120 d) according to the USDA-NOP (2020). Producers from the midwestern region were more concerned with the winter kill on their forage systems probably due to severe winter aspects (e.g., lack of snow cover, ice sheeting from freeze, etc.) observed in that region (Ford, Budikova, and Wright, 2022).

Other factors impacting forage programs

The price received for products was reported by most producers to be significantly limiting or somewhat limiting. This is likely related to the current oversupply of organic milk that consequently led to declining prices of organic milk on the market (Brito and Silva, 2020). However, the most important limiting factor affecting the forage system was found to be weather fluctuations as reported by most respondents. Climate change projections suggest an increase in extreme heat, severe drought, and heavy precipitations which can affect crops and livestock (US GCRP, 2014). Moreover, the combined effects of seasonal temperature and precipitation patterns influence not only forage productivity but also the growing season and plant phenology (George et al., 2001).

Other factors affecting forage systems included labor costs and availability which were also indicated to be somewhat limiting to forage systems. Labor is the second largest expense in any dairy production system, and the availability of skilled labor might be a concern for producers (Hennessy et al., 2020). In the current study, plain-sect producers were more concerned about labor costs likely because most of them managed small herds (11–50 mature cows). According to Tranel (2020), hired labor is usually related to the size of the herd, wage rates, milk production, and labor efficiency factors. MacDonald, Law, and Mosheim (2020) reported that, on average, larger dairy farms have substantially lower total costs than small farms. Hence, labor costs may be a great challenge for small dairy operations, more importantly during periods when milk prices are declining.

Producer satisfaction and knowledge of forage systems and the impact on dairy production

Despite highlighted constraints regarding the forage program and management, most organic dairy producers indicated that they were somewhat satisfied with the diversity of forages in fields, type of forage, pasture yields and quality, storage forage yield and quality, storage of stored feed, and legume content and persistence. Moreover, most respondents also indicated having good knowledge about feeding high-forage rations and managing forage systems to optimize milk production. Satisfactory level of producer knowledge about many aspects of forage management could be attributed to the long experience of producers (median of 12 yr) but also consistent support from extension dairy programs, regional organic dairy programs, and increased use and sharing of information resources available on the internet especially for non-plain producers (Chase, Ely, and Hutjens, 2006).

The combination of producer satisfaction with forage systems and their knowledge supports the positive effects observed on dairy production parameters such as enhanced milk production, herd health, reproduction, healthy young stock, and farm income. In our study, producers showed a positive attitude about their dairy operations despite different challenges. Bigras-Poulin et al. (1985) reported that producer attitudes, ambitions, education, and other socio-psychological characteristics are important to impact dairy farm success. Despite the satisfaction with the forage program and adequate knowledge/skills of most producers, 26% of respondents indicated the lack of resources to implement knowledge on selecting soil fertility amendment.

Producer information resources for forage program decision-making

Currently, there are several informational tools and resources available to support organic dairy producers. Considering the responses from about half of the time to always, it was observed that most producers used peers as the main information resource. This suggests that producers may learn from each other through peer advisory groups, producer-to-producer discussions, or focus groups, to share insights on experiences and performances for decision-making (Gasson, 1973; Chase, Ely, and Hutjens, 2006). Informational resources such as university/extension programs, producer publications, and organic education organizations were used for some time or never used by most respondents. Even if the age and education level of respondents were not included in the survey questions, Solano et al. (2003) reported that producer age, education level, dedication, and farm's characteristics, herd size, and distance to population centers have a significant influence on the choice of the producers toward different information sources. According to the USDA-NAS (2017), the average age of all US producers in 2017 was 57.5 yrs and have been on their current farms for an average of 21.3 yrs. Hence, the experience factor may be one explanation for trusting other producer experiences so heavily.

Knowledge or skills needed for improving forage production and management

Respondents emphasized the need for pasture renovation with reduced or no-till. The reason producers would like the reduced or no-till technique is likely due to its broad benefits as it favors moisture conservation, preserves existing desirable sod grasses, reduces erosion, provides greater renovation forage yield, enhances water quality, and reduces contribution to the greenhouse gas emissions (Leep et al., 2015). Additionally, respondents may view the no-tillage technique as economical as it saves on fossil fuel costs due to reduced equipment use (Leep et al., 2015).

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Respondents also emphasized knowledge about forage mixtures, including improved and diverse forage species that can be resilient to frequent weather fluctuations. This agrees with Undersander et al. (2004) and Ball et al. (2008) who reported that forage and pasture diversity systems are among the strategies used on-farm to extend forage supply during the growing season and contribute to maintaining soil health. Such skills would be complemented by in-person training and pasture walks, as was reported by producers.

Additionally, respondents reported the need for improved knowledge of different economic fertility sources such as manure or commercial fertilizers and their management. In this study, most producers decided to fertilize forage fields based on the amount of manure available at the farm. According to Heckman (2020), soil fertility needs for pastures do not receive the same attention as annual cultivated row crops because forages are harvested by animals and forage yields are not easily measured in this management system. Moreover, according to Heckman (2020), nutrient deficiency is not visually apparent in perennial pasture species as it might be for annual row crop species.

Consistent with producer survey findings, potential topics for forage research and educational needs identified by focus groups mostly focused on strategies that aimed at improving forage operation systems that are resilient to climate change. Improving forage diversity or forage mixtures that are suitable to resist drought periods was among the important research priorities. This was consistent with skills and knowledge gaps identified through producer survey whereby most respondents reported the need for training on pasture renovation using forages that are adapted to the environment and changing weather patterns.

Additionally, training on economic fertility sources such as the use of manure or other commercial fertilizers would be of great importance to improve forage yields. This agrees with producer survey responses as respondents expressed the need for training on economic fertility sources. The use of manure on forage fields could be a cheaper fertilization strategy if fields are near the farm to avoid transportation costs. According to Annicchiarico et al. (2011), manure can, if well managed, substitute for commercial fertilizers without reducing gross production and sustainability of the cropping system and provides the opportunity to recycle the waste product for animal forage feeding.

Research on improving the quality of forages, especially focusing on increasing fiber digestibility, was found to be very important by producers. Currently, organic dairy producers are looking for ways of producing quota per farm at the lowest cost while maximizing milk components and price paid per hundredweight to increase farm profitability.

Conclusions and implications

Producing high-yielding and high-quality forages is the most critical issue for the sustainability of organic dairy farming, especially with the ongoing erratic weather conditions. The results of the survey questionnaire discussed herein revealed forage production practices and management, factors affecting forage operations, and effects of climate on forage systems. Knowledge gaps and skills needed by organic dairy producers were identified and can be used for developing effective educational and outreach programs to create resilience in organic forage production. Future efforts should focus on identifying and evaluating resources that are needed to implement the knowledge and skills acquired by producers. Results from the focus group identified the most critical areas of research aiming at improving forage quality, creating novel forages that adapt well to the local and regional environment, enhancing climate change resilience, and increasing economic returns from forage operation systems of organic dairies. However, the results of this survey revealed that information resources available to support forage program decision-making are less used than expected, and future efforts should focus on refining strategies to channel research-based information to the end-users for efficient application. Additionally, the findings of this research could be as useful starting point and the basis of future in-depth forage research and education needs that will help organic dairy producers to cope with climate change effects on farm's forage systems and improve the economics of organic milk production. Hence, continued discussions with the organic dairy community are needed.

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